Feasibility Study

Enhancing climate resilience in Thailand through effective water management and sustainable agriculture

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Acronyms

Public and government organisations

BMA	Bangkok Metropolitan Administration
CU	Chulalongkorn University
DAE	Department of Agricultural Extension, MOAC
DCP	Department of City Planning, BMA
DDPM	Department of Disaster Prevention and Mitigation, MOI
DDS	Department of Drainage and Sewerage, BMA
DEDE	Department of Alternative Energy Development and Efficiency, MOEN
DEQP	Department of Environment and Quality Promotion, MONRE
DGR	Department of Groundwater Resources, MONRE
DIW	Department of Industrial Works, MOI
DLA	Department of local Administration, MOI
DMCR	Department of Marine and Coastal Resources, MONRE
DMP	Department of National Parks Wildlife and Plant Conservation
DOA	Department of Agriculture
DOAE	Department of Agricultural Extension
DOF	Department of Fisheries, MOAC
DOH	Department of Highway, MOT
DPT	Department of Public Works and Town & Country Planning, MOI
DWR	Department of Water Resources, MONRE
EGAT	Electricity Generating Authority of Thailand
ETA	Expressway and Rapid Transit Authority of Thailand
GISTDA	Geo-Informatics and Space Technology Development Agency
HAII	Hydro and Agro Informatics Institute
HD	Highways Department
LAO	Local Authority Organization
LDD	Land Development Department
MI	Ministry of Industry
MOAC	Ministry of Agriculture and Cooperatives
MoNRE	Ministry of Natural Resources and Environment
MoST	Ministry of Science and Technology

MOT	Ministry of Transportation and Communication
MWA	Metropolitan Waterworks Authority
NDPMC	National Disaster Prevention and Mitigation Committee
NDWC	National Disaster Warning Center, MICT
NESDB	Office of National Economic and Social Development Board
NHA	National Housing Authority
NSO	National Statistic Office
OCS	Office of the Council of the State
ONEP	Office of Natural Resources and Environmental Policy and Planning
OPM	Office of the Prime Minister
OSCWRM	Office of Strategic Committee for Water Resource Management
OTP	Office of Transport and Traffic Policy and Planning, MOT
PCD	Pollution Control Department
PWA	Provincial Waterworks Authority
RFD	Royal Forest Department
RID	Royal Irrigation Department, MOAC
RRD	Rural Roads Department
RTSD	Royal Thai Survey Department, Royal Thai Army
RU	Ramkhamhaeng Univeristy
SCRFD	Strategic Committee for Reconstruction and Future Development
SCWRM	Strategic Committee for Water Resource Management
SLA	Social Local Administration
TAO	Tambon Administration Organization
TMD	Thailand Meteorological Department
WMA	Wastewater Management Authority

International Organization / Agencies

ADB	Asian Development Bank
AIT	Asian Institute of Technology
DHI	Danish Hydraulic Institute
IPCC	Intergovernmental Panel on Climate Change
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

Others

BMR	Bangkok Metropolitan Region
DEM	Digital Elevation Model
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographical Information System
SLR	Sea Level Rise
SRES	Special Report on Emissions Scenarios

Climate modeling terminologies:

ENSO	El Niño–Southern Oscillation
AOGCMs	Atmosphere-Ocean General Circulation Models
CSIRO-Mk3.6	Commonwealth Scientific and Industrial Research Organisation Mark 3.6.0
INM-CM4	Russian Institute for Numerical Mathematics Climate Model Version 4
MIROC5	Model for Interdisciplinary Research on Climate 5
CNRM-CM5	Centre National de Recherches Météorologiques Coupled Global Climate Model, version 5
GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory Earth System Model with MOM, version 4 component
IPSL-CM5A-LR	Institute Pierre Simon Laplace (IPSL) Climate Model 5 – Low Resolution
MRI-AGCM	Meteorological Research Institute Atmospheric General Circulation Model
RCP	representative concentration pathway

Definitions of indices representing mean and extreme events of temperature:

Index	Descriptive name	Definitions	Units	Note
1. Tmax		Annual average of TX	°C	Mean state
2. Tmean		Annual average of daily mean temp.	°C	Mean state
3. Tmin		Annual average of TN	°C	Mean state
4. SU35	Summer days	Annual count when TX > 35 °C	days	Extreme events (frequency)
5. TR25	Tropical nights	Annual count when TN > 25 °C	days	Extreme events (frequency)
6. TN10p	Cool nights	Number of days when TN < 10th percentile	days	Extreme events (frequency)
7. TN90p	Warm nights	Number of days when TN > 90th percentile	days	Extreme events (frequency)
8. TX10p	Cool days	Number of days when TX < 10th percentile	days	Extreme events (frequency)
9. TX90p	Warm days	Number of days when TX > 90th percentile	days	Extreme events (frequency)
10. WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX > 90th percentile	days	Extreme events (duration)
11. CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN >10th percentile	days	Extreme events (duration)

TX =daily maximum temperature
TN=daily minimum temperature

Definitions of indices representing mean and extreme events of precipitation:

Index	Descriptive name	Definitions	Units	Note
1. PRCPTOT	Annual precipitation total	Annual precipitation total of rainy days	mm	Mean state
2. RD	Number of annual rainy days	Annual counts of rainy days	days	Mean state
3. RX5day	Maximum 5-day precipitation amount	Monthly maximum 5-day precipitation	mm	Extreme event (intensity)
4. SDII	Simple daily intensity index	Annual precipitation total divided by the number of annual rainy days	mm/day	Extreme event (intensity)
4. R20	Number of heavy precipitation days	Annual counts of days when PRCP ≥ 20 mm	days	Extreme event (frequency)
5. R95p	Very wet day precipitation	Annual precipitation total of PRCP> 95th percentile	mm	Extreme event (intensity)
6. CDD	Consecutive dry days	Maximum number of consecutive days with PRCP< 1 mm	days	Extreme event (duration)
7. CWD	Consecutive wet days	Maximum number of consecutive days with PRCP> 1 mm	days	Extreme event (duration)

Rainy day when PRCP> 1 mm

Units of Measurement

mm: millimeter (s)

cm: centimeter (s)

m: meter (s)

km: kilometer (s)

km^2: square kilometer (s)

Rai: 1,600 square meter (s)

M^3: cubic meter (s)

MCM: million cubic meters

kg: kilogram (s)

sec: second (s)

kV: kilovolt (s)

MVA: megavolt-ampere (s)

M3/sec: cubic meter per second

Baht: Thai baht (Thai currency)

THB: Thai baht

USD: US dollars

US$: US dollars

MSL: mean sea level

%: Percent

C°: degree centigrade

Conversions/rates used:

USD to THB: US$1 = 35 Thai Baht
Rai to Acres: 1 Rai = 0.39 acres

Executive Summary

A country of 67 million people[1] (with an area of approximately 513,000 km^2) makes Thailand the 20th most populous country in the world.[2] Across Thailand's land mass of 513,000 km^2, roughly one third of the country's population live in urban areas, meaning that two thirds of the country's population live in rural and agricultural settings. Thailand is also a country highly vulnerable to adverse climate change impacts, placed at number 14 of countries facing the highest risks from climate change, alongside its bordering neighbors of Cambodia, Laos and Myanmar. Greater frequency and intensity of flooding during wet season and extended drought periods during the dry season are likely to pose severe challenge to water resources in Thailand.

Thailand's fertile floodplains and tropical monsoon climate have long attracted settlers as an ideal area suited to wet-rice ('tham-na'). The Greater Chao Phraya River Basin area, where the *Enhancing climate resilience in Thailand through effective water management and sustainable agriculture* project is set, in particular has flourished over centuries as a rice growing area.

The *Enhancing climate resilience in Thailand through effective water management and sustainable agriculture* project responds to projected climate change impacts, through a number of climate resilient interventions focused on Thailand's agricultural rice growing area in the provinces of Phitsanulok, Uttaradit, and Sukhothai.

This feasibility study provides an overview and contextual setting of the project area, and climate related impacts to the agricultural area according to preliminary downscaling of climate projections for the area and observed data. Results show that the projected increase in air temperature and potential evapotranspiration (PET) on agricultural water demand in the near future: both crop water demand and irrigation water requirements increase by up to 30% compared to those in historical period - highlighting the need for investments related to climate-informed water management and support to agriculture livelihoods, which are vulnerable to climate impacts. The feasibility study also explores ecosystems based adaptation measures, which can complement grey infrastructure by reducing soil erosion and sedimentation, which would otherwise affect the effectiveness and efficiency of the infrastructure. And to support farmers, various solutions are presented towards sustainable agriculture practices including, agro-ecology, organic farming, conservation agriculture and integrated practices that could provide several co-benefits of assisting agricultural resilience to climate change, enhancing biodiversity, and soil conservation – in turn also leading to more reliable and more climate resilient livelihoods.

The feasibility study further highlights the current and potential options for adapting to climate change in the area including past, present and future scenarios. It outlines the policy and institutional frameworks both supporting and acting as barriers in responding to climate change risks; innovations, research in development and networks and bodies supporting the project; best practice and lessons learnt from implemented and ongoing efforts; approaches that the project supports that build on from these best practices and lessons; the gaps, needs and barriers that the project will address in detail; and finally, the recommended approaches for the project based on the findings of this feasibility study and other feasibility studies conducted for the individual components to the project.

[1] National Statistics Office of Thailand. http://web.nso.go.th/index1.htm [accessed October 2016]
[2] The World Factbook. 2016, http://web.nso.go.th/index1.htm

1. Chapter 1: Climate Risk Profile of Thailand

1.1 Strategic context

The Kingdom of Thailand sits along Southeast Asia's tropical peninsula that stretches down 2,420 kilometers of coast on the Gulf of Thailand and the Andaman Seas, with land borders shared with Cambodia, Laos, Myanmar and Malaysia. A country of 67 million people[3] (with an area of approximately 513,000 km^2) makes Thailand the 20th most populous country in the world.[4] Across Thailand's land mass of 513,000 km^2, roughly one third of the country's population live in urban areas, meaning that two thirds of the country's population live in rural and agricultural settings. Thailand is also a country highly vulnerable to adverse climate change impacts. To date, Thailand has been ranked as the eleventh country most affected by climate-related impacts.[5] Whilst under other indices, Thailand is considered as one of the 16 countries in the extreme risk category that are most vulnerable to future climate change impacts in the coming 30 years. According to the Climate Change Vulnerability Index (CCVI), for example, which is based upon a calculation of the vulnerability of 170 countries to climate change impacts, Thailand is placed at number 14 of countries facing the extreme risks, following closely behind its border-neighbours of Cambodia, Laos and Myanmar.[6]

The IPCC Fifth Assessment Report (AR5), indicates that in Southeast Asia temperatures overall have been increasing at a rate of 0.14°C to 0.20°C per decade since the 1960s, which is predicted to increase from 0.8°C to 3.2°C by the end of the century,[7] with differences between regions and microclimates within and across Southeast Asia. A positive trend in the occurrence of heavy (top 10 percent by rain amount) and light (bottom 5 percent) rain events is predicted[8] with key determinants such as the amount and intensity of rainfall, and the rate of evaporation set to affect surface water flow and water availability.[9] This translates overall to a significantly greater frequency and intensity of flooding during wet season, and extended drought periods during the dry season presenting a significant challenge to effective water management in Thailand. The 2011 flood in Thailand is well-known for its widespread impacts and reach across many Provinces of Thailand, including the capital of Bangkok. The flood impacted heavily not only on Bangkok's greater metropolitan area of around 10.6 million people,[10] but also caused major economic losses across most sectors, and to the livelihoods of so many throughout Thailand. These '1 in 100 year' type floods are set to increase under climate change predictions[11] along with an increase in the occurrence of severe drought.[12]

Thailand's fertile floodplains and tropical monsoon climate have long attracted settlers as an ideal area suited to wet-rice ('tham-na'). The Greater Chao Phraya Greater Basin area, inclusive of the project area for *Enhancing climate resilience in Thailand through effective water management and sustainable agriculture*, has flourished over centuries as a major rice growing area. The Greater Chao Phraya Basin is Thailand's largest watershed and covers approximately 35 percent (157,924km^2) of the country's land area. As climate change impacts upon seasonal rain patterns, shorter and more intense rain events affect flood occurrences in the Chao Phraya River Basin. The

[3] National Statistics Office of Thailand. http://web.nso.go.th/index1.htm [accessed October 2016]
[4] The World Factbook. 2016, http://web.nso.go.th/index1.htm
[5] Intended Nationally Determined Contribution (INDC) Thailand, 2016: *for the period 1994 – 2013 http://www4.unfccc.int/ndcregistry/PublishedDocuments/Thailand%20First/Thailand_INDC.pdf
[6] Maplecroft risk calculators: https://maplecroft.com/about/news/ccvi.html
[7] IPCC. 2013, Climate Change 2013: The Physical Science Basis, *Intergovernmental Panel on Climate Change*, 2013
[8] IPCC. 2013, Climate Change 2013: The Physical Science Basis, *Intergovernmental Panel on Climate Change*, 2013
[9] Chaowiwat, W. Boonya-aroonnet, S. & Weesakul, S. 2016, *Impact of Climate Change Assessment on Agriculture Water Demand in Thailand*
[10] World Population Review 2016: http://worldpopulationreview.com/world-cities/bangkok-population/
[11] Hirabayashi, Y., Mahendran, R., Koirala, S., Konoshima, L., Yamazaki, D., Watanabe, S., Kim, H., Kanae, S. 2013, 'Global flood risk under climate change', *Nature Climate Change*, 3, Pp 816-821
[12] Hunukumbira, P. & Tachikawa, Y. 2012, 'River discharge projection under climate change in the Chao Phraya River basin', *Journal of the Meteorological Society of Japan Ser. II*, 90a, Pp 137-150

frequency of flood events has already increased considerably over the past 50 years.[13] With rainwater as a vital source of water, increases in temperature and longer dry seasons are also leading to water stresses and water scarcity during certain periods in the River Basin area. Improved climate change data information, dissemination, management and accessibility are much needed for responding to the impacts posed by climate change.

Combined with improved water management and agricultural livelihoods, climate change information will greatly assist in building resilience by reducing susceptibility to the increasing droughts and floods in the region. Undertaking comprehensive climate change adaptation actions in the Yom and Nan River basin is of critical importance, given that effective water management in this area would assist in mitigating flooding and buffering against drought agricultural livelihoods in the area. Such actions will in turn have co-benefits further downstream reducing flood impacts in the greater Chao Phraya River and the downstream urban areas that include metropolitan Bangkok. The improvements detailed for the *Enhancing climate resilience in Thailand through effective water management and sustainable agriculture* project are intended to adapt water management and agriculture practices to changing climatic conditions by strengthening long-term resilience to climate impacts and assisting vulnerable agricultural-livelihood based households. Given the formidable cost of upgrading existing water infrastructure, the project also includes ecosystems-based adaptation measures to complement grey infrastructure, including an impact evaluation to inform future necessary infrastructure upgrades by government in a manner that is both greener and cost-effective.

[13] Royal Irrigation Department, Thailand. 2016, *Feasibility Study of Yom and Nam O&M Project*, Bangkok.

1.2 Geographic area

Thailand is generally divided into five distinct areas of the Northern, Northeastern, Central, Eastern and Southern parts according to the climate and meteorological patterns of the country. Phitsanulok Province, Sukhothai Province, and Uttaradit Province. Phitsanulok, Sukhothai and Uttaradit fall within the Northern area shown in yellow in Figure 1 were highlighted by government partners as an adaptation priority given its important role in water management within the Great Chao Phraya River Basin and the reliance on agriculture as a livelihood of people in the area. Phitsanulok, Sukhothai and Uttaradit fall within the Northern area shown in yellow in Figure 1.

Northern area*: is divided into 15 provinces – Chiang Rai, Mae Hong Son, Chiang Mai, Phayao, Lamphun, Lampang, Phrae, Nan, Uttaradit, Phitsanulok, Sukhothai, Tak, Phichit, Kamphaeng Phet and Phetchabun. This is the northern hilly and mountainous region of Thailand, and is the source for many of Thailand's river systems.*

Northeastern area: *Comprises 20 Provinces, of Nong Khai, Bueng Kan, Loei, Udon Thani, Nong Bua Lam Pu, Nakhon Phanom, Sakon Nakhon, Mukdahan, Khon Kaen, Kalasin, Maha Sarakham, Roi Et, Chaiyaphum, Yasothon, Amnat Charoen, Ubon Ratchathani, Sri Sa Ket, Nakhon Ratchasima, Buri Ram, and Surin. This area is the northeastern plateau.*

Central area*: the Central area of Thailand is divided between 18 Provinces: Nakhon Sawan, Uthai Thani, Chai Nat, Sing Buri, Lop Buri, Ang Thong, Sara Buri, Suphan Buri, Ayutthaya, Pathum Thani, Kanchanaburi, Ratchaburi, Nakhon Pathom, Nonthaburi, Bangkok Metropolis, Samut Prakan, Samut Sakhon and Samut Songkhram.*

Eastern area*: South and southeast of the area adjacent to the Gulf of Thailand and including the plains and valleys across to the northern, central and eastern portions – this area covers the Nakhon Nayok, Prachin Buri, Sra Kaeo, Chachoeng Sao, Chon Buri, Rayong, Chanthaburi and Trat Provinces.*

Southern area*: the southern area stretches down the peninsula of Thailand between the Andaman and South China Seas. It covers the 16 Provinces of Phetchaburi, Prachuap Khiri Khaan, Chumphon, Surat Thani, Nakhon Si Thammarat, Phatthalung, Songkhla, Pattani, Yala, Narathiwat, Ranong, Phang Nga, Krabi, Phuket, Trang, and Satun.*

Figure 1: Meteorological zones of Thailand[14]

[14] *Source: Thai Meteorological Department 2014*: http://www.tmd.go.th/mainmenu/images/thailand_map_en.gif

1.3 Socio-economic setting

Thailand became an upper-middle income economy with average per capita annual income of $5,775 in the 2015 period, having made significant progress in social and economic development. Thailand is considered an economic development success stories, moving from low-income to upper-income country status in less than one generation.[15] Poverty has declined from 67 percent in 1986 to 11 percent in 2014.[16] The poverty average overall per head in Thailand, is low at 1.87 percent of the population, based on provincial poverty lines.[17] Although overall inequality on the inequality-adjusted human development index (IHDI) globally sits at 0.57 for Thailand. Income inequality is evident between urban and rural profiles.

	IHDI value	Overall loss (%)	Human inequality coefficient (%)	Inequality in life expectancy at birth (%)	Inequality in education (%)	Inequality in income (%)
Thailand	0.576	20.6	19.9	9.8	16.1	34.0
Viet Nam	0.549	17.5	17.4	12.1	18.0	22.0
Philippines	0.547	18.1	17.8	15.2	11.6	26.8
East Asia and the Pacific	0.572	19.4	19.2	11.7	18.4	27.4
High HDI	0.600	19.4	19.0	10.7	16.8	29.4

Table 1 Thailand's in-equality adjusted human development index (IHDI) for 2014.

Source: UNDP 2015, Human Development Report 2015: Briefing note on the 2015 Human Development Report

Poverty in Thailand predominately has a rural-profile, which fluctuates according to vulnerabilities in the agricultural sector – such as faltering economic growth, falling agricultural prices, and extreme events (i.e. droughts).[18] In 2013, for example, 80 percent of the country's poor 7.3 million live in rural areas, and a further 6.7 million were living within 20 percent above the national poverty line.[19] 48 percent of Thailand's Provinces have a poverty head count of 10 percent or less, and a further 25 percent of Provinces have a poverty headcount rate of between 11 and 20 percent.[20] Proportionally, Sukhothai, Phitsanulok and Uttaradit Provinces, included as part of the Northern Central region, have relatively high poverty levels. Impacts from climate change are more severely felt by those with higher levels of poverty, predominately due to the high level of dependence on natural resources, and in general, a limited capacity in terms of access to resources for responding to climate vulnerability and extremes.[21] Higher levels of poverty for the Northern-Central region in turn, means that this area also has an increased level of vulnerability to climate change impacts, with lower levels of access to resources for adaptation strategies and in which to build climate resilience.

Given the rural-profile of poverty and with almost half of the country's population dependent on the agricultural sector for their livelihoods, minimizing climate change risk to the sector is crucial. The total number of households engaged in agriculture in Thailand is almost 6 million (5, 910, 791 households) comprising a total 23,686,102 (almost 24 million)[22] of the country's 67 million national population. The agricultural sector in Thailand additionally, directly and indirectly, employs roughly half of the country's population.[23] Overall, Thailand's agriculture sector is dominated by smallholder farmers - most of who own their land outright, although tenancy is widespread in parts

[15] Overview, Thailand: http://www.worldbank.org/en/country/thailand/overview
[16] Overview, Thailand: http://www.worldbank.org/en/country/thailand/overview
[17] National Office of Statistics, 2015
[18] Overview, Thailand: http://www.worldbank.org/en/country/thailand/overview
[19] Overview, Thailand: http://www.worldbank.org/en/country/thailand/overview
[20] National Office of Statistics, 2015
[21] Abeygunawardena, P. Vyas, Y., Knill, P., Foy, P., Harold, M., Steele, P., Tanner, T., Hirsch, D., Oosterman, M., Rooimas, J., Debois, M., Lamin, M., Liptow, H., Mausolf, E., Verheyen, R., Agrawala, S., Caspary, G., Paris, R., Kashap, A., Sharma, R., Mathur, A., Sharma, M., Sperling, F. 2003, *Poverty and climate change: Reducing the vulnerability of the poor through adaptation,* http://www.oecd.org/env/cc/2502872.pdf
[22] 'Agricultural Statistics of Thailand for the year 2011- 2012', *Thailand Office of Agricultural Economic*, 2016: www.oae.go.th
[23] National Statistical Office Thailand, 2012

of the Central Plain. On average nationally, farmers own land sizes of around 20 Rai (equivalent to 3.2 hectares). However, in the project area (Phitsanulok, Sukhothai and Uttaradit), land ownership sizes tend to be larger, ranging from 25 to 29 Rai (4.00 - 4.64 hectares) per household with the area also employing a significant portion of the area's population in seasonal labouring.

1.4 Environmental profile

Thailand traverses a region of many terrains, distinct ecological regions, and biomes. In particular, Thailand straddles two mountain systems – the Central Cordillera and the Cordillera of Annam. The wide depressions between these two mountain systems contain the alluvial plains of the Chao Phraya and Khorat plain.[24] Thailand in total has 2,600km of coastline rich in fisheries, coral reefs, mangroves and marine habitat.[25] There are 11,625 species of vascular plants[26] as well as 1,715 known species of amphibians, birds, mammals and reptiles, 5.1 percent of which are endemic, and 5.8 percent of which are threatened species. Dramatic economic growth in Thailand is attributed with causing a number of environmental problems in the country. These include air and water pollution, wildlife declines, deforestation, soil erosion, water scarcity, and waste issues. Overall, Thailand has nine ecological regions that are distinct as well as three different biomes across a total landmass of 513,000 km^2. Thirteen percent of which is protected.[27] These ecological regions are the following:

Ecological Region	*Biome*
Kayah-Karen Montane Rainforests	*Tropical and subtropical moist broadleaf forests*
Northern Indochina Subtropical Forests	*Tropical and subtropical moist broadleaf forests*
Tenasserim-South Thailand Semi-evergreen Rainforests	*Tropical and subtropical moist broadleaf forests*
Cardamom Mountains Moist Forests	*Tropical and subtropical moist broadleaf forests*
Penisular Malaysian Lowland and Mountain Forests	*Tropical and subtropical moist broadleaf forests*
Central Indonchina Dry Forests	*Tropical and subtropical dry broadleaf forests*
Mekong River	*Freshwater*
Salween River	*Freshwater*
Andaman Sea	*Marine*

Source: WorldAtlas – Ecological Regions of Thailand, 2016[28]

Thailand's three biomes are:

1. The tropical and subtropical moist broadleaf forest along the equatorial belt: which includes the Kayah-Karen Montane Rainforests, Northern Indochina Subtropical Forests, Tenasserim-South Thailand Semi Evergreen Rainforests, Cardamon Mountain Moist forests, Penisular Malaysian lowland and mountain forests, as well as central Indonchina dry forests. These areas are habitat to many of the endangered plant species (e.g. the Hopea pierrei canopy tree) and animal species (Asian elephant, Indochinese tiger, clouded leopard, Malayan sun bear, Sumatran rhinoceros).

2. The freshwater biome: the Mekong River and the Salween River ecological regions – characterized by rivers, lakes, streams, coastal rivers and estuaries, floodplains and wetlands. The Mekong River (as part of the 12th longest river system in the world) has the second richest level of biodiversity of any other (transboundary) region

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[24] 2016. 'Physiographic regions, Physical Environment of Thailand', Soil Resource, *Land Development Department*: http://www.ldd.go.th/web_eng56/Soil_Resource/Physial_Environment_of_Thailand/Physiographic_Regions.html
[25] Paw, J., Bunpapong, S., White, A. & Sadorra, M. 1988, *The coastal environmental profile of Ban Don Bay and Phangnga Bay, Thailand*, Association of Southeast Asian Nations/United States Coastal Resources Management Project Technical Publications Series 2
[26] Thailand, Mongabay: http://rainforests.mongabay.com/20thailand.htm
[27] Ecological Regions of Thailand http://www.worldatlas.com/articles/ecological-regions-of-thailand.html
[28] WorldAtlas, 2016 – Ecological Regions of Thailand: http://www.worldatlas.com/articles/ecological-regions-of-thailand.html

globally – being home to 20,000 plant species, 1,200 bird species, 430 mammal species, 850 freshwater fish species, and 800 reptile and amphibian species. It also includes the Irrawaddy dolphin, Siamese crocodile, and smooth coated otter. The Salween River region is also rich in biodiversity – being home to teak trees, Asian redwoods, and cherry woods amongst others.

3. The Marine biome: the marine biome of Thailand includes the Andaman Sea ecological region, are home to and support diverse mangrove and sea grass areas, endangered dolphins, leatherback turtles, hawksbill turtles, green turtles, olive ridley turtles, and extensive coral reef and fish systems. [29]

1.4.1 Water resources

Thailand has 25 river basin systems (including 254 sub-basins). Of these river basins – there are two principal systems, the Mekong and Chao Phraya River systems. The Mekong River forms much of the border between Thailand and Laos, eventually flowing through southern Laos into Cambodia and on to Vietnam. The Chao Phraya River system is the main river system flowing through the heart of Thailand and defining much of central and northern Thailand, including Bangkok. The Chao Phraya River and its tributaries form the largest watershed in Thailand, covering approximately 35 percent of the nation's land, and draining an area of 157,924 km^2. In total, the Chao Phraya serves a population of around 25 million people living within its catchment area. With its tributary headlands gathering in the northern mountains of Thailand, the Chao Phraya River starts with the confluence of its tributaries - the Yom and Nan Rivers and the Wang and Ping Rivers at Nakhon Sawan. The principal tributaries are the Pa Sak River, the Sakae Krang River, the Nan River (along with its principal confluent the Yom River), the Ping River (with its principal confluent the Wang River), and the Tha Chin River. Each of these tributaries (including the Chao Phraya itself) are further branched by additional minor tributaries often referred to as Khwae, and the eight sub-river basins including the Ping, Wang, Yom, Nan, Chao Phraya, Sakaekrung, Pa Sak and Tha Chin. The Yom and Nam River Basins in Uttaradit, Phitsanulok and Sukhothai Provinces, are part of the middle-upper catchments of the Greater Chao Phraya River Basin area. After Nakhon Sawan, the Chao Phraya flows from north to south for 372 km from the central plains through Bangkok to the Gulf of Thailand. In Chai Nat province, the river splits into the main river course and the Tha Chin River, which then flows parallel to the main river section and exits to the Gulf of Thailand in Samut Sakhon Province. In the low alluvial plain which begins below Chai Nat Province, many small canals (khlong) split off from the main river. These canals are used for the irrigation of the region's rice paddies. Each are highly vulnerable to climate change, as well as being critical in both determining, and in managing, the river flow to the Chao Phraya River.

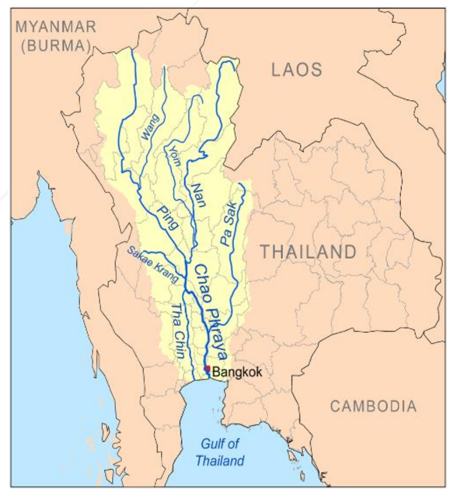


Figure 2: River Basin tributaries of the Chao Phraya

1.4.1.1 Groundwater resources

Within Thailand's 25 main drainage basins are six groundwater basins. These are the North, Upper Central, Central, Lower Central, Northeast and South groundwater basins.

[29] Ecological Regions of Thailand http://www.worldatlas.com/articles/ecological-regions-of-thailand.html

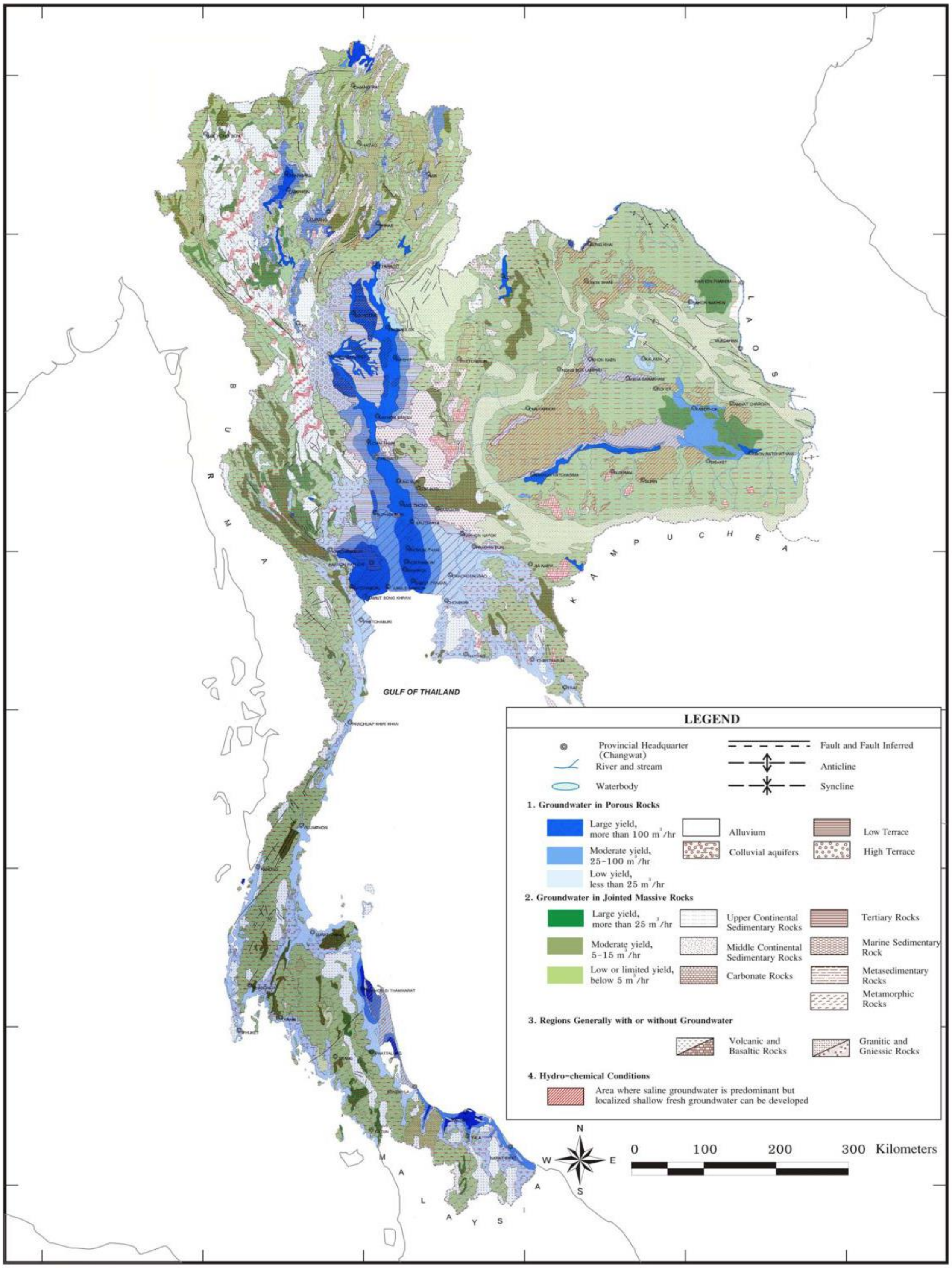
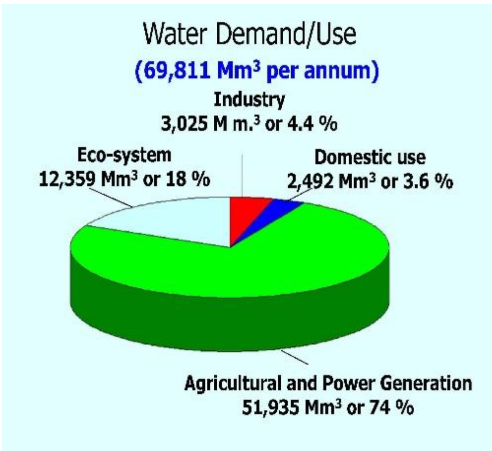


Figure 3: Hydrogeological map of Thailand

Source: Siripornipul, C. 2014, Department of Water Resources, MONRE, Thailand[30]

[30] Siripornipul, C. 2014, 'Technological Demand of Water Management', Department of Water Resources, Ministry of Natural Resources and Environment (MoNRE), ASEM Seminar on Sustainable Management of Water Resources in the context of urbanization, China, May 2014.

Overall, according to a study undertaken in 2013,[31] water demand in Thailand per annum on average totals around 70,000Mm3 per year. Of this, groundwater extraction totals 11,047Mm3 per year (around 11 percent of the recharge). The country has groundwater storage of 1,130,000Mm3 and surface storage of 76,000Mm3. Agricultural users are the dominant consumers of surface water, with estimates being that agriculture use sits at 70 percent of surface water use.[32]



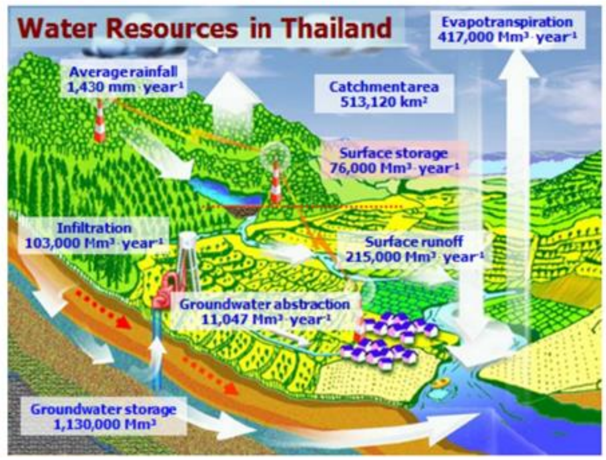


Figure 4: Water demand use

Source: Siripornipul, C. 2014, Department of Water Resources, MONRE, Thailand[33]

The Central Plain area of Thailand, which holds the Provinces of Phitsanulok, Sukhothai and Uttaradit – is a large plain, formed through sediment deposits as a result of fluvial processes into flood plains, terraces and swamp areas. In terms of hydrology, the Central Plain is also the main reservoir of groundwater for Thailand. It holds eight separate aquifers. Overall, groundwater extraction in Thailand has dropped significantly since the 2004 introduction of the Groundwater Act. However, in certain areas there has been extraction of groundwater at a rate higher than can be recharged naturally – which has caused a decline in groundwater levels, land subsidence and seawater intrusion. To monitor the situation, a comprehensive monitoring system using 156 monitoring stations and 474 observation wells operates as an extensive network around greater Bangkok and its vicinity, and across the country 1,351 monitoring wells are in place.

[31] Fornes, J. & Pirarai, K. 2013, 'Groundwater in Thailand', *Journal of Environmental Science and Engineering* B, 3, Pp 304-315. http://www.davidpublisher.org/Public/uploads/Contribute/55078898cb5e0.pdf

[32] Fornes, J. & Pirarai, K. 2013, 'Groundwater in Thailand', *Journal of Environmental Science and Engineering* B, 3, Pp 304-315. http://www.davidpublisher.org/Public/uploads/Contribute/55078898cb5e0.pdf

[33] Siripornipul, C. 2014, 'Technological Demand of Water Management', Department of Water Resources, Ministry of Natural Resources and Environment (MoNRE), ASEM Seminar on Sustainable Management of Water Resources in the context of urbanization, China, May 2014.

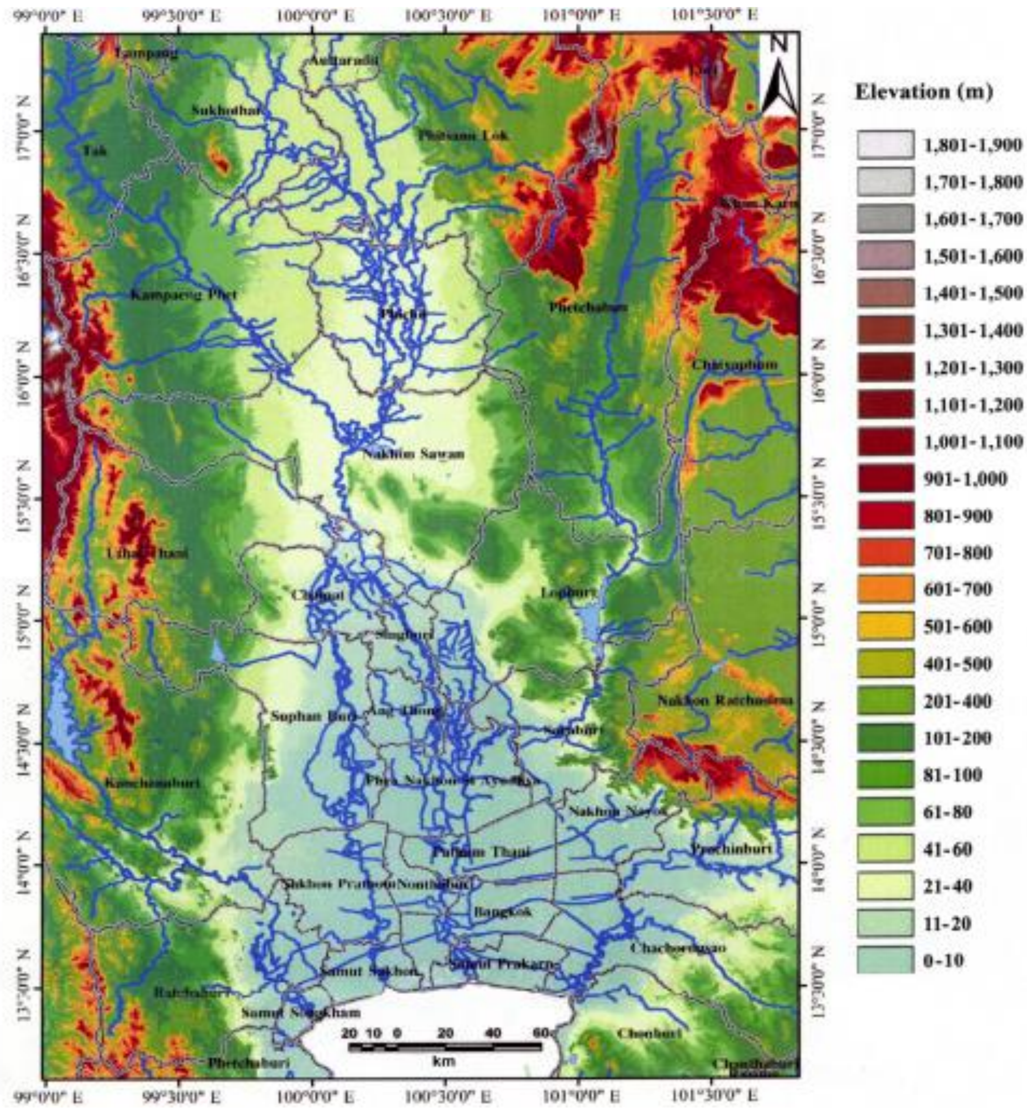


Figure 5: Topographic map showing the Central Plain and project area
Source: Department of Groundwater Resources, Ministry of Natural Resources and Environment, Thailand.

Management of Thailand's groundwater resources falls under the jurisdiction of the Groundwater Resources Department, under the Ministry of Natural Resources and Environment (see 3.3.2). The main issues affecting Thailand's groundwater supplies are pollution; predominately derived from agricultural sources into shallow aquifers, and petrochemical industry organic compounds that affect coastal area aquifers around Bangkok. The upper parts of the Chao Phraya River Basin, in and around Phitsanulok, have faced continuous groundwater level decreases due to over-extraction for irrigation.[34] Within the northeastern area, groundwater too is also largely affected by drought.[35]

[34] Uppasit, S., Silaratana, N., Fuangswasdi, A., Chusanatus, S., Pavelic, P. & Kriengsak, S. 2013, 'Managed aquifer recharge using infiltration pond: Case study of Ban Nong Na, Phitsanulok, Thailand', *Journal of Earth Science and Engineering*, 1. Pp 14-22
[35] Fornes, J. & Pirarai, K. 2013, 'Groundwater in Thailand', *Journal of Environmental Science and Engineering* B, 3, Pp 304-315. http://www.davidpublisher.org/Public/uploads/Contribute/55078898cb5e0.pdf

1.5 Climate Profile of Thailand

Thailand is one of the 16 countries identified globally as being in the 'extreme risk' category of those most vulnerable to future climate change impacts over the next 30 years.[36] The main impacts due to climate change in Thailand being related to droughts and floods.[37] Extreme, severe drought and flood are likely to be experienced increasingly in the near and longer-term future, as a result of the combined effects of a more vigorous hydrological cycle, combined with enhanced surface drying due both to anthropocentric climate change and the anomalous oscillations of ENSO.[38] Climate change is expected to increase both the magnitude and frequency of extreme precipitation events, leading to more intense and frequent flood events. At the same time, Thailand has already experienced increases in temperatures, with an overall decrease in the number of days of rain, and an increase in the daily rainfall intensity.[39]

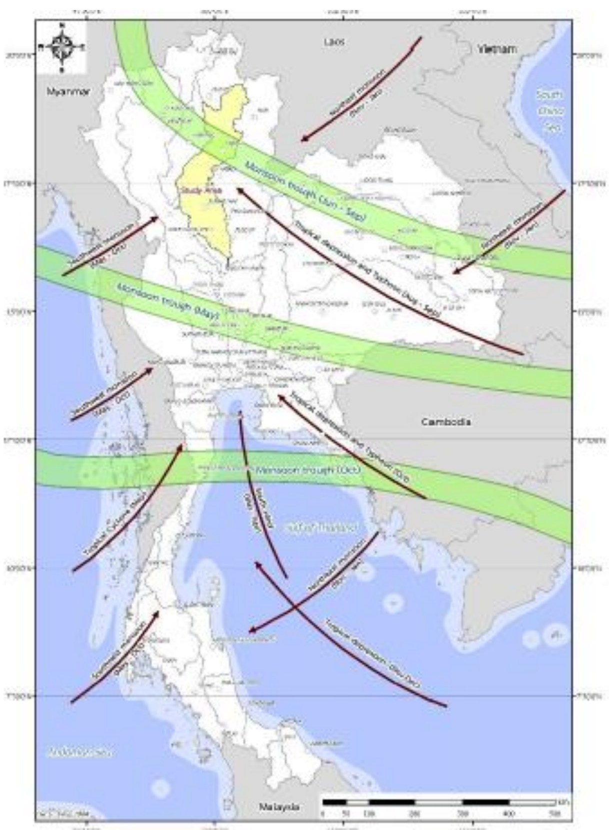


Figure 6: Monsoon duration and directions in Thailand

Source: Thai Meteorological Department data

1.5.1 Climatic zones of Thailand

Thailand is situated in the center of peninsular Southeast Asia between 5°37'-20°27' North and 97°22'-105°37' East. The climate of Thailand is under the influence of seasonal reversals of monsoon winds (i.e. southwest monsoon and northeast monsoon, experiencing a wet and humid tropical climate throughout the year). Figure 6 (left) shows moving directions and periods of monsoons over the country. From the meteorological point of view, the climate of Thailand can be allotted into three seasons of: 1) rainy or southwest monsoon season (mid-May to mid-October), when the southwest monsoon prevails over Thailand and abundant rain occurs over the country; 2) winter or northeast monsoon season (mid-October to mid-February), when there is a mild period of the year with cold in December and January in upper Thailand but there is a great amount of rainfall in Southern Thailand's East Coast, and; 3) summer or pre-monsoon season, mid-February to mid-May, which is the transitional period from the northeast to southwest monsoons, and the weather becomes warmer, especially in upper Thailand, with April as the hottest month.

According to climate pattern and meteorological conditions, Thailand is divided into five parts i.e. Northern, Northeastern, Central, Eastern and Southern Parts. The climate of Thailand is under the influence of monsoon

[36] Intended Nationally Determined Contribution (INDC) for Thailand http://www4.unfccc.int/ndcregistry/PublishedDocuments/Thailand%20First/Thailand_INDC.pdf
[37] Thampanishvong, K. 2014, *Farmers' Adaptation to Extreme Weather Events in the Chao Phraya River Basin*, Thailand Development Research Institute, October 15 2014
[38] Limsakul, A., Chidthaisong, A. and Boonpragob, K. 2011, *Thailand's First Assessment Report on Climate Change: Working Group I-Scientific Basis of Climate Change*, Thailand Research Fund.
[39] Intended Nationally Determined Contribution (INDC) for Thailand, 2015: http://www4.unfccc.int/ndcregistry/PublishedDocuments/Thailand%20First/Thailand_INDC.pdf

winds, namely Southeast, Southwest and Northeast. Rainfall during this period is not only caused by the southwest monsoon but also by the Inter Tropical Convergence Zone (ITCZ) and tropical cyclones, which produce a large amount of rainfall. These monsoons have influence over the Chao Phraya River Basin. The Southwest monsoon, which occurs from May to October, brings a stream of warm moist air from the Indian Ocean towards Thailand causing abundant rain over the country, especially the windward side of the mountains. After that, from October to February, the Northeast monsoon brings cold and dry air from the anticyclone Mainland China to major parts of Thailand in winter season. The Yom-Nan area is normally influenced by depressions and typhoons in October and heavy rainfall usually occurs. From March to April, the south wind moves from the Gulf of Thailand to the shore and other parts of the country. It brings warm air from the equator, which leads to a temperature rise in the country and including the Yom-Nan area during the summer time. Upper Thailand (i.e. the Northern, Northeastern, Central and Eastern parts), usually experiences a long period of warm weather because of its inland nature and tropical latitude zoning. In the southern region however, temperature is generally mild throughout the year because of the maritime characteristic of that region. Table 3 below shows seasonal mean temperature in the various parts of Thailand. Seasons in Thailand are generally referred to as cool/winter (November – January), hot/summer (February – April) and rainy (May – October. They are the rainy season, which is from May until October, the cold season, which is from November until January, and the hot season, which is from February until April.

Region	Winter	Summer	Rainy
North	23.4	28.1	27.3
Northeast	24.2	28.6	27.6
Central	26.2	29.7	28.2
East	26.7	29.1	28.3
South			
-East Coast	26.3	28.2	27.8
-West Coast	27.0	28.4	27.5

Based on 1981-2010 period

Table 2: Seasonal mean temperatures (°C) in various parts of Thailand

For rainfall, upper-northern areas of Thailand usually experience dry weather in winter because of the northeast monsoon, which is a main factor in controlling the climate of this region. Rainy season in the southern part is different from upper Thailand. Abundant rain occurs during both the southwest and northeast monsoon periods. According to a general annual rainfall pattern, most areas of the country receive 1,200mm to 1,600mm a year. Some areas on the windward side, particularly Trat province in the Eastern Part and Ranong province in the Southern Thailand's West Coast, have more than 4,500mm a year. Table 4 below shows seasonal rainfall variations across each area of Thailand.

Region	Winter	Summer	Rainy	Annual rainy days
North	100.4	187.3	943.2	122
Northeast	76.3	224.4	1103.8	116
Central	127.3	205.4	942.5	116
East	178.4	277.3	1433.2	130
South				
-East Coast	827.9	229.0	680	145
-West Coast	464.6	411.3	1841.3	178

Based on 1981-2010 period

Table 3: Seasonal rainfall (mm) in various parts of Thailand

1.5.2 Climate in Thailand: past, present and future impacts

The most urgent problems attributed to climate change in Thailand are floods and droughts.[40] [41] Recent studies have shown that Thailand has indeed experienced significant country-wide warming over the last four decades, as well as extreme events associated with both the cold and warm extremes of daily minimum and maximum temperature distributions that have changed accordingly. Recent studies conducted have concluded that Thailand as a whole has warmed up over the last 50 years.[42] There is evidence that maximum, mean and minimum temperatures in Thailand as a whole have increased significantly by 0.86, 0.95 and 1.45°C over the 1955-2009 period (see Figure 7). For temperature extreme indices, a significant upward trend is seen over the annual number of warm nights and days, the annual occurrence of warm spells, tropical nights, summer days, and the highest and lowest values of daily minimum temperatures. Changes in these temperature extreme indices are consistent with a significant shift in the temperature distribution toward warmer conditions over the recent decades. In contrast, significant downward trends are observed in the annual number of cold nights and days, the annual occurrence of cold spells, diurnal temperature range and annual extreme temperature range. A recent examination of 44 long record quality controlled first order surface weather stations across Thailand for the period from 1955 to 2011 indicated that precipitation in Thailand has become less frequent throughout most areas and there is a significant reduction in the occurrence of wet days – while precipitation events have become more intense.[43] These impacts are consistent with the fifth assessment report (AR5) from the Intergovernmental Panel on Climate Change (IPCC), which indicates that temperatures in Southeast Asia have been increasing at a rate of 0.14°C to 0.20°C per decade since the 1960s, and predicts increases from 0.8°C to 3.2°C for the overall region by the end of this century.

[40] Shrestha, S. 2014, 'Chapter 2: Assessment of Water Availability Under Climate Change Scenarios in Thailand', *Climate Change Impacts and Adaptation in Water Resource and Water Use Sectors*, Springer International Publishing, Switzerland

[41] SEA START RC, 2009

[42] e.g. Limsakul, A. and Singhruck, P. (2016). Long-term trends and variability of total and extreme precipitation in Thailand. *Atmospheric Research*, 169, 301-317; Limjirakan, S. and Limsakul, A. (2012). Observed trends in surface air temperatures and their extremes in Thailand from 1970 to 2009. *Journal of the Meteorological Society of Japan*, 90(5), 647−662.; Limsakul, A., Chidthaisong, A. and Boonpragob, K. (2011). *Thailand's First Assessment Report on Climate Change: Working Group I-Scientific Basis of Climate Change*. Thailand Research Fund.
Limsakul, A., et al. (2016). Thailand's Second Assessment Report on Climate Change: Working Group I- Updated climate change knowledge and information of Thailand.; Limsakul A, Limjirakan S. Suthamanuswong B. (2010). Asian summer monsoon and its associated rainfall variability in Thailand. EnvironmentAsia, 3, 79-89; Limsakul, A., and S. Limjirakan, (2011). Observation of surface and atmospheric climate change in Thailand (in Thai). Thailand's First Assessment Report on Climate Change-Synthesis Knowledge on Scientific Basis (Eds: Boonpragob K, Limsakul A, Chidthaisong A). Thailand Research Fund, Thailand, 39-62.

[43] Limsakul, A. and Singhruck, P. 2016, 'Long-term trends and variability of total and extreme precipitation in Thailand', *Atmospheric Research*, 169, Pp 301-317.

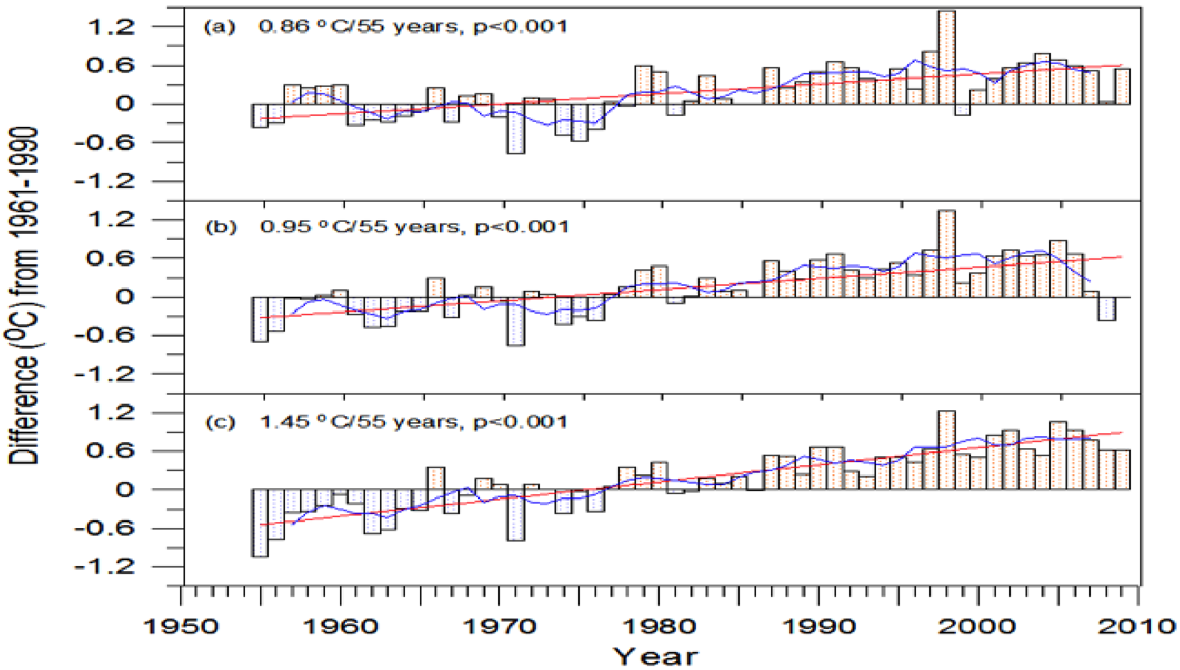


Figure 7: Maximum, mean and minimum temperature

Shows annual anomalies of maximum temperature (a), mean temperature (b) and minimum temperature (c) relative to the 1961 to 1990 mean. The red and blue lines represent linear trends and 5-year running means. Non-parametric Kendall' tau based slope estimator is used to test statistical significance of linear trends.[44]

There was no significant nationwide average change in precipitation patterns between 1955 to 2014, according to one study, based on daily precipitation data from surface weather stations of the Thai Meteorological Department (TMD) (see figure 8).[45] However, when considering the linear averages of different regions (8c-f) it becomes apparent that there are significant regional differences with the Northeastern and Eastern part of the South of Thailand experiencing an increase in precipitation, while the East and Western part of the South experienced a decrease in precipitation intensity. Another noteworthy finding from the study is the observation that Bangkok Metropolis has experienced wetter and more intense conditions and a concomitant increase in the frequency and magnitude of heavy precipitation events.

[44] Thailand's Intended Nationally Determined Contribution (INDC), (2015). United Nations Framework on Climate Change Convention (UNFCCC)
[45] Limsakul, A. and Singhruck, P. 2016, 'Long-term trends and variability of total and extreme precipitation in Thailand', *Atmospheric Research*, 169, Pp 301-317.

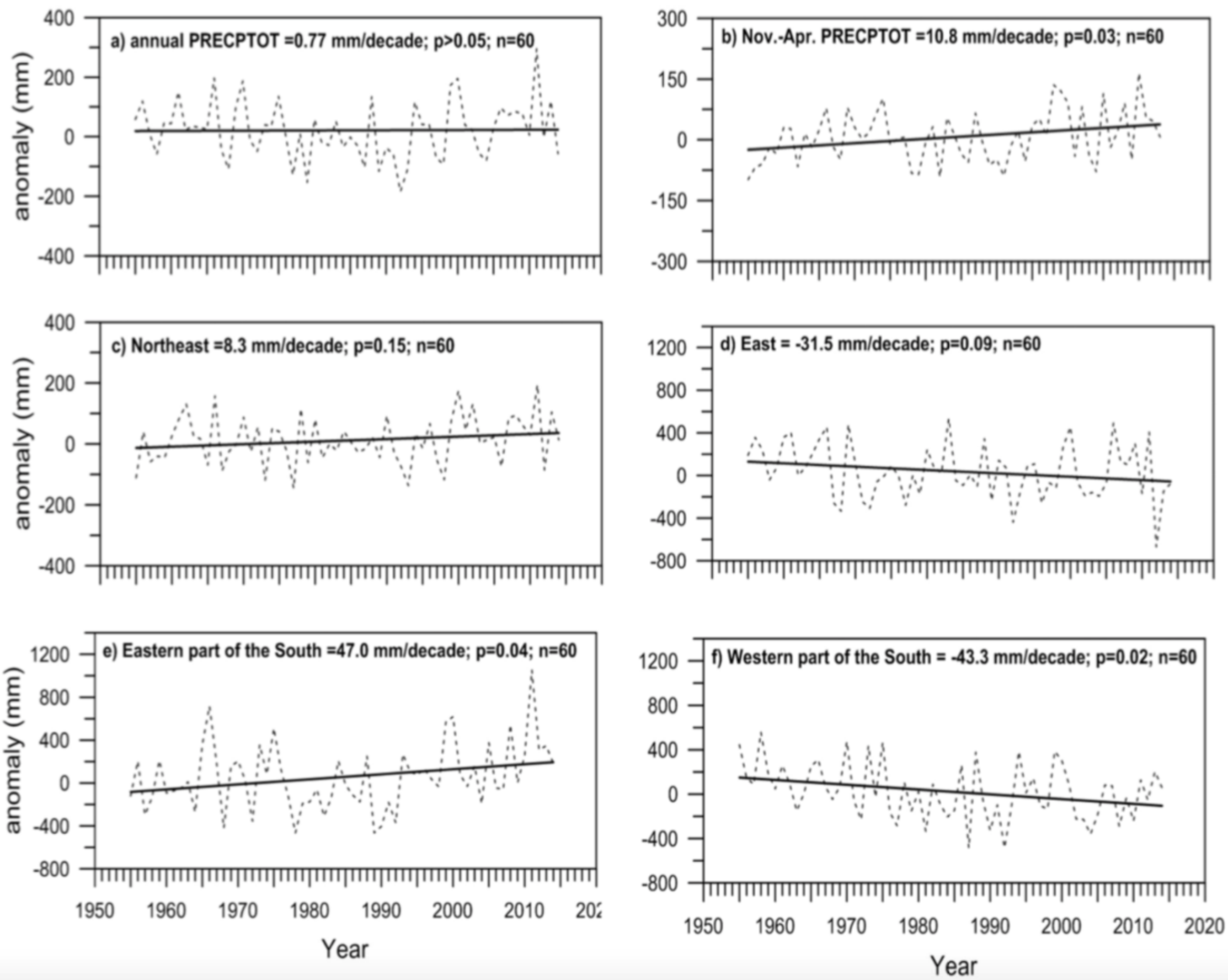


Figure 8: Regional-average anomalies of (a) annual PRCPTOT[46] and (b) Nov.–Apr. PRCPTOT, and subregional-average anomalies of annual PRCPTOT for (c) Northeast, (d) East, (e) western part of the South and (f) eastern part of the South. The solid lines represent linear trends, and the significance of the trends was assessed by Kendall's tau test. The 1971–2000 means at the individual stations for PRCPTOT which the anomalies are departure from are in range of 981–4718 mm.[47]

1.5.2.1 Downscaling of climate data

To provide information on the changes in key climate variables at a local scale over the Yom-Nan River Basin and project area, daily minimum, mean and maximum temperatures and precipitation data with 20 x 20 km grid resolution extracted in the region of 16.6° – 17.8° latitude and 99.4° – 100.2° longitude which covers Sukhothai Province were analyzed for the period of 1980 - 2069. These data were downscaled by the PRECIS (Providing REgional Climates for Impacts Studies) regional climate model carried out by Southeast Asia START Regional Center (SEA START RC). The Global Circulation Model (GCM) ECHAM5 and HadCM3 outputs simulated under moderate projection of greenhouse gases (SRES A1B scenario) had been used as initial data downscaled by the PRECIS. The extracted data comprises 18 grids as shown in Figure 9 were used to analyse trend and long-term means of past

[46] Precipitation Totals = PRCPTOT
[47] Limsakul, A. and Singhruck, P. 2016, 'Long-term trends and variability of total and extreme precipitation in Thailand', *Atmospheric Research*, 169, Pp 301-317.

(1980 - 2009), present to near future (2010 – 2039) and middle future (2040 - 2069) periods both mean and extreme events of temperature and precipitation.

Core temperature and precipitation indices mostly focused on extreme events that are recommended by the World Meteorological Organization- Commission for Climatology (WMO-CCI)/World Climate Research Program (WCRP)/Climate Variability and Predictability (CLIVAR) for calculations. These indices are commonly chosen for assessment of many aspects of the changing climate including the changes in intensity, frequency and duration of temperature and precipitation events. They represent events that occur several times per year, giving them more robust statistical properties than measures of extremes which are far enough into the tails of the distribution so as not to be observed during some years.

These temperature and precipitation indices were calculated for downscaling at each grid and an averaged time series was then created for every index by averaging all grids. Linear trends were calculated from the annual and seasonal series of temperature and precipitation indices using a non-parametric Kendall's tau-based slope estimator. This method is more suitable for addressing non-normal distributions of data and robust to the effect of outliers in a series. In addition, 30-year means as a time frame recommended by WMO to detect any anthropogenic –induced long-term changes in climate were calculated for the period 1980-2009 as the base period, 2010-2039 as the present to near future and 2040-2069 as the middle future. The means for the present to near future and the middle future were visually and statistically compared with the mean of the base period.

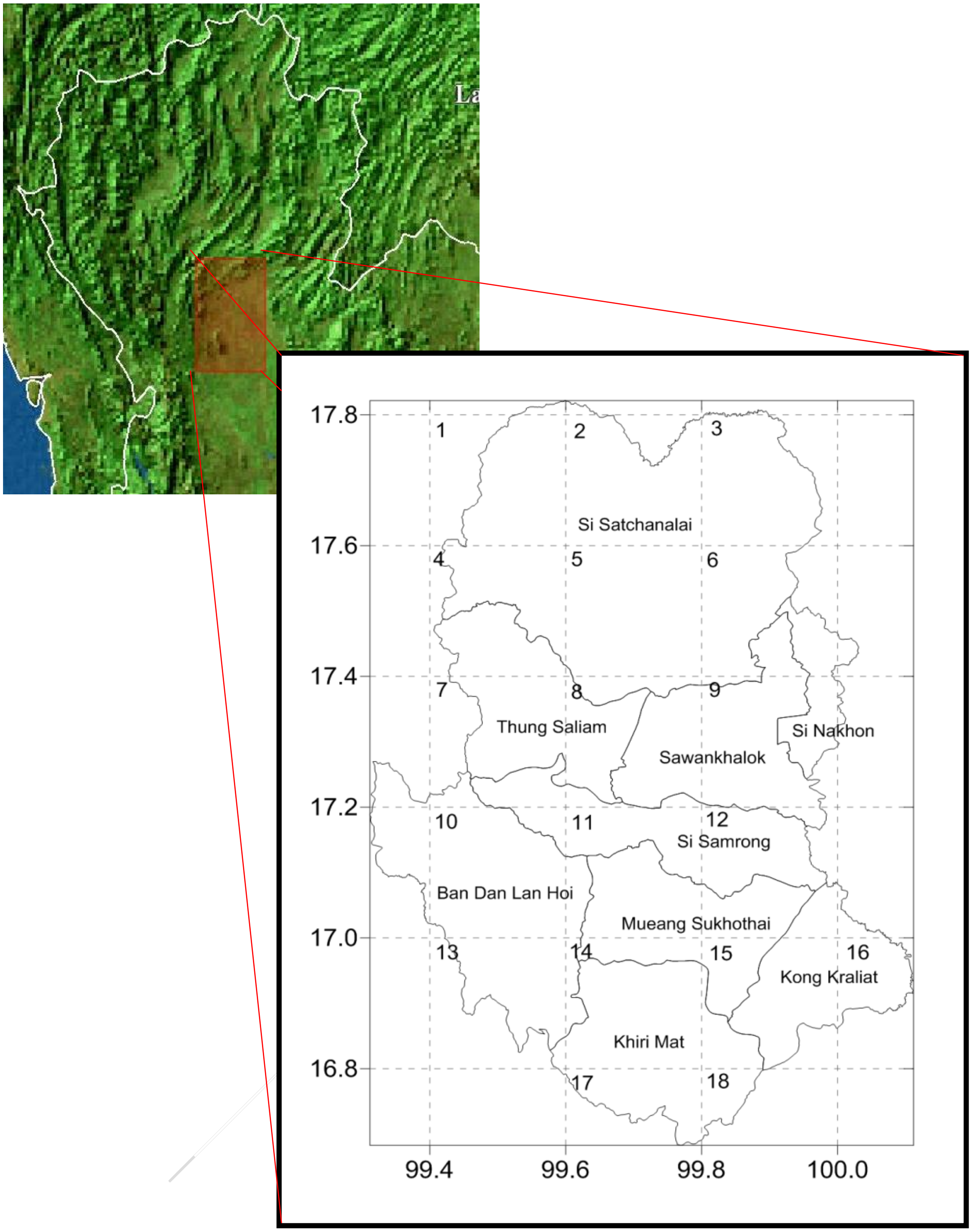
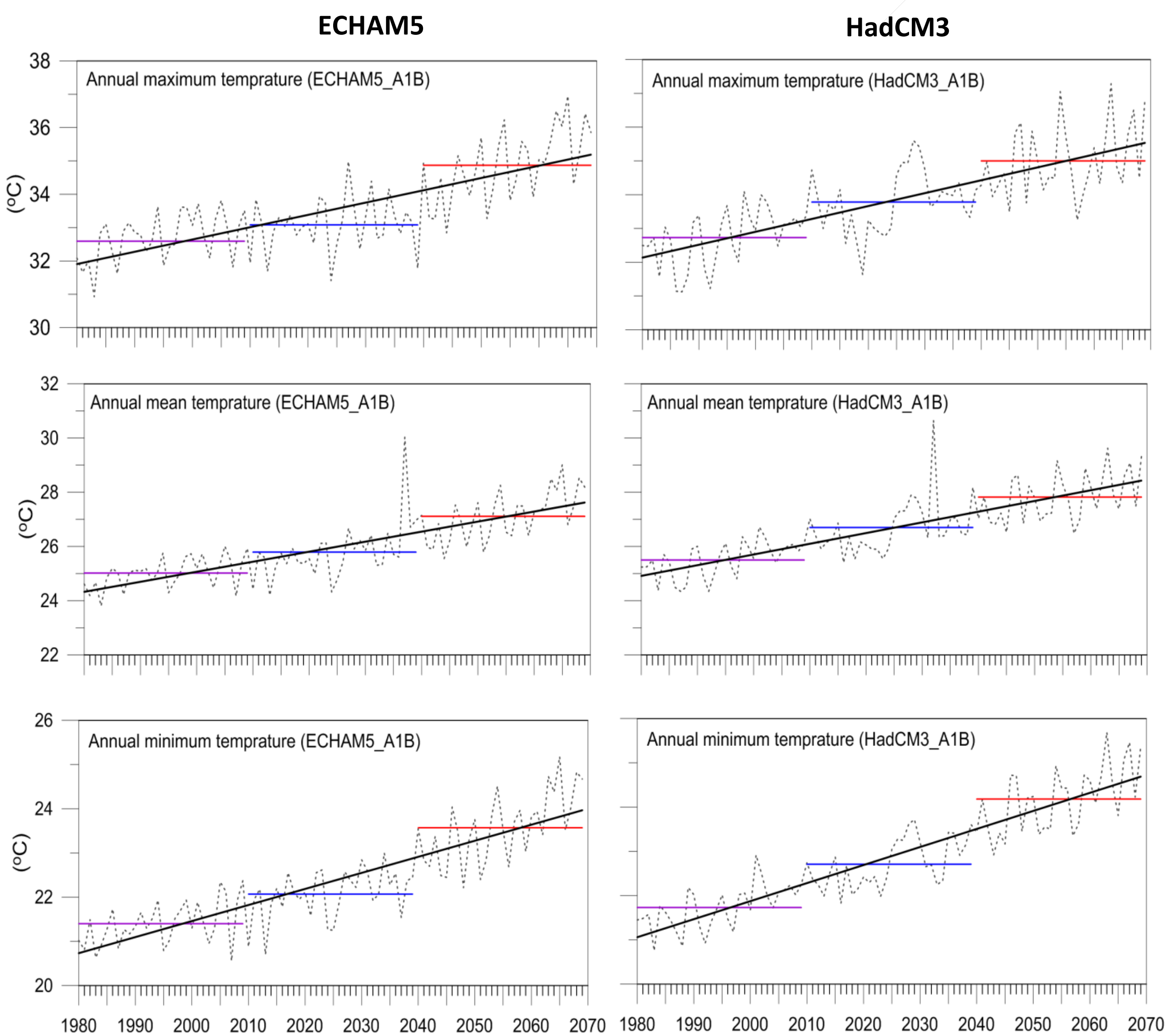


Figure 9: the boundary of the gridded minimum, mean and maximum temperature and precipitation data

*extracted for the database of the SEA START RC in the region of 16.6º – 17.8º latitude and 99.4º – 100.2º longitude which covers Sukhothai Province. The gridded size is 20 x 20 km and total extracted data are 18 grids as shown in Figure 9.

1.5.2.1.1 Temperature

When modeled by Conformal Cubic Atmospheric Model (CCAM) under IPCC SRES scenario A1Fl, the average temperature is expected to increase by 1-2°C. Statistical downscaling from the GCM GFL-R30 under B2 scenario for the project area indicates the temperature increase to be below 1°C for 2040 – 2059. However, dynamical downscaling from MM5-Regional Climate Model by using CCSM3 indicates that during 2010-2039 under SRES A1B scenario, summer temperatures over Thailand are projected to increase by 0.1-0.6°C. Similarly, in the ensemble study it was shown that compared to the average during 1980-1989, the average temperature during 2040-2059 will increase by 1-2°C, especially during the summer months the temperature would increase by 3-5°C. The annual average daily mean temperature and precipitation from the downscaling of GCM-GFDL-ESM2M GCM-MPI-ESM-LR and GCM-HadGEM2-ES under 3 CMIP5-RCPs scenarios, including RCP4.5, 6.0 and 8.5 indicates that average daily mean temperature for the whole country area show an increase under RCP4.5, 6.0 and 8.5 scenario conditions in all GCMs except the RCP4.5 of GCM-GFDL-ESM2M. Annual average daily mean temperature change for the end of 21st century over the area of Thailand is to exceed 2°C relative to the 1951 – 2011 long term average for all GCMs



and RCP scenario except GCM-GFDL-ESM2M. Increase of mean temperature in 2100 for GCM-GFDL-ESM2M, GCM-MPI-ESM-LR and GCM-HadGEM2-ES under RCP8.5 scenario of these three GCMs relative to 1951 – 2011 is projected to be 1.7°C, 4.0°C and 4.8°C.

Figure 10: Annual averages of maximum, mean and minimum temperatures averaged over the region of 16.6 ° – 17.8 ° latitude and 99.4 ° – 100.2 ° longitude for ECHAM5 and HadCM3.

*The straight black line represents a linear trend while the pink, blue and red lines are 1980-2009, 2010-2039 and 2040-2069 means.

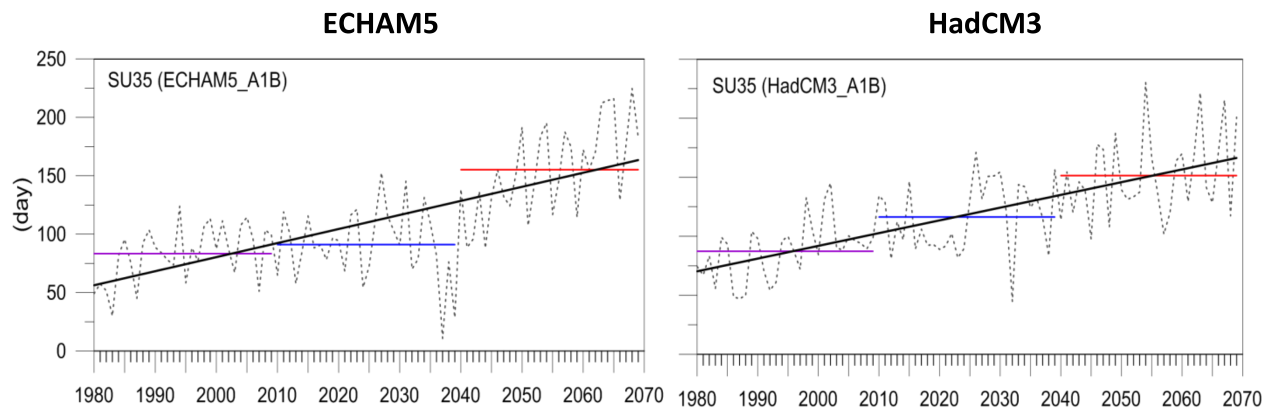


Figure 11: Number of summer days averaged over the region of 16.6 ° – 17.8 ° latitude and 99.4 ° – 100.2 ° longitude for ECHAM5 and HadCM3.

*The straight black line represents a linear trend while the pink, blue and red lines are 1980-2009, 2010-2039 and 2040-2069 means.

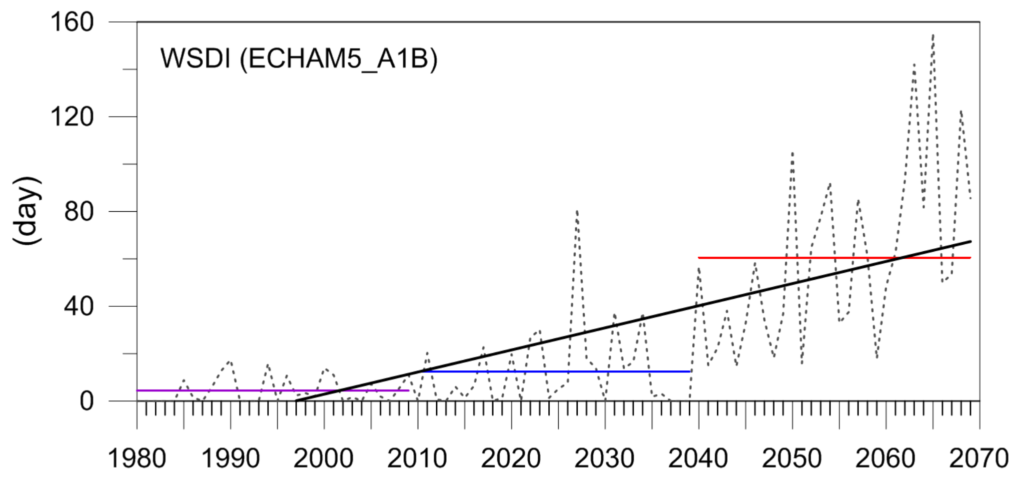


Figure 12: Warm spell duration indicator over the region of 16.6 ° – 17.8 ° latitude and 99.4 ° – 100.2 ° longitude for ECHAM5.

*The straight black line represents a linear trend while the pink, blue and red lines are 1980-2009, 2010-2039 and 2040-2069 means.

1.5.2.1.2 Precipitation

In the results from downscaling from ECHAM4 GCM using PRECIS, projections are that precipitation will increase over the whole country under both A2 and B2 scenarios. The length of rainy season will be likely similar to the present (2016), indicating the rainfall intensity will be increased. Already high precipitation in some areas (e.g. the southern peninsula) is set to see heavier rainfalls, while other areas with lower precipitation levels expected to decline to even lower amounts (inland and northeastern region).

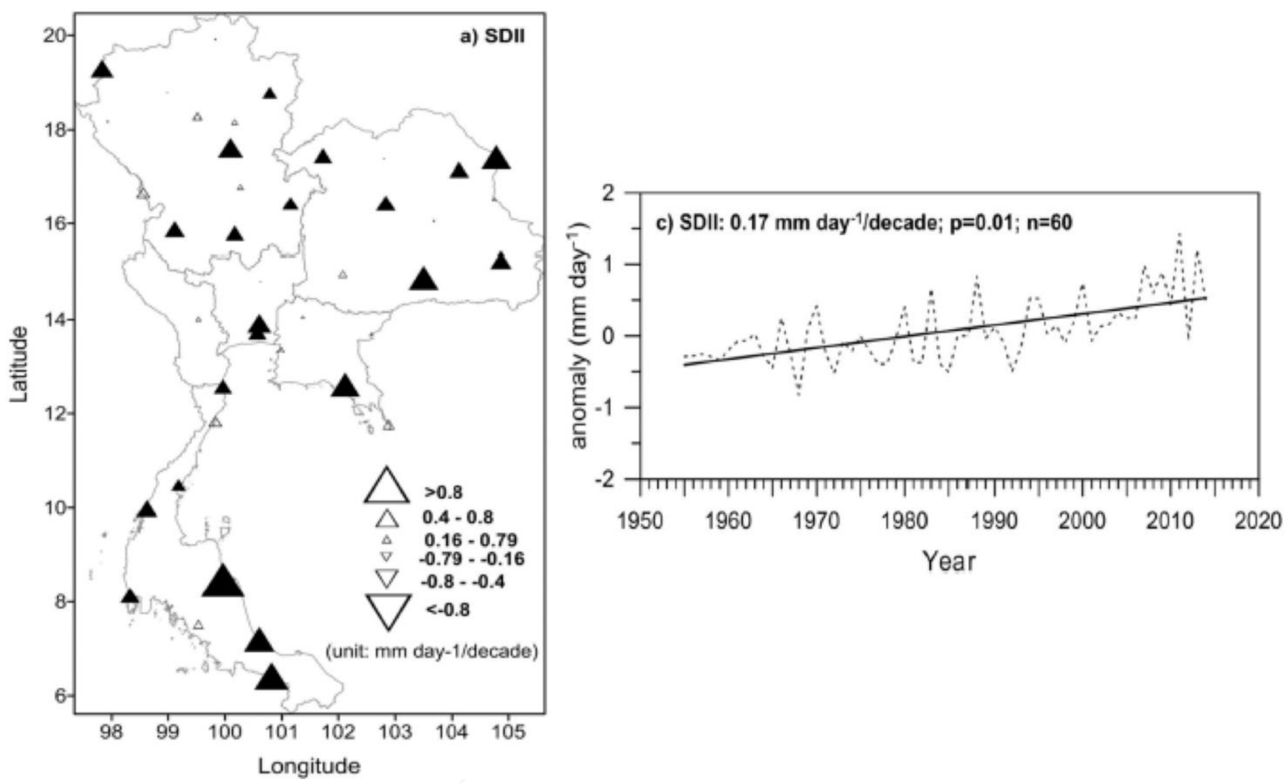


Figure 13: Spatial distribution maps of trends and regional-average anomalies time series for Simple Daily Intensity Index (SDII) for the period from 1955 to 2014. [48]

The upward-pointing triangles show increasing trends, while the downward-pointing triangles indicate decreasing trends. Significant changes at the 5% level are indicated by filled black triangles.[49]

[48] Limsakul, A. and Singhruck, P. 2016, 'Long-term trends and variability of total and extreme precipitation in Thailand', *Atmospheric Research*, 169, Pp 301-317.
[49] Limsakul, A. & Singhruck, P. 2016, 'Long-term trends and variability of total and extreme precipitation in Thailand', *Atmospheric Research*, 169, Pp 301-317.

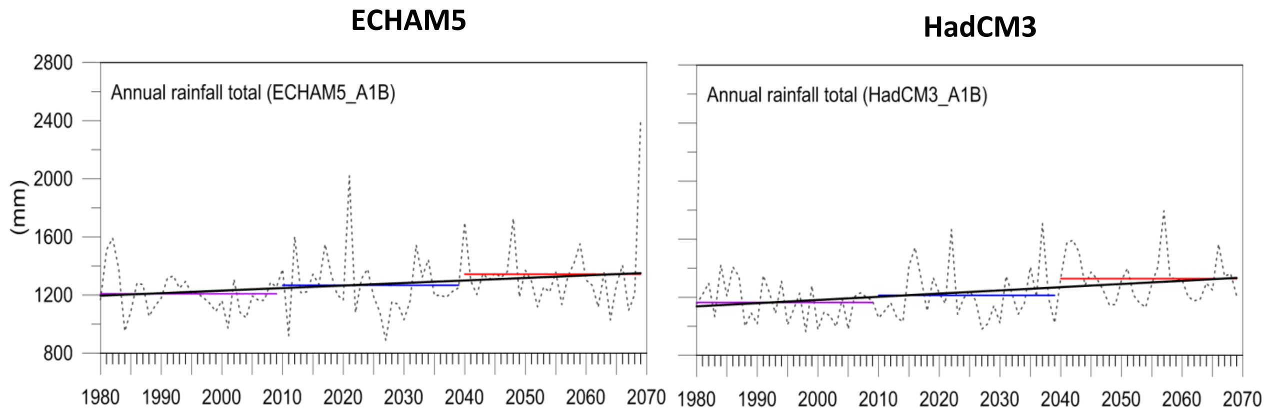


Figure 14: Annual precipitation total averaged over the region of 16.6 º – 17.8 º latitude and 99.4 º – 100.2 º longitude for ECHAM5 and HadCM3.

*The straight black line represents a linear trend while the pink, blue and red lines are 1980-2009, 2010-2039 and 2040-2069 means.

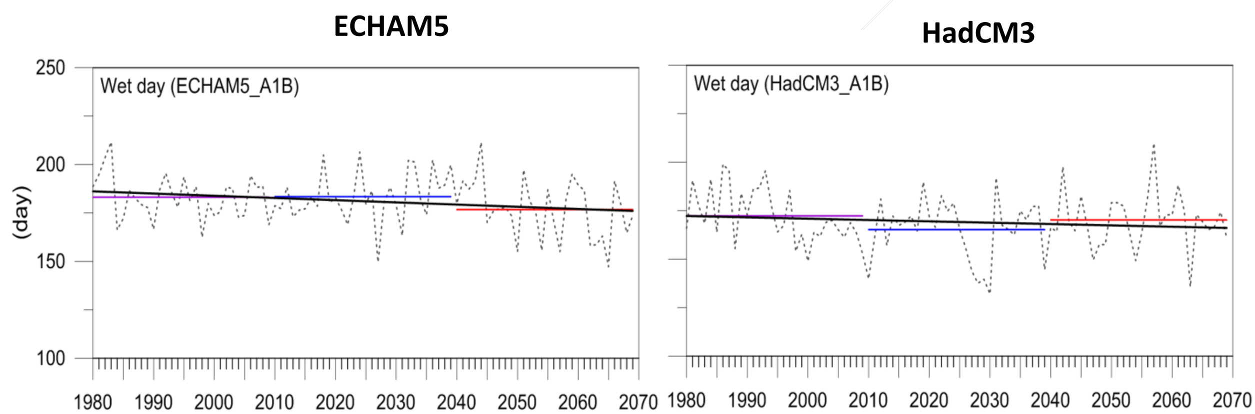


Figure 15: The number of annual wet days averaged over the region of 16.6º – 17.8º latitude and 99.4º – 100.2º longitude for ECHAM5 and HadCM3

*The straight black line represents a linear trend while the pink, blue and red lines are 1980-2009, 2010-2039 and 2040-2069 means.

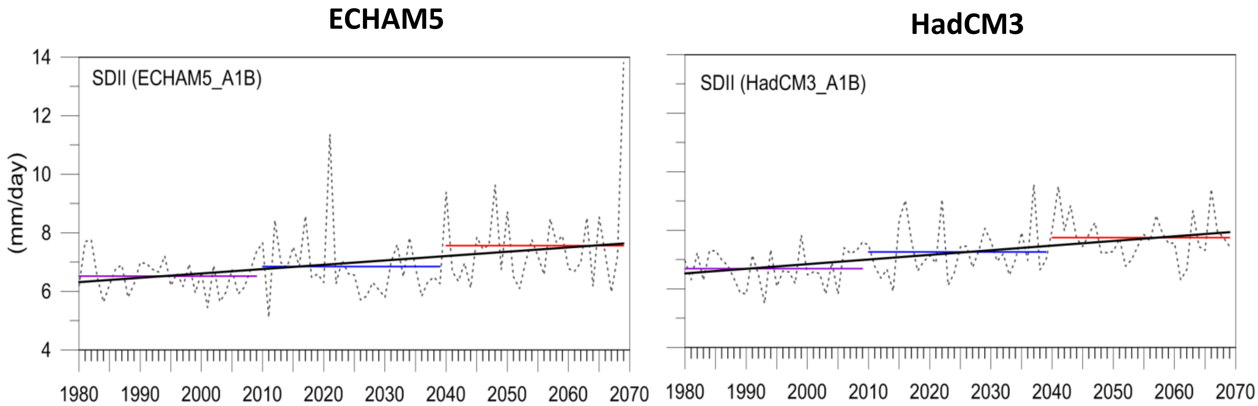


Figure 16: Simple daily intensity index averaged over the region of 16.6º – 17.8º latitude and 99.4º – 100.2º longitude for ECHAM5 and HadCM3.

*The straight black line represents a linear trend while the pink, blue and red lines are 1980-2009, 2010-2039 and 2040-2069 means.

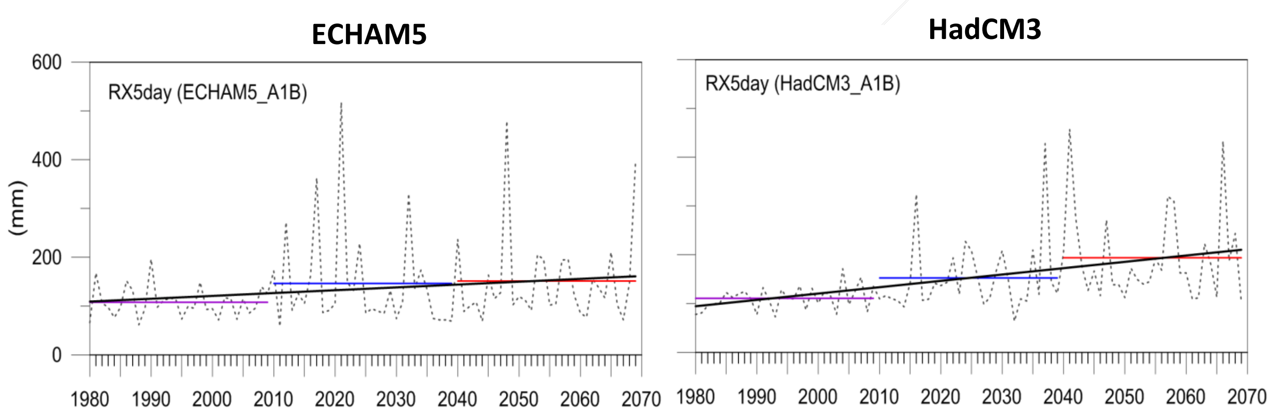


Figure 17: Maximum 5-day precipitation amount averaged over the region of 16.6º – 17.8º latitude and 99.4º – 100.2º longitude for ECHAM5 and HadCM3.

*The straight black line represents a linear trend while the pink, blue and red lines are 1980-2009, 2010-2039 and 2040-2069 means.

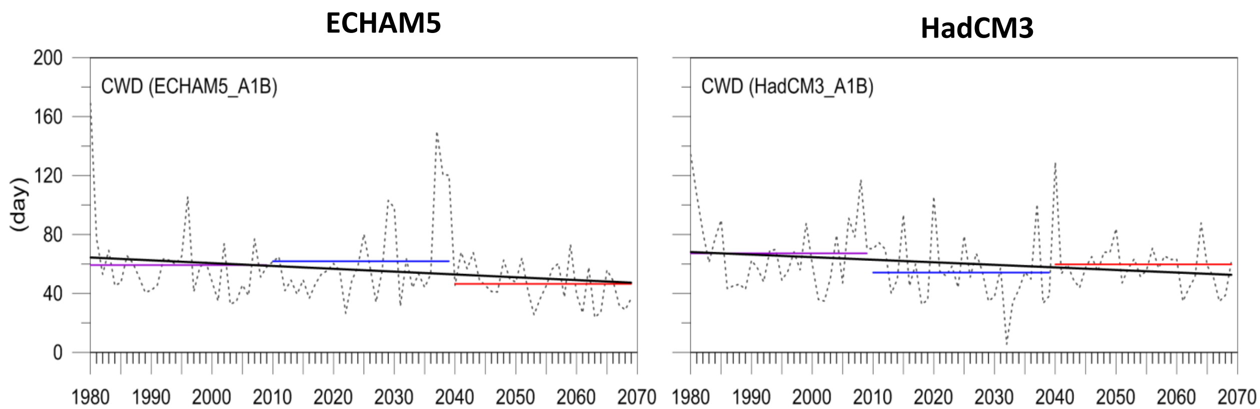


Figure 18: Consecutive wet days averaged over the region of 16.6^{o} – 17.8^{o} latitude and 99.4^{o} – 100.2^{o} longitude for ECHAM5 and HadCM3.

*The straight black line represents a linear trend while the pink, blue and red lines are 1980-2009, 2010-2039 and 2040-2069 means.

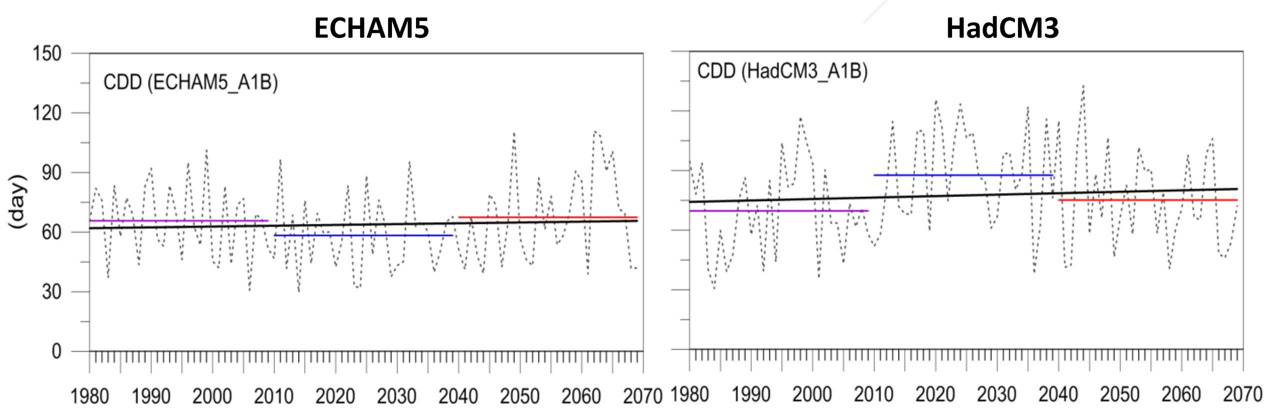


Figure 19: Consecutive dry days averaged over the region of 16.6^{o} – 17.8^{o} latitude and 99.4^{o} – 100.2^{o} longitude for ECHAM5 and HadCM3.

*The straight black line represents a linear trend while the pink, blue and red lines are 1980-2009, 2010-2039 and 2040-2069 means.

Analysis of long-term trends and variability of total and extreme precipitation indices during 1955-2014 based on quality-controlled daily station data reveals that while precipitation has become less frequent in most parts of Thailand with a significant reduction in the occurrence of consecutive wet days, precipitation events have become more intense. The indices that measure the amount of intense precipitation contributed by very wet day events and the maximum single-day precipitation amounts also indicated a trend toward wetter conditions, with heavy precipitation events contributing an increasing fraction of annual totals. One consequence of changes in these indices is the increased frequency and severity of flash floods, as recently evidenced in many parts of Thailand. Another noteworthy finding is that in 2011 Thailand experienced extensive flooding in a year characterised by exceptionally extreme precipitation events.

1.5.3 Disaster risk, climatic hazards and extreme events in Thailand

Thailand over the last decade has already experienced extreme weather patterns, with fluctuations from severe drought to major floods.[50] Future climate change influence on these extremes, according to climate projections, is set to increase both in the magnitude and frequency of these extreme events. Thailand is affected by the El Niño Southern Oscillation (ENSO), which brings greater rainfall variability with increasingly dangerous floods and droughts, which are in turn further exacerbated by climate change. Rain amount and intensity, alongside the rate of evaporation[51] affect both surface water flow and availability. In Thailand, this has meant both greater intensity of flooding during wet-season with an increased frequency of flooding, as well as extended drought periods during the dry season. Although Thailand is hit by tropical cyclone every year, during 1951-2010 there were 185 tropical cyclones, which made land in Thailand over a 60-year period. Over the second half of the 20th century and the first decade of the 21st Century, the frequency of tropical cyclones entering Thailand displayed a downward trend. Long-term tidal data and short-term altimetry measurements show that sea level in the Gulf of Thailand have risen significantly faster than global average rates.

Following are examples of major flood and drought events in Thailand. In economic terms, the 2015-2016 drought is estimated to have resulted in losses of US$3.4 billion, while the 2011 floods are estimated to have cost around US$46.5 billion in loss and damage.[52] This is placed among the most costly disasters in recent history.[53]

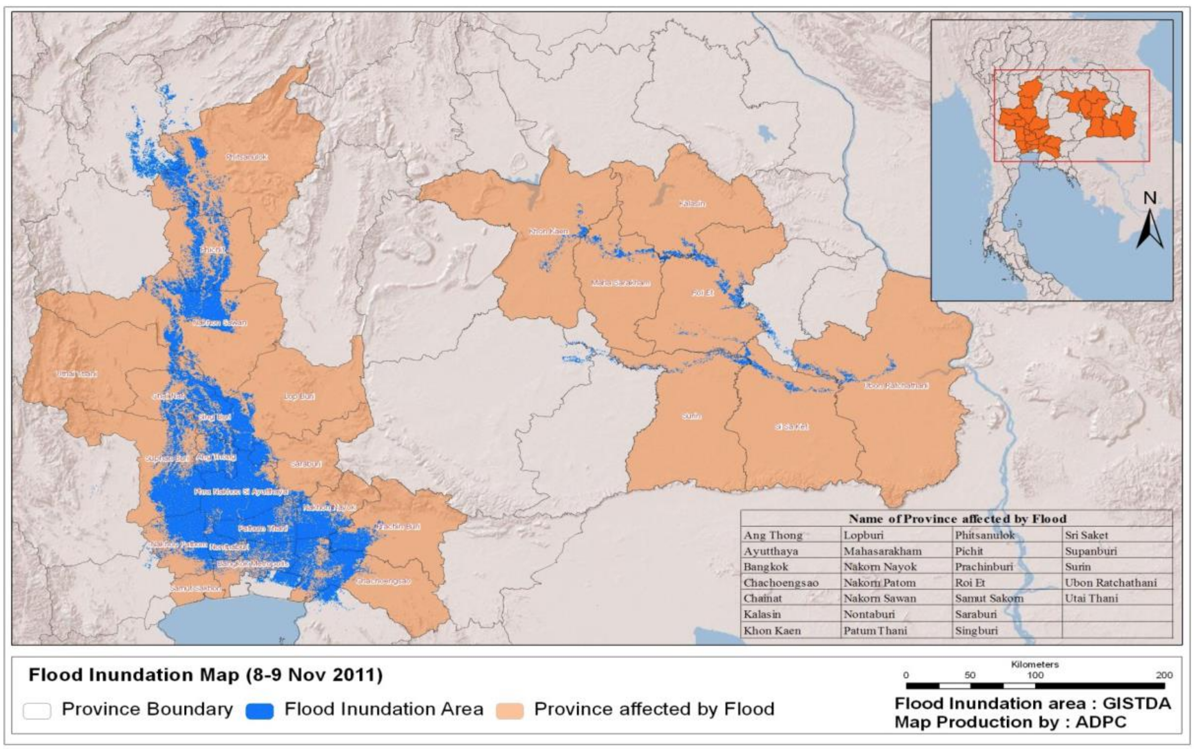


Figure 20 Map of Flood Inundated Areas, 8-9 November 2011

Source: The World Bank (2012). Original source of satellite image is GISTDA.

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[50] Kisner, C. 2008, 'Climate change in Thailand: Impacts and adaptation strategies', Climate Institute, http://climate.org/archive/topics/international-action/thailand.htm

[51] Chaowiwat, W., Boonya-aroonnet, S. & Weesakul, S. 2016, *Impact of Climate Change Assessment on Agriculture Water Demand in Thailand*

[52] Poaponsakorn & Meethom, 2013, *Impact of the 2011 Floods, and Flood Management in Thailand ERIA* Discussion Paper Series (Indonesia: Economic Research Institute for ASEAN and East Asia)

[53] AON Corporation, 2012

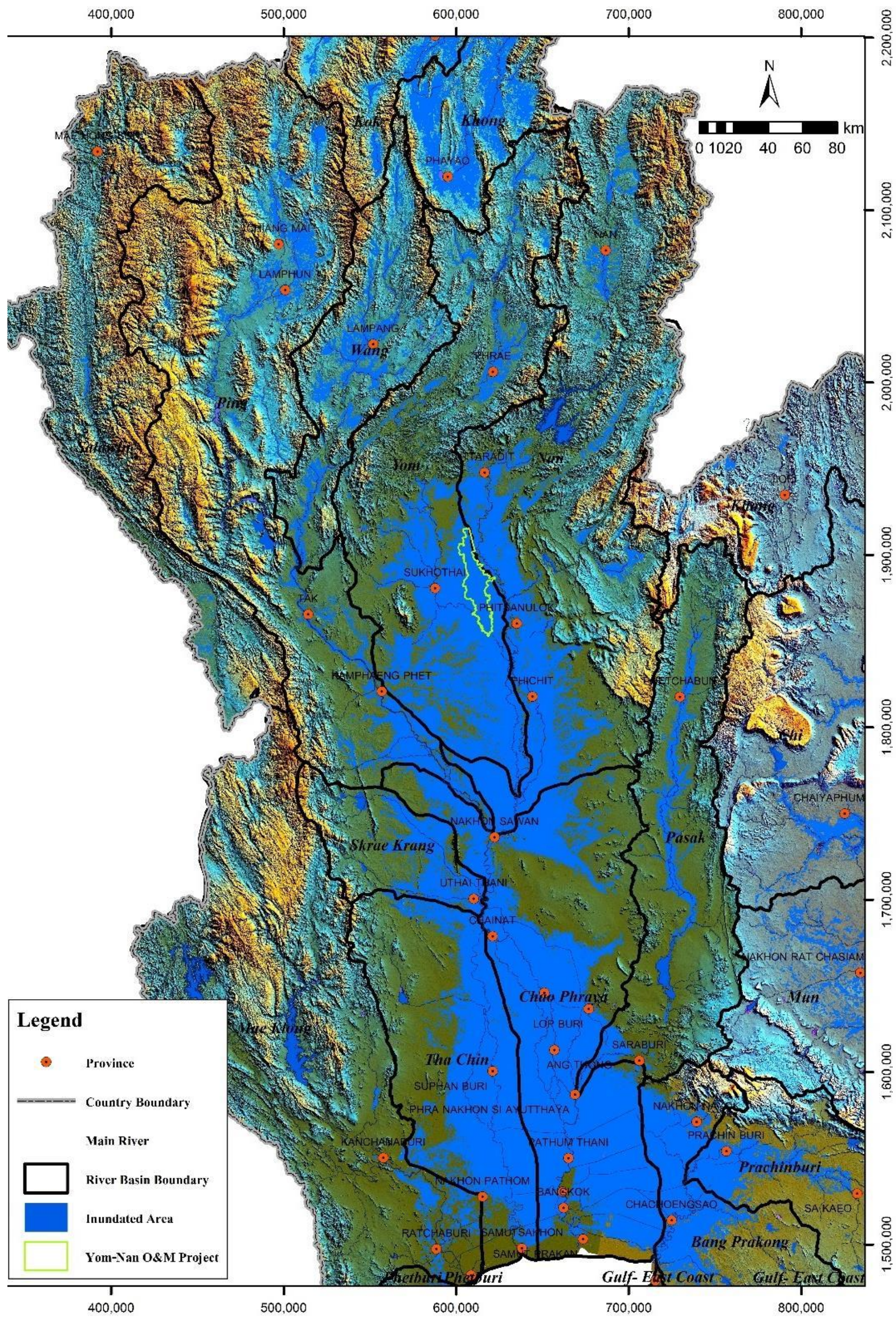


Figure 21: Flood map

Source: data 2005-2014 by GISTDA, http://flood.gistda.or.th

The 2011 flood was the worst flood in modern Thai history, inundating 9.1 percent of the total land area of the country, affecting more than 13 million people, causing total damage and loss of US$46.5 billion, and paralysing

Bangkok and its vicinity for two months, which seriously affected investors' confidence.[54] Eight hundred and fifteen lives were lost across Thailand,[55] and three people remain reported as missing from that time. The 2011 flood severely affected crops, livelihoods and infrastructure throughout Thailand.[56] While losses are estimated to be more than US$45 billion, rehabilitation and reconstruction needs over the two years following were estimated to be borne at around US$48 billion split across the private and public sectors. Flood at its greatest impact in 2011, touched 66 of Thailand's total of 77 Provinces. The 2011 flood damaged 10.417 million rais (16,668.55 square km) of agricultural area[57] and 9,859 factories.[58] The manufacturing sector carried roughly 70% of this cost resulting mainly from the flooding of the industrial estates in Ayuthaya and Pathum Thani during the October to November period of 2011. It also affected 660,000 jobs as of 25 November 2011. These were predominately the provinces located in the northeastern and central regions – and particularly those located across the Greater Chao Phraya River Basin. When the increase of water levels in the Yom River alone subsided, large water volumes remained to drain still into the river slowly – leaving around 22.70 million cubic metres of water in the area, and still averaging about 0.6 metres in flood inundation height.[59] As much of the central basin of the Chao Phraya basin, and area around the lower parts of the Yom and Nan River areas is flood plain lowland, much of the water remained left in the area for a long period. Unable to drain, there was not any effective means for distributing the water, or diverting the water into farmlands of the lower part of the plain. The lowlands situated in the upper part of Tung Bang Rakam plain submerged, starting in the middle of the rainy season and continuing until the end of the rainy season. Compounded by large amounts of runoff in the last half of the season, the flood then expanded to cover vast area of farmlands. The total volume of floodwater was measured at 88.06 million cubic meters, with a height level inundating farmlands at around 1.5 meters. When the water level in the Yom River subsided, large volumes of water gradually drained into the river, leaving about 22.70 million cubic meters of water in the area (the flood level inundating farmlands was about 0.60 meter averagely). Due to the characteristics of the lowland area, this amount of water was left in the area for a long period of time. It was unable to flow from the area and there were no efficient distribution systems in place to drain water into farmlands on the lower part of the plain.

[54] Poaponsakorn & Meethom, 2013, *Impact of the 2011 Floods, and Flood Management in Thailand ERIA* Discussion Paper Series (Indonesia: Economic Research Institute for ASEAN and East Asia)
[55] Emergency Operation Centre for Flood, Storms and Landslides, 2012, Thailand
[56] Kranz N, Menniken T, Hinkel J. 2010, 'Climate change adaptation strategies in the Mekong and Orange-Senqu basins: what determines the state of play?', *Environ Sci Policy,* 13:648–659
[57] Ministry of Agriculture 2012
[58] World Bank. 2012, 'Thailand flooding 2554 Rapid Assessment for Resilient Recovery and Reconstruction Planning', Ministry of Finance – Royal Thai Government and the World Bank
[59] World Bank. 2012, 'Thailand flooding 2554 Rapid Assessment for Resilient Recovery and Reconstruction Planning', Ministry of Finance – Royal Thai Government and the World Bank

Disaster Effects according to Ownership

Sector	Damage	Losses	Total	Public	Private
Infrastructure					
Water resources management	284	-	284	284	-
Transport	768	226	995	990	5
Telecommunication	42	83	126	52	73
Electricity	104	187	291	176	115
Water supply and sanitation	114	65	179	179	-
Cultural heritage	145	100	245	99	146
Productive					
Agriculture, livestock and fishery	185	1,133	1,318	-	1,318
Manufacturing	16,773	16,100	32,874	-	32,874
Tourism	168	2,927	3,095	13	3,081
Finance & banking	-	3,763	3,763	2,418	1,345
Social					
Health	55	70	125	53	71
Education	426	59	485	346	138
Housing	1,498	1,237	2,735	-	2,735
Cross Cutting					
Environment	15	6	18	7	11
TOTAL	**20,575**	**25,956**	**46,531**	**4,618**	**41,913**

Table 4: Damages and Losses by Sector (mil US$)

Source: World Bank, 2012. Note Exchange rate is 30.6366 Baht/USD.

In terms of agriculture and agricultural livelihoods, losses were incurred to major agriculture crops, such as wet season rice, sweet corn, vegetables, flowers such as orchids and marigolds, and fruits including bananas, guava and mangoes. Most, if not all, plants and permanent trees die after two weeks of immersion. Other affected crops included sugar cane, maize, cassava, coconut, and fruit trees. Wet season rice – the main seasonal crop in the Chao Phraya basin, normally planted in August and harvested in November/December - was the most affected crop.[60] Inland fisheries/aquaculture and artisanal fishing livelihoods play an important role in land communities by providing protein as well as source of cash income to local households, whilst using very little land, but with significant losses in the fisheries sector also reported. Of 26 assessed provinces, the total losses to the fisheries sub-sector are estimated to be roughly THB809 million in 2011.[61] In most cases, large quantities of fish, many grown for export, were lost. The most common species for domestic sale and export produced in the 26 assessed provinces suffered major losses. Inland fisheries, mainly aquaculture, across an area of 261,065 Rai – which serve as a major source of cash income for many subsistence fishermen were also greatly affected. The flood is reported to have damaged cages, nets, and other fishery assets as well as aquaculture infrastructure, and in come case large stocks of fish and fingerlings.

[60] World Bank. 2012, 'Thai Flood 2011', Rapid Assessment for Resilient Recovery and Reconstruction Planning, World Bank.
[61] World Bank. 2012, 'Thailand flooding 2554 Rapid Assessment for Resilient Recovery and Reconstruction Planning', Ministry of Finance – Royal Thai Government and the World Bank

In million Thai Baht:

	2011	2012	2013	2014
Crop	**27,522**	**1,927**	**1,204**	**482**
Rice	26,645	0	0	0
Sugar cane	288	0	0	0
Fruit trees	227	1,927	1,204	482
Flowers	144	0	0	0
Maize	16	0	0	0
Other	202	0	0	0
Livestock	**1,997**	0	0	0
Poultry	1,159	0	0	0
Swine	46	0	0	0
Cattle	722	774	0	0
Other	70	0	0	0
Fisheries	809	0	0	0
Tilapia	319	0	0	0
Catfish	256	0	0	0
Shrimp	234	0	0	0
Striped snakehead fish	1	0	0	0
Total	**30,328**	**2,701**	**1,204**	**482**

Table 5: Agricultural sector losses from flood during 2011-2014 by commodity

Source: Estimates based on data from MOAC and field survey[62]

**Note: Total Losses in 2011 consists of 3 components; (1) Total production losses (2) Higher production cost and (3) Losses due to forced early sale. Total losses in 2012-2014 consist of losses of production of permanent tress, losses of meat and egg production due to death of animals.*

Crops most affected by the 2011 floods, as shown above for example, were rice, sugar cane, cassava, sweet corn, maize, vegetables, and fruit trees such as banana, guava, mango which cover approximately 11,460,00 Rai across Thailand (the main agricultural crops of Thailand). Additional losses from flood also implicated were the resulting higher costs of rice production in the repetitive flood areas.

On the other side of experiencing severe floods, Thailand also experiences severe droughts. Thailand has recently experienced the worst drought in decades, with significant impacts on water availability, and to the agricultural sector and in turn, on food security. While flooding negatively impacts crops, livelihoods and infrastructure across the country – drought affects crop production, most drastically in the Northeast region.[63] El Niño Southern Oscillation (ENSO) events, exacerbated by climate change, bring greater rainfall variability with increasingly dangerous floods and droughts. Due to the late onset of the rainy season, Thailand has just experienced its worst period(s) of drought in decades, with significant impacts on overall food production and water availability. In 2008, for example, 10 million people across 55 of Thailand's Provinces, experienced water shortages due to severe drought.[64] Drought in 2015 however, disproportionately impacted the agricultural sector, and particularly so for subsistent farmers. The 2015 drought, whilst affecting more than 250,000 people, cost US$400 million in government spending. In 2016, the Ministry of Agriculture and Cooperatives made available to farmers US$2 billion

[62] World Bank. 2012, 'Thailand flooding 2554 Rapid Assessment for Resilient Recovery and Reconstruction Planning', Ministry of Finance – Royal Thai Government and the World Bank
[63] Kranz N, Menniken T, Hinkel J. 2010, 'Climate change adaptation strategies in the Mekong and Orange-Senqu basins: what determines the state of play?', *Environ Sci Policy,* 13:648–659
[64] Secretariat of the Cabinet of Thailand, 2008

in soft loans, in order to mitigate the impact of water shortage (drought) to the agricultural sector.[65] Estimates of total losses resulting from the 2016 drought are estimated at US$3.4 billion or 0.85 percent of GDP.[66] In March 2016, the Asian Development Bank lowered its forecast for Thailand's GDP growth (in 2016), cutting its projection from 3.5 percent to 3 percent, due to a slowdown in growth in major industrial economies. The actual growth figures for 2016 could be worse as drought impacts continue to be tallied, and the expected flood impacts of the recent rainy season are not yet known at the time of this being written.

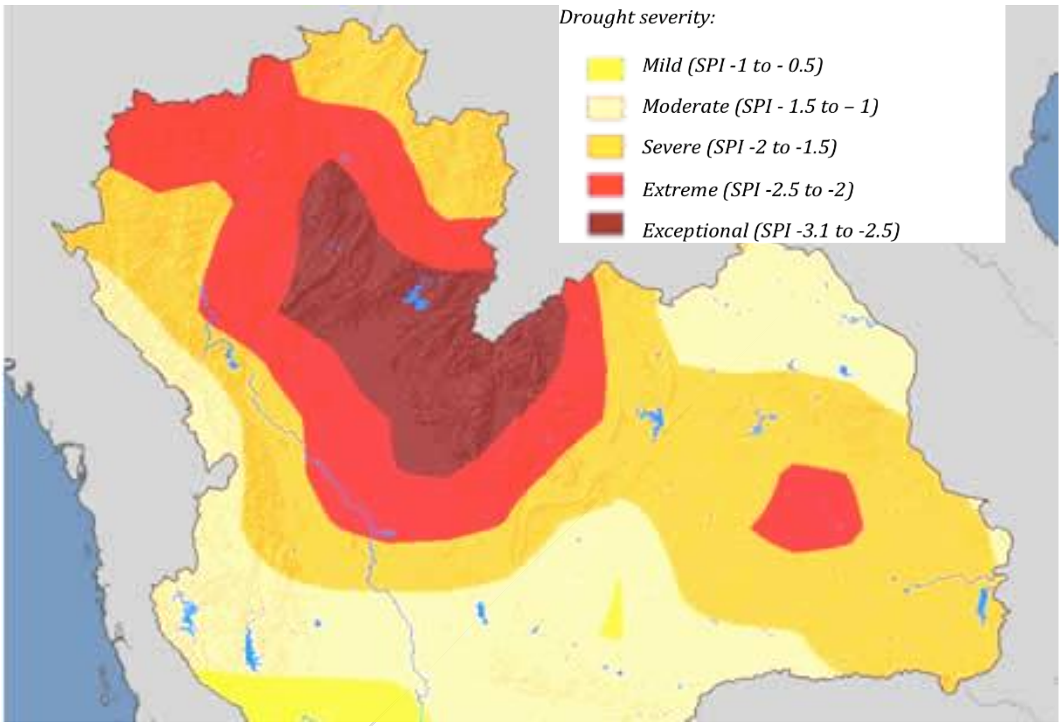


Figure 22: Thailand's 6 month drought conditions – areas affected, September 2015

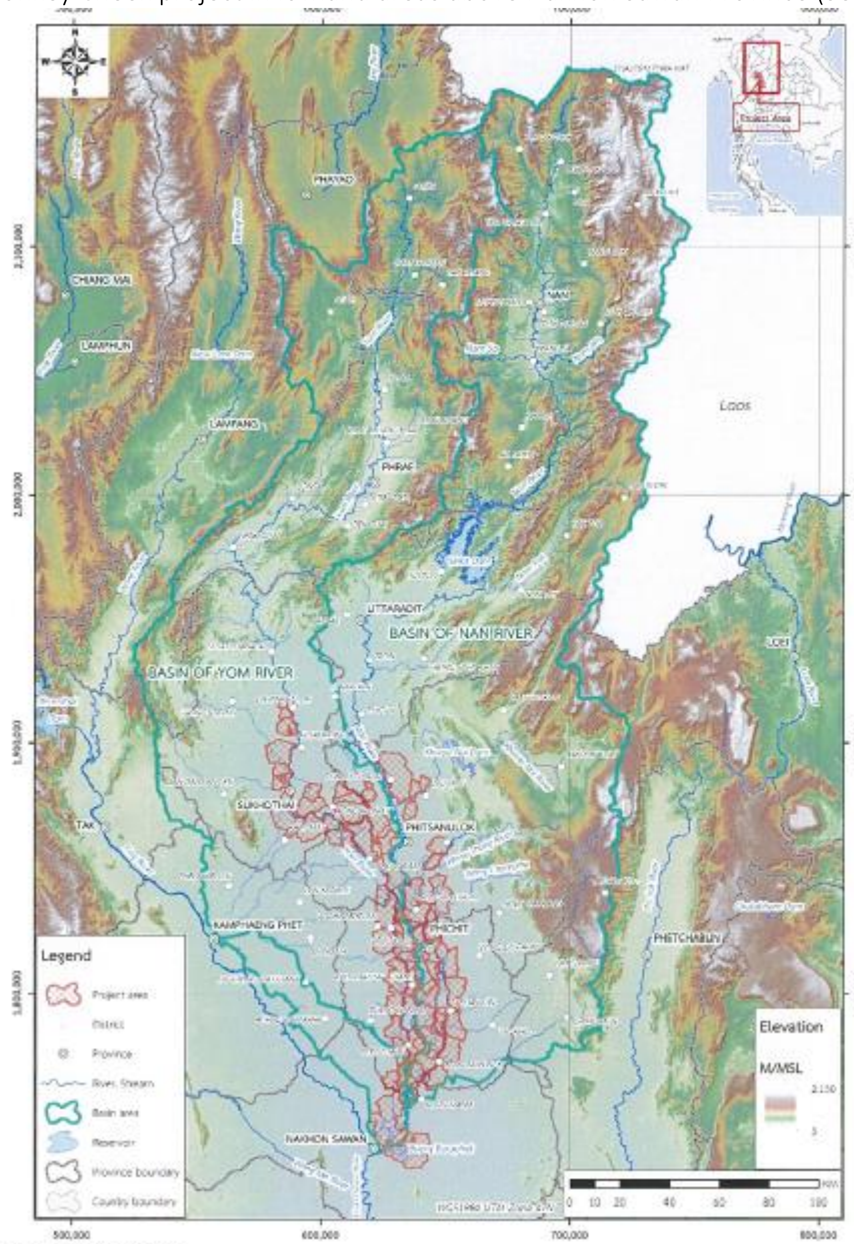
Source: SPI Rainfall Model[67]

According to problem analysis of the grestest flood 2011, the Royal Thai Governmnet has adopted long-term prevention and mitigation approach for water management to cope with climate change, one of which is development of lowlands (from Nakhon Sawan province to Sukhothai, Utraladit, Phisanulok, Phichit provinces) into the water retention and detaintion areas called "Monkey Cheek areas".

Detention and retention basins are depressions or excavations, which can be used for temporarily storing flood water to reduce peak flow downstream. Detention basins are similar to retention basins except for the fact that the latter do not have controlled outlets. Detention basins hold the water temporarily and then slowly release it through a natural or man-made drainage channel, while water collected within retention basins slowly percolates into the ground or evaporates. According to the topography, the type and size of detention and retention basins can be different. They can be brought into operation at the desired stage of a flood wave, enabling reduction in flood peaks downstream. Often, natural depressions are also used for agricultural purposes.

[65] 'Thailand's drought weakens agricultural outlook', Oxford Business Group, May 19, 2016: http://www.thailand-business-news.com/economics/53473-thailands-drought-weakens-agricultural-outlook.html
[66] 'Relief as rain falls, but drought's aftermath to linger', Bangkok Post, http://www.bangkokpost.com/news/general/994313/relief-as-rain-falls-but-droughts-aftermath-to-linger
[67] Drought Monitor Classification, USDA Commodity Intelligence Report

The Water and Flood Management Committee has designated that those areas as temporary water detention in the Master Plan of Water Management and Flood Mitigation. The Royal Irrigation Department (RID) enganged the consertium of consulting firms to carry out the feasibility study and Environmental Impact Assessment (EIA) of the Monkey Cheek project in lowland areas above Nakhon Sawan Province (See Figure 23).



Source: The Consultants

Figure 23: Topographic Condition of the Monkey Cheek project areas and vicinity

1.6 Climate change impacts on agriculture and livelihoods

Agriculture is one of the sectors most heavily impacted by climate change worldwide, and potentially the most sensitive economic sector to climate change given the influence of climatic conditions on agricultural production.[68] [69] [70] [71] [72] Climate change is predicted to impact heavily on Thailand's agriculture sector. Changes in climate patterns, rainfall changes, temperature increases and extreme events – affect the productivity of crops. Projected negative impacts are estimated to Thailand's agriculture nationally during 2040 – 2049 to range from loss and damage impacts of $24 to $94 billion.[73]

Agriculture is one of the key sectors in the country's economic and social development in Thailand – and is also the source of primary materials for downstream industries. Overall, agricultural activities in Thailand generate around $40 billion in revenue, over 10 percent of national gross domestic product (GDP)[74,75] and account for 74 percent of water consumption in Thailand, along with electricity generation.[76]

Rice remains central to Thailand in terms of food culture, constituting one of the main food sources for most Thais, with the average annual intake per capita being around 114.5kg.[77] Thailand until a few years ago, was the largest exporter and leading rice supplier in the world, as well as exporting other food types such as chicken and shrimp products, processed foods – e.g. canned tuna, and pineapples, which also contribute a total 13.3 percent of Thailand's export revenue (2008).[78] By 2011, Thai rice was feeding more people globally than domestically; with milled rice export comprising 11 million tons and outstripping the domestic consumption of 9 million tons, according to the Office of Agricultural Economics (OAE).[79] Thailand remains the 2nd largest exporter of rice globally, and across the nation 16 million people are rice farmers.[80] In 2011, this was a total export value of 210,527 million baht (US$5917 million),[81] although this figure has significantly dropped since the 2015 and 2016 drought. Despite rice crops dropping by 30 percent from previous years, in 2015 Thailand still exported 21.4 percent of the world's rice supply (around $4.5 billion in value).[82] Meeting the production demand for rice in terms of food security and consumption demands nationally and internationally, as well as export quotas and fulfilling livelihood and employment needs - remains critical. Yet meeting such demands is posited to become increasingly challenging - given predicted climate change impacts to the rice growing area.

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68 Inter-governmental Panel on Climate Change (IPCC) 2007
69 Mendelsohn, R., W. D. Nordhaus, and D. Shaw. 1994. The impact of global warming on agriculture: a Ricardian analysis. American Economic Review 84: 753–71.
70 Deschenes, O., and M. Greenstone. 2007. The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. *American Economic Review,* 97 (1): 354–85.
71 McCarl, Villavicencio & Wu 2008 McCarl, B. A., X. Villavicencio, and X. Wu. 2008, 'Climate Change and Future Analysis: Is Stationarity Dying?', *American Journal of Agricultural Economics*, 20:1241-47.
72 Schlenker, W & Roberts, M. 2009, 'Nonlinear temperature effects indicate severe damages to US crop yields under climate change', *PNAS*, Vol. 106, No.37, September 2009
73 Attavanich, W. 2012, *The effect of climate change on Thailand's agriculture,* https://www.researchgate.net/profile/Witsanu_Attavanich/publication/262067789_The_Effect_of_Climate_Change_on_Thailand's_Agriculture/links/566a311a08ae1a797e379c9b.pdf
74 Office of the National Economic and Social Development Board, 2012
75 World Bank. 2016, http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS)
76 National Water Management Strategy, Thailand. 2015
77 FAO. 2013, 'World rice statistics online query facility', International Rice Research Facility (IRRI)*, Food and Agriculture Organisation of the United Nations.*
78 Chaowiwat, W., Boonya-aroonnet, S. & Weesakul, S. 2016, *Impact of Climate Change: Assessment on Agriculture Water Demand in Thailand*
79 Rerkasem, B. 2015, 'The Agroecosystem of Thai Rice: a Review', *Plant Genetic Resource and Nutrition Laboratory, Chiang Mai University*
80 Blake, C. & Suwannakij, S. 2016, 'Thai Junta Flip-flop on Populism too late for suffering farmers', *Bloomberg*
81 Nara, P. Mao, G. & Yen, T. 2014, 'Climate change impacts on agricultural products in Thailand: a case study of Thai rice at the Chao Phraya River Basin', *APCBEE Procedia,* 8, Pp 136- 140
82 Workman, D. 2016, *Rice exports by country*: http://www.worldstopexports.com/rice-exports-country/

Thailand's consecutive years of below-normal rainfall have the potential to cripple the agricultural sector and slow the country's economy.[83] Table 6 below, shows the trend in rice production, indicating volatility and declining production due in part to the increasingly dry conditions and drought impact.

Year	Planted area (1,000 rais)	Harvested area (1,000 rais)	Production (1,000 tons)	Yield per rai (Kgs.)	Farm price (THB per ton)	Farm value (Million THB)
2006	57,542	53,500	23,108	432	7,198	166,331
2007	57,386	53,892	23,583	438	10,054	237,103
2008	57,422	54,385	23,509	432	9,632	226,439
2009	57,497	54,740	23,431	428	10,129	237,333
2010	64,574	59,690	25,743	431	10,535	271,202
2011	65,304	56,752	25,867	456	11,671	301,894
2012	64,951	58,766	27,234	463	11,245	306,246
2013	62,080	58,136	27,090	466	10,015	271,306
2014	60,791	58,247	26,270	451	9,130	239,845
2015	58,063	55,096	24,312	441	9,070	220,510
2016	58,645	56,546	25,236	446	8,073	203,730
2017	59,221	54,963	24,934	454	8,817	219,887
2018	59,215	53,359	24,223	454	9,842	238,393

Table 6: Major rice: area, production, yield per rai, farm price and farm value for the years 2006-2018
Source: OAE. 2019. 'Agricultural Statistics of Thailand', *Office of Agricultural Economics*

Agriculture accounts for more than 70 percent of Thailand's water consumption, leaving the sector as well as the national economy highly vulnerable to low rainfall. Thailand's total rice production (including primary and second crops) fell to under 25 from to 27 million tonnes due in part to drying conditions. These declining rice yields impact not only Thailand's economy, but have significant impact directly on farming households, and affect household incomes as well as market-price related economies. In 2016, the Thai Rice Packers Association stated that its members would have to increase the prices of packaged rice - Thai rice was already at a two year high of US$441/ton, up from US$397.[84] Low-income consumers feel these impacts on market prices most acutely, as higher food prices cut into disposable income, ultimately having ripple effects throughout the economy. During 2016, the government owned Bank for Agriculture and Agricultural Cooperatives (BAAC) approved loans of up to 300,000THB (US$8,415) for farmers who stored rice to curb supply. This was as domestic and international demand for rice would be around 25 million tonnes, as opposed to the 27.17 million tonnes expected – and which is usually around 30 million tonnes[85]. Amidst approval for $285 million worth of assistance to drought-hit rice farmers, Thailand's Prime Minister also asked farmers to reduce how much rice they grow in order to respond to the pressures of limited water resources as a result of the drought.[86] With the trend of increasing weather volatility, the government subsidy for crop losses will likely increment and cause future fiscal burdens.[87]

[83] USDA. 2015, 'Thailand: Irrigation shortage reduces 2015/16 rice production', *Commodity Intelligence Report,* United States Department of Agriculture (USDA) Foreign Agricultural Service, October 29, 2015: http://www.pecad.fas.usda.gov/highlights/2015/10/th/index.htm
[84] 'Relief as rain falls, but drought's aftermath to linger', Bangkok Post, http://www.bangkokpost.com/news/general/994313/relief-as-rain-falls-but-droughts-aftermath-to-linger
[85] Tanakasempipat, P. 2016, 'Thailand plans steps worth $285 million to help drought-hit rice farmers', *Business Insider,* Reuters, Feb 26, 2016: http://www.businessinsider.com/r-thailand-plans-steps-worth-285-million-to-help-drought-hit-rice-farmers-2016-2?IR=T
[86] Tanakasempipat, P. 2016, 'Thailand plans steps worth $285 million to help drought-hit rice farmers', *Business Insider,* Reuters, Feb 26, 2016: http://www.businessinsider.com/r-thailand-plans-steps-worth-285-million-to-help-drought-hit-rice-farmers-2016-2?IR=T
[87] **Puttanpong, N, 2013, Impacts of climate change on major crop yield and the Thai economy, Thammasat Economic Journal, Vol 31, No. 3, September 2013**

Below are projections in yields and economic impacts for various crops in Thailand, undertaken by CIAT. While rice shows a modest increase overall, it should be noted that climate change will have varying impacts on different regions and will depend largely on farmers' ability to adapt to slow onset changes as well as respond to extremes.

Item	Change in yields (2010-2050)	Economic impact: direct calculation (THB)	Economic impact: Surplus analysis (THB)
Cassava	2.67%	277,270	15,002
Maize	-11.28%	-1,850,799	-694,636
Rice KDML 105	3.6%	651,799	177,867
Rice (others)	0.48%	430	207,900
Sugarcane	-4.33%	-2,209,-14	-2,493,207
Total		-3,130,425	-2,787,074
Durian	-49.36%	-2,697,929	-4,372,572
Longan	-98.22%	-1,281,148	-5,259,612
Lychee	-19.07%	-106,586	-130,615
Mango	-0.63%	-894,657	-80,000
Mangosteen	-7.92%	-180,947	-64,135
Palm oil	-4.8%	-83,024	-32,895
Orange	-13.37%	-57,032	-16,025
Pineapple	-17.44%	374,780	-122,834
Rubber	-125.64%	-1,123,283	-1,120,898
Rambutan	-0.7%	-76,173	-11,713
Soybean	2.4%	116,618	23,228
Total overall		-9,889,366	-13,975,145

*Direct calculations assume only yield has changed in the calculations, while other variables remain unchanged. Surplus analysis measures the total change in welfare of the producers and consumers. In Estimation, a partial equilibrium model with dynamic prices is used.

Table 7: Climate change impact estimations on agricultural yields for Thailand 2010 – 2050

Source: CIAT 2010

The effect of climate change on Thailand's agriculture and implications under future climate change scenarios were analysed allowing for a variety of the adaptation options used by farmers in response to changing economic and climate conditions. A 2007 study[88] on this found that both temperature and precipitation significantly determine farmland values. Summer temperature, precipitation in the early rainy and summer seasons negatively affect the farmland values, while winter temperature, precipitation in the late rainy and winter seasons enhance the farmland values. Overall, the projected negative impacts of climate change on Thailand's agriculture during 2040-2049 ranges from $24 to $94 billion. Extensive assessment of country-wide impacts of future climate change on annual field crops in Thailand shows that future projections of major annual field crops (rice, maize, sugarcane and cassava) in Thailand are characterized by large fluctuations of their yield and production over time and space. Studies undertaken on the productivity of crops and climate change looking into field cropping and climate change using various crop model tools, found mixed results. Overall, in terms of the findings for rice – the results illustrate the complexity of climate change effects on rice yields – and highlight that different climate changes call for different adjustment strategies. In Thailand, yields of rice are projected to decline by as much as 57 percent as compared to the baseline, depending on climatic conditions, soil types and crop practices according to the Crop Environment Resource Synthesis (CERES) model.[89] A study undertaken by Attavanich (2012) found that higher summer temperature and higher early rain levels and summer precipitation were harmful to crops, while higher winter temperatures and higher late wet season and winter precipitation levels tended to be beneficial to crops.[90] In

[88] Deschenes, O., and M. Greenstone. 2007. The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. *American Economic Review* 97 (1): 354–85.
[89] Office of Environmental Policy and Planning, 2000
[90] Attavanich, W. 2012, *The effect of climate change on Thailand's agriculture,* https://www.researchgate.net/profile/Witsanu_Attavanich/publication/262067789_The_Effect_of_Climate_Change_on_Thailand's_Agriculture/links/566a311a08ae1a797e379c9b.pdf

effect, this was estimated to mean decreases of around $479 per rai for higher summer temperatures of 1 degree Celsius, but increases of $299 per rai for winter temperature increases of 1 degree Celsius.[91] Other findings overall also suggest that while farmers are unable to neutralise the adverse effects of more extreme climate change, they are able to cope with milder climate change and in some cases benefit from some changes.[92] There are exceptionally large year-to-year variations, implying that short-term variability in climate patterns in the future will cause the annual productivity to fluctuate substantially. As a result, even though total production of the country may not be severely changed, some areas will be critically affected from climate change. Most of rain-fed rice yield in the Northeast are relatively lower than that of base-year period. Whereas, simulated irrigated rice yield averaged for Thailand as a whole shows a decreasing trend with by the end of 21st century being lower than base-year period by about 17.9 percent. In the future, sugarcane production is projected to increase in the North, Central and East. Among major field crops simulated, future change in cassava exhibits an obvious long-term trend, which by the end of this century the production will decline by about 40 percent compared with that of base-year period. Taking into account these predictions, agricultural adaptation activities under the project will focus further on resilience measures for rice cropping in the area, ecosystem service resilience enhancements and water security efforts, as well as focusing on diversification options to buffer climate impacts and events.

1.7 Climate change in Chao Phraya Basin

Climate change projections for the Chao Phraya basin from the perspective of future climate risks, in particular to ascertain the evidence for increasing risks of both floods and droughts was carried out based on a review of available literature and analyses of primary observational (available station data from TMD and CRU gridded datasets) and climate model projections (CMIP5, CMIP6 and CORDEX).

Overall, the results show that total rainfall trends in the 1951-2019 period are small although predominantly upward. The statistically significant increase is present only in stations near Bangkok (Figure 24). Overall whilst total rainfall changes are both positive and negative there are consistent increases in rainfall intensity and decreases in rainfall frequency.

Trends in rainfall characteristics of the main part of the rainy season (Aug-Oct) are diverse. Again whilst there seems to be no consistent trend in total season's rainfall, there are increases in rainfall intensity, compensated by a (mostly statistically significant) decrease in the number of rain days (Figure 25). Trends in the Bangkok area appear to be somewhat different than in the rest of the analysed stations - there is an increase in the number of rain days compensated to a certain extent by the decrease in maximum rainfall intensity.
Trends in total annual rainfall in the gridded CHIRPS data correspond moderately well to those recorded at rainfall stations. In general, they indicate an increase in total annual rainfall across the entire basin. CHIRPS trends are only locally statistically significant, mostly in the upper section of the basin, which is in contrast with trends in station data (Figure 26). Additionally, the CHIRPS data shows there to be some systematic spatial patterns in rainfall trends, with higher trends along the main N-S axis of the basin, and in the Yom and Wang sub catchments.
There is a clear and statistically significant upward trend in 1981-2019 annual mean and annual mean of minimum temperatures (Figure 27). Trends in annual mean of maximum temperatures are still upward, but weaker, significant in 12 out of 16 stations.

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[91] Attavanich, W. 2012, *The effect of climate change on Thailand's agriculture,* https://www.researchgate.net/profile/Witsanu_Attavanich/publication/262067789_The_Effect_of_Climate_Change_on_Thailand's_Agriculture/links/566a311a08ae1a797e379c9b.pdf
[92] Sawano, S. Hasegawa, T., Goto, S., Konghakote, P., Polthanee, A., Ishigooka, Y., Kuwagata, T., Toritani, H., 2008, 'Modelling the dependence of the crop calendar for rain-fed rice on precipitation in Northeast Thailand', *Paddy Water Environ*, 6, pp. 83–90

1.7.1 Extreme rainfall and temperature indices

Trends in extreme rainfall indices do not show any consistent sign, nor clear spatial pattern (Figure 28). In terms of temperature extremes, only trends in tnn (annual minimum value of minimum daily temperature) and txge35 (number of days per year with maximum temperature greater than 35 deg C) are upward and statistically significant (the latter at fewer stations). Station data do not show any trend in txn (annual maximum of maximum daily temperature).

1.7.2 Drought indices

Trends in drought indices evaluated over the 1920-2019 period. SPI trends are upward (i.e. towards reduction of drought intensities), but not statistically significant (Figure. 29). Trends in SPEI are, however, downward (i.e. toward increase of drought intensities) and statistically significant in the Yom and Nan sub-catchments (Figure 30). This demonstrates that drought has tended to worsen only when increases in evapotranspiration are accounted for.
Furthermore, trends in the frequency of drought years show a consistent pattern, particularly for SPEI. Whilst the frequency of drought events defined by SPI on both 12 month and 36 month timescales indicate statistically insignificant trends (Figure. 31), the frequency of droughts indexed by SPEI over the same timescales demonstrates consistently increasing trends, which are statistically significant at 12-month time scales (Figure 32).

1.7.3 Long-term rainfall variability

Rainfall variability at centennial time scale (1900-2019) in long-term data (CRU, GPCC) is shown in figures illustrating climate projections (Figure 33). That variability indicates multi-decadal variability, with three phases - an increase in rainfall in the beginning of the 20th century, a decrease in rainfall in the period of 1940-1985, and a rapid increase in rainfall since. Whilst there is a possible plateau or inversion of the trend after ~2005, the observed increase is already as high as the highest estimates from the different multimodal ensemble projections (see discussion below). The station and CHIRPS data capture only the most recent, post-1985 phase, but all the datasets are reasonably consistent in measuring historical rainfall (Figure 34).

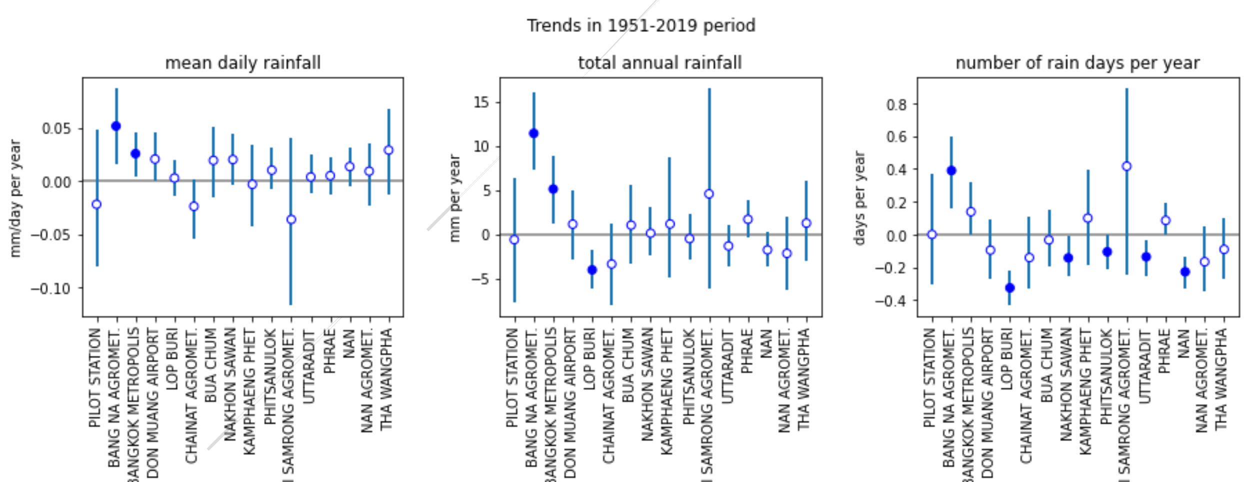


Figure 24: Trends (and their 95% confidence interval) in rainfall attributes in station data. Stations ordered from the most southern to the most northern. Filled symbols - trend significant at 95% level.

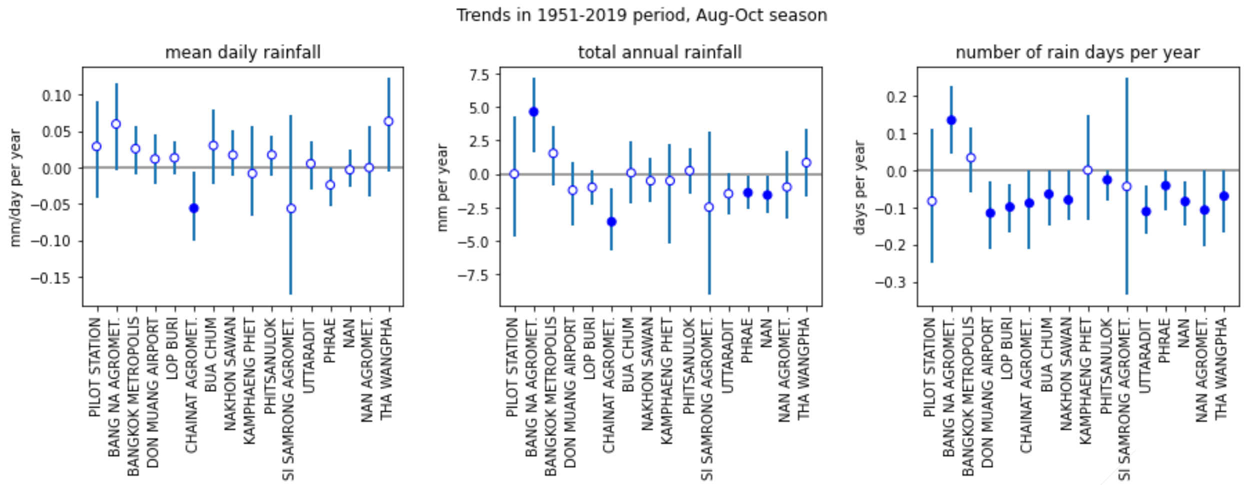


Figure 25: Trends (and their 95% confidence interval) in rainfall attributes in Aug-Oct station data. Stations ordered from the most southern to the most northern. Filled symbols - trend significant at 95% level.

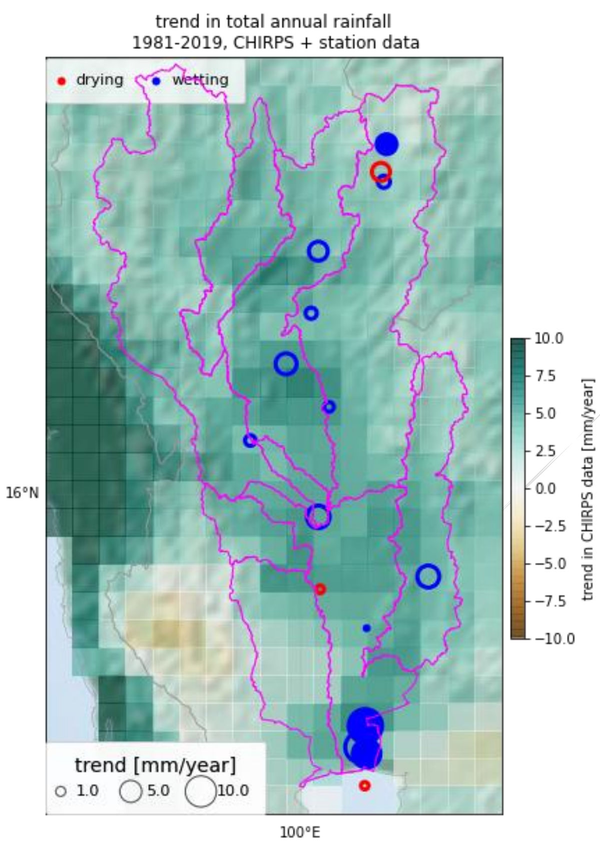


Figure 26: Trends over 1981-2019 in total annual rainfall in station data and in CHIRPS gridded data. Filled symbols - trend significant at 95% level.

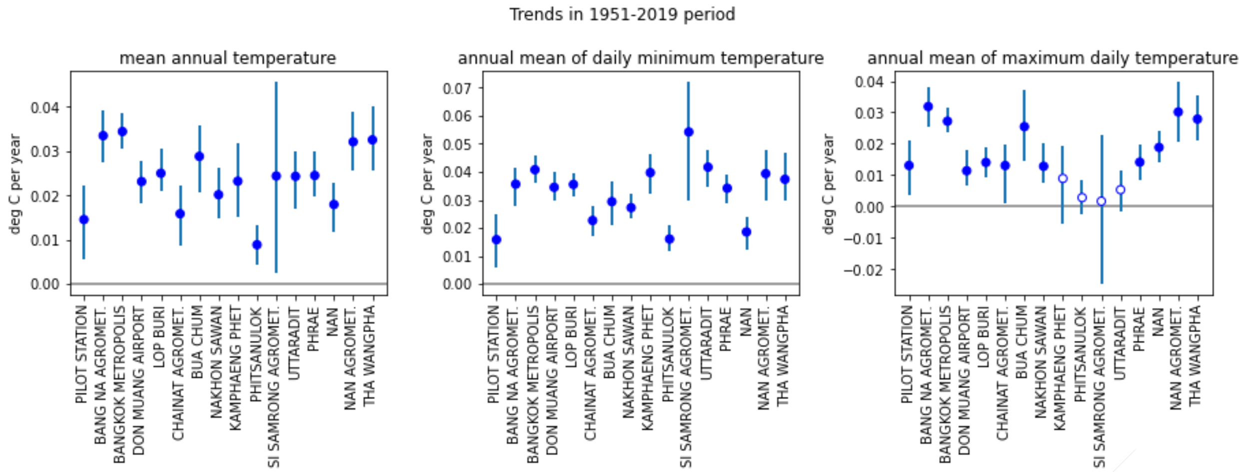


Figure 27: Trends (and their 95% confidence interval) in air temperature attributes in station data. Stations ordered from the most southern to the most northern. Filled symbols - trend significant at 95% level

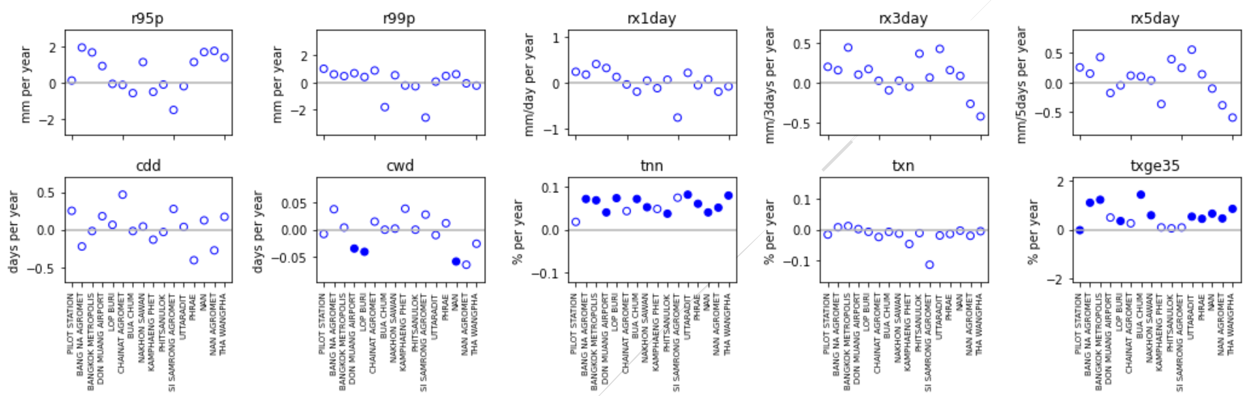


Figure 28: Trends in extreme rainfall indices in station data. Filled symbols - trend significant at 95% level.

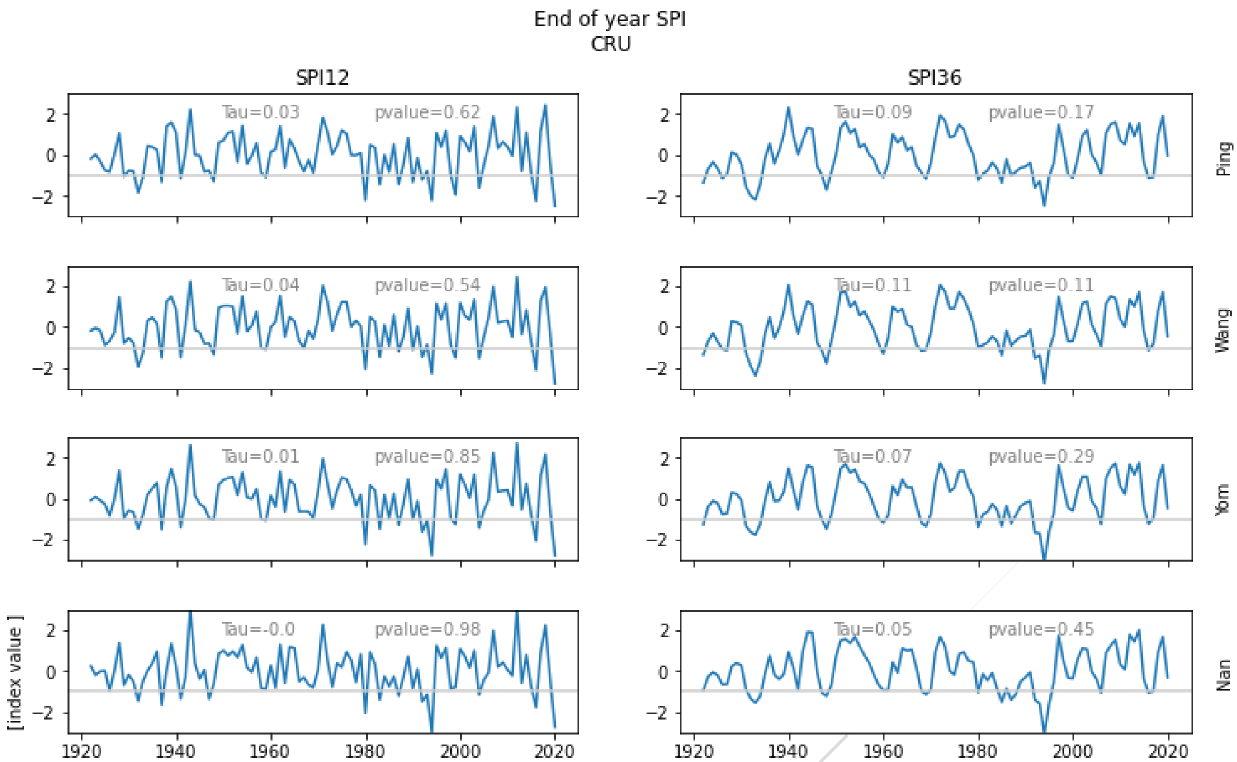


Figure 29: SPI at 12 and 36 months time scale, for individual sub-catchments, based on CRU data. Trend assessed through Mann-Kendall test, with trend significant at 95% level highlighted in bold.

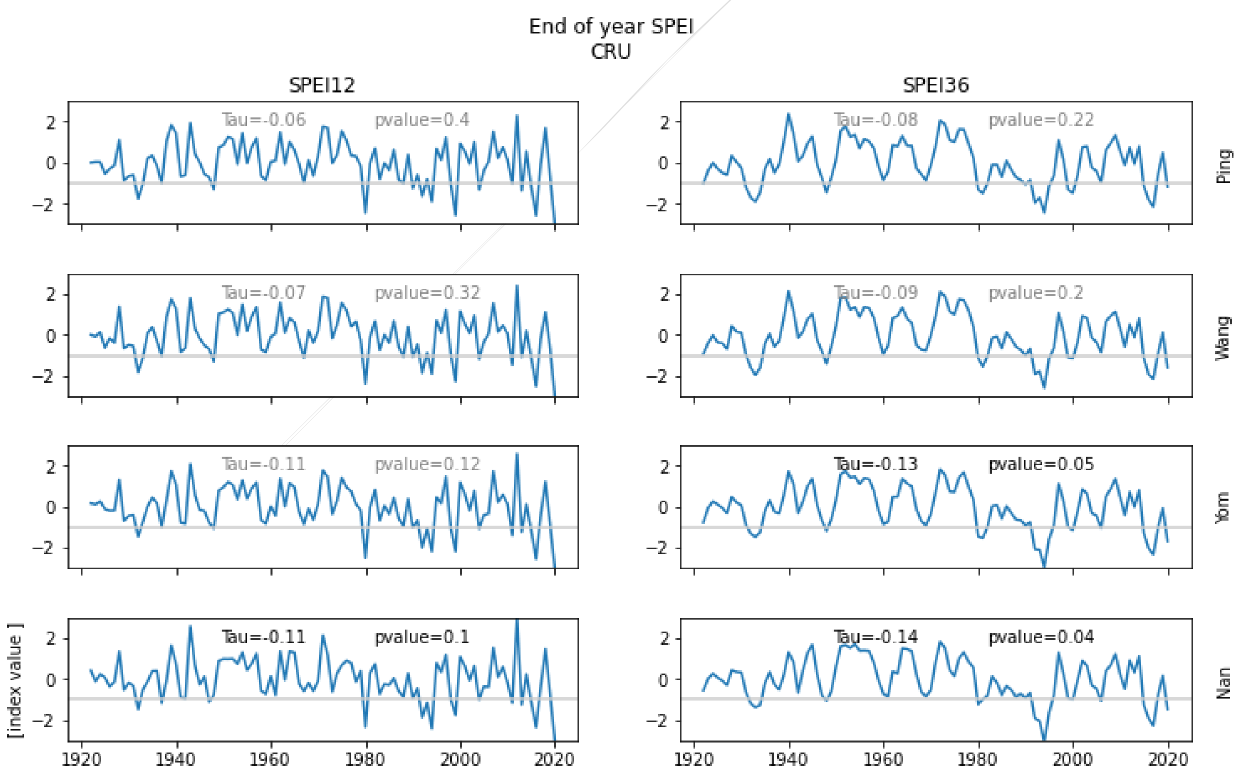


Figure 30: SPEI at 12 and 36 months time scale, for individual sub-catchments, based on CRU data. Trend assessed through Mann-Kendall test, with trend significant at 95% level highlighted in bold.

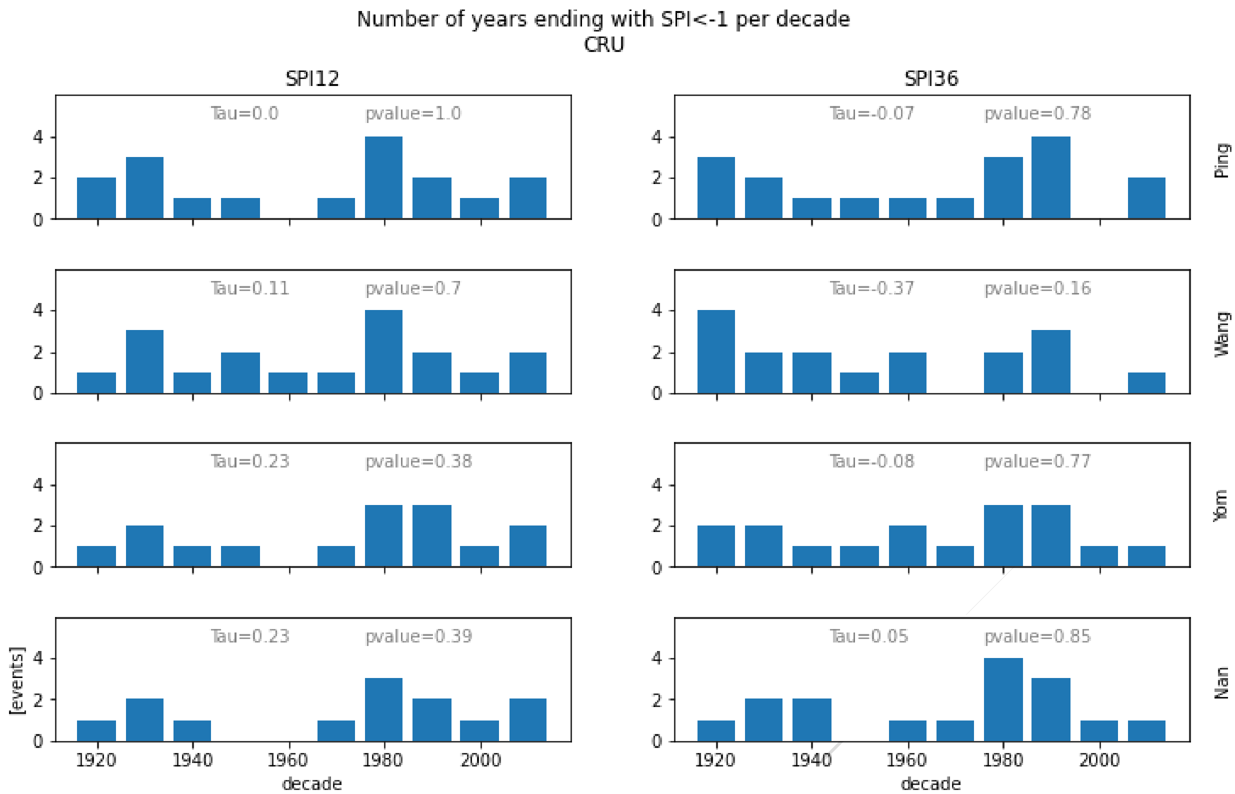


Figure 31: Number of drought years defined by SPI<-1 for 12 and 36-month SPI based on CRU data. Trend evaluated through Kendall Tau with M-K test, when significant highlighted in bold.

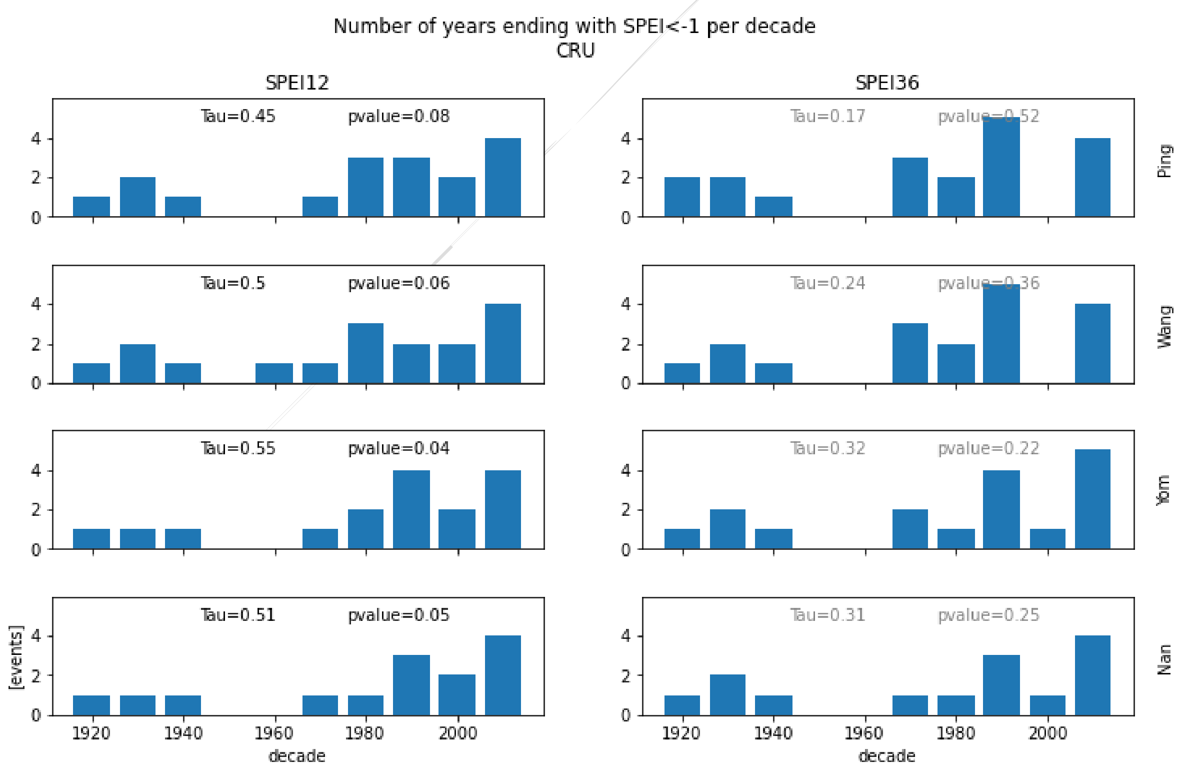


Figure 32: Number of drought years defined by SPEI<-1 for 12 and 36-month SPEI based on CRU data. Trend evaluated through Kendall Tau with M-K test, when significant highlighted in bold.

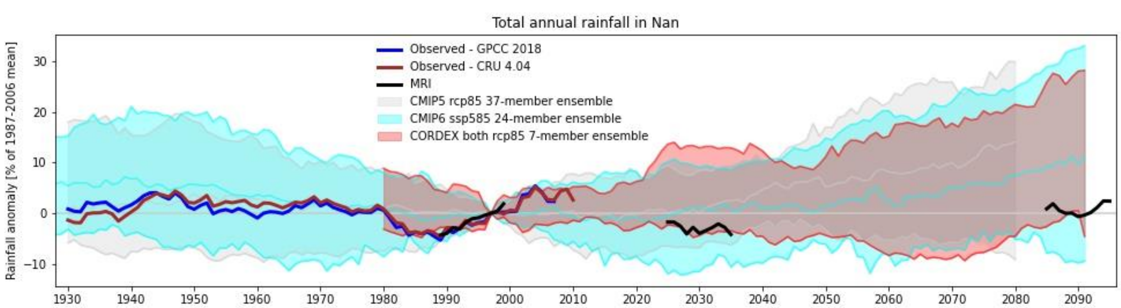
1.7.4 Climate Projections

The following observations can be made projections under the high GHG emission scenario (Figure 33a and Figure 34a):

- There are minimal differences between the various sub-catchments.
- There is a good correspondence between the CMIP5 and CMIP6 GCM ensembles. Regional models CORDEX ensemble shows somewhat different pattern to the GCM ensembles, but this is most likely due to the lower number of ensemble members - the CORDEX ensemble has only 7 members (2 RCMs downscaling 3 and 4 GCMs only), while CMIP6 has 24 members for rainfall and 22 members for temperature) and CMIP5 has 37 members. By nature, the smaller CORDEX ensemble is expected to have lower range than the larger GCM ensembles.
- The projections of future rainfall span the range from no-change to increases which steadily progress toward the end of the 21st century, reaching a range of 0 to 25-30% of the 1987-2006 mean.
- Projections of temperature are consistently towards higher temperatures, with the range spanning 2-6 degrees above the 1987-2006 mean at the end of the 21st century.

The projections for the moderate GHG emission scenario are similar in direction to those for the high GHG emission scenario, but lower in magnitude (Figure 35b and Figure36b). We also evaluate occurrence of future drought by calculating 12-month SPEI drought index and calculating decadal count of droughts characterized by index value of -1 or less. We calculate trends in an identical way to that in historical data. Figure. 37 illustrates the results for the Yom sub-catchment under the high GHG emission scenario (other sub-catchments are characterized by similar results). The results indicate the increase in the frequency of 12-month SPEI drought (in 21 out of 22 models), statistically significant in 3 models.

In order to elucidate how the projected increase in rainfall is distributed throughout the season, we calculate relative change in monthly rainfall climatology between the 2051-2080 and 1987-2006 periods. We subsequently apply that relative change to the observed (CRU climatology) to obtain a bias-corrected future climatology for each GCM. Results indicate that the increase in the annual rainfall is mostly driven by the increase in the Aug-Dec rainfall, and that only 2-3 GCMs do not project rainfall increase in that season (Figure 38). The rainfall change signal in the early rainfall season (Mar-Jun) is less consistent across CMIP6 GCMs, with approx. 50% projecting a decrease.



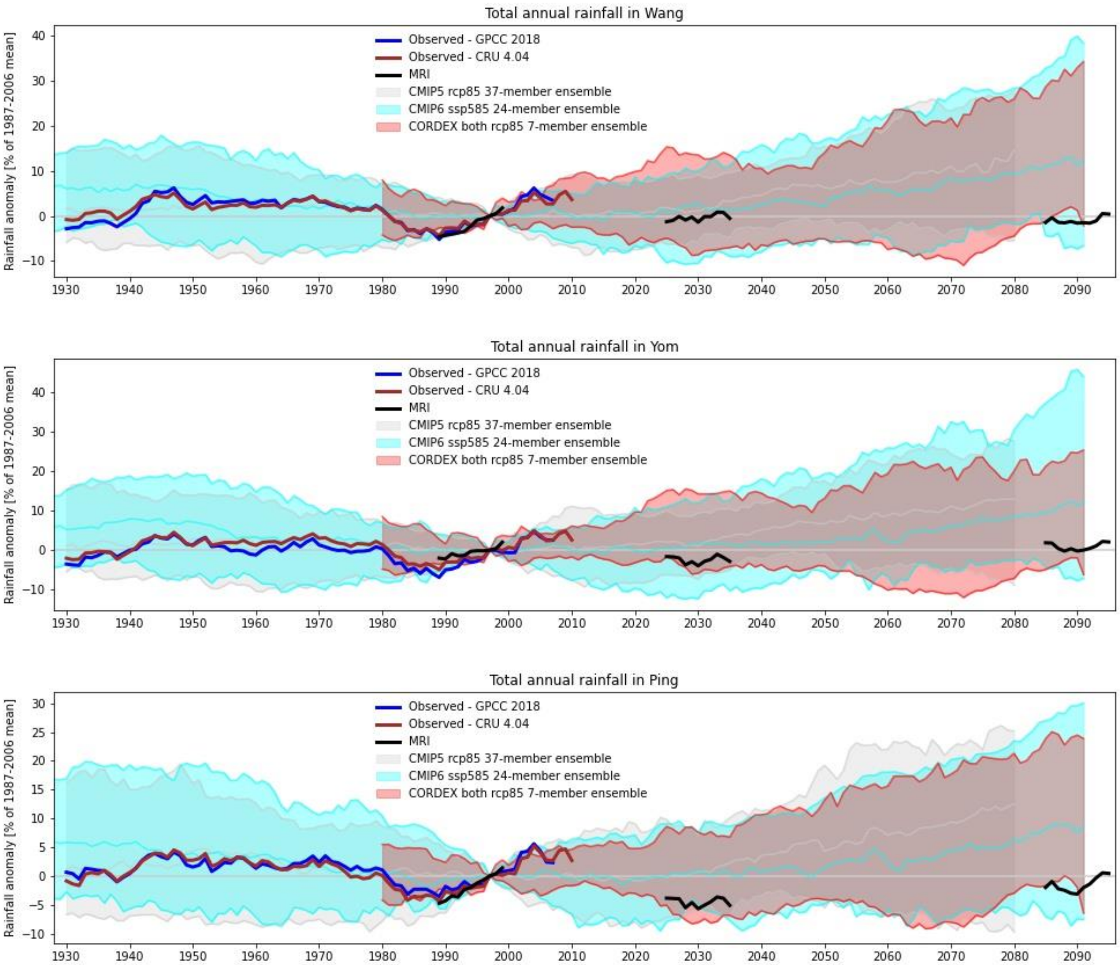
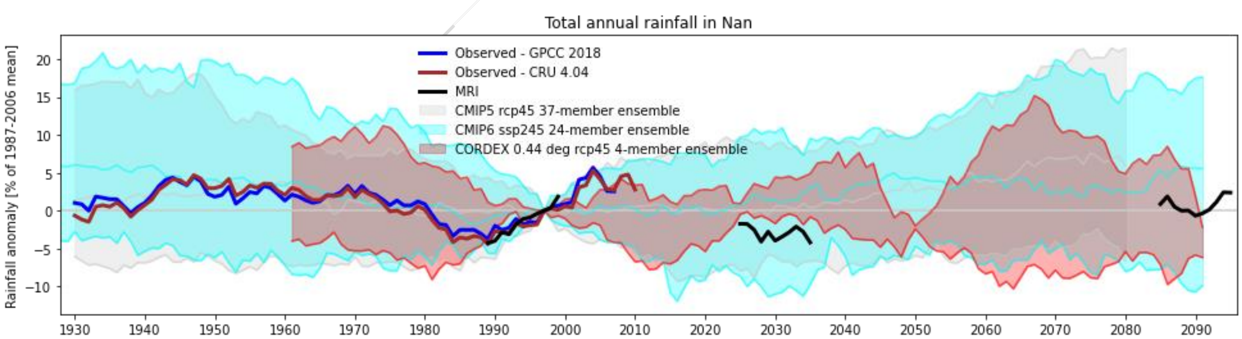


Figure 33a: Historical and projected total annual rainfall under high GHG emissions trajectory (RCP 8.5 and SSP 585), from CMIP5, CMIP6 and merged CORDEX 0.44 and 0.22 deg ensemble. Data from single model projections used in Wichakul et al. 2014 (under SRES A1B) superimposed.



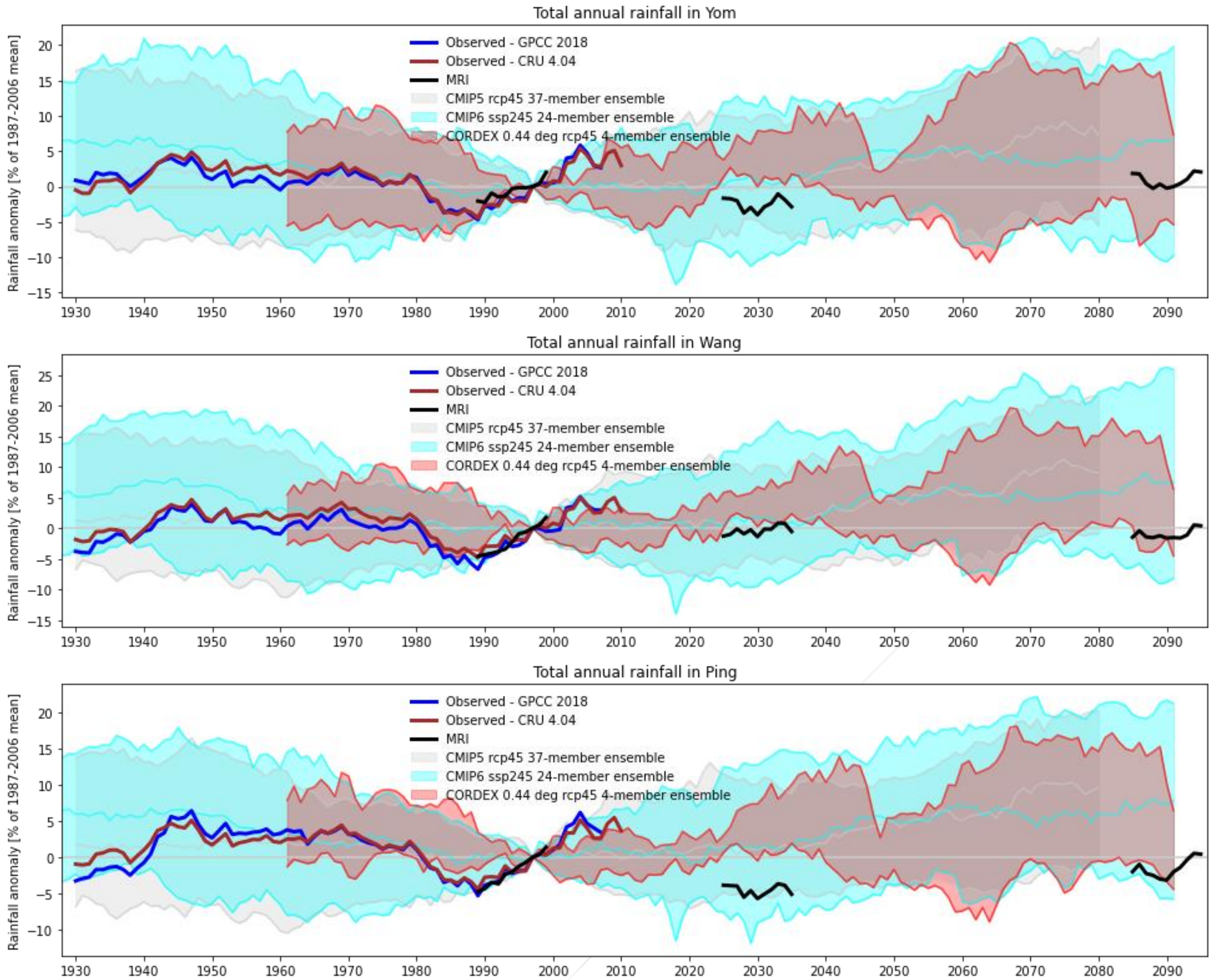
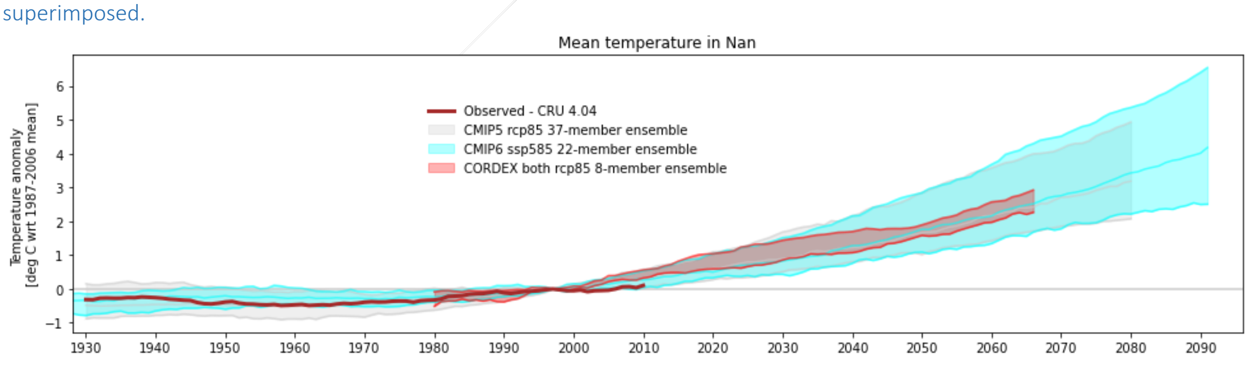


Figure 33b: Historical and projected total annual rainfall under moderate GHG emissions trajectory (RCP 4.5 and SSP 245), from CMIP5, CMIP6 and merged CORDEX 0.44 deg ensemble. Data from single model projections used in Wichakul et al. 2014 (under SRES A1B) superimposed.



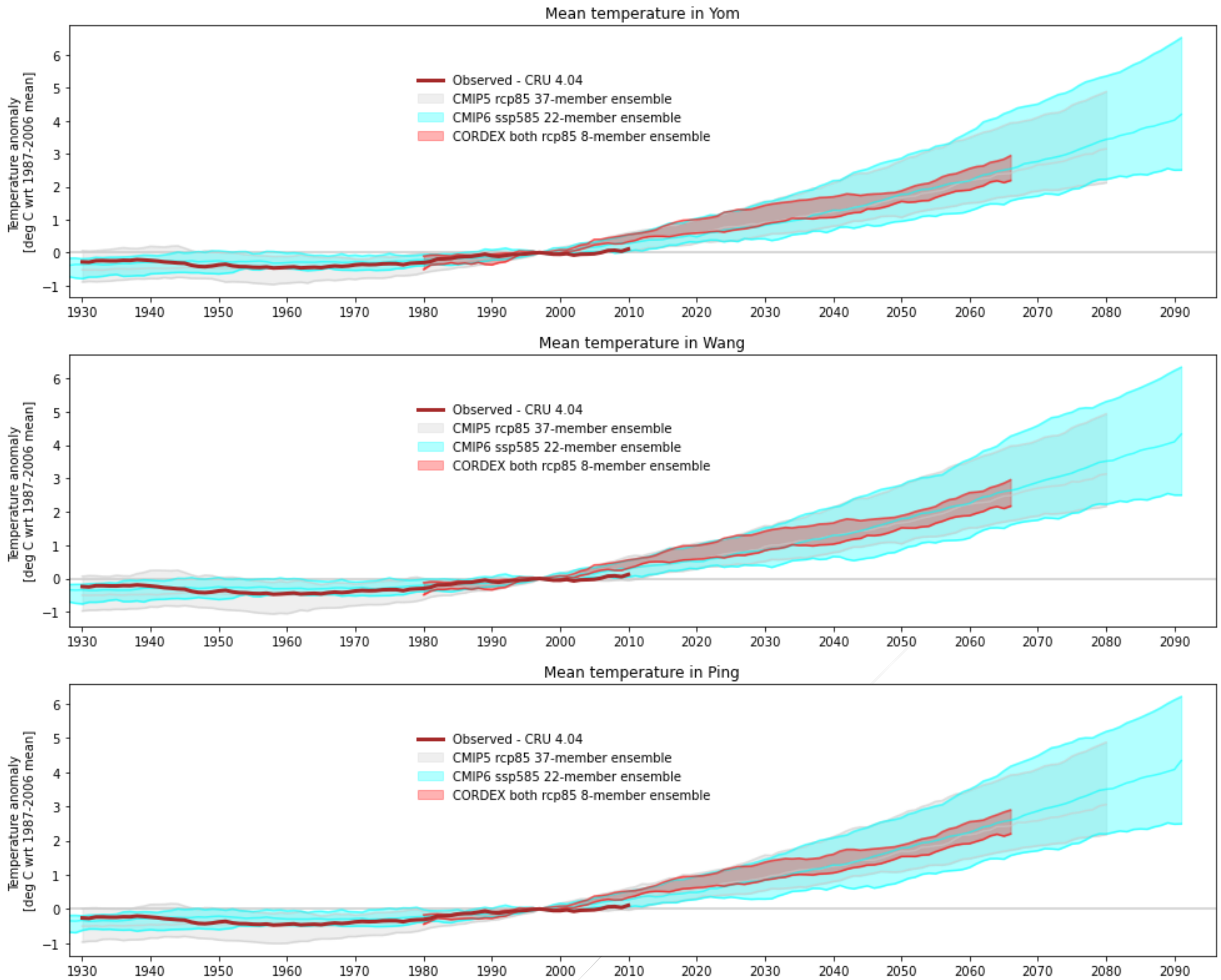
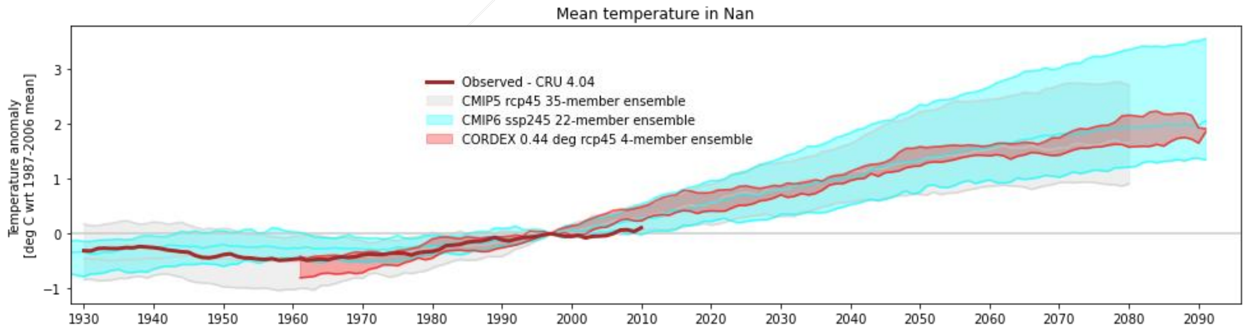


Figure 34a: Historical and projected mean temperature under high GHG emissions trajectory (RCP 8.5 SSP 585), from CMIP5, CMIP6 and merged CORDEX 0.44 and 0.22 deg ensemble



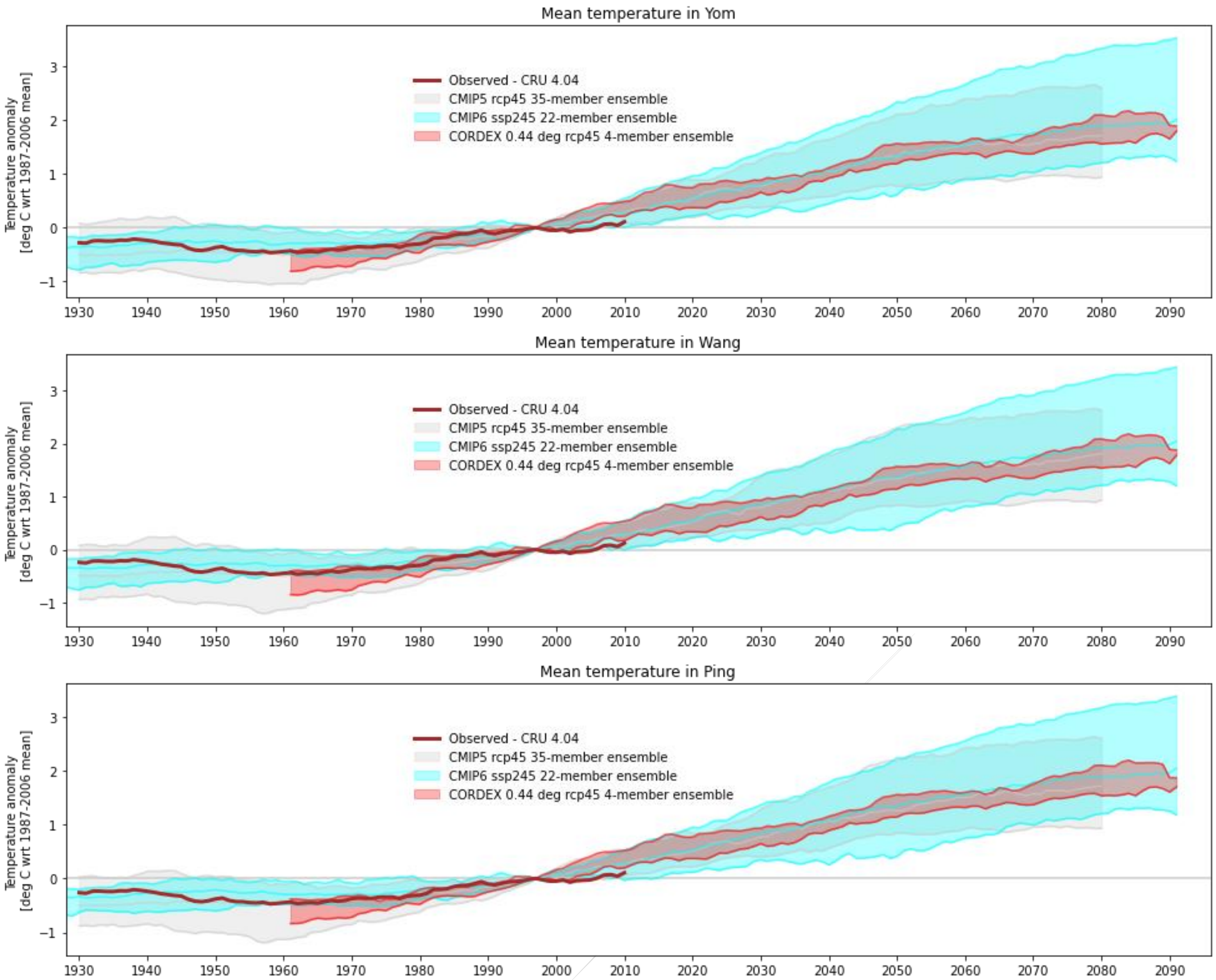


Figure34b: Historical and projected mean temperature under moderate GHG emissions trajectory, from CMIP5, CMIP6 and merged CORDEX 0.44 deg ensemble

Figure 35: Frequency of drought years, and its trend over 2000-2040 in 22 CMIP6 model simulations for the Yom sub-catchment.

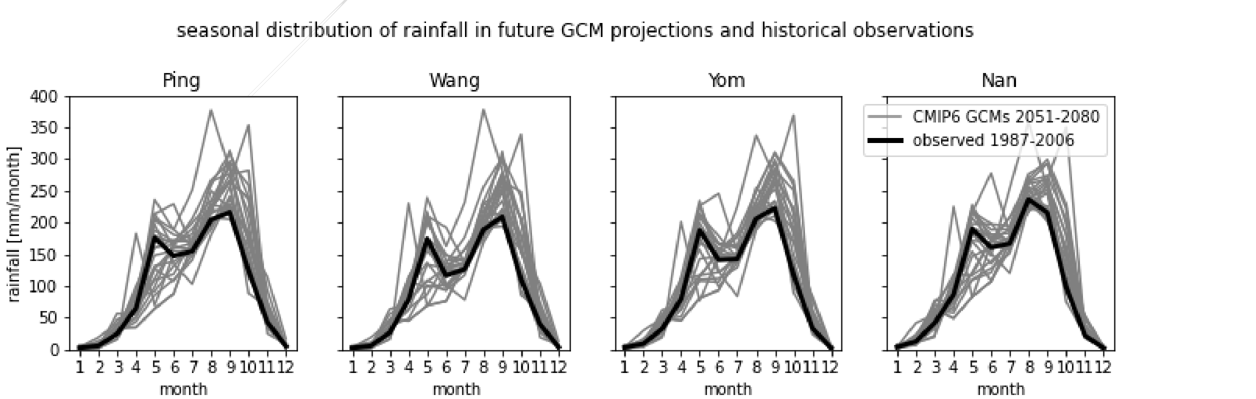
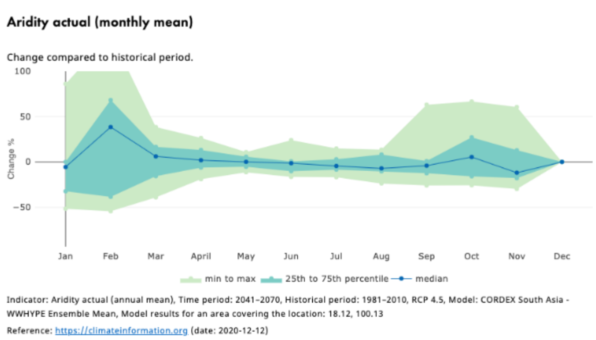


Figure 36: Seasonal distribution of rainfall in GCM projections (bias corrected CMIP6 ensemble) and in historical observations (CRU)

These changes in rainfall, combined with increases in evapotranspiration, will lead to increases in aridity (measured as the ratio of actual evapotranspiration to rainfall) during the dry season and early part of the year (particularly during October and February), with little change during the rainfall season (Figure 37).

Furthermore, the increases in rainfall during the later half of the rainfall season will likely lead to increases in maximum river discharges and hence floods under both RCP4.5 and RCP8.5 in both the near, mid and far future periods of the 21st century (see Figure 38).



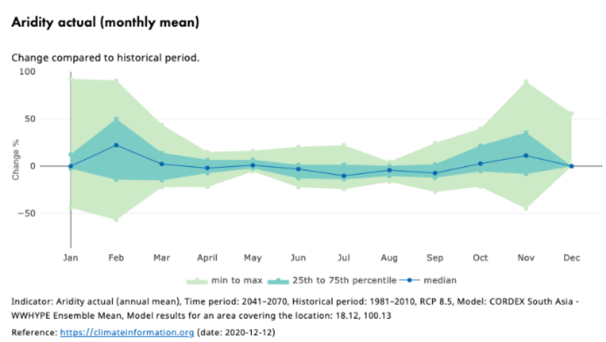
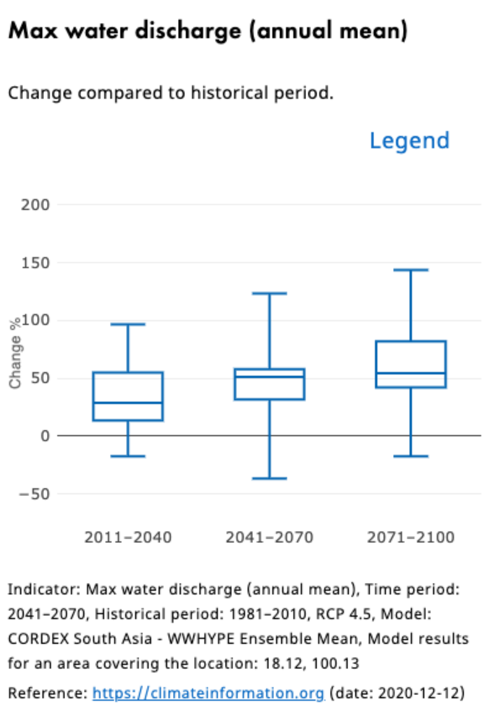


Figure 37: Changes in aridity (ratio of actual evapotranspiration to precipitation) for Phrae (northern Chao Phraya basin) under RCP4.5 (left) and RCP8.5 (right).



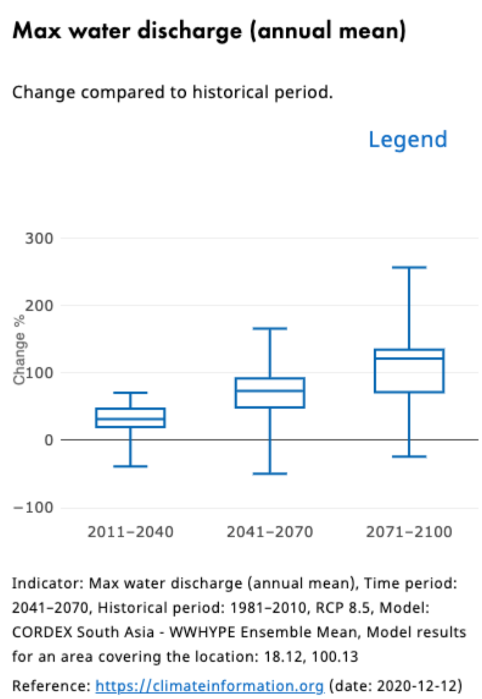


Figure 38: Changes in maximum water discharge at Phrae (northern Chao Phraya) for different future periods under RCP4.5 (left) and RCP8.5 (right).

In order to ascertain implications of anthropogenic climate change on agriculture, as projected by CMIP6 GCMs, we show the historical and projected crop water demand (CWD) defined as CWD=Kc*PET, and irrigation water requirements (IWR) defined as: IWR=CWD-P, where PET is potential evapotranspiration, P is rainfall and Kc is the monthly crop coefficient, depending on the crop growth stage. We use average monthly Kc values for long growth duration rice variety (Hommari 105) to represent rice grown in the Dec-Apr season, and short growth duration variety (RD) to represent rice grown in the May-Jul season. The results (Figure 39) indicate that both crop water demand and irrigation water requirement are projected to increase in near future (2021-2050) compared to historical (1987-2006) period. These increases are a result of an increase in PET, that is not compensated by an increase in P, and are simulated by all models in the ensemble. The results, therefore, robustly show that anthropogenic climate change will cause rice to require more water in the future which cannot be met by increases in rainfall alone. Therefore to maintain current rice cropping yields and areas in the basin, under current practices, will require more water or greater efficiencies in the use of water e.g. utilising precision agriculture to reduce water wastage in the application of irrigation.

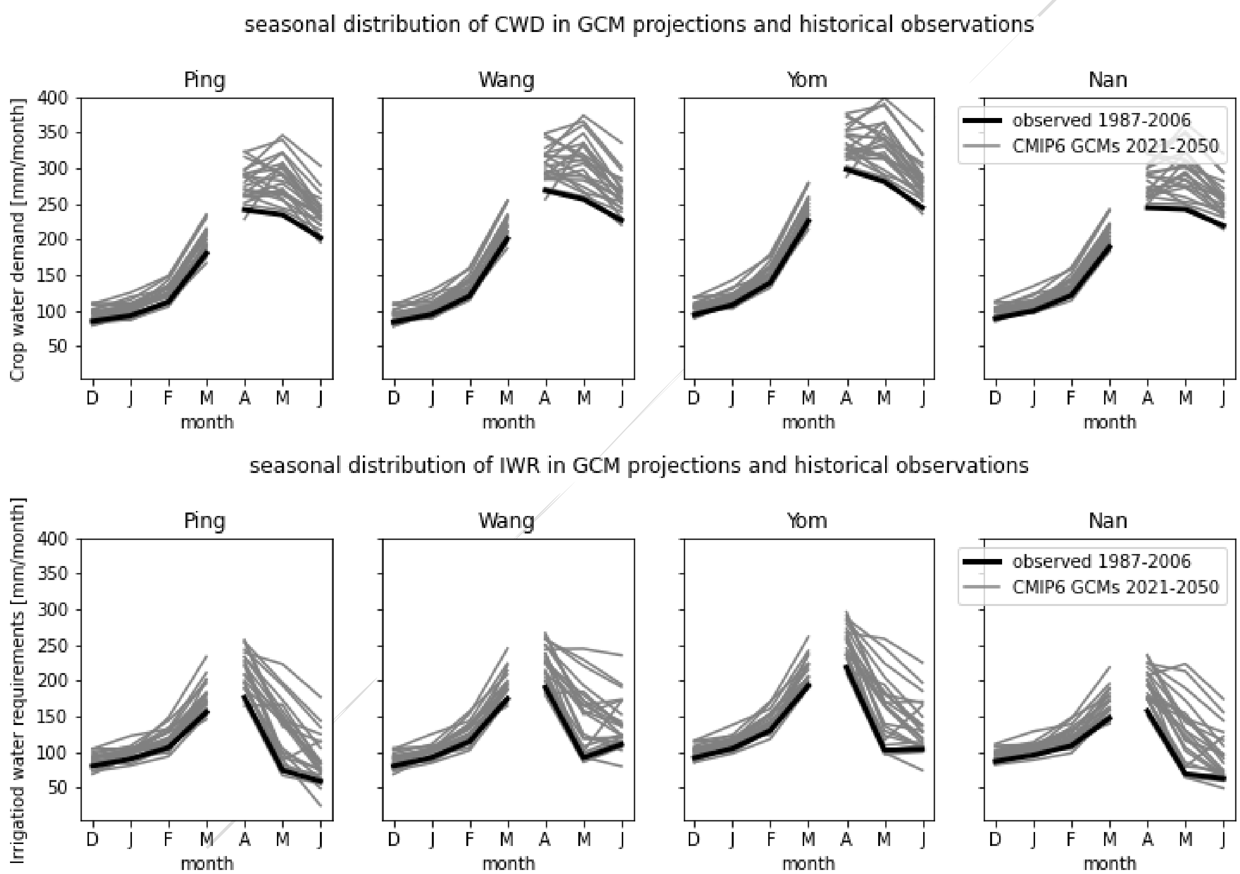


Figure 39: Crop Water Demand (CWD) and Irrigation Water Requirements (IWR) for the two main rice growing season in the analysed region, using Kc values for Hommari 105 rice for the Dec-Mar season and RD rice for the Apr-Jun season. Calculations based on PET derived from air temperature data and precipitation data for each of 22 members of the CMIP6 ensemble under SSP585 emission scenario. Historical values based on CRU data. GCM data are bias corrected in mean so that each individual ensemble members have P and PET (and thus CWD and IWR) identical to observations in the 1987-2006 period.

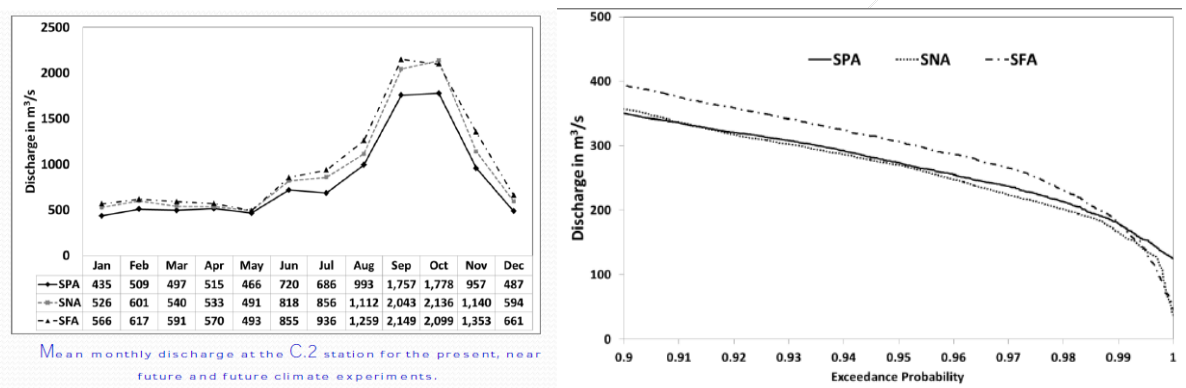
From the early study, Wichakul et al. (2014) conducted a baseline study for Chao Phraya basin (Ping, Nan, Yom, and Wang sub-basins), evaluating hydrological impacts of climate change on streamflow in that basin. They utilized a bespoke comprehensive distributed hydrological model that accounted for rainfall-runoff processes, flood wave propagation processes as well as water management activities and water abstractions in the basin. The model has been calibrated against observed river discharges.

The study utilized climate projection from a single global climate model: MRI-AGCM3.2s with spatial resolution: ~20km. The projection was modelled under SRES A1B GHG emission scenario, which is non-conservative ("worst case") used in the CMIP3 global climate modelling experiment.

In that study, GCM rainfall and potential evaporation data were bias corrected to observations, and the hydrological model was used to simulate three continuous periods: historical (1979-2007), near future (2015-2044), far future (2075-2104).

Results were presented in terms of impacts at the outlet of the basin at C2 gauge (thus combining all 4 sub-catchments). The study demonstrated (see Figure 40):

- an increase in mean annual discharge in both near and far future,
- a decrease in flows during the low flow period in near future,
- an increase in flooding frequency in both near and far future.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SPA	435	509	497	515	466	720	686	993	1,757	1,778	957	487
SNA	526	601	540	533	491	818	856	1,112	2,043	2,136	1,140	594
SFA	566	617	591	570	493	855	936	1,259	2,149	2,099	1,353	661

Figure 40: Historical and projected discharges of Chao Phraya River based on MRI-AGCM3.2s under the SRES A1B scenario (Wichakul et al. 2014).

Since the Wichakul et al. 2014 results are based on a single GCM projection, there is a need to contextualize those results within the broader landscape of multi-generation, multi-model projections considered here. In order to illustrate how the MRI-AGCM3.2s rainfall projections relate to the other models/ensembles used here, we superimposed the sub-catchment average rainfall figures from that model onto the plume plots in Figure. 40. As that figure illustrates, the MRI-AGCM3.2s projection is a moderately "dry" projection in the near future, and is one of the "driest" projections in the far future. In other words, approx. 60-75% of ensemble members of CMIP5 and CMIP6 ensembles simulate wetter near future than MRI-AGCM3.2s, while for the far future, that number is about 90%. This is consistent with the results of Kotsuki et al. (2014) who demonstrated that a suite of 6 CMIP5 GCMs all simulate increases in average runoff over the Chao Phraya basin under both RCP4.5 and RCP8.5, for both near (2040-2059) and far future (2080-2099) periods during the 21st century (Figure 41). Only the CSIRO GCM under RCP4.5, and IPSL (near future RCP4.5 and far future RCP8.5) indicate small regions towards the north east of the basin that will likely have decreases in runoff. This study estimates large increases in runoff (>20%) under both RCP scenarios at C.2 (beginning of Chao Phraya river) due to increases in mid-season rainfall (Figure 42). Increases in annual runoff in the C.2 catchment were 45.8 mm (5.0 x10^9 m^3) and 85.4 mm (9.4 x10^9 m^3) under the near-future climate scenario, and 83.9 mm (9.2 x10^9 m^3) and 129.5 mm (14.2 x10^9 m^3) under end-of-the-21st-century climate scenario, for RCP 4.5 and RCP 8.5, respectively. Compared to the capacities of the Bhumibol and Sirikit dams (13.5 and 9.5 x 10^9 m^3), projected increases in runoff at the end of the 21st century are high and will likely require new flood management and mitigation plans, including the construction of new dam reservoirs and changes in the rules for operation of dam gates.

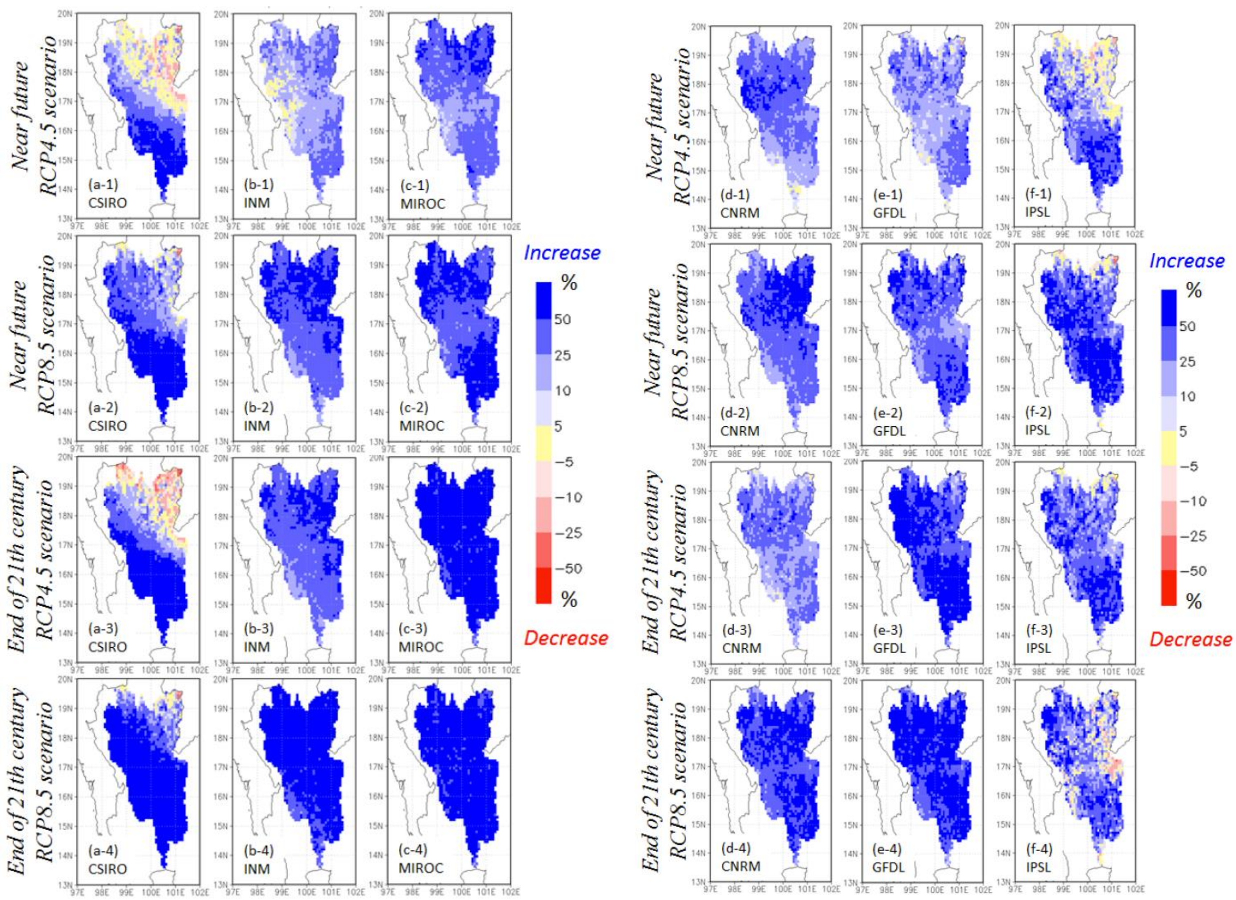


Figure 41: Climatological annual mean runoff change (%) in the future climate relative to the present climate. Top figures (a-1, b-1, c-1, d-1, e-1 and f-1) show projected near-future (2040–2059) change under the RCP 4.5 scenario. Second top figures (a-2, b-2, c-2, d-2, e-2 and f-2) show projected near future changes under RCP 8.5 scenario. Third top figures (a-3, b-3, c-3, d-3, e-3 and f-3) show projected end-of-21st-century (2080–2099) changes under the RCP 4.5 scenario. Bottom figures (a-4, b-4, c-4, d-4, e-4 and f-4) show projected end-of-21st-century changes under RCP 8.5 scenario. Figures a1-a4, b1-b4, c1-c4, d1-d4, e1-e4 and f1-f4 were calculated with CSIRO, INM, MIROC, CNRM, GFDL, and IPSL, respectively. Cold and warm colors represent increase and decrease, respectively. From Kotsuki et al. (2014).

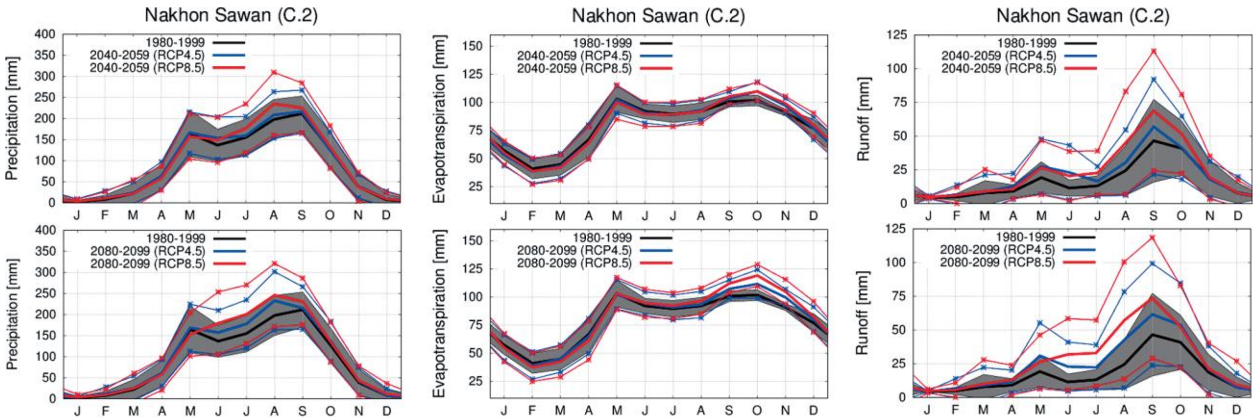
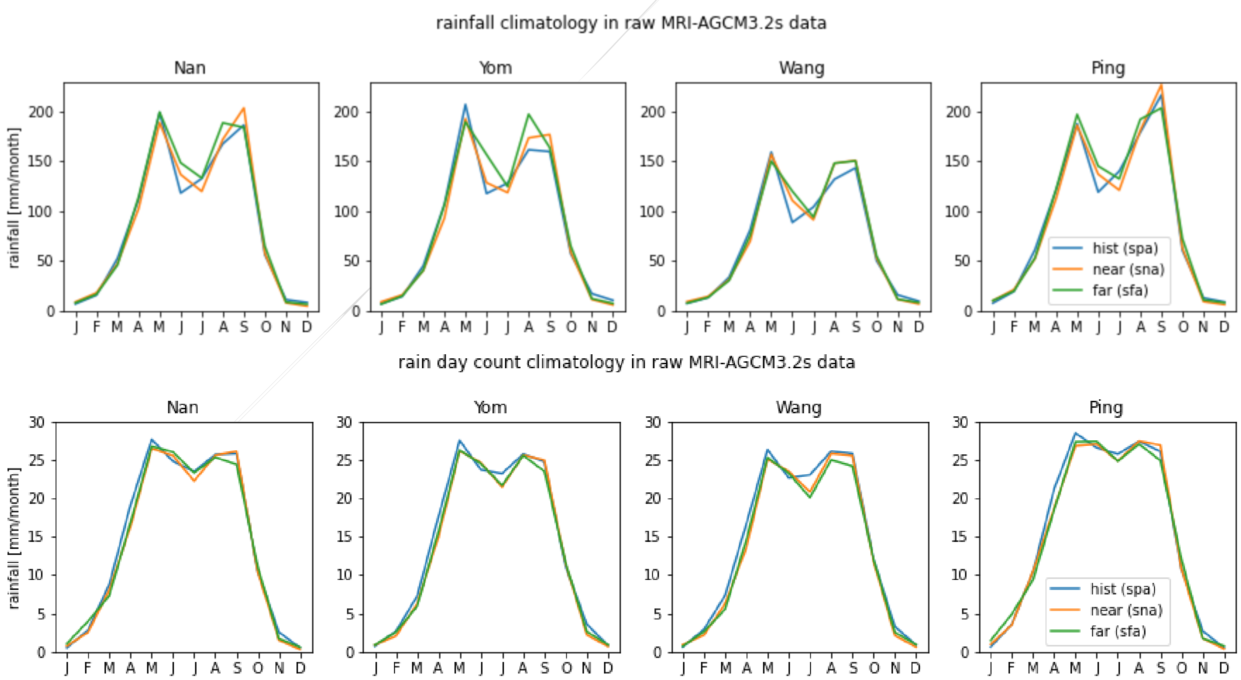


Figure 42: Comparisons of monthly precipitation (a-1, a-2), evapotranspiration (b-1, b-2), and runoff (c-2, c-2) in Nakhon Sawan catchment. Panels a-1, b-1, and c-1 show comparisons between present climate (1980–1999) and near-future climate (2040–2059). Panels a-2, b-2, and c-2 show comparisons between present climate and end-of-21st-century climate (2080–2099). Solid black lines and gray shaded areas show averages and standard deviations for the present climate. Solid blue lines and blue lines with x-marks show averages and standard deviations under the RCP 4.5 scenario. Solid red lines and red lines with x-marks show averages and standard deviations under the RCP 8.5 scenario

In order to further explore the climatic drivers of the relatively strong impacts on the discharges of the Chao Phraya River, we have analysed sub-catchment rainfall climatology in the MRI-AGCM3.2s data in the historical, near future and far future periods (as in Wichakul et al. 2014). Results, illustrated in Figure 43 show that rainfall change in both "futures" are relatively minor, but there is a relatively consistent increase in total rainfall in the Jul-Sep period, driven by changes in rainfall intensity. These changes in seasonality are consistent with the multimodal ensemble shown in Figure 18, and as stated above it is reasonable to assume that forcing from other GCMs would produce similar, if not greater, increases in discharge and flooding.



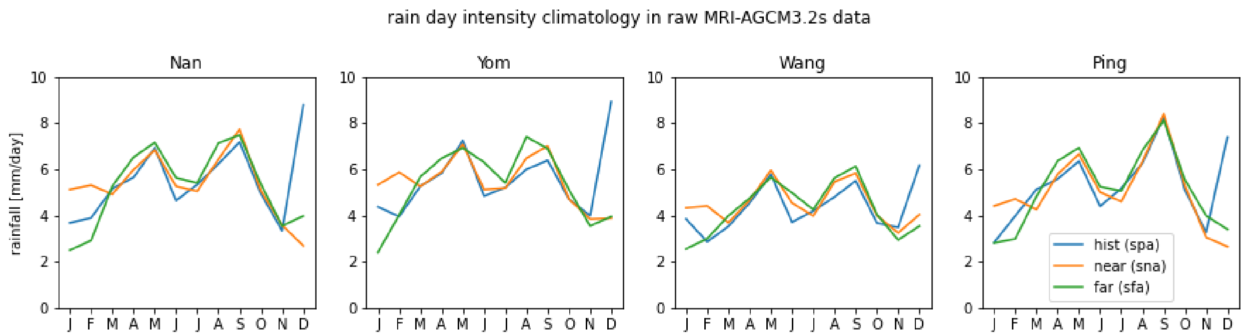


Figure 43: Rainfall (total, rain day count and rain day intensity) climatology in raw MRI-AGCM3.2s data.

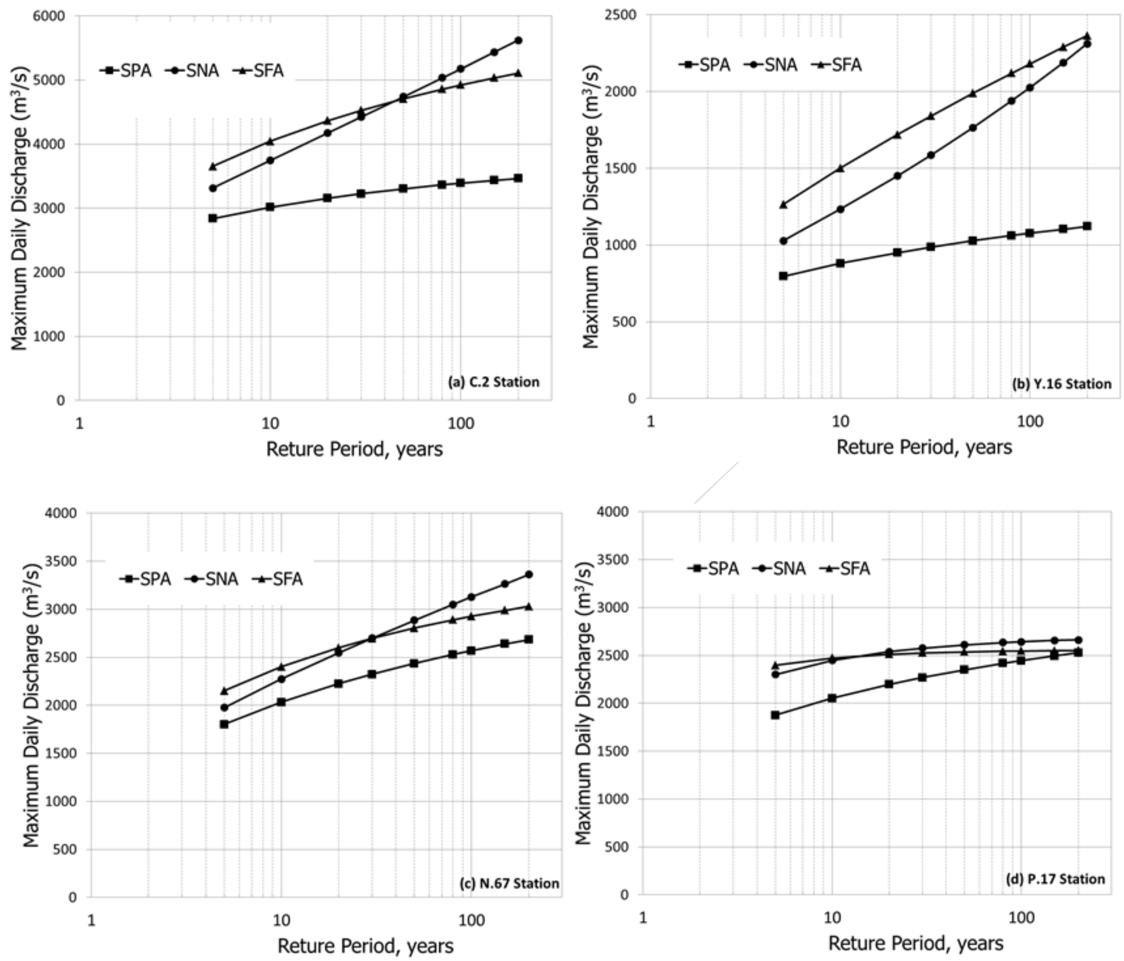


Figure 44: Maximum daily discharge corresponding to different return periods for present climate (SPA), near future climate (SNA) and future climate (SFA) for each location.

A frequency analysis of extreme projected discharges by using the MRI-AGCM3.2s (Wichakul et al. 2014), shows changes in maximum daily discharges for different return periods and are illustrated in Figure 44 for four different locations; (a) for C.2 station the beginning of Chao Phraya River, (b) for Y.16 station at the outlet of Yom River, (c) for N.67 station at the outlet of Nan River and (d) for P.17 at the outlet of Ping River station. The assessment has been conducted by comparing the return period of the 5-year, 10-year, 20-year, 30-year, 50-year, 80-year, 100-year, 150-year, and 200-year discharges. Shorter return periods (shorter than 50-years) affect flood related design structures, such as irrigation structure, urban drainage and bridges. Figure 44a, demonstrates that during the 21st century the magnitude of extreme events at the C.2 station significantly increase for return periods shorter than 50-years and also it is larger than the magnitude of discharges in the near future climate (2015-2043). For long return periods (> 80-years), the magnitude of discharge is extremely high in the near future climate. That change in the C.2 station mostly corresponds to change in flood magnitude in the P.17 and N.67 stations for both near future and future periods (Figures 44c and 44d). Flood frequency analysis of the Y.16 station showed different patterns from other locations, as illustrated in Figure 43b because the location of the Y.16 station is far for the location of the other three stations. Flow from the Y.16 station merges with the Nan river at the confluence located upstream of the N.67 station. The corresponding discharge of the C.2 station (5,034 m^3/s) at 80-year return period of the near future is larger than the peak discharge of Thai's flood 2011 (4,686 m^3/s). Consequently, the simulated discharges shows that flood risk will increase in the future, likely at a scale/level greater than seen in 2011.

1.7.5 Summary of climate-related trends and projections

1.7.5.1 Historical trends in climate

Trends at individual stations are difficult to interpret, as they may be affected by systematic and non-systematic errors in the data series, whereas long-term gridded data are conditional on the continuity of station record contributing to the dataset. We have therefore used both datasets to show where they are consistent and trends can be considered robustly independent of the dataset used.

Whilst rainfall trends, as calculated in the analysis above in the Chao Phraya basin, do not suggest a systematic driver of historical droughts or floods, there is evidence for consistent reductions in the numbers of rainy days and increases in average rainfall intensity. This is also consistent with the available peer-reviewed literature which identifies increases in rainfall intensity over the last 60-70 years. Whilst, linking the weak and statistically not-significant rainfall trends present in the Chao Phraya basin to anthropogenic climate change is difficult to do with any certainty, as such trends may arise purely as a random effect of natural climate variability compounded by the presence of multi-decadal variability, it is noteworthy that these changes in rainfall characteristics are consistent with model projections of future change.

There are, however, relatively strong and consistent historical trends in air temperature, with a stronger signal in mean and minimum temperatures, and weaker in maximum temperature, with consequent implications for drought. As demonstrated, although there is no clear signal in rainfall-based drought indices, a rainfall-evaporation based index (SPEI) shows clearer and consistent signals, with an overall increase in drought, and statistically significant increases in the frequency of SPEI-indexed drought during the last 100 years.

The increase in drought frequency is also conditional on factors such as the quality of the data (it is derived from gridded CRU data, and might be affected by a changing set of stations in that dataset) and the adopted evaporation formula (SPEI is a combination of rainfall and potential evaporation, the latter calculated from air temperature). Whilst different potential evaporation formulas have different sensitivities to temperature, the results are consistent with the strong trends in temperature in gridded and station data. These trends are consistent with global temperature trends and trends in GHG concentrations. This particular trend is therefore expected to increasingly affect local climates in the future.

1.7.5.2 Future changes in climate, flood risk, drought and crop water requirements

Climate projections, utilizing multi-model, multi-method and multi-generational ensembles, indicate increases in annual rainfall in the long-term, with signals emerging in the near future. Importantly, while there is a considerable uncertainty about the trajectory of the future climate as manifested by the spread of the multi-model ensembles, it should be noted that there are few projections of a "drier" future, i.e. one characterized by lower than historical annual rainfall. Importantly, all projections indicate increases in rainfall during the main rainfall season.

Projections show that climate change affects the two main variables of hydrological significance - rainfall and air temperature - in a way that the changes ay compensate for each other to some extent - i.e there is an increase in rainfall, but also an increase in potential evaporation. Importantly, however, the increases in these two variables follow slightly different trajectories and manifest differently for different seasons. This has implications for drought, with one consequence that future drought risk on annual and longer timescales is expected to reduce in the long-term, once increases in annual rainfall totals exceed increases in potential evapotranspiration. However, as demonstrated through the drought frequency analyses, near future drought will be dominated by increases in evaporation and the frequency of droughts, with increases in rainfall not yet of a magnitude that can compensate for increases in evaporation.

The strong impact of the projected increase in air temperature and PET on agricultural water demand is evident already in the near future, where both crop water demand and irrigation water requirements increase by up to 30% compared to those in the historical period. This means that crops will continue to require more water to meet their physiological needs in the future and that future changes in rainfall are insufficient to meet those needs. This will require either access to more irrigation water, improvements in water use efficiencies, use of less water intensive crops, or climate smart agricultural practices to reduce evaporation and irrigation requirements.

Projected increases in annual total rainfall are largely due to a relatively strong increase in rainfall during the peak of the rainy season (Aug-Oct), which has strong implications for flood risk. The Wichakul et al. 2014 study of hydrological impacts, based on a single projection (climate model) characterized by a relatively weak signal of rainfall change, indicates increases in flood risk in the future. It is clear from that study that the weak rainfall signal is amplified in the hydrological model (and the actual hydrological system) resulting in increases in streamflow in the lower parts of the basin that are manifested throughout the year, but mostly during peak flood conditions. Additionally, the Wikachul et al. 2014 results are more than likely a lower estimate of potential increases in streamflow as the rainfall used in the Wikachul et al. 2014 simulations is at the lower bound of estimated increases from the full suite of GCMs/RCMs analysed here. Although hydrological responses from rainfall increases projected by the broader suite of GCMs/RCMs have not been explicitly modelled, it is clear from the comparison of ensemble rainfall projections with the projected rainfall used by Wikachul et al. 2014, that any such hydrological modelling would simulate significantly higher increases in flood runoff and streamflow in the future.

Such a conclusion is supported by Kotsuki et al., (2014) utilising a range of GCMs and scenarios. That study also shows that increases in streamflow are simulated using all models and scenarios for both near and long term. Importantly, increases in flood streamflow are of a magnitude comparable to the holding capacities of the main dams. Increases in maximum discharges of the order of 50% (median estimate) are also simulated by the ensemble of CORDEX models. It is therefore clear that future changes in climate are expected to result in considerable increases in flood risk in the Chao Phraya river.

1.7.5.3 *Key approach and summary for climate rationale*

The key approach for the climate rationale for the project can be summarized as:

- Use **all available data**: stations, CRU, GPCC, CHIRPS, CMIP5(RCP4.5/8.5), CMIP6(RCP4.5/8.5), CORDEX
- Compare historical trends with ensembles (multiple models) of future projections (**IPCC approach**)
- Use gridded data to understand the basin-wide climate and supplement with station data and peer reviewed literature where available
- Objective is to assess whether Climate Change will **increase** the flooding and agricultural drought **hazard risk**, assuming social, ecological and engineering vulnerabilities remain at current levels.

The first three bullets emphasize the importance of using as many sources of data and models as are available, both in order to best characterize risk (and its probability distribution) and to recognize that each data source has different strengths and weaknesses (e.g. downscaled vs GCM based scenarios, station vs gridded data). This is inline with approaches developed by the IPCC, but appears to not be the preferred ITAP approach (see response to paragraph 52). The fourth bullet sets out the approach to demonstrating that climate change will exacerbate current risks (the climate rationale). By focusing on the hazard and showing that climate change will worsen the relevant hazards (rainfall intensity, discharges, evapotranspiration), we show that in the absence of adaptation of key vulnerabilities/exposure, climate change will heighten risks associated with these hazards.

The following key conslusions underpin the climate rationale for the project and informs the design of the interventions:

- Whilst station trends are mostly <95% significance, there are consistent trends between stations showing: **increases** in daily rainfall intensity, **decreases** in number of rainy days (this is consistent with future projections). This is consistent with existing peer-reviewed literature;
- Historically, there has been an **increasing risk in drought** as measured by SPEI (measures rainfall-evapotranspiration) but not SPI, implying that increases in evapotranspiration are mostly responsible and are greater than any increases in rainfall;
- Ensemble projections [CMIP5 (37 GCMs), CMIP6 (24 GCMs) and downscaled CORDEX (4-7 RCMs)] clearly show future projected increases of **10-15% in annual rainfall**. The MRI model is at the lower end of these estimates, but still shows **increases in rainfall intensities which lead to increases in discharges** during the main rainfall season when combined with a calibrated hydrological model;
- Future temperature increases of about 2°C under RCP4.5 are virtually certain and consistent with station and gridded datasets. **This leads to increases in evapotranspiration;**
- Crop water requirements (due to increases in evapotranspiration) and irrigation water requirements (accounting for changes in rainfall) **both increase in all months**; growing both rainfed and irrigated rice **will require more water and more efficient farming methods in the future; and**
- Significant **increases (approximately 50%)** in modelled maximum discharges (using CORDEX models) are consistent with the **+10% in annual precipitation** since the catchments amplify the rainfall signal and the increases occur during the rainy season. This is also consistent with simulated increases in runoff for the basin found in peer-reviewed literature.

2. Chapter 2: Yom-Nan River Basin

The geographic areas of the Yom and Nan Rivers, which are part of the Greater Chao Phraya River Basin area, are highly vulnerable to the impacts of climate change and have been prioritised by government for the project in response to this area being faced with the greatest extremes of climate impacts in Thailand, namely, flood and drought.

2.1 Project area in the Yom-Nan River Basin

The United Nations Development Programme (UNDP), and the Royal Irrigation Department (RID) under the Ministry of Agriculture and Cooperatives (MoAC), are jointly working to formulate a five-year project on *Enhancing Climate Resilience in Thailand through Effective Water Management and Sustainable Agriculture* to access climate finance assistance through the Green Climate Fund (GCF). The main objective of the project is to improve water management in the northern region of Thailand to better respond to climate change – to mitigate flooding, to prepare for times of drought, and to ensure efficient use of water resources for sustainable and climate resilient livelihoods.

The Yom River is the main tributary of the Nan River (which itself is a tributary of the Chao Phraya River). Its catchment area covers 23,618 km^2 of 11 provinces comprising Payao, Nan, Lampang, Phare, Tak, Kampangphet, Sukhothai, Uttaradit, Phitsanulok, Phichit and Nakhon Sawan. The Yom River from there runs about 735km to the south. The Nan River originates in the Luang Prabang Range, Nan province. Its catchment area covers 34,331km2 of four provinces comprising the provinces along the river after Nan province, which is Uttaradit, Phitsanulok and Phichit. The Yom River joins the Nan River at Chum Saeng district, Nakhon Sawan province. When the Nan River joins together with the Ping River at Pak Nam Pho within the town of Nakhon Sawan, it becomes the Chao Phraya River. The Nan River runs about 630km to the south. The Yom River has its source in the Phi Pan Nam Range in Pong district, Phayao province. Leaving Phayao, it flows through Phrae and Sukhothai as the main water resource of both provinces before it joins the Nan River at Chum Saeng district, Nakhon Sawan province. Under historic rainfall patterns, the Yom and Nan river basins, in Uttaradit, Phitsanulok and Sukhothai provinces, provided the critical function of managing the river flow. However, with frequent consecutive dry years and severe flooding in wet seasons, these basins are retaining less water and are unable to slow runoff. A large number of people are vulnerable within the area and flood and drought have become more severe, causing losses and damages to crop production and farmers' income. The Yom-Nan area allocated for enhanced water management and practices covers approximately 312,600 rai, the equivalent of around 500.16 km^2 across Phitsanulok, Sukhothai and Uttaradit provinces. The planned enhancements are for the agricultural area of rice paddy and villages scattered throughout the catchment between the Yom and Nan River. Within this area are a number of pre-existing hydraulic infrastructures with canals providing water resources.

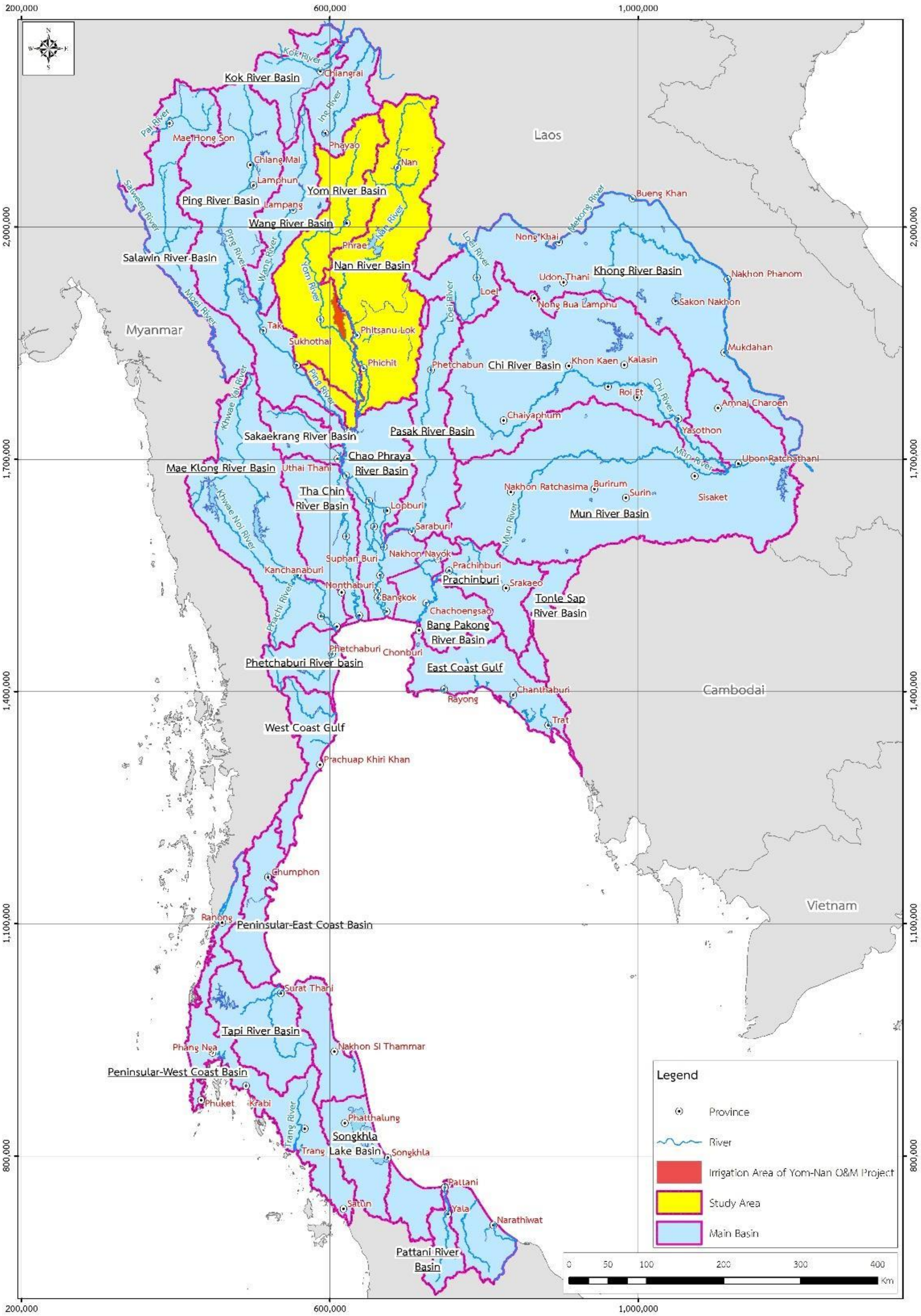

Laos
Myanmar
Cambodai
Vietnam
Kok River Basin
Yom River Basin
Ping River Basin
Wang River Basin
Salawin River Basin
Nan River Basin
Khong River Basin
Chi River Basin
Sakaekrang River Basin
Pasak River Basin
Chao Phraya River Basin
Mae Klong River Basin
Tha Chin River Basin
Mun River Basin
Prachinburi
Tonle Sap River Basin
Bang Pakong River Basin
Phetchaburi River basin
East Coast Gulf
West Coast Gulf
Peninsular-East Coast Basin
Tapi River Basin
Peninsular-West Coast Basin
Songkhla Lake Basin
Pattani River Basin
Legend
Province
River
Irrigation Area of Yom-Nan O&M Project
Study Area
Main Basin
0 50 100 200 300 400 Km
200,000
600,000
1,000,000
2,000,000
1,700,000
1,400,000
1,100,000
800,000

Figure 45: shows the 25 river basins in Thailand and the location of the project within these (in yellow)

The project covers a total area of 500.16 km^2 and stretches from the northern surrounding area of Phichai down to the observation station of Bang Rakam in the South. Within the area of the Yom and Nan River Basin, the project will be beneficial across three Provinces - of the Northern central region of Thailand: Phitsanulok, Sukhothai and Uttaradit. Within the three Provinces, in the districts of Phichai, Srinakorn, Kongkrailas, Sawankhalok, Phromphiram, Bangrakham and Muang, a total of 20,000 households totaling a population of 62,000 are included in the project targeting, covering area of 37 villages on a village-wide area coverage of 312,600 Rai (50,016 hectares).[93] This area is controlled and managed by several weirs, diversion structures and irrigation canals – with the discharge of the Yom River reducing from 2500m^3/s at the upstream section to 550m^3/s at Sukhothai, and then around 350m^3/s at the outlet of the project area, predominately due to reduced transport capacity and encroachment of the natural floodplain along the sections.

2.1.1 Reasons for selecting Yom and Nam River Basin as targeted project area

Floods pose great risk, and on a larger scale are set to displace millions of people in Asia alone by 2100 according to the IPCC, while food insecurity is likely to grow in response to the increase of flood and droughts, alongside changes in other growing conditions. The Greater Chao Phraya River Basin area is particularly vulnerable to the impacts of climate change, and specifically, extremes fluctuating between flood and drought. The average rainfall to the Chao Phraya River Basin area is 1,100mm, while its average runoff is approximately 34,600 million m^3. The Yom River Basin is the main river basin in the northern central region of Thailand. It is an important tributary of the Chao Phraya River Basin, with over 23,616 km^2 of area for receiving rainfall. The Chao Phraya River Basin is the largest of Thailand's river catchments, covering an area of 160,000km^2, it is also considered one of the most fertile regions of the country – with the largest irrigated area, across 35 percent of Thailand's total land area. The highest level of precipitation ever recorded in Thailand during rainy season caused the 2011 flood in Thailand.[94] During Thailand's 2011 flood, large volumes of water flowed from the north through the Ping, the Wang, the Yom, and the Nan Rivers – which converge in the Nakhon Sawan Province. In Nakhon Sawan Province, this cumulative flow was measured at 32,876MCM from 1 July to 13 November 2011. Both the Bhumibol and Sirikit reservoirs could only partially store some of the floodwater amounts. By October 2011, the floodwater had reached the Chao Phraya River and parts of Bangkok became inundated, with flooding persisting in some areas until January of the following year. A recent feasibility study undertaken by the Royal Irrigation Department,[95] showed that large volumes of water coupled with large amounts of runoff in the last half of the 2011 wet season, meant that flood expanded to cover vast areas of farmland, totalling 88.06 million cubic metres – with an average inundation height of 1.5 metres. The total amount of precipitation measured at 1,439mm is equivocal to 143 percent of the average wet season rainfall (pre-2002), and meant that 2.4 times the average runoff rate flowed through to the upper parts of the Chao Phraya River Basin.[96] The Chao Phraya River will not overflow provided that the speed of the water flow does not exceed 2,800 cubic metres per second. The average annual rainfall for the Greater Chao Phraya River Basin is 1,100mm. Yet, the average annual flow generated by runoff is 34,600 million cubic metres. In the northern region of the greater River Basin, the entire storage capacity is around 34,600 million cubic metres. Further downstream in the central region of the greater River Basin, the storage capacity is only 1,808 million cubic metres.

These rivers and their river system are highly vulnerable to climate change, as well as being critical in both determining, and in managing, the river flow to the Chao Phraya River. Several studies have projected the future

[94] Komori, D. & Oki, T.. 2012, Facing the floods in Thailand. *Japan Science and Technology Agency*.
[95] Royal Irrigation Department, Thailand. 2016, 'Feasibility Study of Yom and Nam O&M Project'
[96] Komori, D. & Oki, T.. 2012, Facing the floods in Thailand. *Japan Science and Technology Agency*.

river discharge in the Chao Phraya River Basin, using future climate forcing from global circulation models (GCMs), which predict that peak discharge is expected to occur within the next 30 years.[97] [98] [99] Climate data has also been downscaled for this feasibility study that is specific to the Yom-Nan area (see 1.5.2.1 – downscaling of climate data). This downscaled data reflects these trends in increased temperature and increased consecutive dry days with higher intensities of rainfall on a decreased number of days. These results strongly indicate a need for improved water management in order to better respond to climate change conditions in coming years – to mitigate flooding, as well as to prepare for drought periods, and to ensure more efficient use of water resources.

The Chao Phraya River Basin, and the flood plains surrounding, receive rainfall from the mountainous northern region of the country. This means that all the tropical rainfall that gathers in the mountains to the north, eventually trickles down to the Greater Chao Phraya Basin onto the rivers' lower reaches, to the capital Bangkok, which flanks the Chao Phraya River just north of where the river drains into the Gulf of Thailand. Under historic temperature and rainfall patterns, the Yom and Nan river basins, in the Uttaradit, Phitsanulok, Sukhothai provinces, provided the critical function of managing the river flow. However, with longer dry seasons and shorter more intense wet seasons, these basins are retaining less water and are unable to slow runoff to the central plains and ultimately the greater Bangkok area. With longer dry seasons projected, and more intense periods of rainfall to occur – these river basins will retain less water. There is significant concern as a result, over the capacity of existing water infrastructure to be able to cope with the current, and projected conditions in terms of being able to contain the increased intensity of rainfall throughout the wet season, as well as for ensuring the retention of adequate amounts of water during the dry season. The project target area was selected based on this urgent concern and level of vulnerability under future impacts, given the proximity of the communities in the project area to the overwhelmed river basins, and their reliance on water-intensive agriculture as a livelihood.

At present, the Yom and Nan River Basin area is faced with repeated water crises moving between extremes of floods and droughts that heighten the vulnerability of people living in the Yom and Nan River Basins. In this area, the flood height is approximately 1.5 – 2m above the rice field during the rainy season. Normally, in non-flood years, the project area provides a flood plain water retention function to the river system, slowing the flow of water before it gets to central plain and Bangkok area. Controlled water management through the use of canals and floodgates have contributed to the predictability of this practice. Climate change however, has shifted rainfall pattern timing and changed the intensity of the rainfall during wet season. These changes have forced adjustments to controlled water management in becoming more responsive to changing conditions, but of which have not yet systematically applied climate change forecasting at planning and management stage. Climate impact changes have not yet been adequately analysed and reflected in public water management, nor have they been tailored to the needs of farmers and disseminated to inform agriculture practices.

Strengthening water management around key river basins and improving the resilience of farmers to climate change could have potentially exponential benefits in also serving to improve climate resilience downstream and its integration cross-sectorally. Even though farmers in these areas have tried to avoid damage from flood by adjusting crop planting times and/or using short growth duration crop varieties, the unexpected quantity of rainfall coupled with an inability to accurately forecast flood, continues to damage rice production. The problem of the second dry season rice crop in contrast to the flood impacts that face the first rice crop, are determined by limited water supply – water scarcity and limited resource access to supplies such as groundwater due to a prevalence of over-drawing paired with limited groundwater replenishment. With water scarcity being one of the greatest threats

[97] Ogata, T., Valeriano, O., Yoshimura, C., Liengcharenrnsit, W., Hirabayashi, Y. 2012, 'Past and future hydrological simulations of Chao Phraya River basin', Journal of Japan Society of Civil Engineers Ser. B1, 68, Pp 97-102
[98] Champathong, A., Komori, D., Kiguchi, M., Sukhapunnaphan, T., Oki, T. 2013, 'Future projection of mean river discharge climatology for the Chao Phraya River Basin', Hydorlogical Research Letters, 7, Pp 36-41.
[99] Watanbe, S., Hirabayashi, Y., Kotsuki, S., Hanasaki, N., Tanaka, K., Mateo, C., Kiguchi, M., Ikoma, E., Kanae, S. & Oki, T. 2014, 'Application of performance metrics to climate models for projecting future river discharge in the Chao Phraya River Basin', Hydrological Research Letters, 8:1, Pp 33-38

posed under a climate change future, water retention based and effective management adaptation options offer effective interventions for supporting local communities, with land-based and natural-resource dependent users being the most vulnerable to climate change for this area. Effective water management pursuing water retention during wet periods, has dual-value in not only slowing water flow during periods of flood, and reducing the volumes of water that continue downstream during wet periods, but also serves to secure water to be saved for use during the dry periods, assisting to maintain soil fertility and reduce sediment loss from agricultural lands, providing environmental flows and retaining ecological system functions, as well as allowing recharge and permeation to groundwater sources.

2.1.2 Historical social, cultural and agricultural profile of Sukhothai, Phitsanulok and Uttaradit Provinces

The Yom-Nan project area and surroundings possess a prominent role in Thailand's history as the agricultural and cultural centres of Siam evolving over many centuries. These Provinces sit across the former area of the early Kingdom of Sukhothai, which existed from 1238 – 1583. Sukhothai (meaning 'the dawn of happiness') is well known for its ancient city founded on the edge of the Khmer empire in the 13th Century, and the Kingdom of Sukhothai that existed during the reign of King Ramkhamhaeng some 800 years ago. It covered the entire area of the upper valley of the Chao Phraya River, and is widely considered the foundation of the Thai nation. Founded over 600 years ago, as well as being the former Provincial centre for the Angkorian Empire, the Kingdom of Ayutthaya grew and became the ruling Kingdom, and the Sukhothai Kingdom was eventually merged and controlled by the Kingdom of Ayutthaya during the 15th and 16th Centuries. The modern day jurisdiction of the Sukhothai Province has its capital as Sukhothai Thani, and has nine districts – Mueang Sukhothai, Ban Dan Lan Hoi, Khiri Mat, Kong Krailat, Si Satchanalai, Si Samrong, Sawankhalok, Si Nakhon, and Thung Saliam. Numerous sites within the Sukhothai Province are designated as UNESCO World Heritage sites. Being in the confluence of the Yom and Nan Rivers, this area has thrived as a key agricultural area and the center of life over centuries – functioning as an epicenter for rice growing in 'the rice bowl of Asia'.[100]

[100] Nara, P. Mao, G. & Yen, T. 2014, 'Climate change impacts on agricultural products in Thailand: a case study of Thai rice at the Chao Phraya River Basin', *APCBEE Procedia,* 8, Pp 136- 140

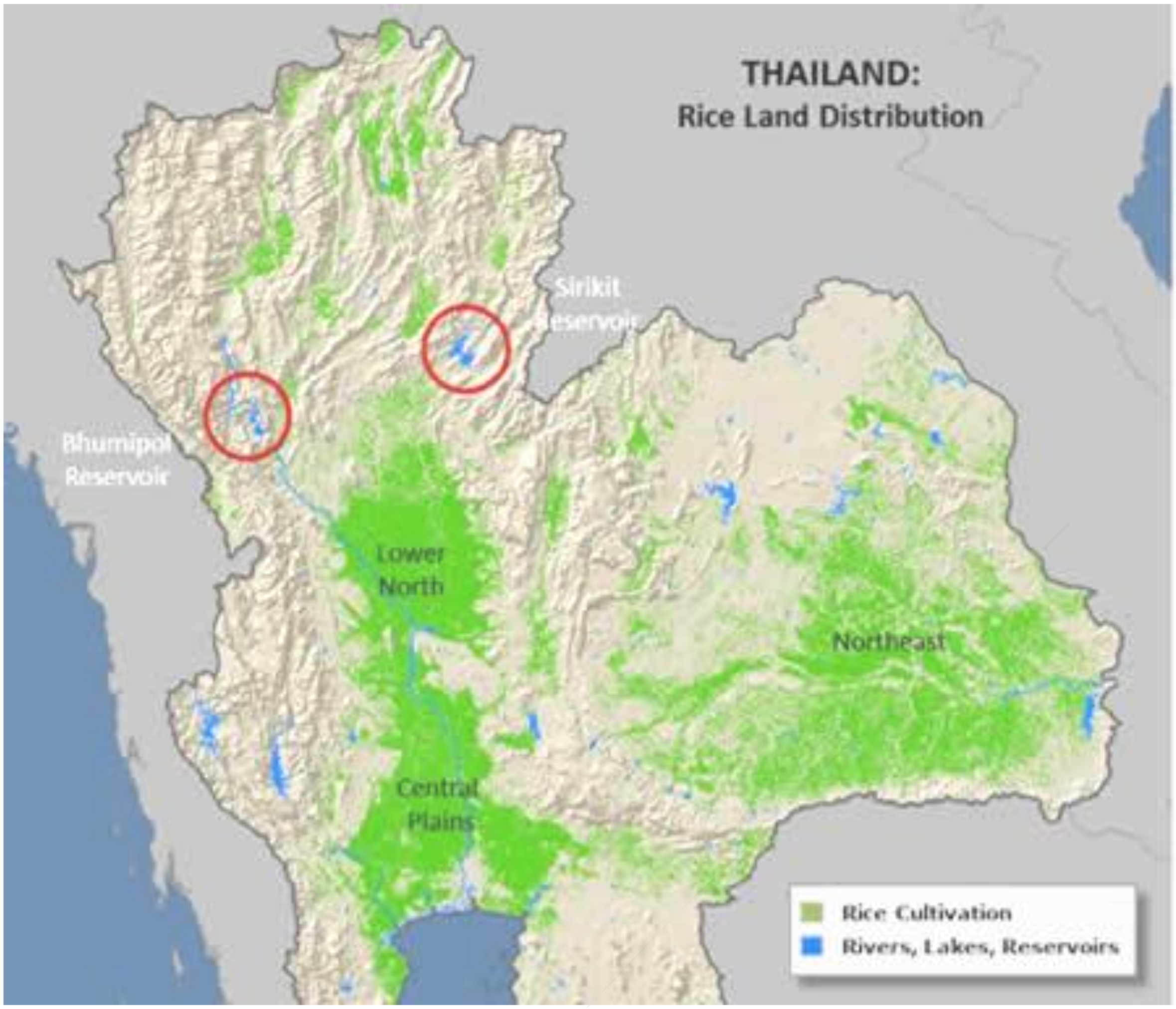


Figure 46: Thailand's rice growing land distribution

Source: Landsat 30m Land Cover, LULC 2010, USDA Commodity Intelligence Report 2015

Phitsanulok which sits downstream of Uttaradit and Sukhothai Provinces, has nine district regions – Mueang Phitsanulok, Nakhon Thai, Chat Trakan, Bang Rakam, Bang Krathum, Phrom Phiram, Wat Bot, Wang Thong, and Noen Maprang. Phitsanulok in the northern area is known for being the birth town of the King Naresuan the Great (King Naresuan of Phitsanulok and Crown Prince of Ayutthaya), who had a significant role in Thailand's history, as he was responsible for expanding the Thai Kingdom of Siam to its widest territory reign after conquering large portions of Burma and Cambodia. Phitsanulok was part of the Sukhothai Kingdom prior to the Kingdom of Ayutthaya, and then later, during the rule of Ayutthaya (the old Kingdom of Siam). Phitsanulok briefly became the capital during the reign of King Boromma Trailokanat of Ayutthaya (for a 25 year period). The area of Phitsanulok and its surrounds have had changing borders and have come into dispute up until as recently as 1988, in the Thai-Laotian border wars. Phitsanulok forms part of Thailand's breadbasket – providing rice as the dominant crop, but also other crops for consumption in Thailand as well as for export outside of the country. The Province relies greatly on the Nan River and its tributaries, which bring fertile soil for agriculture from the uplands, and water for irrigation. The adjacent Uttaradit Province sits touching both Phitsanulok and Sukhothai Provinces, with a border to Laos on its Eastern side. Uttaradit Province covers the districts of Muean Uttaradit, Tron, Tha Pla, Nam Pat, Fak Tha, Ban Khok, Phichai, Laplae, and Thong Saen Khan. Formerly the trade centre of the Nan River – it forms the Nan River Valley, which is also the location of the Sirikit Dam. Uttaradit Province was once widely covered by Teak forest – which used to be the main product of the area. Uttaradit was part of the tension points of dispute under the 1988

Thai-Laotian border war.

2.1.3 Socio-economic profile of the Yom-Nan River Basin Area

The target communities of this project are in three provinces of the northern region of Thailand: Phitsanulok, Sukhothai and Uttaradit. Gross Provincial Product (GPP) from 2014-2016 of these provinces was approximately 14.5 percent of the northern region's total GPP. The GPP of Phitsanulok, Sukhothai and Uttaradit for the agricultural sector alone in 2016 was 25.4 percent, 31.2 percent and 22.5 percent respectively, with the per capita GPP following as 96,957 THB (US$ 2938), 64,732 THB (US$ 1961) and 77,340 THB (US$ 2343) per person.

	Phitsanulok			Sukhothai			Uttaradit		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
Agriculture	28,432	23,591	22,105	18,130	14,474	12,492	11,323	8,366	7,550
Non-Agriculture	57,436	61,571	64,852	25,966	27,360	27,546	23,954	23,133	26,040
Gross Provincial Product (GPP)	85,868	85,162	86,958	44,096	41,834	40,038	35,278	31,499	33,590
GPP per capita (Baht)	95,084	94,627	96,957	70,823	67,407	64,732	80,873	72,377	77,340
Population (1,000 persons)	903	900	897	623	621	619	436	435	434
Year	2014			2015			2016		
3 provinces GPP	165,241 (14.8%)			158,495 (14.5%)			160,585 (14.2%)		
Northern region GPP	1,112,844			1,090,870			1,132,861		
Average 3 years of GPP of these 3 provinces to Northern region GPP = 14.5%									

Table 8: Gross Domestic Product at current market prices according to industry origin, 2014-2016.

Source: Office of the National Economic and Development Council[101]

Surveys were undertaken across the area with householders residing in the project area during late 2016 and early 2017 for the purposes of informing the development of this proposal. According to the households surveyed, the main source of income of those in the interviewed area was from rice farming. Results from an earlier (2013) survey undertaken by the Royal Irrigation Department of households in the area, also indicated that maize, sugarcane, vegetable crops and fruit trees are additionally grown in the area. However, maize, sugarcane, vegetable crops and fruit tree crops at that time only comprised around 1-2 percent of the farming area for the villages. Various reasons are responsible for the prominence of rice versus the other crops in the area. For example, sugarcane is grown less, as it requires a full duration of 9 months for cultivation. This cultivation period clashes with the period of normal flood, as well as cultivation of other crops. If sugarcane is grown in March after harvesting of the first dry season of rice, then the cultivation period crosses into the flood period, as too does the fruit-growing period.

[101] National Economic and Development Board: www.nesdb.go.th

Information received from focus group discussions (FGDs) undertaken for this project in late 2016 reflected that 5-10 percent of households have private ponds in their rice fields. These ponds are not only for rice production, but also are for raising fish. These fish generally arrive with the regular flooding of the wet season, which takes place mostly after farmers have been planting rice for 90 days or about two weeks before the harvesting could be made. The average flood level was 1.5-2 meters above the paddy ground. The flood would on average last 73 days while 82 percent of farmlands have been submerged almost every year. After harvesting the first dry season rice in February, fish in these ponds are caught and sold.

The breakdown of agricultural cropping activities per household and the corresponding percentage of land allocated for each is shown in the table below:

Livelihood activity	Number of households	Percentage
Rice Farming	384	95.8
Orchard/tree crops	4	1.0
Farming	2	0.5
Livestock	3	0.7
Employment	4	1.0
Government officer	1	0.2
Trading	1	0.2
Other	2	0.5
Crop revenue (on average) per year	THB174,345	
Livestock revenues	THB 31,652	
Fishing revenue	THB 2,895	

Table 9: Livelihood sources by household according to field survey results

Household incomes in the area are split on average as THB 174,345 (around US$5000) per year income generated from crop revenues THB 31,652 (around US$900) from fishing revenue, and THB 2,895 (around US$100) generated from livestock revenues annually. Rice is the major crop of these 3 provinces. In 2014, paddy land, upland field crop and orchard and perennial crop, were 59.93 percent, 23.42 percent and 10.24 percent of total land uses respectively.

Province	Total land	Paddy land	Upland field Crop	Orchard and perennial crop	Vegetable and ornamental plant	Other Agricultural Landuse
Sukhothai	1,823,937	1,215,015	393,530	128,331	9,548	77,514
Phitsanulok	3,057,529	1,777,793	727,441	345,998	14,718	191,579
Uttaradit	1,248,199	680,842	314,762	153,599	12,663	86,332
Total	6,129,665	3,673,650	1,435,733	627,928	36,929	355,425
Percentage	100.0	59.93	23.42	10.24	0.6	5.8

Table 10: Agricultural land use of Thailand according to province and region, 2014.

Source: Agricultural Statistics of Thailand, 2015

*Note - vegetable crops include: long bean, chili, and bitter gourd; while permanent crops incorporate mango, lime, guava, and banana

Agricultural livelihood activities of the households surveyed were divided according to one of three types, either: 1) crop cultivation, 2) livestock and animal husbandry or 3) aquaculture, for the purposes of grouping the results. It was found that in most of the agricultural holdings surveyed, 323 people (81 percent of the households interviewed) are cultivating crops only. The number of agricultural livelihood activities varied between households, with some households undertaking dual agricultural livelihood activities (16 percent), while others undertook three agricultural livelihood activity types (3 percent only).

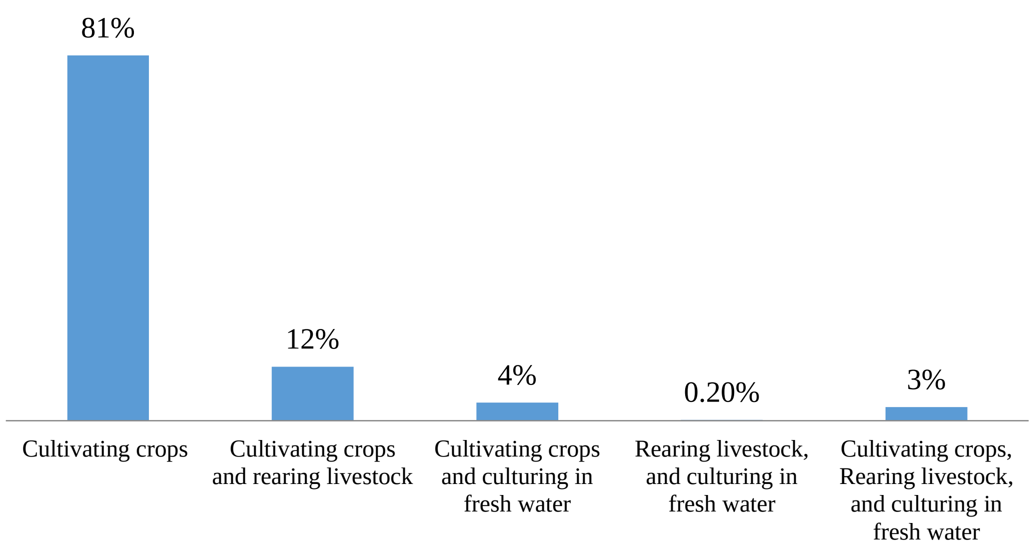


Figure 47: Percentage of agricultural activity by type in Yom-Nan area

Earnings from agricultural livelihoods varied on the scale of farms and produce. Total average household income from the main livelihood and including additional livelihood revenue streams was about 477, 264 THB (US$13798) a year. The total income earned after agricultural expenses (and related costs) are deducted, was on average 73,967 THB (US$2,138) a year on average. This is based upon estimates deducting the cost of cultivation according to land preparation, sowing, cost of transplanting rice seed, harvesting, fertiliser/herbicide/insecticide inputs, amongst others. Agricultural production costs are classified roughly as seed expenditure comprising around 15 percent of outgoing cost, fertiliser as 26 percent of outgoing costs, labour and machinery at around 19 percent, pesticide as around 20 percent, and groundwater pumping and access costs comprising around 20 percent. These levels of income were considered to be sufficient for 52.59 percent of households, yet insufficient by 29.31 percent of the households, while 18.10 percent of households found that they were also able to generate some savings from their earnings. Most of the households however, were in debts of around 291,245 THB (US$8,420) a year on average. When compared with the annual income these debts are substantial, and in effect, place many of the agricultural households of the area in a precarious financial situation – and in turn accelerating vulnerability and limited access to resources for self-sufficiently and the improvement of adaptive capacity outcomes for climate change impact response.

Items	Season 1		Season 2		Season 3	
	Plot 1	*Plot 2*	*Plot 1*	*Plot 2*	*Plot 1*	*Plot 2*
Area (rai)	24	21	25	22	2	21
Land preparation (THB/rai/season)	361	364	370	376	307	307
Sowing (THB/rai/season)	85	56	57	56	53	53
Cost of transplanting rice seed (THB/rai/season)	727	313	1,200	1,200	-	-
Harvesting (THB/rai/season)	446	450	446	448	416	416
Fertiliser/ Herbicide / Insecticide (THB/rai/season)	120	144	165	149	163	163
Others (THB/rai/season)	349	294	331	300	-	-
Total	986	930	996	967	647	610

Table 11: Cost of cultivation separated by plots and season

Note: Plot 1 is the largest plots. Plot 2 is the sum of left over plots

For each of the agricultural households interviewed in the Yom-Nan area, in total, the average farming investment cost per household was about 3,312 THB (US$96) per rai. This compares closely with the average harvest, which in the 2016/7 survey interviews was about 730kgs per rai. This means households make roughly 5,227 THB (US$151) per rai on average (when calculated at the selling price of 7,152 THB/US$207 per ton of rice). A total profit per rai is therefore estimated to be 1915 THB (US$55) for most households.

The average rental cost is calculated as being on average around 1300 - 1400THB (US$38) per rai per year (US$95 per acre per annum). The range of rental charged per rai however, varied substantially, with the lowest rent reported at 300-200THB (US$8) per rai per year, and the maximum reported as 3,3 -600, 650baht (US$105) per rai per year, respectively. Profitability per rai accordingly, significantly varies for those who do not own land. Land ownership types in the area are mainly held under the land title deeds (at 86 percent), and others (at 4.84 percent) held Sor Por Kor 4-01 - the land right under Agricultural Land Reform scheme[102] and 6.45 percent hold land under Nor Sor 3 (certificate of use)/Nor Sor 3 Gor (confirmed certificate of use) at less than 1 percent holding land under Por Bor Tor 5,6 (local land tax receipt).

Land Tenure	Plot1	Percentage	Plot2	Percentage
Land ownership	246	61	136	53
Rented land	151	38	119	46
SPK (Sor Por Kor)	2	0.5	1	0.4
Public Land right of use	1	0.2	1	0.4
Other: PBT	1	0.2	0	-
Total	401	100	257	100

[102] 'Sor por gor' (also So Po Ko) land is the government allocated land given to farmers classified as poor to use for agricultural purposes, as well as referring to the policy and legal documents – Sor Por Gor 4-01, managed by the Department of Land Reform and Agriculture. The land reform law qualifies that a farmer being allocated land under the law must have an agricultural background; the land must be used solely for the purposes of agriculture and not for any other use; the land is unable to be sold or to change hands to any other persons, however, it may be passed on to direct family kin heirs; any land unused or un-developed (for agricultural use) must be returned to the government; each person is able to occupy land size totaling up to 25 rai, and a family/household together may occupy land size up to 50 rai in total, and; land in national park area, national forest, or land on a slope of more than 35 degrees, is not able to be occupied.

Table 12: Levels of land tenure are divided in the area: land ownership, rental, SKP, public land, and PBT

Most of the rice varieties cultivated by the households surveyed, were of either Phitsanulok variety (30.83 percent) Suphan variety (27.94 percent) and/or included the Chainat variety (16.63 percent). The growing periods were between March/April and June/July and between November/December and February/March. Annual flood takes place between August and October resulting in a hiatus for the crop growing period. Size of the land owned by each farmer household ranged in size from 0.5 to 170 rai per household (0.2 acres to 67 acres/27 hectares). Roughly 72.58 percent of agricultural households owned their land while a further 27.42 rented land for crops from owner-landlords. Agricultural labour hire is a major income source for many in the area – either to supplement as additional income for those who have limited agricultural activity, or for the main livelihood income source for those that did not own agricultural land. Of those attending the focus group discussion for example, villagers reported that in one of their areas, agricultural activities took place over 95% of their area, whereas for other areas, agricultural activities took place only in 50 percent of their area. In this case, 15 percent reported that they leased their land for farming activities. Overall, households tended to also grow crops to meet their own needs – with rice, vegetables and taro (at approximately 5 percent of the land use area) being grown in both the dry and wet seasons.

Out of a sample of just over 400 households, the average demographic compositions for each house were of 4 person households, with an even gender composition. The average age of people in the area is 51 years, with 48 percent of householders having primary school level education. While most households had early school education, many had high school education (10 percent), while only a few were tertiary educated, and some had not received any schooling also.

Education	No. of households surveyed	Percentage
Uneducated	28	7
Prathom (elementary school) 1-3	192	48
Prathom (elementary school) 6-4	93	23
Junior High School	42	10
Senior High School/Vocational Certificate	29	7
High Vocational Certificate	9	2
Bachelor degree	6	1
Master degree	2	0.5

Table 13: Level of education attained by survey respondents in the project area

2.1.4 Climate change impact on water resources

As part of part of this feasibility study for the project - downscaling of climate change projections were undertaken for the Sukhothai area in order to determine future climate change impacts to the project area. Projections using the Global Circulation Model (GCM) ECHAM5 and HadCM3 on scenarios as given under the Inter-governmental Panel on Climate Change Special Report on Emission Scenarios (SRES) A1B scenario, and downscaled under PRECIS. This was used to analyse trends and long-term past (1980-2009), present to near future (2010 – 2039) and middle future periods (2040 – 2069) mean temperature and precipitation and extremes. These downscaled predictions found a significant difference between past and future weather patterns. Looking at the key climate variable at a local scale over the site, daily minimum, mean and maximum temperatures and precipitation data with 20 x 20 km grid resolution extracted in the region of 16.6° – 17.8° latitude and 99.4° – 100.2° longitude which covers Sukhothai Province were analysed for the period of 1980 - 2069. Information on this process and the results for temperature and rainfall in the Yom-Nan area are detailed at section 1.5.2.1 – downscaling of climate data.

Under future climate change scenarios in Thailand, future climate is likely to adversely affect water resources and the water flow regime in Northern Thailand. Projections of hydrological changes under near-future and end-of-21st-century climate in the Chao Phraya River Basin, using the outputs from six AOGCMs (CSIRO-Mk3.6, INM-CM4, MIROC5, CNRM-CM5, GFDL-ESM2M, and IPSL-CM5A-LR) under the bias-corrected RCP4.5 and RCP8.5 scenarios similarly show a large increase (>20%) in runoff in Nakhon Sawan province under both RCP scenarios. Ensemble mean increases in precipitation and runoff are higher under RCP 8.5 than under the RCP 4.5 scenario in both projected periods, implying that higher global mean temperature would cause higher precipitation and runoff in the basin. Hydrological responses to climate change in the Chao Phraya River Basin (CPRB) were analyzed using the watershed hydrologic model with bias-corrected MRI-AGCM 3.1 and 3.2 projections under A1B scenario. The simulation results show that the mean annual flow discharge will clearly increase in the late future (2075–2099) at Nakhon Sawan (C.2) upstream of the Bhumibol dam and at the outlet point of the Wang River Basin in both MRI-AGCM3.1 and 3.2 due to increased rainfall. Flood frequency analysis further shows increases in annual maximum daily flow toward the end of the 21st century at Nakhon Sawan and points upstream of the Bhumibol dam. The magnitudes of the daily high flows in the late future period are comparatively higher than their counterparts during the historical period (1980–2004). The projected annual volume increase at Nakhon Sawan for the late future period is about 3 billion m^3, which is about 12.5% of the total main dam's reservoir storage capacity (24 billion m^3). Projected near future and end of the 21st Century climate related hydrological changes in the Chao Phraya River Basin, as according to outputs from six AO GCMS (CSIRO-Mk3.6, INM-CM4, MIROC5, CNRM-CM5, GFDL-ESM2M, and IPSL-CM5A-LR)and bias corrected for RCP4.5 and RCP8.5 scenario, undertaken by Kotsuki[103] show a similarly large increase in the runoff (>20%) to the Nakhon Sawan province under both RCP scenarios.

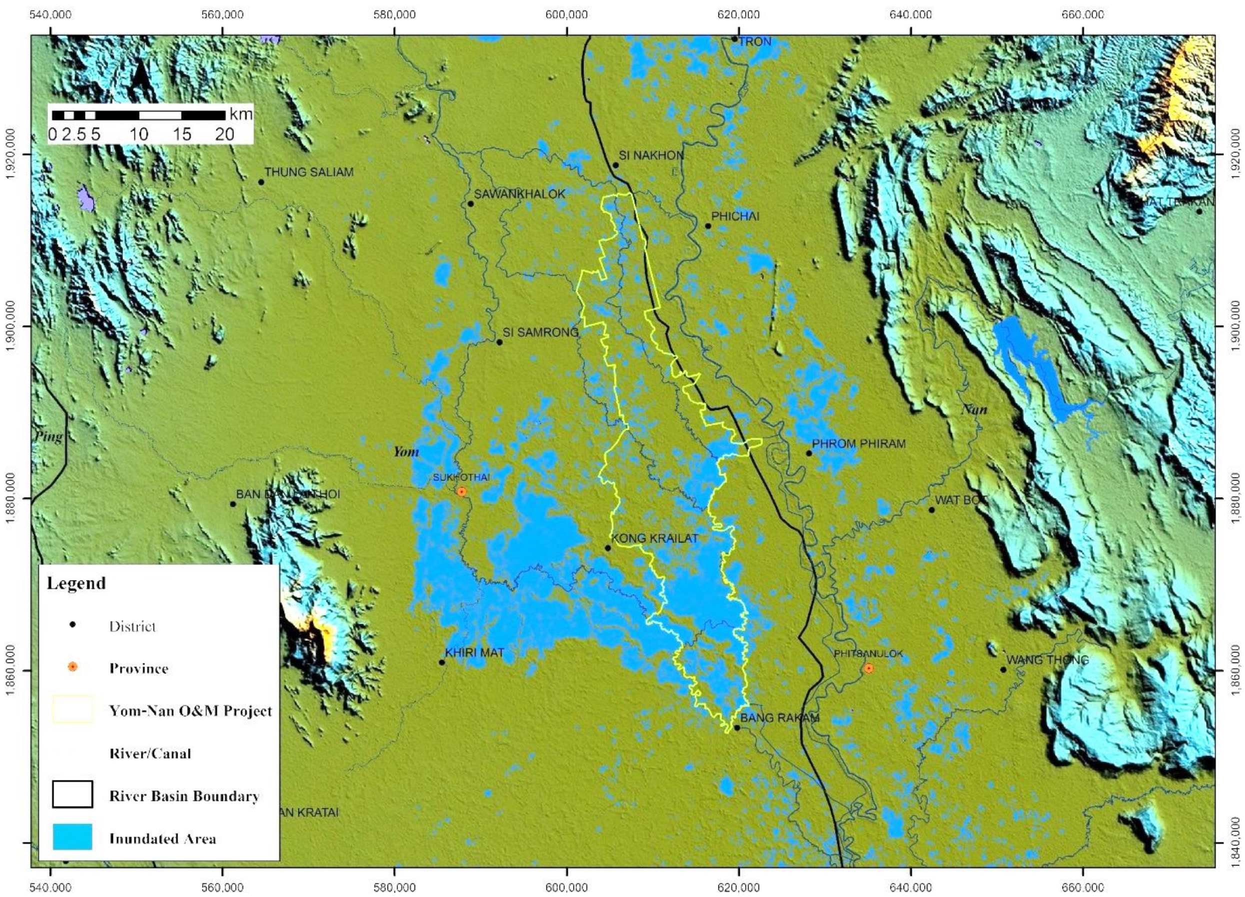


Figure 48: Project area in flood during 2014

Source: GISTDA data (2005-2014): http://flood.gistda.or.th

[103] Kotsuki, S., K. Tanaka, and S. Watanabe, (2014). Projected hydrological changes and their consistency under future climate in the Chao Phraya River Basin using multi-model and multi-scenario of CMIP5 dataset. Hydrological Research Letters, 8(1), 27–32.

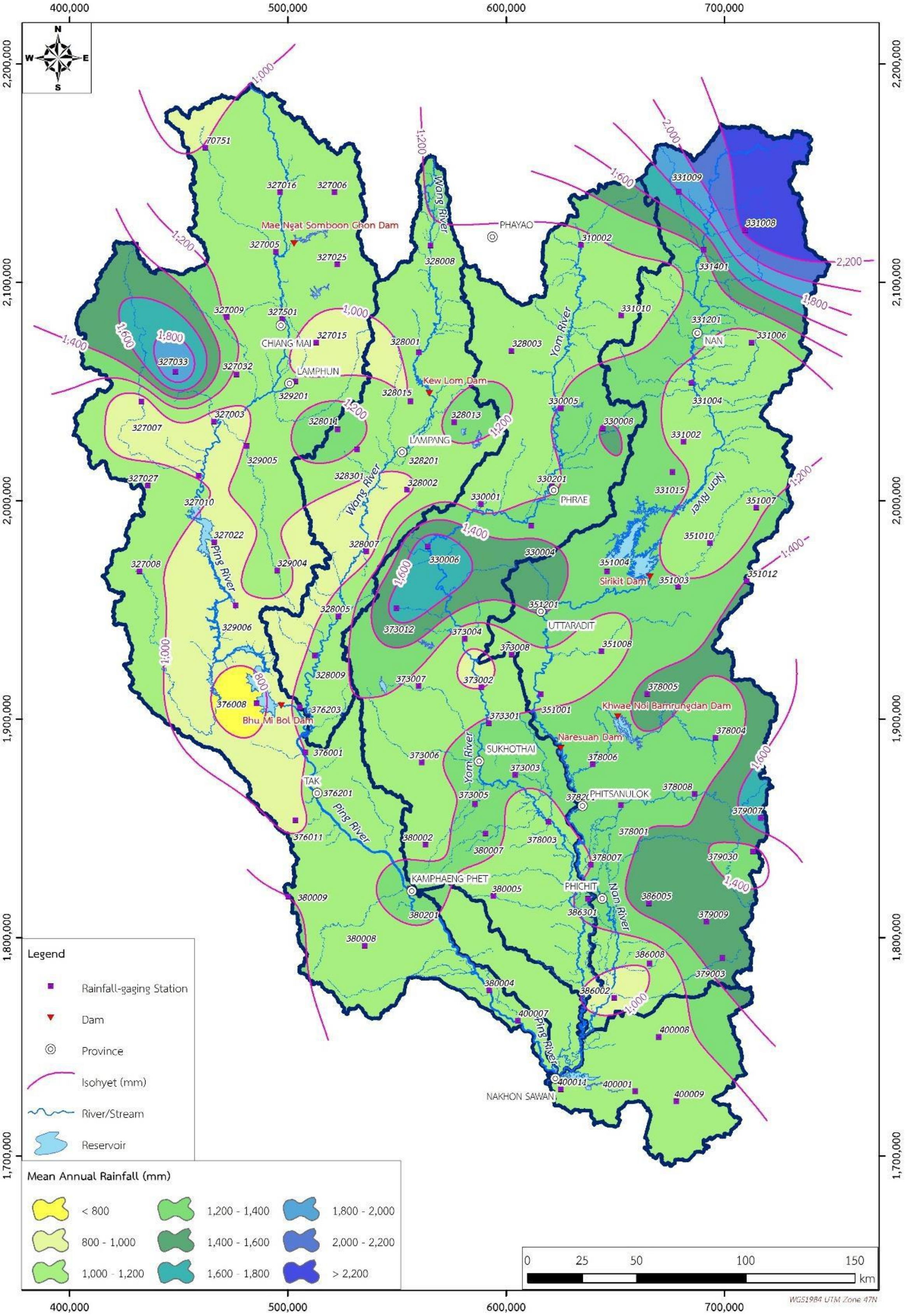


Figure 49 : Annual rainfall isohyte of the Upper Chao Phraya River Basin

Source: Thai Meteorological Department data

This project focuses on Yom-Nan basin. The channel capacity of the Yom River at Si Satchanalai district is 2,397cms, which then reduces to 565cms when it arrives in the downtown Sukhothai . In addition, the longitudinal river slope decreases from 1:2,300 to 1:11,000 at this point, and creates a point of overflow in the area of Sukhothai that connects Phitsanulok and Phichit provinces. This change in capacity along the river as well as the reduction in slope incline, is shown below in Figure 50.

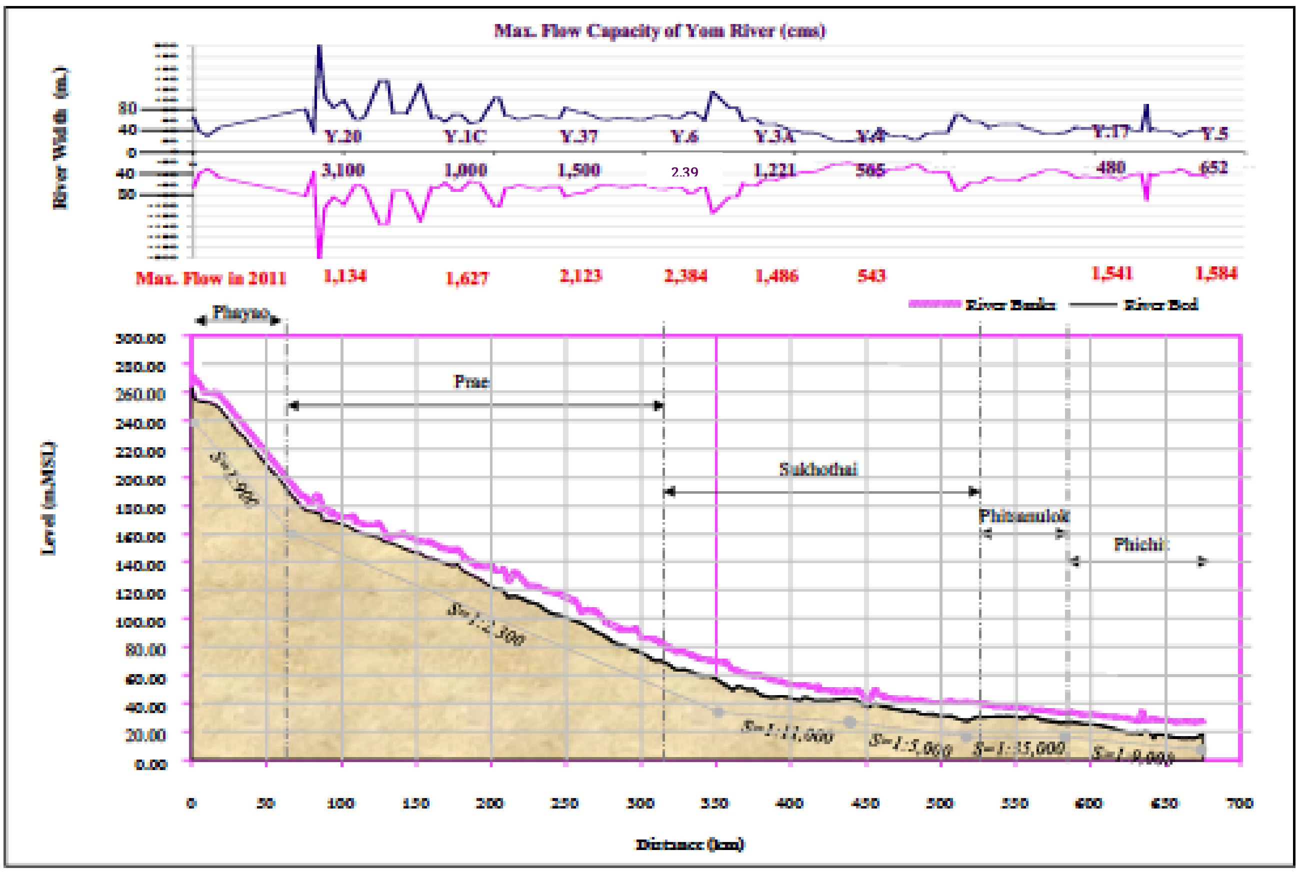


Figure 50 Longitudinal profile and capacity of the Yom River

Source: Royal Irrigation Department (RID), 2016

There are many stream flow-gauging stations in the Upper Chao Phraya River Basin. However, the three stations were selected to be analysed as follows: 1) Y.6 gauging station in the Yom River at Si Satchanalai district, Sukhothai province, catchment area of 12,769 km^2. This station is located upstream of the diversion point into the project area and upstream of Sukhothai province; 2) N.60 gauging station in the Nan River at Phichai district, Uttaradit province, catchment area of 18,447 km^2. This station is located upstream of the diversion point into the project area and upstream of Phitsanulok province; 3) C.2 gauging station in the Chao Phraya River in Nakhon Sawan province, catchment area of 109,973 km^2. This station is the beginning of the Lower Chao Phraya River, which is the confluence of the Ping and Nan rivers. It should be noted that in the Ping and Nan river basins, there are large storage dams that store runoff during the wet season to be released during the dry season; hence the patterns of runoffs in the Ping and Nan river basins, including the Chao Phraya River Basin, are not natural. There is no large storage dam in the Yom River Basin, therefore, its runoff is a natural pattern of flow (in terms of not being controlled through dam timings) until it reaches the flood plain and the project area, before Sukhothai province.

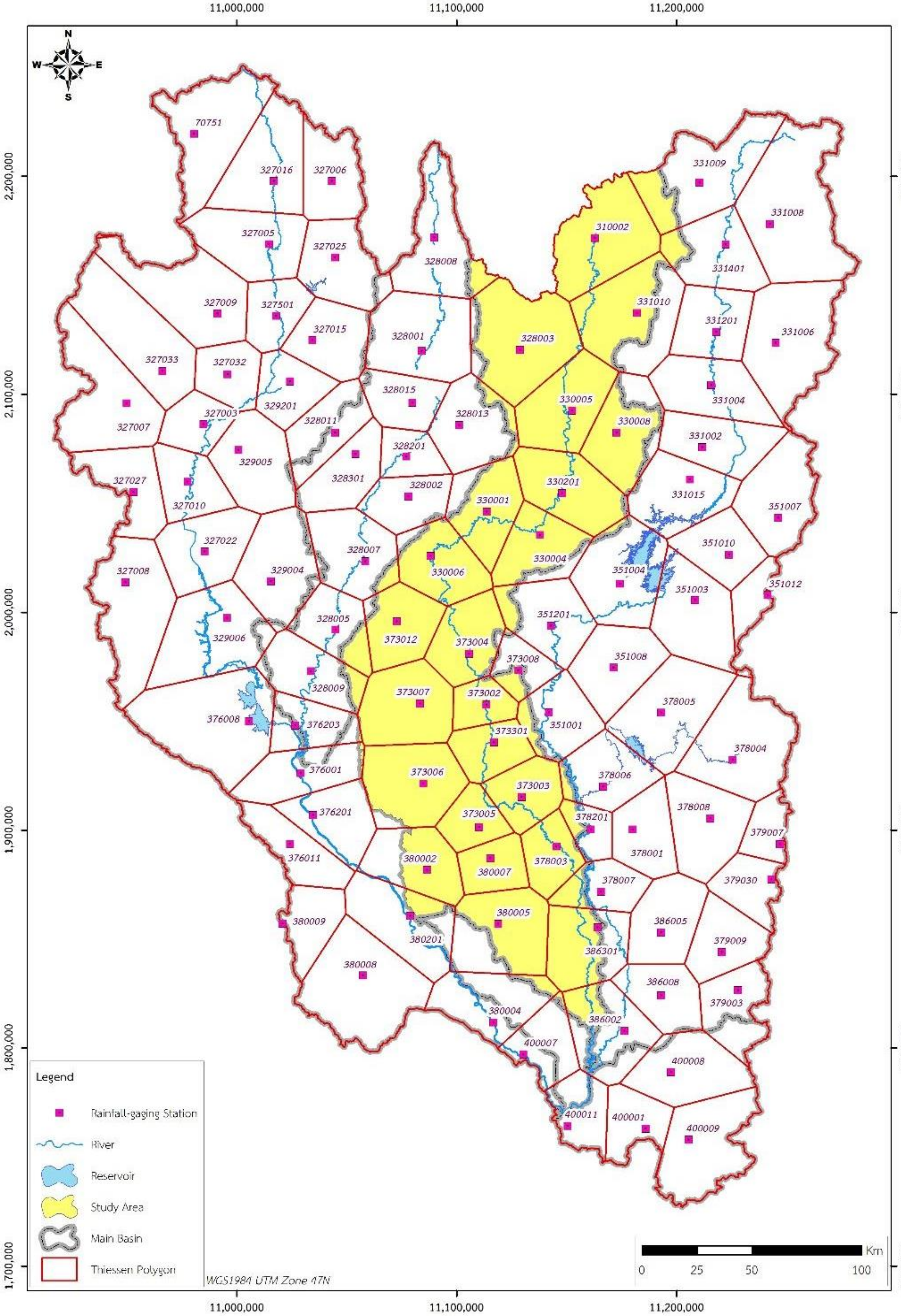


Figure 51: Catchment and influence areas of the selected rainfall stations
Source: Thai Meteorological Department data

A statistical analysis was carried out to estimate probable maximum monthly and annual runoffs at the three selected gauging stations by applying the Gumbel distribution method to the runoff data. Comparing the runoffs, the return period of runoff in 2011 is around 100 years when considering the volume of runoff and is only 25 years when considering the maximum discharge.

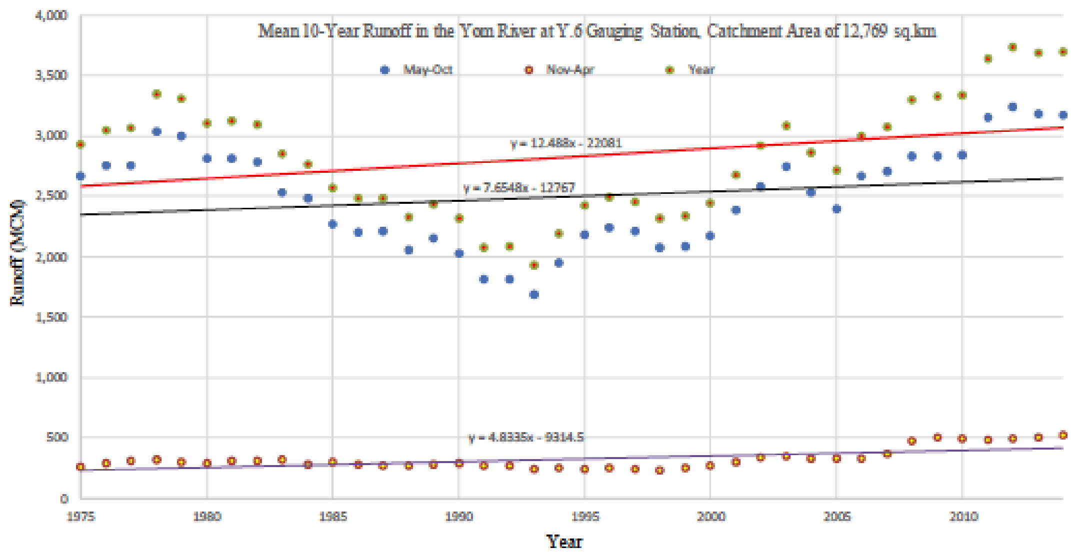


Figure 52: 10 year mean runoff at y.6 gauging station in the Yom River

Source: Royal Irrigation Department (RID), 2016

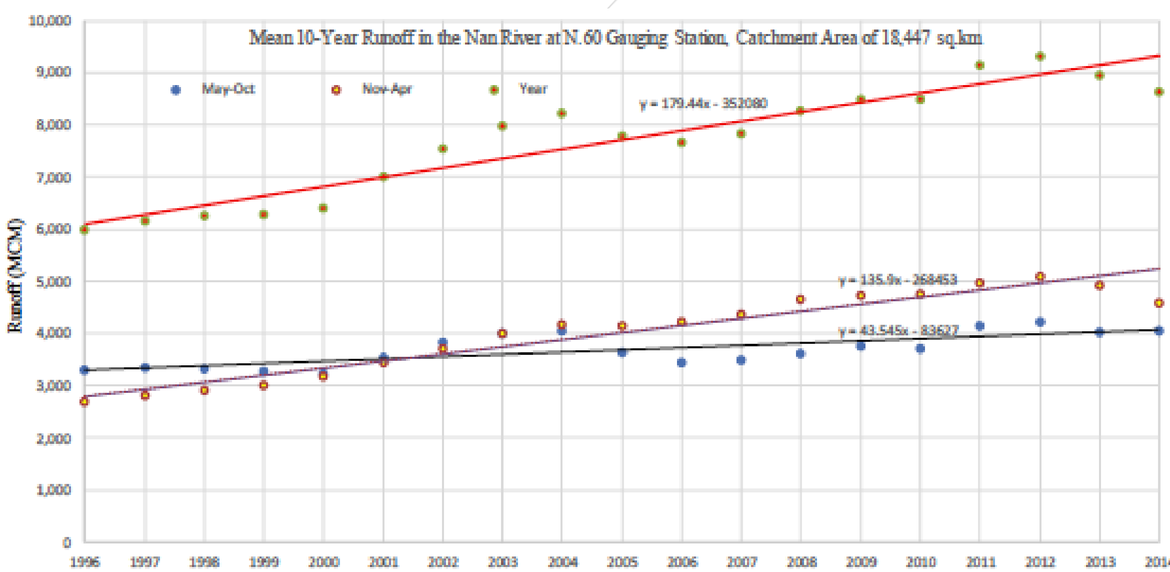


Figure 53: 10 year mean runoff at the N.60 gauging station in the Nan River

Source: Royal Irrigation Department, 2016

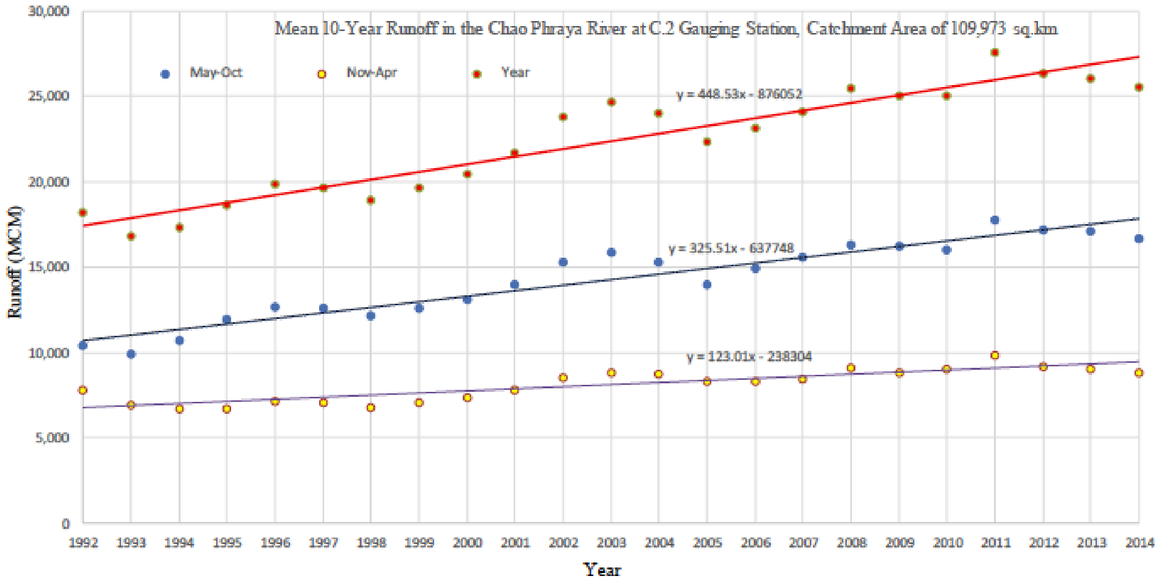


Figure 54: 10 year mean runoff at C.2 gauging station in the Chao Phraya River
Source: Royal Irrigation Department, 2016

The catchment area under the Yom-Nan area is heavily altered by agriculture patterns, and village and urban settlements, and irrigation canals cut through the landscape. However, small pockets of ecological habitat appear throughout the landscape, and flora and fauna habitats exist between paddy fields. Much of the area exists as natural floodplains, and a large existence of bird species reign across the plain. Of particular ecological significance to note for the Yom-Nan River Basin, is the area downstream of the project site in the Bueng Boraphet wetlands in Phra Non, Mueng Sawan District, Nakhon Sawan. These wetlands cover 224 km^2 in the area to the east of Nakhon Sawan, and the South of the Nan River, as are nominated for RAMSAR.[104]

Sediment and erosion within the Chao Phraya watershed is significant throughout. Within the Yom-Nan River systems, according to the data on the average annual sediment loads from 88 stations in the Yom River Basin and nearby areas, the average annual sediment loads reach about 1.98 million tons/year, varying from 64.51 to 93.96 tons/km^2. The erosion rate ranges between 0.050 and 0.072 mm/year. The relationship between discharge and suspended sediment at Y.6A gauging station in the Yom River at Si Satchanalai district, Sukhothai province, catchment area of 12,769km^2 and at N.7A gauging station in the Nan River in Phichit province, catchment area of 27,897 km^2 was analysed as shown in Figure 55.

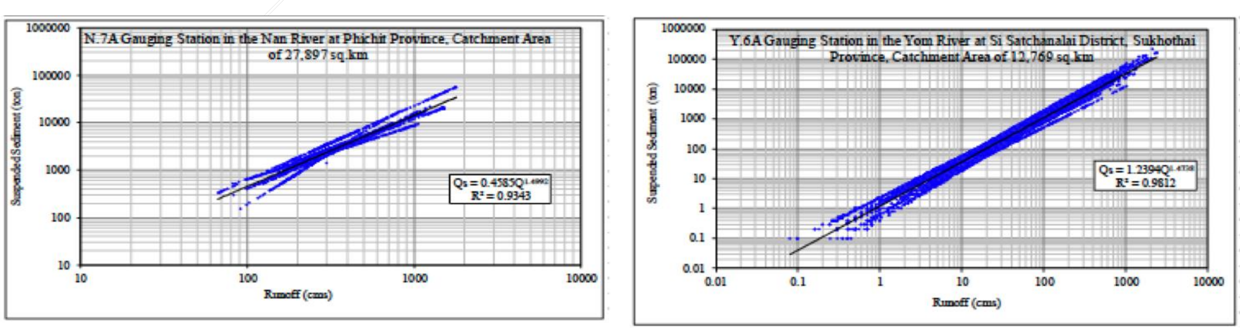


Figure 55: Relationship between suspended sediment and discharge in the Yom River (Y.6A) and the Nan River (N.7A).
Source: Royal Irrigation Department (RID) data

[104] The Convention on Wetlands of International Importance (the Ramsar Convention)

2.1.5 Climate change impact on agriculture

For this project the future crop water requirements were analysed according to the Climate Change Scenario A1B (IPCC AR4 Report) by applying future climate projections analysed under two climate change models: ECHAM5 and HadCM3. The future climate daily data at Sukhothai and Phisanulok from 1980 to 2069 were applied. The method of estimating crop water requirement is based on the guidelines for computing crop water requirement, FAO Irrigation and Drainage Paper No.56[105]. The results were analysed to indicate trend of future crop water requirement changed due to the climate change. In terms of climate change adaptation activities, rice farmers currently try to reschedule crop timings to respond and to adjust to the seasonal changes and the changes in seasonal patterns. In some of the areas where interviews took place for focus group discussions, rice farmers usually attempt to do three rounds of rice cropping per year. At the moment, they collaborate closely with the Royal Irrigation Department in order to irrigate and plan for the crop accordingly. This cropping was drastically changed in 2015-2016 and into this year regarding water availability.

In the Chao Phraya River basin region, climate projections show trends of increasing temperature with fluctuating precipitation.[106] Calculations for the region, found that on average (with variations between the provinces) during 2040 -2049, farmland values per rai, are projected to decrease from $2,703 to $2,068 and $2,538 per rai in climate scenarios A2 and B2 respectively.[107]

As part of the feasibility study, farmers in the proposed project site were interviewed about their perceptions on climate change. The study was carried out in four districts across of two of the project area provinces; Bang Rakam, Phrom Phiram, Mueang Phitsanulok, and Kong Krailat Phitsanulok, and Sukhothai, during November 25 to December 1, 2016.

The table below shows farmer perception on the rates of climate impacts experienced in the four districts within the project area.

Items		Frequency	Percent
Number of farmers reporting impact		369	92
Number of farmers reporting no impact		32	8
Type of impact:	Flood	352	87
	Drought	255	63
	Pest and disease incidence	176	44
	Weed infestations	70	17
	Crops disease outbreaks	111	26
	Animal disease outbreaks	23	6

Table 14: Agricultural livelihoods – ranking of climate impact and frequency by farmers

The responses regarding perceptions to climate change by farmers in the area also indicative of some of the climate change adaptation strategies and responses underway, and provide some insight into both existing and the

[105] Allen, R. 2016, FAO Irrigation and Drainage Paper No. 56 Crop Evapotranspiration (guidelines for computing crop water requirements): https://www.unirc.it/documentazione/materiale_didattico/1462_2016_412_24101.pdf

[106] Attavanich, W. 2012, *The effect of climate change on Thailand's agriculture*, https://www.researchgate.net/profile/Witsanu_Attavanich/publication/262067789_The_Effect_of_Climate_Change_on_Thailand's_Agriculture/links/566a311a08ae1a797e379c9b.pdf

[107] Attavanich, W. 2012, *The effect of climate change on Thailand's agriculture*, https://www.researchgate.net/profile/Witsanu_Attavanich/publication/262067789_The_Effect_of_Climate_Change_on_Thailand's_Agriculture/links/566a311a08ae1a797e379c9b.pdf

potential for future adaptive capacity and climate resilience existing that can be fostered through the implementation of effective strategies and activities of the project.

The table below shows the level of change perceived and the ways and rates of response (adaptation) strategies in practice throughout the four districts in the project area:

List	Feel change	Character of change		Top three ways of coping
Temperature	93 percent	88 percent hotter	Farming	46 percent postpone the total crop 45 percent postpone some part of crop 45 use groundwater
			Livestock	Build water storage Change animal/livestock types
Rain	91 percent	81 percent less rain 71 percent less frequency 53 percent less intense	Farming	37 percent postpone the total crop 36 percent postpone some part of crop 20 percent use groundwater
			Livestock	Change animal/livestock types Invest in new breeding
Droughts	88 percent	90 percent more frequency of droughts 85 percent more dry 86 percent longer drought	Farming	52 percent postpone the total crop 47 percent postpone some part of crop 40 percent use groundwater
			Livestock	Change animal/livestock types Invest in new breeding
Floods	84 percent	62 percent less 45 percent less severe 45 percent shorter duration	Farming	52% Postpone the total crop 48% Postpone some part of crop 21% Stop cultivating and do other career
			Livestock	2% Change types of animals 9% Invest in new breeding
Disease and insect infestation	73 percent	86 percent occur more often 68 percent worse than before 63 percent take longer time than before	Farming	21% Postpone some part of crop 19% Postpone the total crop 13% change to plant varieties resistant to the disease
			Livestock	2% Change animal/livestock types 2% Build water storage

Table 15: Level of climate change perceived by farmers and climate adaptation strategies used to mitigate these impacts.

The four district areas surveyed, reported sourcing weather information from a range of techniques and sources. Of particular bearing was relying on the past experiences of weather patterns to determine the future patterns in planning for agriculture - on average, determining future patterns based on the patterns of the last 2-3 years. Similarly, finding out about predicted weather in forecasting was sourced through official channels, or media sources such as radio, television, radio and so forth. In focus groups discussions, farmers also noted the use of smart phone apps as a major source of information sharing for finding out about weather patterns upstream (e.g. particularly regarding flood potential).

Items	Yes	%	No	%
1. Using past weather to predict next year's weather	269	67	132	33
2. Number of years for considering back 2.47 years				

Table 16: Patterns of predicting future weather based on past patterns

Sources	Yes	%	No	%
1. Expert opinions; i.e. official	320	80	78	20

2. Newspaper	235	59	164	41
3. Radio	315	79	84	21
4. TV	357	89	43	10
5. Others	6	2	393	98

Note: Others; Searching internet, Training, Monitoring current's weather condition, Neighbors

Table 17: Sources of data for predicting weather

Farmers in these areas reported on the incidence of climate change related impacts in the long-term past (10-20 years ago). The incidence of flood and the intensity of flood reported in the past, is mixed – although the majority of those surveyed found both that the frequency and intensity had increased on their farms over the last 10-20 years, along with an increase in flood duration.

		Yes	%	No	%
Experiences of long term shifts in flood trends over the last 10-20 year period		337	84	63	16
Frequency of flood	More	129	38		
	Less	213	62		
Intensity of flood	More	113	33		
	Unchanged	74	21		
	Less	157	46		
Duration of flood per time	More	111	32		
	Unchanged	76	22		
	Less	157	46		
		Frequency		Percent	
Number of farmers reporting flooding		348		88	
Number of farmers reporting no flooding		49		12	
Frequency of Flooding	Every years	134		39	
	Recurring, but not every year.	139		40	
	One time in the past five years.	35		10	
	Two time in the past five years.	24		7	
	Others ; occurring in 2011	14		4	
Period	August - October				
Flood duration) days)	78)min. 7 , max. 240)				
Plant - Resistance against flooding)days)	13)min. 0 , max. 90)				
Livestock/fisheries - Resistance against flooding) days)	14)min. 2 , max. 30)				

Table 18: Farmers' perceptions of flood

As part of the reporting on incidences of climate change impacts, farmers in the 4 districts interviewed within the project area, noted the severity of the 2011 flood, and the loss, damage and beneficial implications of this particular event. They noted the following levels of damage:

Items	Crops	Livestock	Fisheries
Damage	30) min. 1 , max. 170) rai	95)min. 6 , max. 400) head	5,000 head
Percentage of damage incurred	86%)min. 2 , max. 100)	86)min.50, max. 100)	100 head
Cost of Damage	4,716) min. 625, max. 18,750) THB/rai	) 878min. 50, max. 3,333) THB/head	39,) 666min. 3,000, max. 150,000) THB
Cost of Damage	122,022 (min. 3,000, max. 672,000) THB	13,700)min. 625 , max. 18,750) THB	44,600)min. 625 , max. 18,750) THB
Details of Damage	Rice crop flooded	Stable/livestock housing flooded	Pond flooded
Value of Benefit)THB/rai) (THB/head(			16,000)min. 2,000 , max. 30,000) THB/rai
Details of Benefit			Catching fish

Table 19: Loss, damage and beneficial impacts under the 2011 flood

When observing the occurrence of drought over the last 10-20 years, special reference is also made by the farmers interviewed to the recent 2015 drought, as the benchmark for severe drought experience. An overall consensus seems to be marked on the frequency, intensity and duration of time for droughts increasing over the last 10 – 20 year period. The ratio of farmers noting these increases is roughly 3:1.

		Yes	%	No	%
Experiences of long term shifts drought trends over the last 10-20 year period		350	88	49	12
Frequency of drought	More	322	90		
	Less	34	10		
Intensity of drought	More	303	85		
	Unchanged	34	34		
	Less	18	5		
Duration of drought per time	More	306	86		
	Unchanged	33	33		
	Less	16	5		

		Frequency	Percent
Number of farmers reporting drought		289	74
Number of farmers reporting no drought		104	26
Frequency of Drought	Every year	84	28.93
	Recurring, but not every year.	126	43.96
	One time in the past five years.	24	8.79
	Two time in the past five years.	25	9.16
	Others ; occurring in 2015	31	9.16
Period	April - May		
Drought duration) days)	90)min. 12 , max. 270)		
Plant - Resistance against drought)days)	23)min. 3 , max. 100)		
Livestock/fisheries - Resistance against drought)days)	22) min. 2 , max. 100)		

Table 20: Farmers' perceptions and experiences of drought impact

Corresponding to the experience of drought by farmers in the four districts interviewed, changes in rain amounts are also noted over the last 10-20 years. This is particularly so for changes to the amount of rain and intensity of rain during a rain event, and with less agreement on the frequency of rain or the duration of rain events.

		Yes	%	No	%
Noticing long-term shifts in amount of rain on farm in the period of 10-20 years		364	91	36	9
Amount of rain is changed in the period of 10-20 years	More	301	81		
	Less	71	19		
Frequency of rain	More	59	16		
	Unchanged	47	13		
	Less	26	71		
Intensity of rain during a rain event	More	107	29		
	Unchanged	68	18		
	Less	197	49		
Duration of rain per time	More	69	18		
	Unchanged	62	17		
	Less	241	65		

Table 21: Farmer perceptions of rainfall changes

Finally, farmers were also asked about their perception and experience of temperature shifts over the last 10-20 years, in terms of a gradual overall temperature shift, as well as overall increases and decreases in temperature. All respondents reported that there had been a shift in temperature during the period of 10-20 years, and some (12 percent) reported that it had become cooler), while 88 percent reported that it had become hotter. The survey questionnaire did not allow for qualifications regarding the differences between night and day temperatures changing. However, in some of the qualitative responses of the focus group discussions carried out – farmers reported greater temperature variations, that night temperatures had become sometimes cooler, which affected the rice crop's ability to seed; while day time temperatures had become much hotter.

	Yes	%	No	%
Noticing long-term shifts in temperature on farm in the period of 10-20 years	373	93	28	7
Temperature become cooler	45	12		
Temperature become warmer	331	88		

Table 22: Farmers' perceptions of temperature

Pests and disease incidents were also reported to have increased, although the questionnaire did not ask about the causes of change for these shifts (e.g. attributed to climate changes or changes in farming practices, or a combination of both). A high number of farmers (86 percent) reported an increased frequency in the incidence of pest and disease occurrence.

		Yes	%	No	%
Noticing long-term shifts in pest and disease incidence occurring in the period of 20-10years		110	27	290	73
Frequency of pest and disease incidence	More	264	86		
	Less	42	14		
Intensity of pest and disease incidence	More	209	68		
	Unchanged	66	22		
	Less	31	10		
Duration of pest and disease incidence	More	193	63		
	Unchanged	77	25		

	Less	36	12		

Table 23: Farmers' perceptions of pest and disease incidence

Thailand in general has two rice cultivation periods, which are in season (rainy season starting from May to Mid-September), and off season (dry season starting from November to February). The geography of project area which is lowlying area constrains the agricultural practices, which are now divided into three main activities:

1. Growing off season rice during December – April
2. Growing in season rice during May – Mid-September
3. Growing in season rice (continued from the second activity) or fishing during September – November, depending on whether the irrigated water is sufficient for the cultivated areas and/or the cultivated areas are flooded.

With regard to the first and second activities, the water is allocated according to the cropping season, starting in May. Cultivated areas, however, are flooded from August onwards that may hinder the farmers from harvesting and fishing timely in their second and third activities, causing damages of crop products.

Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Fishing	Growing off season rice					Growing in season rice / Fishing					

According to consultations undertaken as part of the feasibility study, farmers have been dependent upon their past experiences in gauging the water conditions for these times, and in flood forecasting tend to rely upon information passed on by farmers further upstream being impacted by flood. To reduce their risk to conditions limiting the ability to complete the cultivation season cycle (e.g. in terms of flood forecasting errors, or impacts of water insufficiency), most farmers in the area have settled on using short growth duration varieties of rice (70 – 85 days). Examples of the short growth duration rice varieties include RD51, RD61, 039 Rajini, and 75-day variety. Unfortunately, these varieties are considered lower quality than long duration rice, and the prices that farmers receive for this variety less accordingly.

Items	Frequency	Percent
1. Non-glutinous	390	54.7
- Group of RD (RD 41, RD 43, RD47)	213	24.8
- Group of Phitsanulok	97	17.1
- Group of Suphan Buri	67	2.6
- Khao Dawk Mali 105 KDML105	10	0.5
- Khao Hom Rajini	2	0.3
- Pathum Thani	1	0
2. Glutinous: Sanpatong	2	0.3
Total	392	100

Table 24: Types of rice varities

Statistically between 2013 and 2018 (referred to table 25), focusing on only major rice production, the planted area, harvested area and yield in the three provinces show volatility. Farmers interviewed for this feasibility study, reported willingness for learning how to do other crops, but any decisions regarding changes in crop type or diversification of cropping types, would be heavily dependent upon whether and the extent of the 1) access to a market or marketability of a new product and 2) access to knowledge for growing new/alternative crops.

Province	2013	2014	2015	2016	2017	2018
	Planted area (rai)					
Uttaradit	616 339	589,182	473,513	544,985	568,725	569,625
Phitsanulok	1,444,387	1,359,936	1,314,035	1,304,183	1,337,171	1,339,068
Sukhothai	1,126,723	1,036,758	758,610	960,884	1,034,748	1,036,081
	Harvested area (rai)					
Uttaradit	610, 573	585,648	459,307	536,950	556,242	565,314
Phitsanulok	1,414,567	1,344,194	1,287,755	1,254,339	1,227,901	1,298,896
Sukhothai	1,102,800	1,012,633	729,874	952,449	896,574	1,000,081
	Production (tons)					
Uttaradit	388,020	361,239	292,809	322,086	334,022	340,867
Phitsanulok	876,308	782,776	725,113	747,444	723,701	736,832
Sukhothai	645,638	577,418	392,207	534,346	499,245	583,007
	Yield per rai (kgs)					
Uttaradit	636	617	638	600	600	603
Phitsanulok	619	582	563	596	589	567
Sukhothai	585	570	537	561	557	583

Table 25: Major Rice – area, production and yield per Rai by Province

Source: Agricultural Statistics of Thailand 2019, Office of Agricultural Economics

Despite the issues of flood, farmers in the project area noted in a series of focus group discussions undertaken for this feasibility study during late 2016, that their main challenge related to water availability. Farmers in the focus group discussions suggested that water storage on their farmland would be beneficial, as it would secure water for agricultural usage – providing more readily available water supply during the dry periods. This is particularly important given that they currently (2015-2016 period) report that they do not have enough water to plan for the April-May crop. Farmers interviewed in the project area conveyed that they would like to keep water for longer on their farm – because it has a number of benefits, both in that it improves the soil quality and also provides water access and security for agricultural livelihood activities and planning. They further noted that the irrigation network in their area hasn't been maintained since 1994. There are 40 canals currently in just one of the villages. They further noted also that any improvements would limit the current level of flood damage occurrence (in some way). Furthermore, the farmers expected that the enhancement of the existing infrastructures could increase the performance of water management by at least 50 percent through the capacity of flow management.

The interview revealed that there have been flood damage regularly starting from the end of August, floods stay for around 3 months. In the project area, at least 200,000 rai were affected (looks largely like a floodplain lake or wetland area during this time) (figure 56). Farmers reported that a village further upstream have 100 percent (complete area) flooding across their farming area. Interestingly, 55 percent of those being flooded reported there was no issues with flooding (see table 21) as the topography is naturally low lying area, but they prefer to know in advance when the flood will come and how long it will stay based on the reliable information and manageable water traffic.

Area percentage and frequency of flood reported by farmers in the project area:

Items	Frequency	Percentage
Number of people reporting flood as being problematic	176	45
Number of people reporting no issue with flooding	216	55
Frequency of flooding:		
Annual incidence of flooding	61	36
Recurring flood (but not annual)	84	49
Flood occurring once in the last five years	7	4
Flood occurring twice in the last five years	10	6
Other frequency	8	5
Period	August –November	
Flooding duration) day)	89 (min. 30, max. 240)	
Flooded area	19,132 sqm.	
Percentage of flooded area	92% (min. 22, max. 100)	
Details	landscape is flooded	

Table 26: Reporting by farmers in the project area on flood occurrence and impact

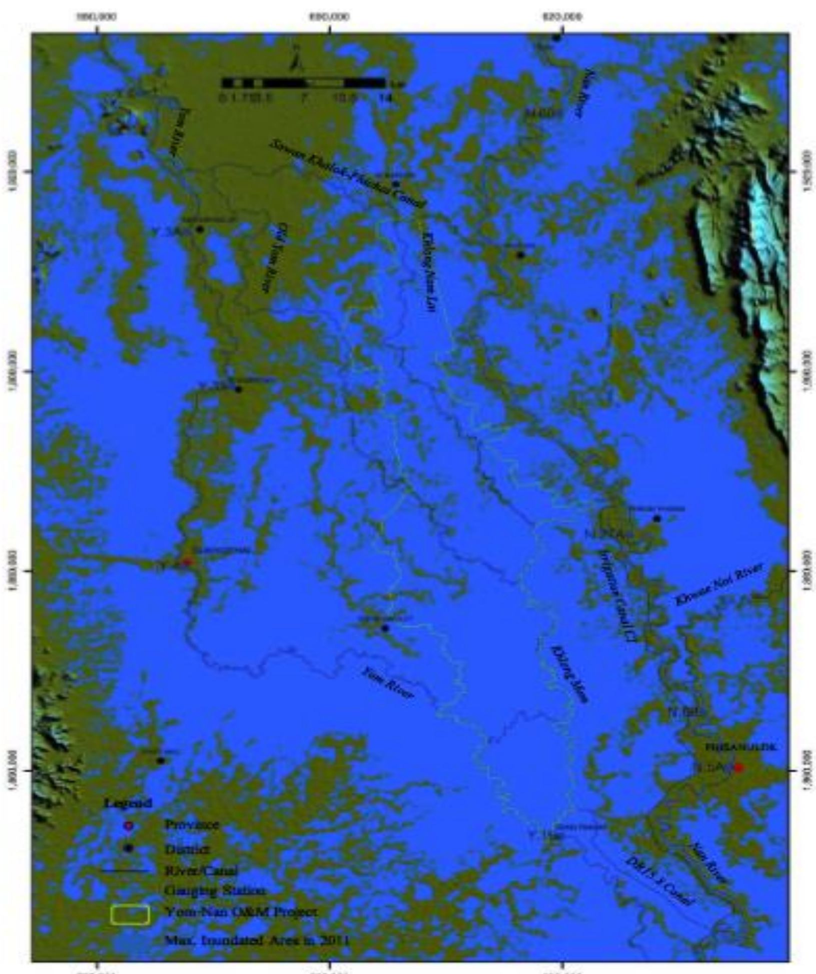


Figure 56: Maximum inundated area of the Project area, during the 2011 flood period.

Source: Royal Irrigation Department

Apart from flood, the project area also encounters with other agricultural problems, such as drought, insects, weed infestations. These are illustrated in tables 22-29.

Level of drought frequency and occurrence in the project area:

Items	Frequency	Percent
Number of people reporting drought as being problematic	117	30
Number of people reporting no issue with drought	275	70
Frequency of drought:		
Annual incidence of drought	39	33
Recurring drought (but not annual)	57	49
Drought occurring once in the last five years	7	6
Drought occurring twice in the last five years	1	1
Other frequency	7	6
Period	April –June.	
Drought duration) day)	49 (min. 7, max. 90)	
Drought Area	22,404 sqm.	
% of Flooding Area	73% (min. 20, max. 100)	
Details	Lacking of drinking water	

Table 27: Reporting by farmers in the project area on drought occurrence and impact

Level of damage incurred by drought during 2015:

Items	Crops	Livestock	Fisheries
Damage	31)min. 2, max. 119) rai	61)min. 6, max. 200) head	
Percentage of damage	78)min. 4, max. 100)		
Cost of Damage	3,896)min. 181, max. 15,000))THB/rai(	1,613)min. 20, max. 3,333))THB/head(	68,000)min. 2,000, max. 150,000))THB/head(
Details of damage	Harvested, but yield less. Unable to cultivate	Lacking water Water cost increased	No water for fish Inadequate water

Table 28: Reporting by farmers on drought damage in 2015

Incidence of insect infestations:

Items	Frequency	Percent
Number of people reporting insects as being problematic	267	68
Number of people reporting no issue with insects	127	32
Frequency of Insect infestations:		
Annual incidence of insect infestation	179	67
Recurring insects (but not annual)	73	27
Pest infestation occurring once in the last five years	9	3
Pest infestation occurring twice in the last five years	6	2
Insect infestations duration) day)	69) min. 7, max. 90)	
Plant - resistance against insect infestations)day)	16)min. 1, max. 90)	
Livestock/fisheries - resistance against insect infestations) day)	2)min. 2, max. 2)	

Table 29: Incidence of insect infestations by farmers in the project area

Extent of damage caused by insect infestations to farmers:

Items	Crops
Damage	23)min. 1, max. 115) rai
Percentage of damage	62)min. 1, max. 100)
Cost of Damage	3,222)min. 200, max. 9,677) THB/rai
Details of damage	Dried leaves, lowered yields

Table 30: Level of damage cause by insect infestations in 2014

Incidence of weed infestations to farmers:

Items	Frequency	Percent
Number of people reporting weed infestations as being problematic	188	48
Number of people reporting no issue with weed infestations	205	52
Frequency of weed infestations:		
Every years Annual incidence of weed infestations	147	78
Recurring weed infestations (but not annual)	38	20
Weed infestation occurring once in the last five years	2	1
Weed infestations occurring twice in the last five years	1	0.5
Other	1	0.5
Period	all year round	
Weed infestations duration) day)	68)min. 3, max. 365)	
Plant - Resistance against weed infestations)day)	24)min. 3, max. 100)	
Livestock/fisheries - Resistance against weed infestations)day)	31)min. 31, max. 31)	

Table 31: Incidence of weed infestations in 2014

Level of damage caused by weed infestations to farmers:

Items	Crops
Damage	21(min. 1, max. 115) rai
Percentage of damage	57 (min. 100, max. 10,000)
Cost of Damage (THB/rai)	3,307)min. 100, max. 10,000)
Details of Damage	Lowered yield

Table 32: Level of damage caused by weed infestations in 2014.

Incidence of plant diseases:

Items	Frequency	Percent
Number of people reporting plant disease as being problematic	247	63
Number of people reporting no issue with plant disease	147	37
Frequency of plant disease:		
Annual incidence of plant disease	151	61
Recurring plant disease (but not annual)	71	29
Plant disease occurring once in the last five years	5	2
Plant disease occurring twice in the last five years	7	3
Other frequency	12	5

Plant disease duration) days)	67)min. 5, max. 180)
Plant - resistance against plant disease)days)	21)min. 3, max. 120)
Livestock/fisheries - resistance against plant disease)days)	33)min. 7, max. 60)

Table 33: Incidence of plant diseases experienced by farmers in 2014 (ragged stunt disease, blast disease)

Damage to farmers by plant disease incidence:

Items	Crops
Damage	22)min.1, max. 80) rai
-% of damage	62)min. 2, max. 100)
Cost of Damage	2,964)min. 100, max. 8,333) THB/rai
Details of Damage	Less grain produced, lower yields.

Table 34: Level of damage caused by plant diseases experienced by farmers in 2014 (ragged stunt disease, blast disease)

In terms of access to agriculture credit, according to a study undertaken by the Thailand Development Research Institute, occurrence of average rainfall during the rainy season, access to and level of land tenure, number of household members and household socio-economic characteristics and head of household, are the main factors driving approaches to flood adaptation by farmers in the Chao Phraya River Basin (Thampanishvong, 2014:1). Conversely, different factors were found to the drivers of adaptation to drought. These were – access to credit, land ownership, vehicle ownership, household size, and household head gender profile. Findings of this study also concluded that adaptation to flood has been occurring in the Chao Phraya River Basin area for more than 25 years – and have resulted in increases to the wet-season rice productivity. However, adaptation to drought in the area, does not draw the same conclusions.[108]

A study by Thampanishyong (2014:12) found that in adapting to climate change impacts, while lack of land ownership factored into whether farmers adapted to flood – in adapting to other types of climate impacts (e.g. drought), lack of ownership of farm land did not play a role – but rather, those households with higher portions of members engaging in farm activities, had a higher likelihood of adopting climate change adaptation strategies – particularly in terms of drought.

2.1.6 Current and potential levels of coping and adaptation

Farmer households and farmer communities are widely considered as the most vulnerable groups in Thailand. In the context of groups most at risk to climate change impacts, this is even greater so, as they rely on a fine balance of weather conditions in order to be able to maintain a basic livelihood income from farming. In response to changing conditions, agriculture households have been adapting to climate change autonomously (e.g. raising the floor of their homes and/or returning to the area's traditional architecture which utilises stilt housing methods; shifting to other crops such as fruit trees, and/or adopting and/or returning to use of aquaculture or aquaculture-diversified livelihoods). Similarly, fast growing and/or water resistant crops are used in the areas that are submerged by flood for long periods. Fishing and fish products are also utilised when rice and agricultural livelihood productions are inhibited by shorter grow periods and the early onset of rainy season or reduced rainfall and drought periods. Therefore, a more holistic and well planned adaptation approach by the government can strengthen the current adaptation to be more climate resilient.

In response to the changes that farmers experienced, a number of adaptive strategies have been taken to farming practices. Changing crops and/or crop patterns and timing were high on the list of responses and strategies used

[108] Thampanishvong, K. 2014, *Farmers' Adaptation to Extreme Weather Events in the Chao Phraya River Basin*, Thailand Development Research Institute, October 15 2014

to adapt to the changes in climate patterns. Some the strategies used were swapping to crops that were less water-intensive, while the most extensively used approach by farmers was an increasing dependence on groundwater use as a supplementary water supply.

Crops	Yes	%	No	%
Changed planting dates-partial	167	45	205	55
Changed planting dates-total	173	46	202	54
Change crop varieties that consume less water	105	29	260	71
Change crop varieties that resist to flood	34	10	317	90
Change crop type that consume less water	43	12	305	88
Change crop types that resist to flood	21	6	325	94
Using ground water	159	45	191	55
Using water from pond /well	54	16	288	84
Saving water	27	7	314	93
Change livelihood type (temporarily)	57	17	273	83
Livestock/fisheries				
Change Livestock/fisheries type	8	3	229	97
Invest in new breeds	7	3	229	97
Made investment for water (such as digging well)	8	3	227	97

Table 35: Farmers' adaptation responses to shifts in temperature

In the instance of increased flooding there were numerous cases where fish and fish products were used to supplement shorter rice growing periods or where there was the early onset of rainy season. In the 2011 floods, for example, one rural community in Watkao, Phitanulok was inundated – with the rice being destroyed that they were just about to harvest. In desperation to secure their sole livelihood source, as soon as the floodwater started to recede, farmers quickly started to plant their 3-month crops, which include diversified crop options such as beans, cabbage, sweet potatoes. Diversification of livelihoods also included initiating discussion followed by a process for community aquaculture/fisheries. In the discussion with the neighbouring village(s) and a community organisation, it was decided that not only would the small lake serve to function as a shared aquaculture/fishing zone, it would double to be developed into and serve a water retention function; maintaining water throughout dryer periods and limiting the level of flood damage.[109] Some farmers responded in interviews that they implement integrated agricultural management practices – e.g. combining the benefits of co-farming rice and fish, and/or ducks and rice. They noted that the ducks particularly also helped to protect against pests as well as adding additional fertiliser benefits. Farmers noted that they don't really have any knowledge on how to make the ratio of fertiliser amounts when using co-farming of ducks and fish, however, they report using current averages around 50kg per rai of fertiliser input. They further state that the reason they don't do integrated farming at a more extensive level is based on the level of access (or lack thereof) to markets.

In terms of responses to flood, particularly in the case of the 2011 flood – the most widely undertaken strategy was to switch to catching fish, amongst the four districts interviewed in the project area. This strategy of adopting fishing as a livelihood stream was closely matched in level of adoption by diversifying livelihoods – in terms of seeking additional income or alternative employment. Other strategies were the adoption of structural measures – constructing dykes, digging shallow canals to store water or digging water vent channels to release water more quickly. Non-structural measures were also adopted – including pumping water from the flooded area, using sandbags to block floods, closing drainage doors at the Yom river, seeking government and private sector relief assistance, relocating assets, as well as changes in agricultural patterns of shifting planting dates, harvesting rice crops by boat and growing plants in highland areas to avoid flood impacts.

[109] Water infrastructure Feasibility Study – Royal Irrigation Department (RID)

Agricultural practices remained the most altered in the response to flood impacts, with several changes taking place for most agricultural livelihood dependent households:

Crops	Yes	%	No	%
Changed planting dates-partial	163	48	175	52
Changed planting dates-total	176	52	162	48
Change to crop varieties that consume less water	41	13	281	87
Change crop varieties that are flood resistant	18	6	292	94
Change crop type that consume less water, i.e.	20	6	288	94
Change crop types that resist to flood, i.e.	16	5	292	95
Using ground water	30	10	275	90
Using water from pond /well	25	8	282	92
Saving water	3	1	275	99
Stop planting for a while to other career	65	22	238	78
Livestock/fisheries				
Change Livestock/fisheries type	19	9	188	91
Invest in new breeds	5	2	201	98
Made investment for water (such as, digging well)	4	2	202	98

Table 36: Farmers' adaptation to flood

More recently, drought had been a huge contending change to climate patterns for the four districts interviewed. They responded by employing strategies that are wide-ranging. However, constructing artesian wells to access groundwater, was by far the most widely employed on-farm response for dealing with drought, despite the significant costs involved. Similarly, diversifying income streams with external employment was equally matched as a widely employed method for responding to drought.

Adaptation response	Frequency
Constructing artesian well	17
Involving in the government project of canal dredging	3
Digging wells	2
Using groundwater	34
Requesting for water from RID	1
Looking for employment	34
Stop planting/crop growing	11
Planting with less use of water	8
Remaining in natural condition	6
Growing crops, that can resist drought, by consuming less water	5
Requesting for assistance from the government sectors	5
Growing less plants/lowering agricultural activities	4
Changing planting dates	2
Pig raising	1
Catching fish	1
Burning charcoal	1

Table 37: responses to the 2015 drought

Overall, responses differed slightly between changes in rainfall, and in long periods of dry and drought:

Crops	Yes	%	No	%
Changed planting dates-partial	133	36	238	64
Changed planting dates-total	136	37	234	58
Change crop varieties that consume less water	54	15	299	85
Change crop varieties that resist to flood.	17	5	343	95
Change crop type that consume less water	27	8	314	92
Change crop types that resist to flood	17	5	324	95
Using ground water	67	20	273	80
Using water from pond /well	35	10	299	90
Saving water	10	3	314	97
Pursue other employment (temporarily)	55	14	274	83
Livestock/fisheries				
Change livestock/fisheries type	4	2	222	98
Invest in new breeds	4	2	221	98
Made investment for water (such as digging well)	3	2	222	98

Table 38: Farmers' adaptations to precipitation changes

Similarly to responses to precipitation changes, farmers in the area used the same strategies of adaptation, however, the incidence of drought when compared with precipitation changes, resulted in higher response rates.

Crops	Yes	%	No	%
Changed planting dates-partial	166	47	188	53
Changed planting dates-total	184	52	169	48
Change crop varieties that consume less water	83	24	267	76
Change crop varieties that resist to flood	30	9	298	91
Change crop type that consume less water	45	14	282	86
Change crop types that resist to flood	11	3	317	97
Using ground water	132	40	201	60
Using water from pond /well	48	15	273	85
Saving water	7	2	280	98
Pursue other employment (temporarily)	70	22	251	78
Livestock/fisheries				
Change Livestock/fisheries type	7	3	214	97
Invest in new breeds	7	3	214	97
Made investment for water (such as, digging well)	8	4	213	96

Table 39: Farmers' adaptations to drought

Increased levels of pests and disease affecting crops have also forced farmers in the four districts to alter their practices and employ strategies for overcoming these impacts. The following strategies were used, with the changing of crop timings, as well as use of water-efficient varieties and pest and disease resilient strains rating highly as adaptations.

Crops	Yes	%	No	%
Changed planting dates-partial	64	21	241	79
Changed planting dates-total	59	19	247	81
Change crop varieties that consume less water	38	19	263	87

Change crop types that resist to Pest and Disease Incidence	21	7	262	93
Stop planting for a while to other career	19	7	262	93
Livestock/fisheries				
Change Livestock/fisheries type	4	2	199	98
Invest in new breeds	4	2	199	98
Made investment for water (such as, digging well)	5	3	197	97

Table 40: Farmer strategies for mitigating the impacts of pest and disease incidence.

2.1.6.1 Inputs and access to markets

Rice cultivation is the main crop of Thailand's repetitive flooding areas, such as Yom-Nan Area. Farmers grow rice on average twice a year in the area, although some pockets grow rice crops three times in the year. Both cultivations are in the dry season period. Farmers called dry season 1 and dry season 2 rice. The varieties of rice seed used in these flooding areas are the white rice variety such as Phitsanulok 2, Suphanburi 1 and 2 and some varieties of short growth duration rice such as RD51, RD61, RD 81 and 039 Rajini. The average amount used is between 30-40 kilograms per rai higher than the amount recommended by department of agricultural and cooperatives (DOAC) which is 15 kilograms per rai. These kinds of varieties are varieties produced for selling only, and are not used by farmers for their own household consumption as they are fragrant rice varieties such as Pathumthani 1 and Hom mali. The average yield is 600-900 kilograms per rai depending on many factors such as the amount of chemical fertiliser and chemical substances used coupled with whether sufficient levels of water are available.

Pesticide and fertiliser use is high in the area, and combined with cost of seed – comprise significant input costs for rice farmers:

Items	Plot 1		Plot 2	
	Crop 1	Crop 2	Crop 1	Crop 2
Inorganic fertilizer applied (kg/.rai)	49	-	47	-
Inorganic fertilizer cost (THB/kg.)	12	-	12	-
Organic fertilizer applied (kg/.rai)	18	-	26	-
Organic fertilizer cost (THB/kg.)	21	-	12	-
Pesticide applied (powder) (kg/.rai)	0.6	-	0.8	-
Pesticide cost (powder) (THB/kg.)	318	-	355	-
Pesticide applied (liquid) (litre)	1	-	1	-
Pesticide cost (liquid) (THB/litre)	497	-	415	-
Seed quantity bought (kg/.rai)	29	-	44	-
Seed cost (THB/kg.)	17	-	20	-

Table 41: Fertiliser, pesticide and seed inputs in season 1, separated by plot

During season 2, the table below shows the rise in costs for the second crop round for fertilizer inputs, for pesticide inputs:

Items	Plot 1		Plot 2	
	Crop 1	Crop 2	Crop 1	Crop 2
Inorganic fertilizer applied (kg/.rai)	45	50	46	21
Inorganic fertilizer cost (THB/kg.)	12	13	12	-
Organic fertilizer applied (kg/.rai)	27	-	26	-
Organic fertilizer cost (THB/kg.)	12	-	11	-
Pesticide applied (powder) (kg/.rai)	0.8	-	0.8	-
Pesticide cost (powder) (THB/kg.)	402	800	410	-
Pesticide applied (liquid) (litre)	2	-	2	-
Pesticide cost (liquid) (THB/litre)	498	300	410	-
Seed quantity bought (kg/.rai)	111	-	93	-
Seed cost (THB/kg.)	26	-	22	-

Table 42: Fertiliser, pesticide and seed input in season 2, separated by plot

Season three crops keep similar prices, however, there is a significant rise in the level of pesticide inputs for this season.

Items	Plot 1		Plot 2	
	Crop 1	Crop 2	Crop 1	Crop 2
Inorganic fertilizer applied (kg/.rai)	41.00	-	43.75	-
Inorganic fertilizer cost (THB/kg.)	9.00	-	11.25	-
Organic fertilizer applied (kg/.rai)	37.50	-	31.67	-
Organic fertilizer cost (THB/kg.)	8.00	-	10.33	-
Pesticide applied (powder) (kg/.rai)	2.75	-	-	-
Pesticide cost (powder) (THB/kg.)	487.50	-	-	-
Pesticide applied (liquid) (litre)	18.00	-	48.33	-
Pesticide cost (liquid) (THB/litre)		-	242.4	-
Seed quantity bought (kg/.rai)	333.00	-	396.20	-
Seed cost (THB/kg.)	20.33	-	11.75	-

Table 43: Fertiliser, pesticide and seed inputs in season 3, separated by plots.

Within the past few years, the average prices received were between 5,000 – 7,000 baht per metric ton. Factors determining the level of prices received are the quality of grain, such as humidity content for example; since the harvesting period of the second dry season rice is still in the rainy season. The percentage of humidity evident in the rice crop is usually the main cause for low selling prices. The average cost of production of the dry season 1 and 2 are between 4,000-4,500 baht per rai. The production cost of the second dry season rice is higher than that of the first season due of the costs of fuel and fertilizer needed in the second season (for pumping groundwater and for raising the soil fertility to a level enough to cultivate the second crop), which are approximately 30-40 percent of the total cost while the cost of hired labor and machinery is a further 30-35 percent. Roughly 95 percent of rice product is sold through local millers and local collectors. The remaining 5 percent is kept for seed for future use. Farmers stated in focus group discussions for the study that there are no direct market access options and that they would like a program that helped to establish market access in some way for them. Agricultural cooperatives are another method of gaining market access and a buying source of rice. Unfortunately, there are only a few cooperatives in the areas and the location of these cooperatives is too far from production areas. So, most of farmers prefer selling their paddy to local millers and local collectors. Millers then determine prices received by farmers. Farmers state that they have no bargaining power in the exchange. There are no central markets in the areas*. Several rice groups exist however in each province:*

Sukhothai:

1. Husked Rice of Ban Bueang Krob, Husked Rice, Premium Thai Hom Mali Rice
2. Safe Rice Promotion Group of Ban Namphu, Milled Rice, Riceberry Rice
3. Organic Production Cooperative of Ban Kwao, Milled Rice, Riceberry Rice

Uttaradit

1. Rice Seed Production of Rai Charoen Community**,** Brown Rice, Khao Hom Nil

Phitsanulok

1. Safe Rice for Organic Agriculture Group of Ban Pha Rang Mi, Thai Hom Mali Brown Rice, Thai Hom Mali Rice
2. Organic Rice Production Group of Wang Nam Khu, milled rice

2.1.6.2 Existing water infrastructure

Thailand already practices water management techniques in the critical Chao Phraya River Basin in order to stave off flood during wet season and during increased precipitation intensity periods, as well as to ensure water availability during the dry season and drought periods, using canals and regulators and reservoir operations. In the upper area of the Chao Phraya River Basin, dams and reservoirs are used both to store and to regulate the flow of water. In the central (flood plain) area, water is drawn into designated low lying areas in order to store water for certain periods for release at the end of the rainy season and to prevent flooding in the lower basin area (urban Bangkok area). Within the lower, urban and industrial area of the basin, flood diversion canals are used to divert excess water to the gulf of Thailand. In addition, dams are used in the upper areas to further regulate the distribution of water for industrial and agricultural use. The Yom River has no retaining structure (reservoir) in its upstream area, whereas the Nan River holds large structures along its course such as the Sirikit dam in the upstream area and the Naresuan Dam. The Yom River typically has periods without surface water flow during the dry season, whereas the Nan River has surface flow throughout the year as the Sikirit Dam is used to provide flow during the dry season. While these systems operate downstream in the lower basin, and dams in the upper areas – this level of infrastructure is no longer adequate in retaining and managing water, particularly in the central basin and flood plain area, in the context of increasing climate change events and impacts.

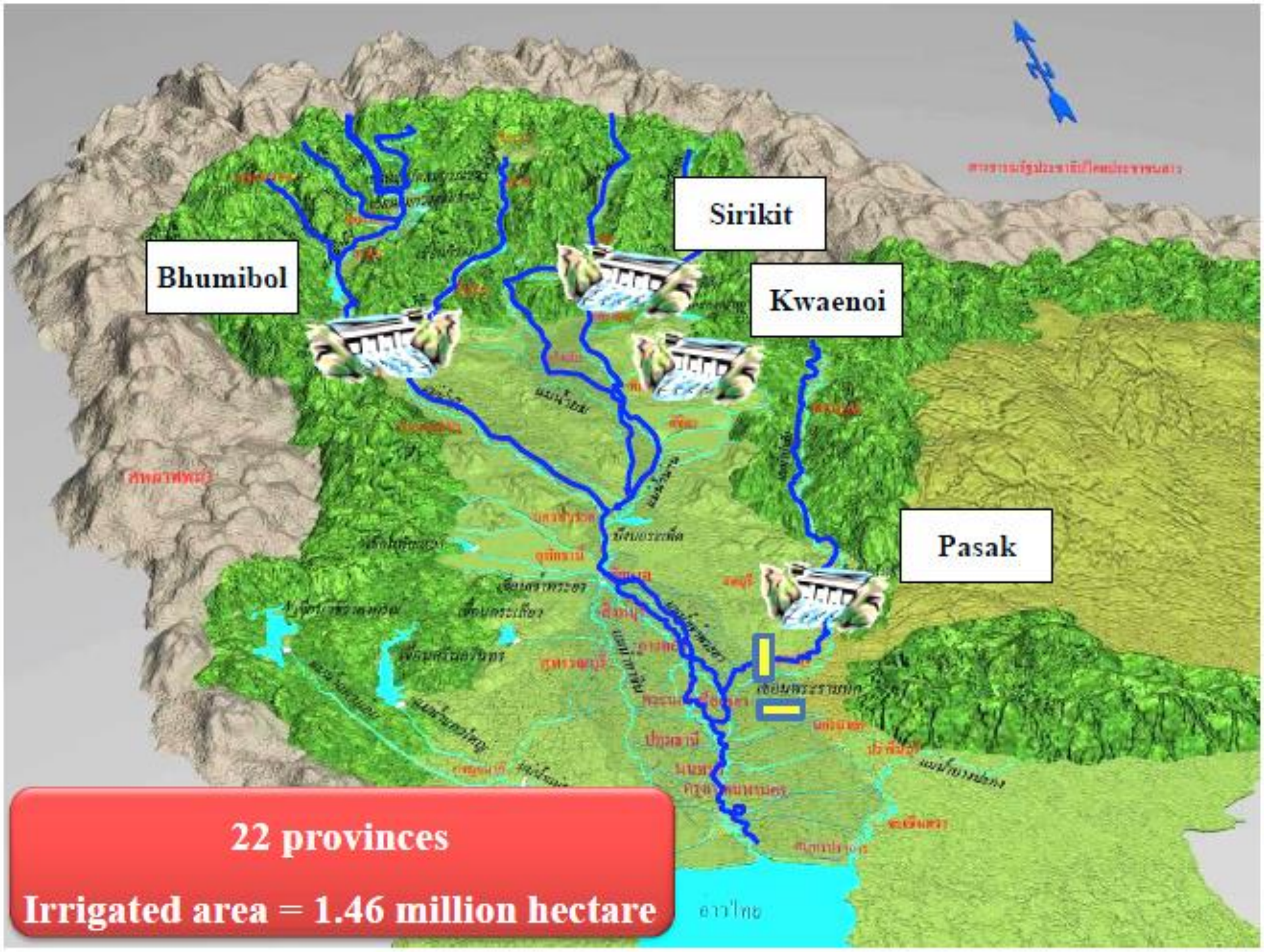


Figure 57: Dry season management in the Greater Chao Phraya River Basin

Source: Amnatsan, S. 2015, 'Dry season planning and management', Office of Water Management and Hydrology, Royal Irrigation Department

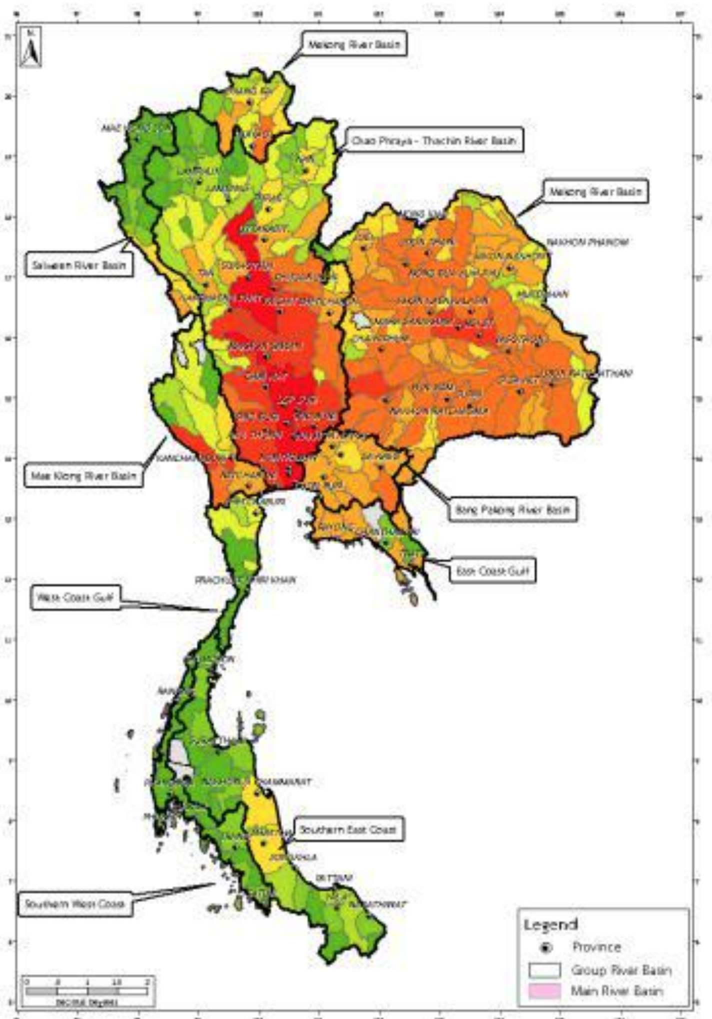
<u>Existing level of access to irrigation systems in the project area:</u>

Phisanulok Irrigation Project

1. The Phitsanulok Irrigation Project was established after the Naresuan Dam had been completed in 1980. The project comprises five operation and maintenance projects as follows:
    1) Phlai Chumpon O&M Project, irrigable area 218,000 rai, water source from Sirikit reservoir.
    2) Naresuan O&M Project, irrigable area 91,000 rai, water source from Sirikit reservoir.
    3) Khwae Noi Bamruang Dan O&M Project, irrigable area 155,166 rai, water source from Khwae Noi Bamruang Dan reservoir.
    4) Don Setthi O&M Project, irrigable area 186,000 rai, water source from Sirikit reservoir.
    5) Tabua O&M Project, irrigable area 168,400 rai, water source from Sirikit reservoir.
2. The Sirikit Dam was completed in 1972, storage capacity of 9,510 MCM, and the Khwae Noi

3. Bamruang Dan Dam was completed in 2012, storage capacity of 769 MCM.

Figure 58: Irrigated areas in Thailand



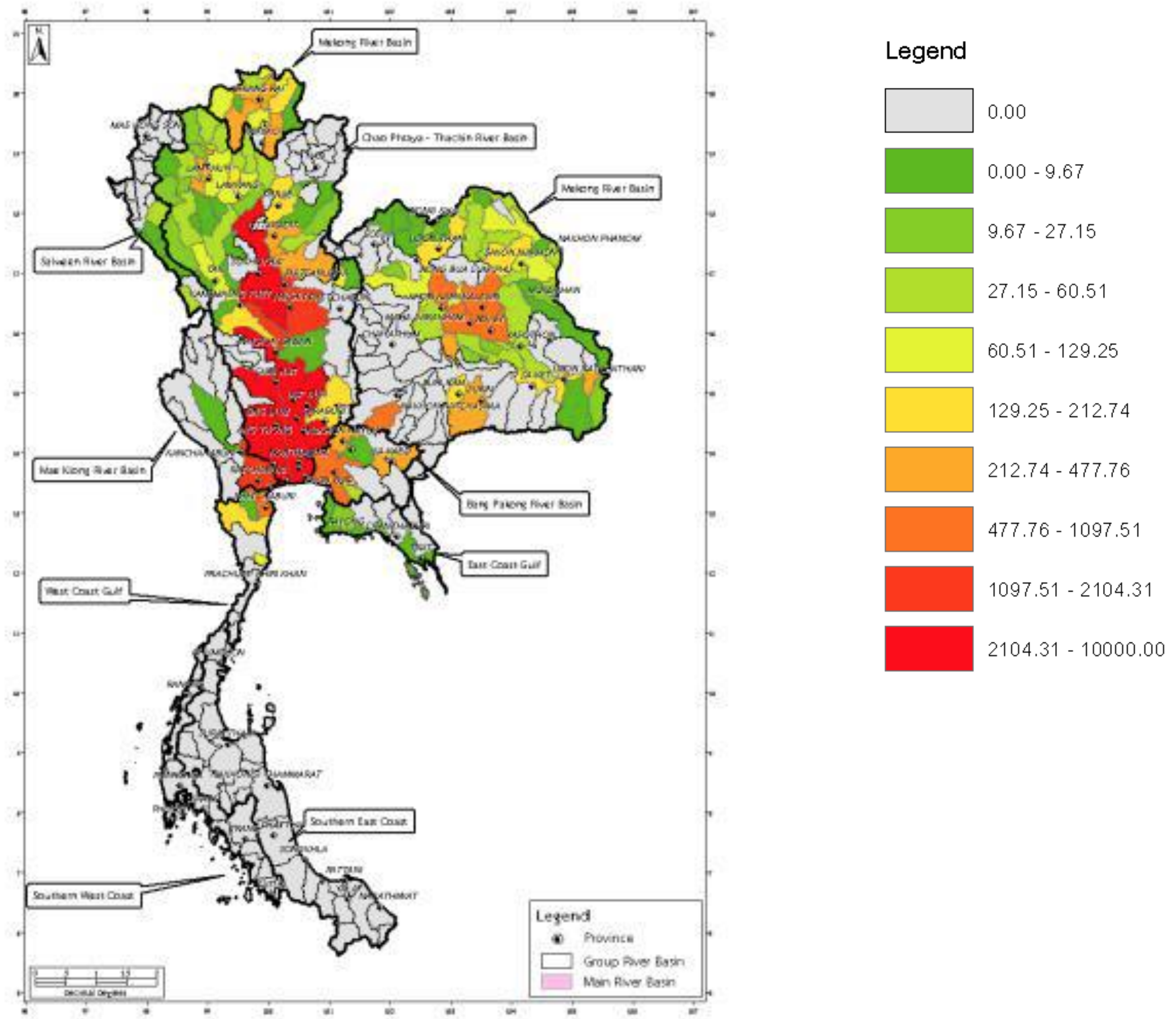


Figure 59: Rainfed areas in Thailand

Source: Chaowiwat, W. Boonya-aroonnet, S. & Weesakul, S. 2016, Impact of Climate Change Assessment on Agriculture Water Demand in Thailand

Yom-Nan Operation and Maintenance Project

Previously the project area was located out of the Phitsanulok Irrigation Project; hence, local people requested the Royal Irrigation Department (RID) to allocate water from the Nan River to this area during the dry season that the water shortage problem and conflicts in water allocation among farmers had long been problems. According to RID's regulation, the water can be allocated in the area that is declared as an irrigation project only. Therefore, the Yom-Nan Operation and Maintenance Project was established in 2013, aiming to provide water for cultivated areas of local farmers of about 312,600 rai (500.16 sq.km or 50,016 ha) in seven districts as documented.

Province	District	Sub-district	Cultivated area (rai)
Uttaradit	Phichai	Phrayaman	21,264
		Thamafuang	20,104
		Korrum	10,861
Total			52,229
Phitsanulok	PhromPhiram	Wang Won	38,338
		Taluk Thiam	19,697
		Si Phirom	24,508
		NongKhaem	13,319
		Matong	1,895
		Tha Chang	7,583
	Muang	Ban Krang	9,784
	Bang Rakam	Tha Nang Ngam	28,668
		Churn SaengSongkram	21,593
		Bang Rakam	1,555
Total			166,940
Sukhothai	Kong Krilat	Ban Mai Suk Kasem	19,883
		KokRaet	20,626
		KriNok	27,264
		KriKlang	11,306
		KriNai	4,951
		Dong Dueai	672
	Srinakorn	Klongmaplup	355
		Nongbuo	1,633
	Sawankhalok	Paknam	6,742
Total			93,431
Total			312,600

Table 44: Cultivated area within the project area

Source: Yom-Nan O&M Project

The water sources for the project area are from the Nan River and the Yom River are:

- The two headworks on the right bank of Nan River are to divert water into the project area with support from the Naresuan Dam in controlling water level and Sirikit Dam in releasing water stored in reservoir. The two headworks are Khlong Ton Pho Culvert Regulator in the Nan-Khlong Mem feeder canal (15 cms capacity) or called YN1 feeder canal and Khlong Oom Culvert Regulator in the Nan-Khlong Wang Khon feeder canal (10 cms capacity) or called YN2 feeder canal.

- The Khlong Hok Bat Regulator (250 cms capacity) on the left bank of the Yom River is to divert water into the Old Yom River (150 cms capacity) and Sawan Kalok-Phichai canal (100 cmscapacity), connecting to Khlong Nam Lai canal (100 cms capacity). The Old Yom River and Khlong Nam Lai canal flows into the project area. It should be noted that along the Khlong Nam Lai canal to the Yom River downstream, it is in different names according to the area where the canal flows pass through such as Khlong Mem and Khlong Bang Kaew called at downstream.

The proposed interventions under this proposal focus on data management and analyses and the improvement of the existing water infrastructure, including the strengthening of canals and construction of retention ponds to enhance water management within these.

This project is different from the Phitsanulok Irrigation Project, which has a complete irrigation canal network to supply water to the irrigated area in command. The Yom-Nan O&M Project area uses the existing natural canal network to supply and store water by constructing regulators in the canals to control water. Because the area is low-lying, farmers have to pump water from the canals to their farmlands and this area is frequently flooded for 2-3 months from August to October. The establishment of this operation and maintenance project would result in more effective water management and be able to increase the number of cultivated farmlands.

The Yom-Nan Operation and Management Project is classified as an inundation scheme. Cultivation activities will be rain-fed when the rainy season contains normal rainfall (May to October). In the dry season (November to April), water will flow from the Nan River via the two feeder canals into the project area. The amount of water is about 160-180 MCM annually. Up to present, the canals in the project are being improved to store and drain water effectively and regulators are being repaired or reconstructed to control water levels in the canals. Flood is one major problem in the project area; hence, the management of drainage system must be taken systematically and swiftly to prevent damages to the harvest. However, there is no large storage dam in the Yom River Basin; hence, this area is frequently flooded and the cultivated area of rice field in particular, is at risk at the end of rainy season (August to October). While water shortage during the dry season, especially in February, occurs repeatedly and at this time effective water management must be implemented in order to ease the hardship of farmers in the project area. The Sukhothai Irrigation Project has responsibility in developing, operating, and maintaining small to medium irrigation projects and flood protection schemes in the boundary area of Sukhothai province. Besides, the project plays a vital role in flood management during the flood crisis.

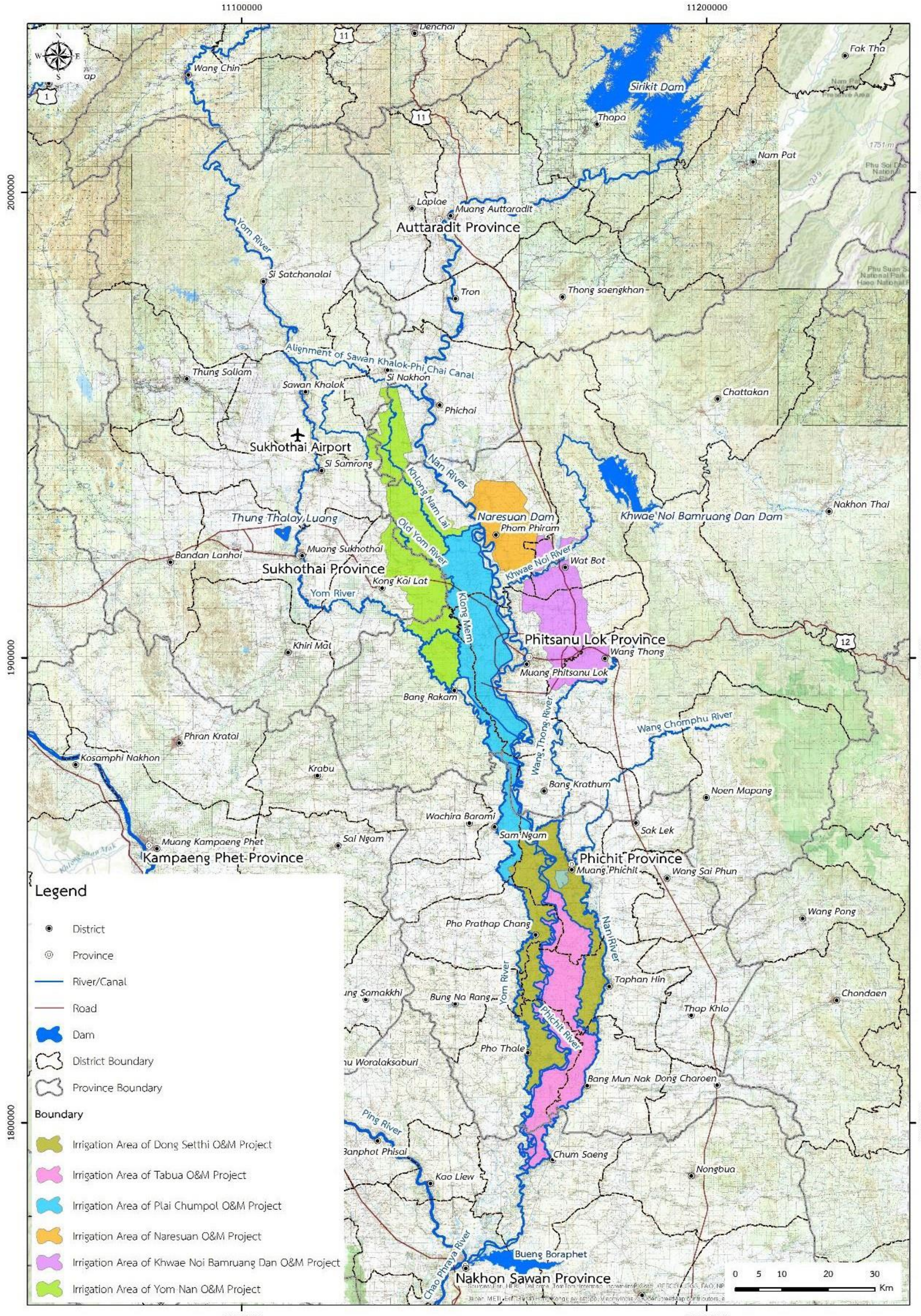


Figure 60: Irrigation project area boundaries

Source: Royal Irrigation Department (RID) data

There are two main purposes served in the existing water infrastructure throughout the area. These are primarily 1) flood protection: with several cities being located along the Yom River downstream, some of which are also of high cultural value – including the 'Sukhothai Historical Park', UNESCO World Heritage Site; and 2) water storage provided through the irrigation canals, weirs, backwater area, diversion structures and embankments – all of which are widely utilised during dry season.

2.1.7 Potential to cope with climate change impacts and ranking based on hydrology and related physical parameters

The average rainfall to the Chao Phraya River Basin area is 1,100mm, while its average runoff is approximately 34,600 million $m^{3.}$ The northern part of the Chao Phraya River Catchment holds an entire storage capacity of approximately 27, 446 million m^3, and the central part of the Basin can store only 1,808 million m^3. Avoiding overflow of the Chao Phraya River, means that discharge of the river must be under a rate of 2,800 m^3 per second – as the Chao Phraya will not overflow its banks if the discharge does not exceed this amount. Under previous historic rainfall patterns, the Yom and Nan River Basins throughout Uttaradit, Phitsanulok, and Sukhothai Provinces provided critical river flow. However, under longer dry spells with increased levels of rainfall intensity over shorter periods, the Yom and Nan Rivers are unable to maintain their critical function in the upstream reaches of the Chao Phraya River Basin, as they retain less water, and slow less runoff to the central plains and central part of the Basin, and onto greater metropolitan Bangkok region, further downstream.

The canals and regulators currently in place in the Yom and Nan River Basins, can no longer cope effectively with the increased pressures of climate change. Studies undertaken by the Royal Irrigation Department have favoured improvements in water resource management that support communities' quality of life, make use of excess water, and which reduce impact from flooding in the lower (urban-industrial metropolitan region) basin. Recommendations from the study include identified strategic upgrades to flood gates and canals, in order to best support flood and drought mitigation.

The Yom-Nan O&M Project has distributed water from Sirikit Dam for irrigation purpose within the project area. Water travels from the Naresuan Dam project area through two main canals while natural waterways act as irrigating and draining canals; however, farmers have to pump water from waterways into their own farmlands. Farmers normally cultivate two crops of rice per year, each of which take eight months, while during the other four months of the year the farmlands are flooded. People's participation is needed in water management of the area due to the current shortage of irrigation officers. These following steps are the process of the water management in the area:

1. Farmers begin cultivating after the flood subsided around November and December by utilizing water remaining in the area during the first two weeks of cultivation activities. Then water is drawn from outside sources or from irrigation water. The cultivation starts in the area located on highland in the upper part and later gradually covers farmlands on the lowland in the lower part. The local irrigation officers evaluate the volume of water supply from Sirikit Dam at the end of the rainy season and cooperate with the Royal Irrigation Department's Office of Water Management and Hydrology to make a decision on water allocation plan in the dry season. Farmers in this area want small amount of water for farming activities only when dry spell occurred in the rainy season, but they are also affected by flood that inundates their farmlands every year. Therefore, the management of water in this project area has to consider problems of flood and drought altogether.

2. The cultivation plan is adapted to fit the water allocation plan as well as water supply. Participation from water user groups is needed in order to prevent conflicts and to reduce risks from water shortage. Water distribution efficiency and cooperation from water user groups are taken into accounts in the process of drafting

water distribution and cultivation plans of which the plans must be approved by the user groups. The cultivation plan must be harmonized with the annual cultivation calendar because most of the project area, the lowland, is often flooded resulting in the start of the cultivation season falling in November and December after the flood subsides. An increase in water demand occurs (usually) in January and February. The harvesting season of rice crop is in March and April. The next crop continues in May when the rain season begins, and irrigation water is needed in case the annual rain comes late. The harvest of this second crop must be made within August in order to avoid damages from floods. Apart from being responsible for irrigation works, officers have responsibility for the drainage systems to the farmlands in the area as well.

The cultivation activities during the dry season are limited because of water supply. Considering the location, volume of water supply and duration of water demand, and the water distribution would be planned on a weekly basis in order to distribute irrigation water to farmlands thoroughly and adequately. Cooperation and participation of farmers and water users are needed and should be promoted to create strength among these groups.

The Yom-Nan Operation and Maintenance Project is newly established and equipped with a small number of officers. Its operation system has been designed to obtain participation from water user groups in managing the water resources as the following details:

a. Irrigation volunteers are in charge of controlling main irrigation structures and distributing water in accordance with the distribution plan.

b. The chairman of each water user group is responsible for examining the cultivation area and volume of water allocated to their quotas.

c. Irrigation officers examine the implementation of the plan as well as coordinate among related agencies and concerned groups.

d. Project officers follow up the water allocation quotas as well as settle disputes among user groups and work to create cooperation in water management.

e. The operation of water distribution is evaluated and amended at any period of time in order to boost its efficiency.

Farmers in the area start cultivating after the flood subsides at the end of the rainy season around November and December. The preparation works of farmlands in this two-months period does not require irrigation water but the demand for water commences (usually) in January when rice is growing. The volume of water distributed by the Yom-Nan O&M Project is set under the Dry Season Water Allocation and Management Plan in the Chao Phraya River Basin. The Phitsanulok Irrigation Project, which is in charge of the operation of two head regulators, would request a quota of water from the RID for 160-180 MCM annually. The Office of Water Management and Hydrology has agreed with this quota which has to be drawn from 'water usage for other purposes of the Nan River.' Such allocation has been managed during the past seven years already. While the other two newly established projects in the Nan River Basin, which comprise of the Pha Chuk Diversion Dam Project and the Phitsanulok Left Bank Irrigation Project, would maintain enough volume of water, according to the analysis on water balance of the Chao Phraya River Basin.

During the rainy season in the Yom River Basin, the Sukhothai Irrigation Project carries out flood watch. Rainfalls at gauging stations in the Upper Yom River Basin such as Phrae and Sukhothai climate stations are being monitored together with water levels at gauging stations along the Yom River such as Y.1C at Mueang Phrae and Y.14 at Si Satchanalai district. If the rainfall is more than about 100 mm/day in the Upper Yom River Basin, it is expected that flood will flow to Y.14 gauging station in 24 hours. The present river networks and flood controlling structures in the area of Sukhothai province can manage flood discharge in the Yom River at Si Satchanalai district not more than 1,150 CMs. If the flood discharge is more than that, flooding is expected to occur along both banks of the

Yom River and in the low land areas in the areas of Si Satchanalai, Sawan Khalok, Si Samrong, Mueang Sukhothai, Kong Kai Lat, and Bang Rakam districts. The flooding information will be disseminated to the officers concerned they will then inform local people (and farmers) to prepare for facing flooding.

The Sukhothai Irrigation Project controls released discharge at Ban Hat Sapanchan regulator not more than 900CMs. If the flood flow is more than that, the water will flow into the Yom-Nan diversion canal (max. capacity 250CMs) via Khlong Hok Bat regulator that will flow into the Old Yom River (max. capacity 150CMs) via Old Yom regulator and into the Khlong Nam Lai (max. capacity 100CMs) via Khlong Nam Lai regulator. The minimum flow will go into the Nan River upstream of Naresuan Dam, however, the flow rate depends on the different water levels between the Yom and Nan rivers. If the water level in the Nan River is higher than that in the Yom River, the water cannot flow. Downstream of Ban Hat Sapanchan regulator, around 350CMs will flow into low land areas on the left and right banks of the Yom River via many small regulators on both banks to control discharge not more than 550CMs flowing to Mueang Sukhothai which the Yom River has the maximum capacity of only 565CMs at this point. The flood flows from the Yom River into low land areas on both banks will flow back into the Yom River in the area of Bang Rakam district, causing flooding in this area every year with the flooding duration around two-three months.

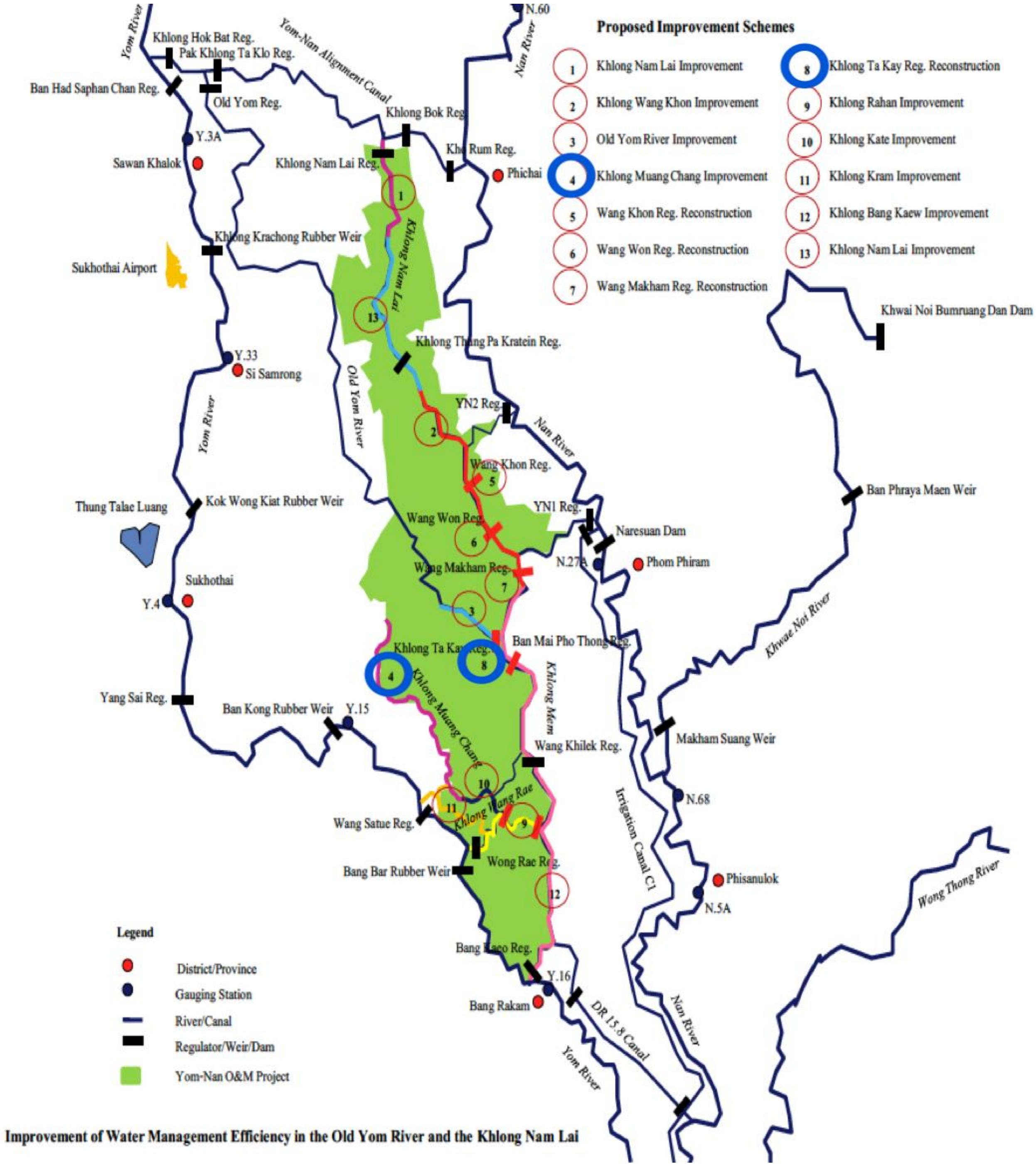


Figure 61: Schematic diagram of the maximum capacity or river/canal and the proposed improvement capacity

Source: Royal Irrigation Department (RID) data

Villages included in the proposed overall improvement of the Yom-Nan Irrigation Area:

Project section:	Province	District	Subdistrict	Villages
1. Improving Khlong Nam Lai and improving the left and	Uttaradit, Sukhothai	Phichai, Srinakorn	Thamafuang, Korrum, Klongmaplup, Nongbuo	Village 8 : Baan Log 17 Village 4 : Baan Paataew

right banks project				Village 9 : Baan Klongnamlai Village 7 : Baanbangna Village 8 : Baan klongmaplup Village 1 : Baanpaakratum
2. Improving Khlong Wang Khon and Improving the left and right banks	Phitsanulok,	Promphiram	Nongkham, Wangwoon, Sriphirom, Thaloktiem	Village 8 : Baanklongtan Village 4 : Baanwangsatoe Village 1 Baanwangwoon Village 2 Baanklang Village 8 Baanwangmaikhan Village 10 Baanwangmaikhan Village 10 Baanbungthammaroong Village 2 Baanthangam Village 3 Baansong Village 6 BaanPhrayabundan
3. Improving Old Yom river and improving the left bank	Phitsanulok, Sukhothai	Promphiram, Khongkairas	Nongkham, Wangwoon, Promphiram, Kokrat	Village 9 Baanwangmakham Village 7 Baanwangnamboe Village 5 Baan klongthakha Village 11 Baanwangnamyen Village 4 baankokrat Village 6 Baankangluang Village 10 Baanthaplai
4. Improving Khlong Muang Chang and building	Sukhothai	Khongkairas	Kainok, Dongdoei	Village 8 baanwangpaisoong Village 4 Baandongyang Village 7 Baandonsamrong
5. Improving Wangkhon water and drainage system	Phitsanulok	Promphiram	Sriphirom, Wangwoon,	Village 10 Baanbungthammaroong Village 10 Baanbunghai Village 9 BaannongThan
6. Improving Wangwoon water draining system	Phitsanulok	Promphiram	Wangwoon	Village 1 Baanwangwoon Village 2 Baanklang Village 3 Baannonghang Village 4 Baanwangsatoe Village 5 Baandongmakrud Village 6 Baanklong Thamnaeb Village 8 Baanwangmaikhen Village 8 Baanwangmaikhen
7. Improving Wangmakham water draining system	Phitsanulok	Promphiram	Wangwoon, Promphiram	Village 9 Baanklong wangmakham Village Baanklongtan Village 11 Baanwangnamyen
8. Improving Klongthakae water draining system	Phitsanulok, Sukhothai	Promphiram, Khongkairas	Wangwoon, Promphiram, Kokrat	Village 7 Baanwangboe Village 9 Baanklong wangmakham Village 5 Baanklongthakha Village 11 Baanwangnamyen Village 6 Baankangluang
9. Improving Klongrahan and building	Phitsanulok	Bangrakham	Thanangngam, Choomsaeng songklam, Baankrang	Village 5 Baanhuoachan Village 3 Baanwangrae Village 10 Baanmaerahan
10. Improving Klong Ked and building	Phitsanulok	Bangrakham	Choomsaeng songklam, Baankrang	Village 3 Baanwangrae Village.9 BaanThabagngam Village 10 Baanmaerahan

11. Improving Klongklum and building	Phitsanulok	Bangrakham	Choomsaeng songklam	Village 3 Baanwangrae Village.9 BaanThabagngam
12. Improving Klong bangkaew water and drainage system	Phitsanulok	Bangrakham, Muang, Promphiram	Thanangngam, Baankrang, Thachang	Village 3 Baanbangkaew Village 5 Baanhuochan Village 8 Baanyanyai Village 10 Baanmaerahan Village 10 Baanwangkhileg Village 12 Baanmaisuksumran
13. Improving Klong Namlai water drainage system	Sukhothai, Uttaradit, Phitsanulok	Srinakhon, Phichai, Promphiram	Klongmaplup, Korrum, Thamafuang, Phrayaman, Thaloktiem, Sriphirom, Wangwoon, Nong Kham	Village 8 Baanklongmapulp Village 9 Baanklongnamlai Village 8 Baanlog 17 Village 6 Baanphrayapandan Village 10 Baannongfugkhoon Village 2 Baanthangam Village 3 Baandansong Village 10 Baanwangmaikhen Village 8 Baanklongtan

According to local administrations and community leaders, the communities and members have realised the nature of the annual flood over their lowland locations and have adapted livelihoods accordingly over a long period of time (see 2.18.2. – Coping with and adapting to change in climate). During flood periods, diversifying livelihoods to incorporate fish products during the periods where flood submerged their farmlands for example. Their main concern was the water shortage in the dry season, and the additional cost for pumping water from groundwater sources.

In the consultations and focus group discussions undertaken with farmers in the Yom-Nan River Basin Area for this study, farmers indicated their understanding of climate change through experience to date. Farmers reported that they saw climate change via the rainy season being shorter, and reported that the amount of rainfall is diminishing based on the reports/information they were receiving on the levels of water remaining in the main dams at the end of rainy season. Farmers' understanding was also that flood would take place roughly every 4 – 5 years, as it had done so in 2006, 2011 and 2016. For drought they had concern that the temperature was getting higher and higher, and that the average temperature in April is above 40 degrees celsius..

2.2 Existing levels of climate data, projections and downscaling

General Circulation Models (GCMs) that range from complex to simple climate models are used as direct output in analysing future climate change. These models range from simple to comprehensive climate models, however, the direct use of output from climate models in the analysis of future climate change and other studies including impacts, adaptation and vulnerability in regional or local scale are not practical due to their coarse grid resolution. Downscaling techniques have to be applied to achieve finer grid resolution –the two main approaches to which, are the statistical and dynamical techniques. These techniques have been applied for the projection on the regional climate studies all over the world including Thailand. Two of the most recent studies in Thailand are the downscaling of a new set of scenarios, the Representative Concentration Pathways (RCPs), under the framework of the Coupled Model Intercomparison Project Phase 5 (CMIP5) of the World Climate Research Programme by using both statistical and dynamical approaches. A study under the Thailand Research Fund titled: *Downscaling of GCMs for the impacts study of climate change on rice production in Thailand*, for example, used downscaling of RCP 4.5, 6.0 and 8.5 of GCM-GFDL-ESM2M, GCM-HadGEM2-ES and GCM-MPI-ESM-LR by using Artificial Neural Network which is a method of the statistical approach. Another downscaling study in Thailand, used the dynamical approach that applied the Regional Climate Model, RegCM4, for the downscaling activity in the project *Capacity Building of Research Potential in Regional Climate Model and Climate Change of Thailand*, also funded by the Thailand Research fund. Downscaling activities are also undertaken under the Southeast Asia Regional Climate Downscaling (SEACLID)/CORDEX Southeast Asia Project funded by Asia Pacific Network (APN). The Ramkhamhaeng University Center of Regional Climate Change and Renewable Energy conducted both projects. The data set of both projects will be available online very soon. Moreover, the climate data set from SEACLID/CORDEX SEA project will be disseminated via as a part of Earth System Grid Federation in the middle of year 2017[110], [111]. More recently, as part of this study – downscaling of climate projection data has been undertaken for the Yom and Nan River Basins to inform this project.

2.2.1 Weather, climate and hydrological forecasts and early warning

An existing hydro-meteorological network is in place. There are many agencies/institutes to carry out monitoring and/or forecasting of meteorology, flooding and drought, including early warning. The active ones are:

- Thai Meteorological Department (TMD)
- Hydro and Agro-Informatics Institute (HAII)
- Royal Irrigation Department (RID)
- Department of Water Resources (DWR)
- Geo-Informatics and Space Technology Development Agency (Public Organization); GISTDA
- Mekong River Commission (MRC)
- National Disaster Warning Center (NDWC)
- Bangkok Metropolitan Administration (BMA)

2.2.1.1 Weather stations and monitoring

[110] Jerasorn Santisirisomboon, Somkiat Apipatanavis, Chitnucha Buddaboon, Jarthat Santisirisomboon, Waranyu Wongseree, Yod Sukamongkol, Benjamas Rossopa, Kwanruthai Srisangchai, Prayat Lewan, Monchai Chobtham, Songsak Chuaibumrung. 2016. Downscaling of GCMs for the impacts study of climate change on rice production in Thailand (in Thai). A research project funded by the Thailand Research Fund (TRF).

[111] Jerasorn Santisirisomboon, Kansri Boonpragob, Jaruthat Santisirisomboon, Waranyu Wongseree, Pattama Singhrak, Kamphol Promjiraprawat, Prayat Lewan, Yod Sukamongkol, Pipatra Shin, Monchai Chobtham, Songsak Chuaibumrung, Kwanruthai Srisangchai, 2016. Capacity Building of Research Potential in Regional Climate Model and Climate Change of Thailand (draft final report in Thai) A research project funded by the Thailand Research Fund (TRF).

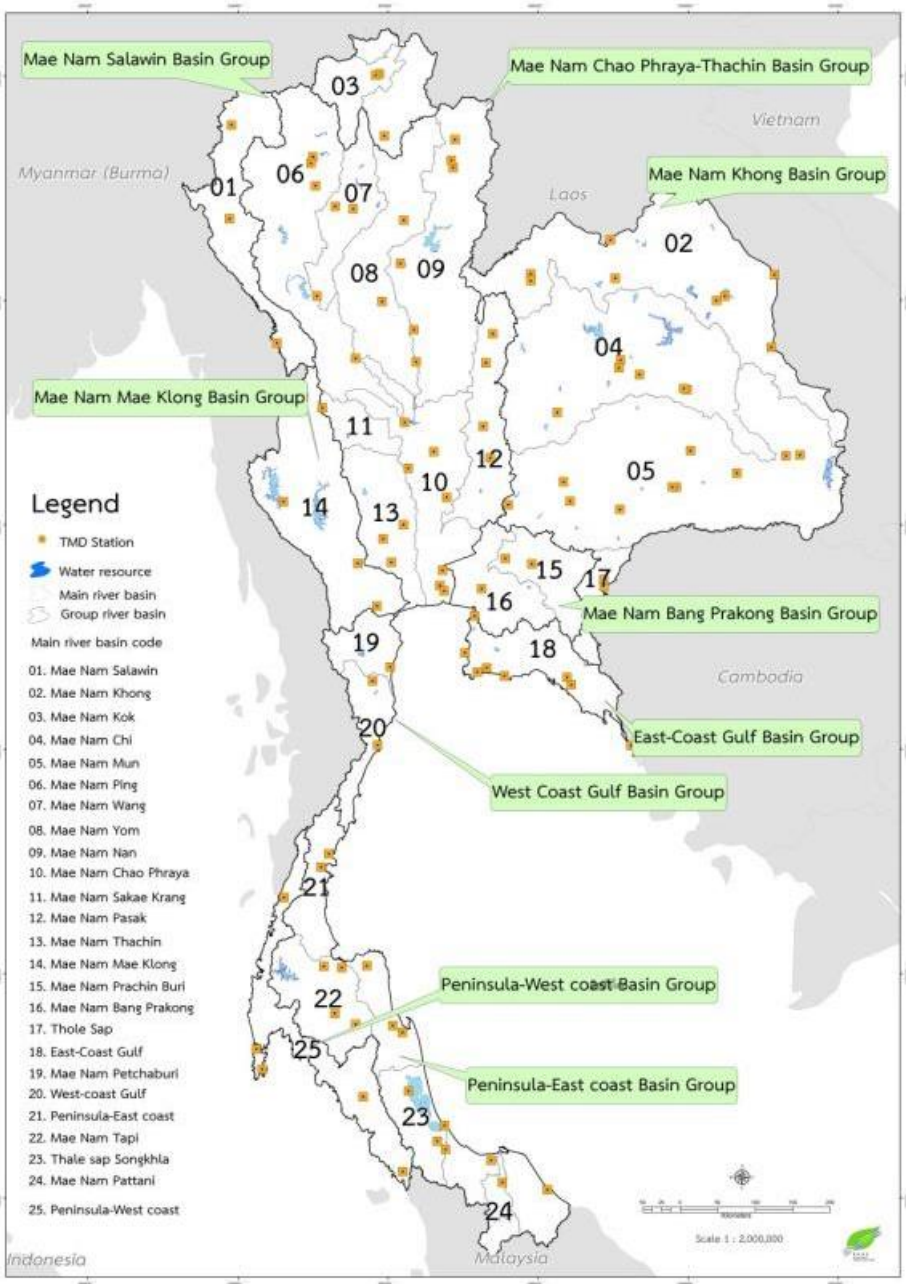


Figure 62: Distribution of weather stations in Thailand

Source: Chaowiwat, W. Boonya-aroonnet, S. & Weesakul, S. 2016, Impact of Climate Change Assessment on Agriculture Water Demand in Thailand

2.2.1.2 NARK 4.0 rainfall forecasting and irrigation management tool

While there is a hydro-meteorological network in place, only recently the data from the network started to get systematically analyzed, tailored for use, and disseminated for agricultural and water management purposes. A key tool for this usage is the NARK 4.0 tool, which was developed alongside a Smart Water Operation Center (SWOC) under the RID for water management in rainy and dry season. It can calculate the amount of rainfall and inflow of water into reservoirs on the rainy season and design water release schedules for the next 12 months. Its mathematical models can be used to forecast inflows into different water sources, increase farming areas along the Chao Phraya River basin, work out water management plans for individual irrigation zones and estimate agricultural yield and revenue. NARK 4.0 is based on a collaborative effort between 5 organizations, which are the Royal Irrigation Department (RID), the Agricultural Research Development Agency (ARDA), the National Research Council of Thailand (NRCT), the King Mongkut's University of Technology North Bangkok (KMUTNB), and the Thailand Research Organizations Network (TRON).

The main purpose of NARK program is to forecast water supply and simulate water flow in seasonal for decision planning in rainy and dry season. It starts from the rainfall forecasting by applying statistical downscaling technique from IRI climate model. After rainfall is forecasted, the inflow is predicted by using NAM model and the reservoir release planning is optimized by genetic algorithm techniques. The reservoir release is recommended for agricultural seasonal planning including other purposes of water use. Subsequently, the river flow is simulated along the river to main canal in irrigated area to forecast cultivated area and estimate yield. The study area is in Chao Phraya River Basin covering 24 provinces and consisting of 4 dams in upper Chao Phraya and 27 irrigation projects in lower Chao Phraya.

NARK Program is developed for Royal Irrigation Department, RID since 2017 and nowadays it is installed in SWOC, RID who are the main operator in seasonal water forecasting and planning in Thailand. Furthermore, the application in IOS namely "WaterSMART" also has been developed to enable RID staffs in assessing water forecasted information from NARK through mobile application. There are 7 parts composed in application such as rainfall foresting, inflow forecasting, reservoir operation, crop forecasting, rainfall forecasting map, river flow simulation for decision support and water allocation in irrigated area.

3. Chapter 3: Supportive Policy and Institutional Frameworks related to climate-resilient development

At the overarching international and national level, a range of frameworks, policies and strategies inform how Thailand governs and plans for the future. A number of these crucial policies and strategies govern Thailand's future and have particular relevance in underpinning this project, as well as driving the imperative for its implementation. These include the following:

3.1 International Environmental Agreements

Thailand is party to a number of United Nations and International Agreements, including on Biodiversity, Climate Change, Climate Change - Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Marine Life Conservation, Ozone Layer Protection, Tropical Timber 83, Tropical Timber 94, Wetlands, as well as being signed but not ratified party to the Law of the Sea. These international agreements frame both governance and some of the principles informing the project and its design, namely in terms of ensuring how project activities relate to environmental impacts – flora, fauna, terrestrial and marine (e.g. through water runoff), pollutants (e.g. agricultural), land use and livelihoods, agriculture and food security, as well as climate change mitigation and adaptation. For example:

- The Convention on Biological Diversity relates to ensuring 'the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from commercial and other utilisation of genetic resources. The agreement covers all ecosystems, species, and genetic resources;

- The Stockholm Convention on Persistent Organic Pollutants aims to eliminate or restrict the production and use of persistent organic pollutants (POPs);

- The International Tropical Timber Agreement (ITTA, 1983) is an agreement to provide an effective framework for cooperation between tropical timber producers and consumers and to encourage the development of national policies aimed at sustainable utilization and conservation of tropical forests and their genetic resources;

- International Tropical Timber Agreement, 1994 (ITTA, 1994 or ITTA2) was drafted to ensure that by the year 2000 exports of tropical timber originated from sustainably managed sources and to establish a fund to assist tropical timber producers in obtaining the resources necessary to reach this objective;

- The United Nations Convention on the Law of the Sea (UNCLOS), also called the Law of the Sea Convention or the Law of the Sea treaty, is the international agreement that resulted from the third United Nations Conference on the Law of the Sea (UNCLOS III). The Law of the Sea Convention defines the rights and responsibilities of nations with respect to their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources;

- The Convention on Wetlands (the Ramsar Convention) provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The convention covers all aspects of wetland conservation and wise use, recognizing wetlands as ecosystems that are extremely important for biodiversity conservation in general and for the well-being of human communities;

- Thailand has signed but not ratified the Convention on the Conservation of Migratory Species of Wild Animals, or the Bonn Convention, aims to conserve terrestrial, marine and avian migratory species throughout their range;

- The Vienna Convention for the Protection of the Ozone Layer;

- CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora, also known as the Washington Convention) is a multilateral treaty to protect endangered plants and animals. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species in the wild, and it accords varying degrees of protection to more than 35,000 species of animals and plants;

- The United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (UNCCD) is a Convention to combat desertification and mitigate the effects of drought through national action programs that incorporate long-term strategies supported by international cooperation and partnership arrangements;

- Thailand has signed but not ratified the International Treaty on Plant Genetic Resources for Food and Agriculture. The objectives of the Treaty are the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security;

- The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes to ensure that hazardous wastes are managed in an environmentally sound manner in the country of impor;

- The United Nations Convention on the Law of the Sea, and;

- The United Nations Framework Convention on Climate Change (UNFCCC) to reduce atmospheric concentrations of greenhouse gases with the goal of "preventing dangerous anthropogenic interference with Earth's climate system.

3.2 National Development Policies and Strategies

A suite of national policies and strategies underpin this proposal and its positioning across government strategy and management mechanisms. Climate change adaptation is mentioned in several key policy documents. The Strategic Plan on Climate Change 2008-2012 includes a strategy to ‘build adaptive capacity to cope with climate change and to reduce vulnerability of various sectors’. Adaption is also an important part of the Climate Change Master Plan 2014-2050 and the 11th National Economic and Social Development Plan 2017-2021. The latter includes plans to support scientific and technological research and innovation in adaptation and to establish mechanisms to evaluate and alleviate climate change impacts. The main national strategies upon which this proposal is based, are outlined below.

3.2.1 Sufficiency Economy

An overarching principle of sufficiency economy guides Thailand in a policy direction of sustainable development. Improved water management is needed to better respond to climate change – to mitigate flooding, to prepare for times of drought, and to ensure more efficient use of water resources. Efficiency is a priority in Thailand’s adaptation strategy, for example, which is guided by the philosophy of Sufficiency Economy – moderation, reasonableness, and the need of self-immunity for sufficient protection from impact arising from internal and external changes.[112] Sufficiency economy philosophy, serving principles of sustainability, is based on a concept of living in moderation, self-dependence/sufficiency without the overexploitation of resources, including natural resources. Sufficiency Economy, imparted by the late His Majesty King Bhumibol Adulyadej, stresses the middle path as an overriding principle for appropriate conduct by Thai people at all levels, from family to community to country. 'Sufficiency' means moderation, reasonableness, and the need of self-immunity and sufficiency in protection from impacts arising from changes both externally and internally. The sufficiency economy philosophy, has been put forth more recently in terms of sustainable development processes. As a principle in which sustainability stands at the forefront, by advancing economic development outside of the short term, shareholder value-centred idea of economic development; instead incorporating Buddhist philosophy and sustainability principles into approach for economic development. Building on from the Sufficiency Economy approach – is the 'New Theory Farming', which compounds integrated farming systems, and the Buddhist approach of self-restraint combined with sustainable agriculture.[113]

3.2.2 National Economic and Social Development Plan

The 12th National Economic and Social Development Plan (2017 – 2021) aims to promote both ecologically sound economic and social growth. This is centred on water management system reformation to ensure user demand and supply balance with the provision of access to water. Similarly, it centres on developing water resource information, establishing water management organisation at the local level (e.g. River Basin Committee and Water Users Association), as well as the enforcement of environmental law (Environment Act) and inter-sectoral collaboration in integrating work plans and budgets.

3.2.2.1 Strengthening Thailand's capacity to link climate change with public finance

Complementing the National Economic and Social Development plan, is the 'Strengthening Thailand's capacity to link climate change with public finance' programme. This programme undertaken by UNDP Thailand with the Ministry of Agriculture and Cooperatives (MoAC), sets about translating the national policy into real and responsive actions on the ground that mainstream climate change into cross-sectoral planning and budgeting processes. Currently using the agricultural sector as a platform to branch more widely into cross-sectoral mainstreaming, the project supports capacity building through a series of workshops and coaching sessions, designed to strengthen climate change response and monitoring – through the integration of climate change analysis into budget proposals, monitoring and evaluation mechanisms. This programme provides a supportive national setting and need for Component 1 of the *Enhancing climate resilience in Thailand through effective water management and sustainable agriculture* project, in developing climate information to be used inter-Ministerially. The two projects link in the national setting by bringing together capacity building and understanding and use of relevant climate information across government Ministries – to support a climate change analysis framework integration approach into all Ministerial planning.

3.2.3 National Climate Change Policy

Thailand's National Climate Change Policy was approved in Cabinet as well as the Strategic Plan on Climate Change

112 Thailand' s Intended Nationally Determined Contribution (INDC), 2015
113 Amekawa. Y., "Rethinking sustainable agriculture in Thailand: a governance perspective" *Journal of Sustainable Agriculture*, 34(4), 389-416. 2010.

(January 2008). It incorporates capacity building, research and development, awareness and public participation, and international cooperation in mitigation and adaptation. The Prime Minister, the Ministry of Natural Resources and Environment (MoNRE) and the Ministry of Financial Affairs (MoFA) chair Thailand's National Board of Climate Change Policy. MoNRE is the Permanent Secretary, with policy formation and the National Focal Point falling under the Office of Natural Resources and Environmental Policy and Planning (ONEP), and the Climate Change Management Coordination Division (CCMC). Under the National Board of Climate Change Policy sits the (2015) Sub-National Board on Policy Integration (Chaired by MoNRE), the (2015) Sub-National Board on Technical Support (Chaired by ONEP), the (2015) Sub-National Board on Negotiation (Chaired by MoNRE), and the (2010) Climate Change Coordinators (CCC) comprised of 30 Agencies: 19 Ministries, and 11 Agencies under the Prime Ministers' Office).

3.2.4 National Strategies for Climate Change

The National Strategies for Climate Change (2008-2012) developed under the Office of Natural Resources and Environmental Policy and Planning (ONEP) provided a first national climate change plan which focused on: 1) Building capacity to adapt and reduce Thailand's vulnerability to climate change impacts; 2) Promoting greenhouse gas mitigation activities based on sustainable development; 3) Supporting R&D to better understand climate change and its impacts as well as adaptation and mitigation options; 4) Raising awareness and promoting public participation; 5) Building the capacity of relevant personnel and organisations to establish a framework for knowledge and technology coordination and integration, and; 6) Supporting international cooperation to accomplish the common goal of climate change mitigation and sustainable development.

These were then developed from the National Strategy for Climate Change into the National Master Plan on Climate Change 2010-2019 to enable implementation. This 10 year master plan focused on three strategies: Strategy 1 – creating adaptability to respond and reduce the impacts of climate change; Strategy 2 – support for greenhouse gas reduction and an increase in carbon sinks under sustainable development plans, and; Strategy 3 – Integrating knowledge, databases, and tools on climate change management.

3.2.5 Climate Change Master Plan 2015 -2050

The Climate Change Master Plan (2015 – 2050) sets out a long-term framework for the management of climate change in Thailand. The Climate Change Master Plan 2015-2050 Vision, is that by 2050 "Thailand becomes a climate change resilient and low-carbon development society following sustainable development pathways". Charged with the developing a National long-term and continuing 'Framework on Addressing Climate Change Situation and Consequences', a National Policy Framework leading to climate change mechanisms and tools, as well as providing guideline and instruction for Agencies in Developing Implementation Plans and financial allocation, and related operations under United Nations Framework Convention on Climate Change (UNFCCC) Obligations. Cabinet approved in July 2015, the Plan sets out adaptation as number one out of three principal areas. The Plan focuses on adaptation across the water management, flood and drought sector; agriculture and food security; human health; tourism; natural resources sector, and; human settlement and security. The *Enhancing climate resilience in Thailand through effective water management and sustainable agriculture* project targets two of these sectors – 1) water management, flood and drought, and 2) agriculture and food security. The pursuit of ecosystem-based adaptation approaches in the water sector has also been included in the Climate Change Master Plan.

3.2.6 National Adaptation Plan (NAP)

Development of Thailand's Climate Change National Adaptation Plan (NAP) commenced in 2015 and was completed in the end of 2018. The NAP currently contains a focus on enhanced water management (including flood management and coping with droughts) and agricultural resilience against climate change, of which the *Enhancing climate resilience in Thailand through effective water management and sustainable and sustainable agriculture* project is complementary to and will strengthen and build upon – particularly through the capacity building and enhanced provision of climate information (under component 1) elements. The NAP aims to make Thailand resilient to the effects of climate change and integrate methods for adaptation in order to increase opportunities and the capacity to develop the nation in a stable and sustainable manner. RID and UNDP will closely monitor its development to ensure that the project remains closely in line with the objectives of the plan, and in contributing to the greater NAP implementation.

3.2.7 The Intended Nationally Determined Contribution (INDC) of Thailand

The Intended Nationally Determined Contribution (INDC) for Thailand includes a shortlisting of adaptation key efforts. These include the prioritisation of efforts which:

- Promote and strengthen Integrated Water Resources Management (IWRM) practices into achieving water security, and effective water resource management to mitigate flood and drought;
- Safeguard food security through the guidance of the Sufficiency Economy Philosophy (e.g. agriculture and land management that promotes appropriate resource allocation and economic diversification at a household level and sustainable management of community forests in order to promote community level food security);
- Promote both sustainable agriculture and Good Agricultural Practice (GAP);
- Increase national forest cover to 40 percent through local participation, including in headwater and mangrove forests to enhance adaptive measures capacities of related ecosystems;
- Safeguard biodiversity and restore ecological integrity in protected areas, as well as in important landscapes – from the adverse impacts of climate change, and with an emphasis on vulnerable ecosystems and red list species;
- Strengthen disaster risk reduction (DRR) and reduce the population's vulnerability to climate risk and extreme weather events through enhanced awareness, coordination and local community adaptive capacity, especially within disaster prone areas;
- Strengthen climate-modeling capacity while promoting collaboration amongst relevant agency;
- Establish an effective early warning system (EWS) and enhance the adaptive capacity of national agencies through multi-hazard risk assessment, systematic observations, integrative research, and the development of database, models, and technology, and;
- Build regional climate resilience by serving as a knowledge hub for fostering regional cooperation and adaptation exchange.[114]

3.2.8 National Communication and UNFCCC Reporting

[114] Intended Nationally Determined Contributions (INDC) http://www4.unfccc.int/ndcregistry/PublishedDocuments/Thailand%20First/Thailand_INDC.pdf

Thailand has completed both a First and Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC). The National Communications are enabling activities undertaken as activities of the parties under the UNFCCC. Thailand's reports have served to provide inventory status, with some interesting findings such as that the forest sector is the key source for emissions sink, the energy sector remains the highest source of emissions, while the agriculture sector has been relatively low and stable in emissions contributions. The Communications found that Thailand is increasing vulnerability to climate change and climate variability and that extreme events remain the biggest challenges of Thailand in addressing climate change. However, the Communications also highlighted that there remains a lack in the technical and technological development to tackling this, which the country will continue to develop.

3.2.9 Thai Designated National Authority for the Clean Development Mechanisms (DNA-CDM)

Established in 2007 the Thai Designated National Authority for the Clean Development Mechanisms (DNA-CDM) operates under the Thailand Greenhouse Gas Management Organisation (TGO) to promote, screen, approve, and monitor CDM projects as well as to oversee cooperation between government agencies on CDM. The TGO comprises of representatives from the Ministry of Finance, the Ministry of Energy, the Ministry of Industry, the Ministry of Science and Technology, the Ministry of Agriculture and Cooperation, the Ministry of Transport, the Ministry of Public Health, the Ministry of Foreign Affairs, and the Ministry of Information Communication and Technology.

3.2.10 Thailand's technology needs assessments for climate change

Thailand undertook a technology needs assessment (TNA) to map and determine the country's new equipment, techniques, services, capacities and skills needs, for both climate change adaptation and mitigation. The identification of the technology needs assessment (TNA) provides the basis also for developing an eventual national Technology Action Plan (TAP) for the prioritization of technologies and an enabling framework for the dispersal of the technologies. Undertaken between the United Nations Environment Programme (UNEP) and the Global Environment Facility (GEF), the TNA and the TAP for Thailand is part of the first round of 15 countries across Africa, Asia, Latin America and Europe to be supported, starting in 2010. Overall, Thailand's TNA and TAP 'identify, assess, and prioritise technological needs for GHG mitigation and adaptation'; enable the access of 'information on technology transfers and increase public awareness on climate change issues'; as well as 'evaluate the various social issues relevant to the proposed policy, conduct an analysis on the pros and cons of different control strategy alternatives, and provide estimates of the costs and impacts of legislative mandates'.[115] Of particular relevance to this project proposal are the needs assessed in agricultural and water sector technologies, Climate forecasting technology, national data centre for climate change information, national data transfer and management process, and WRF modeling (weather research and forecasting).

Agricultural and water sector technologies:

Identified in the TNA for the agricultural sector, and significantly relevant to this project – are that field crops and aquaculture are the two subsectors most vulnerable to climate change and in immediate need of technology

[115] NSTIPO. 2012, Thailand technology needs assessments report for climate change, National Science Technology and Innovation Policy Office, Ministry of Science and Technology, Bangkok, Thailand and UNEP Risø Centre on Energy, Climate and Sustainable Development (URC), Risø DTU National Laboratory for Sustainable Energy, Denmark.

development and transfer. Addressed under Outputs 1 and 3 of this project, the adaptation technology in the TNA for 5 areas that was proposed is: climate forecast and early warning systems; crop improvement and precision farming practices; post harvest technology' and animal nutrition and feed technology. The TNA stakeholder consultations determined that climate forecasting and early warning systems would be most crucial in reducing the risk of damage from extreme climate events and pest/disease outbreaks, as well as serve to assist in crop selection according to planting times and crop cycles.

Climate resilient crop improvement were also important for reducing the risk of yield losses and improving resource use, while precision farming technologies were determined as enabling farmers to make informed choices concerning inputs and operations that maintained maximum output and minimal environmental cost.

Under the TNA, water security and agriculture security are the key goals for water resource management, falling under six technology transfer and dispersal areas: '1) increasing security in terms of capital water supply, 2) building flexibility for management in all types of supply and demand scenarios, 3) minimizing the damage from disasters, 4) maximizing water usage efficiency, 5) including all sectors in the management, and 6) building knowledge/know-how and data for management'.[116] Specifically – in terms of the technologies to be applied, listed under the needs assessment are: environmental observation; weather and hydrological modeling; flood and drought risk management; operation of water infrastructures; community water resource management (CWRM); integrated urban water resource management (IUWRM), and; Early Warning Systems (EWS). The *Enhancing climate resilience in Thailand through effective water management and sustainable agriculture* applies 6 out of these 7 – namely, environmental weather and hydrological observation and modelling, flood and drought risk management, the operation of water infrastructures informed by climate forecasting, early warning systems, and community water resource management. It is also noted in the TNA report that the implementation of these technologies will increase the capacity and efficiency of water resource and disaster management in Thailand – and assist as tools for driving national policies and strategies.

Climate forecasting technology:

The TNA determined with high priority that a national data centre should be established alongside a national data transfer/management process, and a WRF (ARW) model (weather research and forecasting model-advanced research). Again, these priority needs for technologies, are addressed under the Enhancing climate resilience in Thailand through effective water management and sustainable agriculture project.

National data centre for climate change information:

Thailand's 'Technology needs assessments report for climate change adaptation' states:

A data centre contains the essential hardware, a large collection of data from various relevant and creditable sources. In addition, it serves as a data distributor to users and organisations that can benefit from using the network. Without a reliable data centre, it is difficult to obtain a meaningful modeling result. Because modeling climate change impacts can be useful for the adaptation of various sectors, ranging from the climate sector to the health and economic sectors, an integrated data centre is highly desirable. Such a data centre would make it easy for users to access all of the data required for cross-sectorial modeling efforts. Thailand has a few data centres or data sharing structures. In the field of water management, for example, there is a hydro-meteorological network

[116] NSTIPO. 2012, *Thailand technology needs assessments report for climate change*, National Science Technology and Innovation Policy Office, Ministry of Science and Technology, Bangkok, Thailand and UNEP Risø Centre on Energy, Climate and Sustainable Development (URC), Risø DTU National Laboratory for Sustainable Energy, Denmark.

in place and, recently, the data from the network started to get systematically analyzed, tailored for use, and disseminated for agricultural and water management purposes. A key tool for this usage is the NARK 4.0, which was developed alongside a Smart Water Operation Center (SWOC) under the RID for water management in rainy and dry season. It can calculate the amount of rainfall and inflow of water into reservoirs on the rainy season and design water release schedules for the next 12 months with a relatively high level of accuracy. Its mathematical models can be used to forecast inflows into different water sources, increase farming areas along the Chao Phraya River basin, work out water management plans for individual irrigation zones and estimate agricultural yield and revenue. The program is set up be used in 25 provinces all over the country; covering 96.7 million Rai and the two river basins Chao Phraya river and Moon river (Northeast). NARK 4.0 is based on a collaborative effort between 5 organisations, which are the Royal Irrigation Department (RID), the Agricultural Research Development Agency (ARDA), the National Research Council of Thailand (NRCT), the King Mongkut's University of Technology North Bangkok (KMUTNB), and the Thailand Research Organizations Network (TRON). A MoU was signed by all partners, apart from TRON, which plays a minor role compared to the other organisations. Considering the technology needs assessment of Thailand (under the UNFCCC), the initiation of the NARK 4.0 resembles a milestone in enhancing the institutional coordination between the agricultural and irrigation departments, as well as to develop the public forecasting and modelling capacity. However, continuous support is needed to refine and upgrade the NARK 4.0 tool in order to provide forecasts for shorter time frames (e.g. monthly or weekly) and tailor and distribute risk information to the needs of subnational decision makers and farmers/ end-users. This can, ultimately, enable farmers to enhance their resilience against climate change induced droughts and floods through better water management planning.

National data transfer and management process:

Climate related data in Thailand, currently sits across several governmental agencies. Daily monitoring and observation recordings of weather, water and air quality data sit across the Department of Meteorology, the Royal Irrigation Department (RID), and the Pollution Control Department (PCD), respectively. These datasets provide monitoring, however, in terms of climate change forecasting – Thailand is yet to develop an official data collection and transfer process, and database management system that interacts with data across the region. A number of Thai research institutes have collected data for climate forecasting and modeling, as detailed at 3.3.6 and 3.3.7 sections. However, the precision levels of forecasting can be enhanced.[117] This need identified under the TNA, is addressed through the NARK 4.0 upgrade under Output 1 – Enhance climate and risk informed planning in the water and agricultural sectors through improved climate information and cross sectoral coordination

Weather Research and Forecast (WRF) modeling:

Under the TNA the WRF (ARW) model (weather research and forecasting model-advanced research) was ranked in terms of being the 'highest' candidate in integrated model options applicable to Thailand. Particularly for its use in addressing the technological needs for forecasting in the agricultural and water resource management sectors. [118]

3.2.11 Strengthening Thailand's capacity to link climate policy and public finance

[117] NSTIPO. 2012, *Thailand technology needs assessments report for climate change*, National Science Technology and Innovation Policy Office, Ministry of Science and Technology, Bangkok, Thailand and UNEP Risø Centre on Energy, Climate and Sustainable Development (URC), Risø DTU National Laboratory for Sustainable Energy, Denmark.

[118] NSTIPO. 2012, *Thailand technology needs assessments report for climate change*, National Science Technology and Innovation Policy Office, Ministry of Science and Technology, Bangkok, Thailand and UNEP Risø Centre on Energy, Climate and Sustainable Development (URC), Risø DTU National Laboratory for Sustainable Energy, Denmark.

Under the Office of Agricultural Economics (OAE) has called on governmental support to acquire sufficient climate change adaptation technology (ONEP, UNDP, 2010). The Project was launched in 2013 by the United Nations Development Programmes (UNDP) Thailand and the Office of Natural Resources and Environmental Policy and Planning (ONEP) with the aim to support Thailand in strengthening its institutional capacity to link a climate change policy with its budgetary allocations, and to report and measure over time the effectiveness of those policies and expenditures. The project strategically focuses on the agriculture and energy sectors as a stepping-stone for broader interventions at the national level.

3.2.12 National Climate Change Adaptation programming – projects

The Ministry of Agriculture and Cooperatives produced a Strategic Plan on Climate Change for the Agriculture Sector for 2012-2016. Within the sector's current 53 programmes, 27 are for adaptation. A centerpiece of the Integrating Agriculture in National Adaptation Plans Programme (NAP-Ag) in Thailand is its support to develop a new five-year Strategy on Climate Change in Agriculture (2017-2021) which is spearheaded by the Ministry of Agriculture and Cooperatives (MOAC) and its Office of Agriculture Economics (OAE).

A Master Plan on Sustainable Water Resource Management is also under preparation. While areas in development also include local research and studies, accessibility to and contribution of databases, indigenous knowledge database, knowledge and awareness gaps, and socio-economic co-benefits and linkages.

Current local-international cooperation on national climate change adaptation programming includes GIZ-BMUB: CCMP Implementation and Risk-NAP Support; UNDP: MADRiD Mainstreaming Disaster Risk Reduction and Climate Change Adaptation; JICA: ADAP-T; and Ministerial Adaptation Plans: Health, Agriculture. Local area based programmes such as the Watershed-based Adaptation to Climate Change (WACC) initiative, undertake climate vulnerability and capacity assessments (VCA) for the river basin level. Similarly, the National Research Council of Thailand (NRCT) with the Office of Natural Resources and Environmental Policy and Planning (ONEP), the Royal Institute (RI), and ADAPT Asia-Pacific formulated a strategic plan that identified, supported, monitored and assessed a national strategy for climate change research in Thailand as a National Strategy for Climate Change Research.

3.2.13 The economics of climate change in Southeast Asia: A Regional review

The Economics of Climate Change in Southeast Asia was a 15-month long Asian Development Bank (ADB) technical assistance project, funded by the Government of the United Kingdom, that examined climate change issues in Southeast Asia, with focus on Thailand alongside Philippines, Indonesia, Singapore and Vietnam. Reviewing existing climate studies and climate change modeling, it was specifically focused on determining the economic costs and benefits of both unilateral and regional actions it developed a series of measures for incorporating adaptation and mitigation into national development planning processes.

3.2.14 Preparation of climate change scenarios for climate change impact assessment in Thailand

Numerous climate change impact assessments have been undertaken across most sectors for Thailand, at varying national through to local scales. For example, these include:

National climate trends: The Southeast Asia Regional Centre START CC's 'Preparation of climate change scenarios for climate change impact assessment of Thailand'[119], synthesized the climate change trends for Thailand to enable ease of use in understanding the climate scenario data for the country (during 2010). This study combined the high-resolution climate scenarios for long-term climate projections into a Climate Change Data Distribution System – which can be accessed by all technical users who need to use and extract future climate data of Thailand for any research purposes. The SEACLID/CORDEX Southeast Asia program downscales a number of CMIP5-GCMs for the Southeast Asia Region, generates and disseminates high resolution regional climate change scenarios freely via their data portal, and is aimed at overcoming knowledge gaps to regional climate change by increasingly the level of peer reviewed scientific and policy relevant research and publications available. Overall, it is aimed at strengthening research capacity and capability, in terms of numerical regional climate modeling and providing a platform for scientists within and outside the region for collaborative regional climate downscaling. Another[120], analysed 24 climate extreme indices over North Thailand using observed data for daily maximum and minimum temperatures and total daily rainfall for the 1960–2010 period, and HadCM3 Global Climate Model (GCM) and PRECIS Regional Climate Model simulated data for the 1960–2100 period and then applied statistical downscaling to GCM outputs. Other studies have provided assessments as models for development of climate change adaptation planning incorporation into community development plans.[121]

Coastal impacts: Coastal studies[122] have been undertaken looking into the impact of climate change to Thailand's coastal zones, particularly for coastal areas prone to flooding and drought – and the implications for coastal planning. Some of these studies conducted feasibility into and provided guidance on technical options – whilst predicting that Thailand has particularly severe coastal impacts due to an accelerated rise in human induced subsidence from groundwater extraction post 1960, resulting in heightened seas level rise beyond those predicted for other areas[123].

Hydrological impacts: Water availability has been assessed via a hydrological study across the nation[124], using the Hydrological Engineering Centre's Hydrologic Modeling System (HEC-HMS) for 9 different Hydrological Response Unit Areas in Thailand and using decadal climate data from the Regional Climate Model (RCM) Providing Regional Climates for Impact Studies (PRECIS) using emissions scenarios A2 and B2. Overall, this assessment found that a decline in water availability would be experienced during the dry season period, while a univocal increase of water availability is expected during the wet seasons, accompanied by increased frequency and intensity of floods. Other related studies found similar[125,126] Basin level trends have also been examined[127] while flood hazard assessments have been undertaken across most of Thailand's river basins at varying scales, by researchers, by international agencies and donors, regional groups, and by government. Overall, these studies e.g. of the Yang River Basin

[119] Chinvanno, S. 2010, 'Preparation of climate change scenarios for climate change impact assessment in Thailand, Southeast Asia Regional Centre START: http://startcc.iwlearn.org/project/copy4_of_hydro-agronomic-economic-model-for-mekong-river-basin-and-local-adaptation-in-thailand-model-development

[120] Masud, M., Soni, P., Shrestha, S. & Tripathi, N. 2016, 'Changes in climate extremes over North Thailand, 1960-2099', *Journal of Climatology,* Vol. 2016, Pp 1-18

[121] Chinvanno, S. and V. Kerdsuk 2013, Mainstreaming Climate Change into Community Development Strategies and Plans: A Case Study in Thailand, Adaptation Knowledge Platform, Partner Report Series No. 5. Stockholm Environment Institute

[122] Yi Wangt, Bin He, Srikantha Herath, Senaka Basnayake, and Wenrui Huang (*2014*) Climate Change Scenarios Analysis in Coastal Region of Thailand. Journal of Coastal Research: Special Issue 68 - Climate Change Impacts on Surface Water Systems: pp. 160 – 167

[123] Nicholls, R.J., Hanson, S.E., Lowe, J.A., Warrick, R.A., Lu, X., Long, A.J. and Carter, T.R., 2011: Constructing Sea-Level Scenarios for Impact and Adaptation Assessment of Coastal Area: A Guidance Document. Supporting Material, Intergovernmental Panel on Climate Change Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA), 47 pp.

[124] S. Shrestha. 2014, 'Chapter 2: Assessment of Water Availability under Climate Change Scenarios in Thailand', *Climate Change Impacts and Adaptation in Water Resources and Water Use Sectors: Case studies from Southeast Asia*, Springer Water

[125] Shrestha, A. 2014, 'Assessment of water availability under climate change scenarios in Thailand', *Journal of Earth Science Climate Change*, 5:184

[126] Snidvongs, A. 2006, 'Vulnerability to climate change related water resource changes and extreme hydrological events in southeast Asia: A Final report submitted to assessments of impacts and adaptations to climate change (AIACC), Project No. AS07', *Southeast Asia START Regional Centre (SEA START RC).*

[127] Sharma, D. 2007, Downscaling of general circulation model precipitation for assessment of impact on water resources at basin level trends in extreme rainfall and temperature indices for two river basins of Thailand', PhD dissertation, Asian Institute of Technology, Thailand.

system[128], and Ping River Basin,[129] and the Chao Phraya River[130] - predict increased frequency and magnitude of flood events to the river systems, under a mix of future climate scenario models.

Agricultural impacts: Within the agriculture sector, climate change impact assessments have been undertaken on particular crops – for example, on cassava production in Northern Thailand[131], with overall findings of significant impact to the cassava crop in terms of losses and yield reductions, with some benefits also indicated due to increased CO2 affects for plant growth. More widely, climate change impacts and adaptation options for rice production and water resources in Thailand. One study, for example, 'Climate change in Southeast Asia and Assessment on Impact, Vulnerability and Adaptation on Rice Production and Water Resource' [132] used dynamic downscaling of future climate using regional climate model, field experiment on rice production under different soil fertility, simulation of impact of climate change on future rice productivity and water resource based on data from climate model simulation. This study also looked at the vulnerability and adaptation of the farmer community directly. While other studies[133] have explored adaptation measures for rice through modelling and field-based studies in offsetting climate change impacts to rice crop production, and others have focused on changes in crop yields resulting from climate change impacts[134,135,136,137]. In addition, there are currently integrated vulnerability assessments and adaptation option prioritisations undertaken at pilot sites at subnational level as part of the FAO and UNDP led NAP-Ag programme in Thailand.

Impacts to infrastructure and services: Analysis of the impact of climate change to Thailand's future electricity supply has also been analysed.[138] Results for this assessment showed that the electricity demand is set to rise during peak electricity demand periods, as the mean annual temperature for Thailand rises.

3.2.15 Disaster Risk Reduction and Disaster Management Policy

Thailand has developed and implemented several policies and management strategies and protocols for disaster management; response, and; disaster risk reduction at a national level, and incorporated into local level plans. These include the following:

The Disaster Prevention and Mitigation Act of 2007

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[128] Shrestha, S & Lohpaisankrit, W. 2016, 'Flood hazard assessment under climate change scenarios in the Yang River Basin, Thailand', *International Journal of Sustainable Built Environment,* October 2016: Article in Press

[129] Sharma, D. & Babel, MS. 2013, 'Application of downscaled precipitation for hydrological climate change impact assessment in the upper Ping River Basin of Thailand', *Climate Dynamics,* 41(9-10), pp 2589-2602.

[130] Ligaray, M., Kim, H., Sthiannopkao, S., Lee, S., Cho, Hwa Cho, K., Kim, J.H. 2015, 'Assessment on hydrologic response by climate change in the Chao Phraya River Basin, Thailand', *Water*, 7, Pp 6892-6909

[131] Ratchanok, S. 2009, 'Climate change impacts on cassava production in Northeastern Thailand', Masters Dissertation, Pennsylvania State University

[132] Jintrawet, A. & Chinvanno, S. 2008. 'Climate change in Southeast Asia and Assessment on Impact, Vulnerability and Adaptation on Rice Production and Water Resource', *Asia-Pacific Network for Global Change Research.* Chaing Mai University and SEA START RC, Thailand.

[133] AIT, FAO & HAII. 2016, 'Climate change impact and adaptation in agriculture: Examples from climate-water-crop modeling and field studies', *Second World Irrigation Forum*, November 2015, Chiang Mai, Thailand, Asian Institute of Technology, Food and Agriculture Organisation, Hydro and Agro Informatics Institute.

[134] Felkner, J., Tazhibayeva, K. & Townsend, R. 2009, 'Impact of climate change on rice production in Thailand', *American Economic Review*, 99:2, Pp 205-210.

[135] Kawasaki, J. & Herath, S. 2011, 'Impact assessment of climate change on rice production in Khon Kaen Province, Thailand', *Journal of ISSAAS*, Vol. 17, No. 2. Pp 14-28

[136] Kuneepong, P. Kongton, S., Wangwacharakul, V. & Sumdin, S. Modelling economic crop yield and climate change in Thailand, Land Development Department, Ministry of Agriculture and Cooperatives, Department of Meteorology, Ministry of Communications, and Kasetsart University, Bangkok, Thailand.

[137] Kamthonkiat, D. & Kiyoshi, H. 2010, 'Understanding climate change impact on rainfed rice production in Northeast Thailand, ASPRS 2010, Annual Conference San Diego, California, April 26-30, 2010

[138] Parkpoom, S & Harrison, G., 2008, 'Analysing the impact of climate change on future electricity demand in Thailand', *IEEE Transactions on Power Systems*, Vol. 23., Iss. 3

The Disaster Prevention and Mitigation Act of 2007 provides for the organization and management needed in ensuring that mitigation of, preparedness for, response to and recovery from disasters in Thailand is legislated. It regulates the institutional framework for disaster prevention and management and the organization, functioning, powers and responsibilities of the National Disaster Prevention and Mitigation Committee and the Department of Disaster Prevention and Mitigation.

National Plan for Disaster Prevention and Mitigation 2015:

This National disaster Risk Management Plan (2015) has consolidated disaster risk management and disaster prevention and preparedness into a system of knowledge development and strengthened surveillance within the philosophy of the sufficiency economy approach. The National Plan outlines a series of strategies focused on disaster risk reduction through an integrated emergency management system, and a strengthened and enhanced disaster recovery. The Plan serves as a blueprint for all of Thailand's agencies in guiding and framing the approach and handling of national disaster management and related actions. The Plan is based on the international frameworks and agreements in place – *Sendai Framework for Disaster Risk Reduction 2015 – 2030*, the *United Nations Framework Convention on Climate Change* and *Kyoto Protocol*, the *ASEAN Agreement of Disaster Management and Emergency Response*, as well as the *2014 Bangkok Declaration on Disaster Risk Reduction in Asia and the Pacific*. It sets out key responses to flood, drought, landslides, earthquakes and tsunamis, storms, fires/forest fires and haze, transportation hazards, and contagious disease.

Plan for Disaster Response in Agricultural Sector:

Particular elements of the disaster legal framework and supportive systems are set specifically to target the agricultural sector and farmers, such as through the *Regulation of Emergency Relief Assistance for Disaster Affected Farmers-2009* and the *Animal Epidemic Act 1956*,) Regulation of Office o f the Prime Minister on Mutual Fund for Mitigation of Disaster Loss and Damage in Agricultural Sector 2005, and the *Operational Guidelines for Centre for Disaster Monitoring and Mitigation in Agriculture Sector at Provincial level*, for example.

3.2.16 National Water Management Strategy

The Thai government has worked out a 12-year water resource management strategy and has drafted a Water Act, which provides the framework for handling all dimensions of water resource management. Intended for implementation through integrated water resource management in three key areas. The first key area for implementation involves water source management, where emphasis is placed on rehabilitating deteriorated forests and watershed areas and preventing soil erosion. This will help maintain healthy ecosystems and the ecological system resilience. At the same time, the Thai government intends to also retain water in order to prevent water shortages in the long run and to bring about water security.

The second key area involves water consumption. A target has been set to provide over 7,000 villages throughout the country with access to clean water by 2017. This objective is intended to reduce unequal access to this basic right, and since agricultural and industrial sectors also sustain the country's rural economy, there is a need to also ensure water security for these sectors and provide sufficient water sources. The community has been encouraged to play a significant role in managing water consumption for the maximum benefit.

The third key area involves the treatment of wastewater and waste water management, with aims to reduce the supply (or source) generation of wastewater. In order to this initiatives are aimed at increasing the efficiency of the wastewater treatment systems, whilst being aimed at preventing salt water intrusion in coastal areas from infiltrating inland.

Apart from using an integrated water management approach in this strategy, the Thai government is focusing on efforts to prevent and reduce risks from water-related disasters. It has adopted proactive measures, such as the development of water reservoirs through the kaem ling project, initiated by His Majesty the King. Kaem ling (monkey's cheek), or water retention areas, will retain excess water to ease floods and store water to ease drought problems. The selected monkey cheek in the area of the project, for example, is one of many monkey cheek areas being developed under the National Water Management Strategy Committee chaired by the Prime Minister to serve as water retention in order to cope with current and future changes of climate (e.g. rapid flood and drought). RID requested support to enhance this particular quasi-functioning monkey cheek (the priority area in Yom river basin) to be climate risk informed. The successful enhancement of this monkey cheek will have potential scalability for other lower areas in Thailand.

3.2.17 National Flood and Water Management Policy

Water resource management is administered across 7 different Ministries in 30 different state organisations – and involves over 50 laws.[139] Given this, policy and management of flood and water overlaps between authorities for governing jurisdiction. For example, in the maintenance of dredging irrigation canals – responsibility lies across the Royal Irrigation Department (RID), local administrative organistaions (LAOs), and the Marine Department – according to whether purpose is for irrigation, flood prevention or for water transportation.[140] According to a study undertaken by Nikomborirak[141] none of the laws prescribe the authority for water to flow for usage nor specifically concerning flood management. Governance is widely based on prescriptions under the Plan and Procedure for Devolution of Power to Local Administration Act 1999 for responsibility widely falling under local administration. The RID is more broadly charged with the authority of constructing and maintaining waterways and associated infrastructure for flood prevention, including water gates and documenting and reporting on canal water volumes in canals and waterways through provincial operations.[142]

Overall, the Thai government has launched policies and plans on national water resource management, which follow principles and strategies that prescribe to:

1) Solve water resource problems that cause severe socio-economic impacts and must be urgently undertaken (2015–2026);

2) Integrate water management, so as to create happiness to people and provide opportunity of water accessibility to every single user in an appropriate way; and

3) Balance the development and the utilization of water resources in accordance with the basin potential, in response to economic development and sustainably environmental conservations.

3.2.18 Master Plan on Water Resource Management

The Master Plan on Water Resource Management consists of a total 8 work plans and implementation of guidelines, established under the Strategic Committee for Water Resource Management (SCWRM) and the Office of the National Economic and Social Development Board (January 2012)[143]:

[139] Nikomborirak, D. Policy Brief: History of Water Resource and Flood Management in Thailand
[140] Nikomborirak, D. Policy Brief: History of Water Resource and Flood Management in Thailand
[141] Nikomborirak, D. Policy Brief: History of Water Resource and Flood Management in Thailand
[142] Nikomborirak, D. Policy Brief: History of Water Resource and Flood Management in Thailand
[143] ONESDB. 2012, Master Plan on Water Resource Management, Strategic Committee for Water Resource Management, Office of the Strategic Committee for Water Resource Management, Office of the National Economic and Social Development Board, http://www.boi.go.th/upload/water_flood_th_master_0212_eng_98335.pdf

1. Work Plan for Restoration and Conservation of Forest and Ecosystem: aiming to restore watershed forest where water is retained, to develop additional water reservoirs according to the capacity of the areas and to develop land usage plans that fit with their local and socio-geographical conditions by restoring and conserving the degraded watershed areas, developing projects for soil and water conservation by promoting economic and community afforestation while rehabilitating mangrove forest, improving water and land usage, increasing storage capacity, and revising and drafting relevant laws.

2. Work Plan for Management of Major Water Reservoirs and Formulation of the National Annual Water Management Plan: aiming to prevent and alleviate the impacts of possible floods in the future by developing water management plans for major dams and river basins, formulating water management plans under different scenarios, improving the Rule Curves in water management to balance water use in several sectors, and presenting water related information to the public.

3. Work Plan for Restoration and Efficiency Improvement of Current and Planned Physical Structures: aiming to prevent and mitigate the impact of flooding by implementing 4 sub-work plans including (1) renovating dikes, water control buildings, and water drainage systems to ensure effectiveness in every area, (2) improving drainage waterways, dredging canals, removing barriers in canals and draining waterways, (3) increasing efficiency in management of water drainage and overflows in specific areas, and (4) reinforcing dikes and following the King's initiatives. In the long term, several measures will be implemented, including the construction of flood-ways or water diversion channels, and preventive dikes for key economic areas, as well as land use planning.

4. Work Plan for Information Warehouse as well as Forecasting and Disaster Warning System: aiming at developing data systems, creating hypothetical scenarios based on technical principles, setting up water management institutions, and increasing efficiency in the warning system by (1) setting up a national water information center, (2) constructing hypothetical water scenarios, forecasting and disaster warning systems, (3) enhancing the national disaster warning system to become capable of monitoring and analyzing the water situation in a timely manner by improving and increasing the number of water monitoring stations in major rivers, installing CCTVs at the water gates and pumping stations, upgrading satellite and remote sensing systems, and reorganizing and developing disaster warning systems.

5. Work Plan for Preparedness for Emergency Situations in Specific Areas: aiming to build capacity in prevention and mitigation of impacts from floods by developing the systems of flood prevention and mitigation in the important areas such as agriculture, industry, and dense communities, creating a system for negotiating between the affected parties, constructing warehouses for tools, and assessing the impacts of private prevention systems.

6. Work Plan for Assigning Water Retention Areas and Recovery Measures: by assigning water retention areas in the upper and lower Chao Phraya River basins, developing the water retention areas to slow down water flow during flash floods, formulating a plan for diverting water into water retention areas whilst creating measures for special compensation to those areas assigned to be water retention areas.

7. Work Plan for Improving Water Management Institutions: aiming at setting up integrated water management organizations, as a single command authority that can make prompt decisions during a crisis and is responsible for planning, monitoring and evaluation, revising rules and regulations. For the urgency period, this single command authority is the Ad Hoc Committee chaired by the Prime Minister or the assigned Deputy Prime Minister and comprises ministers and permanent secretaries of related ministries as members. In the long term, a national integrated water management agency should be set up permanently.

8. Work Plan for Creating Understanding, Acceptance, and Participation in Large Scale Flood Management from

all Stakeholders: Government and development partners would call for collaboration with community and people in managing the impacts of floods and other major disasters.

3.2.19 Flood Management Master Plan

The Flood Management Master Plan was set up under two committees following the 2011 flood. The Flood Management Master Plan has three objectives: 1) to prevent, mitigate and reduce the damage caused by flooding, 2) to improve the efficiency of the flood prevention and the emergency flood management systems, and 3) to build public confidence and security, to increase national income and to manage natural resources on a sustainable basis.

The Flood Management Master Plan follows a two-pronged approach of undertaking the structural measures of storing and diverting water and non-structural measures or 'soft' measures needed based upon the Royal Initiative. The Ecosystem based Adaptation (EbA) approaches promoted under this project can be considered to be part of these 'soft' measures (see Annex 22). One of the options pursued under the structural measures includes the increase of water reservoir capacities. While others include the construction of 261 floodways to divert water as flood protection structures. The Master Plan is heavily premised on a study undertaken from the Japanese International Cooperation Agency (JICA) and its recommendations for the following:

1. Infrastructure investment and flood management for both short-term and long-term solutions.
2. The non-structural Royal Initiative to create "room for the river", which would allow for increased areas for floods to spread (see section 4.3.15 – 'Room for the River' for further information). Reforestation is also part of this Initiative in order to prevent rapid flooding in upstream river basins. The concept of 'room for the river' consists of the large flood retention areas and Monkey Cheek reservoirs (also known as 'Gamling'). The study of the potential flood retention areas in Bang Ban sub-district in province finds that the Bang Ban area has a potential to be developed into a reservoir for the following reasons[144]:

- Excess water easily flows to designated reservoir areas with flood barriers surrounding the area
- A protection plan for residential houses, industrial sections and agricultural areas, i.e. designated areas for collective residential housing and the building of barriers for houses and farmlands along the waterways
- Bang Ban already has drainage canals, natural water trails and spaces that can serve to being converted into flood diversion channels if the case be needed. This also includes a water-control station consisting of sluice gate, drainage channels and water pumping station.
- The draining of water levels from Ban Bang can be undertaken when areas outside the reservoir decrease (by closing the sluice gate and pumping water out).

[144] Suppaisarn, et al. 2008

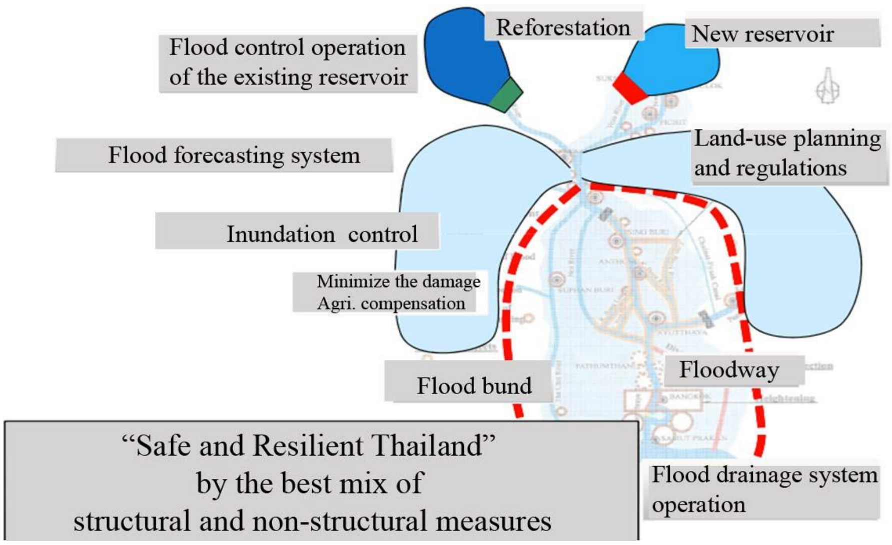


Figure 63: The best mix of structural and non-structural measures developed for the Flood Management Master Plan

Source: Takeya Kimio, 'JICA's Support 'Toward Safe & Resilient Thailand' through revising the Comprehensive Flood Management Plan for the Chao Phraya River Basin'. 20 February 2012.

3.2.20 Master Plan for Integrated Biodiversity Management

Wetlands management is highlighted under the Master Plan for Integrated Biodiversity Management (2015-2021), which is the principal biological diversity plan of Thailand, developed in compliance with Article 6 of the Convention on Biological Diversity, under which it states that each Contracting Party shall develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity. In line with the Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets, which were adopted by the Conference of the Parties to the Convention of Biological Diversity at its tenth meeting, the Master Plan was formulated to address the underlying causes of biodiversity loss. The Master Plan is aimed at conserving, restoring and protecting biodiversity and ecosystem services, as well as enhancing the benefits from them, along with raising public awareness and understanding of the roles and importance of biodiversity to human well-being, and collaborating with all relevant sectors in integrated management. Under this obligation Thailand is required to ensure that wise management of wetlands is undertaken according to the Ramsar Convention on Wetlands to which Thailand has become a Party since 13 September 1998. Similarly, Thailand is required to encourage relevant sectors to formulate management plans for internationally and nationally important wetlands, and urge relevant agencies to incorporate such plans into policies and plans at provincial, local and community levels.

The Master Plan also highlights that the MoNRE should develop and support implementation of good practices for wetland management in urban and suburban areas and incorporate them into provincial and local plans. Agricultural areas, aquaculture, and forestry must be managed in a sustainable manner, with responsibility for the environment assured to conserve biodiversity and ecosystems and includes the incorporation of biodiversity issues into relevant environmental standards. Finally, relating to wetlands, the Master Plan also highlights the control and protection of all marine and coastal resources, wetlands and vulnerable ecosystems that may be affected by community expansion, pollution, overfishing and climate change.

3.2.21 Flood Action Plan and Budget

The action plan budget consists of an immediate flood compensation budget and a budget for the flood action plans:

Assistance, restoration, and compensation budget: The government allocated USD 3,902 million of the central budget (~USD 1,534 in financial year of 2011, and ~USD 2,383 in financial year 2012) to provide assistance, restoration, and compensation to flood victims. From October 2011 to May 2012, state agencies have already spent 79,750 million baht from these budgets through related projects/work plans.

Flood action plan, including two related action plans: an action plan for water management for the emergency period and an action plan for integrated and sustainable flood mitigation in the Chao Phraya river basin:

- Action plan for water management for the emergency period. Its key principle is to reduce losses and damage due to flooding, and to minimize its economic and social impacts. There are 6 main work plans with a total budget of 18,110 million baht (see details in the Flood Management Master Plan 2012).

- Integrated and sustainable flood management action plan. This comprises 8 work plans with a budget of 300,000 million baht. The government has already passed a law enabling it to borrow 300,000 million baht.

3.2.22 Basin Development Plan

The *Integrated Planning of Special Area Development Project*'s Initial Environmental Assessment led to the development plan for alleviating drought and flood in the Yom River Basin. The following plans have been created as results:

1. The master plan for the Yom River Basin Development.
2. The prefeasibility studies and IEAs of four selected medium-sized water development projects.
3. The feasibility study and IEA of the large-sized water development project.
4. The feasibility study and IEA of the special zone development project designated to accommodate affected people from the large-sized development project.
5. The study report of the management of the flood retention area in the lower Yom River Basin.
6. The database and GIS systems for water management in accordance with the guideline for the Yom river development.
7. The operation of public relations activities and the implementation of people participating process.

3.2.23 Agriculture Policy and Planning and Agricultural Strategy

Rice is Thailand's most central crop, with roughly 60 percent of Thailand's farmers depending on growing rice[145] and with rice contributing up to 1.3 percent of GDP.[146] In recent years, Thailand produced more than 30 million

[145] "Thai organic foods have healthy growth potential". *Bangkok Post. SCB Economic Intelligence Center. 6 February 2017*. Retrieved 7 February 2017.
[146] Lee, Brendon (2015-07-20). "Sci Dev Net; South East Asia & Pacific". *SciDev.net*. Retrieved 21 July 2015.

tonnes of paddy annually. The Prime Minister in 2016 has set a target for Thailand to produce between 25 and 27 million metric tonnes of paddy in 2016 in order to prevent oversupply. As a result, incentives will be offered to farmers to reduce rice farming on a voluntary basis and turn to other cash crops. Currently, Thailand's law mandate banks to provide accessible (low rate) credit to farmers, and provides credit through the Bank for Agriculture and Agriculture Cooperatives (BAAC). The Bank for Agriculture and Agricultural Cooperatives, which has joined the agricultural reform, recently offered to support each subdistrict in Thailand to carry out an agro-industry project in order to add value to agricultural products and increase income for farmers.

Agricultural policy reform:

The Government has a policy to reform the agriculture sector to ease problems faced by farmers and to contribute to national development. The agricultural reform sets out seven areas of reform. These are 1) a designated agricultural zoning across all provinces in accordance with each areas specific local geographical and climatic conditions – called the 'AgriMap'. The AgriMap is to be used to suggest to farmers in which area which crops are most suitable to their respective farmland conditions. 2) Involves the establishment of 882 learning centres in order to increase the efficiency of agricultural production. Each district is to have at least one of these learning centres. 3) Farmers and farmland types are to be grouped in order to promote greater efficiency – for cooperating between farmers and the public and private sector supporting strategic and key linkages between each in 'Public-Private and People partnership'. 4) Sets out guidance for agricultural production to follow market demand, particularly in terms of international standards and meeting export demands – to enable agricultural production to be competitive on global markets. 5) Sets out financial mechanisms through the set up of banks for agricultural products to be set up through the grouping of farmers and their participation in management. 6) Seeks to establish a single-command style system in order to translate the agricultural reform plan into action, and finally 7) designated 2016 as the year for reducing agricultural production costs in seeking to ensure for greater opportunity driven by this competiveness.

New Theory: in Agriculture:

The late His Majesty King Bhumibol Adulyadej provided guidelines for agrarian areas in the New Theory approach – which employs a concept of assisting individual farmers to possess small land pockets enough to be able to manage the utilization of the land and water for agricultural activities optimally. This approach stepped out a plan for farmers to follow, where each piece of small land is divided into four parts of use. Part 1 (around 30 percent) is set aside for establishment of a pond to store water for cultivation use - as well as for raising aquatic animals and plants. Part 2, (using around 30 percent) is then to be used for rice farming at a level sufficient to supply the household with rice all year round. Part 3, or another 30 percent of the land is allocated for planting fruit trees, vegetables, field crops and so forth – and which the surplus (of household use) is able to be sold at the market. The remaining 10 percent is then reserved as the area for housing, animal raising and other purposes. This approach is aimed at ensuring that each household ultimately has sufficient water available for cultivation during the dry season, is self-sufficient in household food production, and self-reliant at an economic level.

The approach follows the principle, in line with the sufficiency economy philosophy, that the production system should serve in allowing farmers to become self-sufficient, self-reliant, and frugal. To be viable, this concept requires unity and willingness of the community to work with and assist one another in order to reduce expenses, similar to the traditional practice of Long Khaek (traditional mutual help gathering for an activity such as rice harvests). It follows the logic that if each family carries out rice cultivation over an area of 0.8 hectares they will be guaranteed a whole year's supply of rice for consumption. This means that farmers will not have to buy rice at an unreasonably high price and can lead their lives freely because they have become self-reliant. Another important point is that the storage of water must be sufficient to supply farming during the dry season or dry spells. Therefore, the concept ensures that a part of the land is set aside for the construction of a pond to store sufficient water for all year round cultivation. The guideline proposes that for cultivation of 0.16 hectare, a farmer will need about 1,000 cubic metres of water. Therefore, if an area of 0.8 hectares is used for rice farming and another 0.8 hectares for field or fruit crop farming (a total of 1.6 hectares), approximately 10,000 cubic meters of water will be needed annually – as a guide, but are dependent on the local conditions. It also stipulates for appropriate crops to be grown at appropriate times. For example, it stipulates that in the rainy season, water will be plentiful for rice and cultivation of other crops; yet during drought or dry spell periods, it is most suitable to cultivate crops that do not require large amounts of water, such as beans. The New Theory also provides guidance on recommending the types of crops that farmers can grow:

- Fruit trees and Other Perennial Plants: mango, coconut, tamarind, jackfruit, sapodilla, orange, banana, custard apple, papaya, santol, sesbania, horseradish, neem tree, cassod tree, lead tree, etc.
- Short-lived Vegetables and Flowers: sweet potato, taro, yard long bean, eggplant, jasmine, aztec, globe amaranth, rose, Calotropis, tuberose, etc.
- Mushrooms: nang-fah mushroom (Pleurotus sajor-caju), straw mushroom, abalone mushroom (Pleurotus cystidiosus), etc.
- Herbs and Spices: areca palm, betel pepper, pepper, elephant yam, Centella asiatica, ebony tree, ringworm bush, vetiver grass, as well as certain types of crops such as holy basil, common basil, mint, basilicum, lemongrass, etc.
- Wood and Firewood: bamboo, coconut, palm, camachile, combretum, coral tree, siris, lead tree, eucalyptus, neem tree, cassod tree, Pterocarpus, Dalbergia, Dipterocarpus alatus, etc.
- Field Crops: maize, soybean, groundnut, cowpea, pigeon pea, sugar cane, cassava, castor, kapok, etc. Some types of field crops could be harvested when they are still young and sold in the market because they can get better prices than when they are ripe. Such types of crop are maize, soybean, groundnut, cowpea, pigeon pea, sugar cane, cassava, etc.
- Soil nourishing and ground cover crops: pigeon pea, Caribbean stylo, African sesbania, sesbania, sunhemp, sword bean, cassod tree, lead tree, green pea, etc. After they have been harvested, the soil can be ploughed and turned over to further nurture the soil.

The guidance notes that many plants provide more than one benefit. It emphasises plant selection should focus on perennial plants because they do not need intensive care once they are fully grown; while their products are obtained all year round if different types of plants have been selected. These perennial trees in turn provide shade and moisture to the living area and the environment. Aquatic animals such as common carp, nile tillapia, common silver barb, and catfish will provide additional protein supplements and can also be sold to earn supplementary income. In some areas, frogs can also be bred. Pigs or chickens are raised along the edges of the pond. In this case, pig and chicken dung may be used for fish and duck feed.

The second phase of the guidance in the New Theory suggests that farmers also should pool their efforts, resources, and form themselves into groups or cooperatives to execute the following activities: Production (crop selection, soil preparation, irrigation system, water for storage, pond preparation, crop varieties selection, fertilizers, and other required inputs etc.); Marketing (sun-dry area, silo, rice mill, product distribution, preparations in order to optimize marketing prices of their produce etc.); Well-being (food, clothing, decent living standard etc.); Welfare (public health services, loans, community should offer security and needed services such as a public health station or funds established to provide loans to carry out the community's activities etc.); Education (school, scholarships, promoting the pursuit of education, for example by establishing a fund to support the education for youth etc.), and; Society and Religion. The final phase 3, focuses on joint efforts between groups and cooperatives and organisation or the private sector - making the necessary contacts and coordination to establish a fund or ensure funding from credit sources such as banks or companies, following the theory that this would assist farmers in their investment for activities that improve the quality of their life, and under which, both farmers and the credit sources will receive mutual benefits as follows: 1) Farmers can sell their rice at a higher price (without being suppressed in terms of the price they want in exchange for the products); 2) Credit sources can buy rice at a lower price (since they buy directly from farmers and mill the paddy by themselves), 3) Farmers can obtain consumer goods at a low price because they can buy in bulk (by operating like a cooperative store and having the privilege of buying commodities at a wholesale price), and; 4) Credit sources can dispatch their personnel to various locations to implement different activities, which guarantee better results.

3.2.23.1 Drought policy

Prior to 2015, farmers received compensation for farm-related damage arising in their agricultural practices (particularly for rice cultivation), such as from insect damage, flood, drought, and so on. However, following the drought crisis in 2015 – the Thai government introduced an integrated assistance package project for farmers with damage arising from drought during the 2015 – 2016 period. This project brought together measures inter-ministerially, between the Royal Irrigation Department (RID), the Department of Agricultural and Cooperatives (DoAC), amongst others. These measures are all aimed at increasing the effectiveness of limited water usage, and assisting farmers in drought. Under RID, this centres on the improvement of local ground water sources, and monkey cheeks, as well as improvement of natural canals. For DoAC, programs involve crop plantation measures that use less water (e.g. maize, beans, vegetables, chicken raising to reduce household consumption).

3.2.24 Economic Policy and Planning

The price support program under the name 'the pledging scheme' was first started in 1980 to reduce the quantity of paddy after harvesting. From 1980 to 2003, price under this program was 5-10 percent above market price and implemented on the wet season paddy only. But since 2004 to 2013 crop years except crop years 2006-2007 and 2009-2010, this program was used as one of the political instruments. Prices under this program were lifted up at least 30 percent higher than market prices in 2004-2005 and implemented for both wet and dry season rice. For the crop years 2011 – 2013, the pledging prices were double the market prices causing a very high budget, excess supply of rice, a reduction in exports and increase in ending stocks. This program was terminated in 2014.

3.3 Institutional framework at National level

The Royal Thai Government (RTG) and the Council of Ministers of Thailand, is comprised of 35 ministers of state and deputy ministers, which run the 20 Cabinet ministries who are responsible for the formulation and execution of policies of the government. The National Assembly of Thailand is composed of the Senate and the House of Representatives. The state agencies form Thailand's public sector, and make up the machinery of the government. A significant number of Thailand's Ministries, Departments and Committees are involved in the formation and implementation of policy and strategies that support the overarching objectives of the Enhancing climate resilience in Thailand through effective water management and sustainable agriculture project.

3.3.1 National Committee on Climate Change (NCCC)

The National Climate Change Subcommittee was established when Thailand ratified the UNFCCC in 1992 and was upscaled to become the National Committee on Climate Change (NCCC) under Prime Minister as Chair. The NCCC acts as a high-level committee for policy and framework guidance on climate change and in international negotiations.

3.3.2 Ministry of Natural Resources and Environment

The Ministry of Natural Resources and Environment is a cabinet ministry in the Government of Thailand which oversees several departments – mineral resources, marine and coastal resources, water resources, groundwater resources, forest, national parks, wildlife and plant conservation, natural resources and environmental policy and planning, environmental quality promotion, and pollution control. The Ministry operates as the ministerial administrative centre in developing strategy and transforming policy into action plans.

3.3.2.1 Climate Change Management Coordination (CCMC) Division, Office of Natural Resources and Environmental Policy and Planning

Thailand's Office of Natural Resources and Environmental Policy and Planning (ONEP) under the Ministry of Natural Resources and Environment (MONRE) is also the governmental core agency responsible for climate change national planning, policy, strategy, activity as well as for cooperation in international forums (e.g. climate change negotiations). Thailand's Climate Change Coordination and Management section of the Office of Natural Resources and Environmental policy and Planning (ONEP), under the MoNRE, acts as Thailand's national focal point to the United Nations Framework Convention on Climate Change (UNFCCC), and houses the development of climate change policy for cross-sectorial implementation. The Division is mandated with the development of climate change policy and planning, as well as the development and integration of measures, tools and other mechanisms for climate change adaptation (CCA) and Climate Change Mitigation (CCM). This includes all related climate change policies, strategies and implementation plans, as well as research and studies to support their development; Directives, Regulations and the implementation of mechanisms and negotiation of positions, and supportive collaborative measures, monitoring and coordination, as well as; all actions as the Secretariat of the National Board of Climate Change Policy – and associated actions to support other organisations as assigned.

3.3.2.2 Department of Water Resources

The Department of Water Resources is charged with integrated water resource management in the area of climate change. The Department of Water Resources as the core agency for the national water resources under the Ministry of Natural Resources and Environment, and is mandated to establish a basin-based water resources management system in order to be able to supply adequate water for consumption and production; to conserve and rehabilitate water resources and to provide surveillance and warning system for water disaster, and to ensure the participation of all stakeholders in all sectors. Overall, the Department is charged with formulating policy and planning for basin-based integrated water resources management both at national and international levels; the promotion, support and increase in capacity of river basin organisations and networks; conserving, rehabilitating and developing water resources to increase their efficiency and maintain ecosystem and wetland balance; as well as to develop the knowledge base, information systems, and standards of integrated water resource management as well as a warning system to be applied in all sectors as well as in developing consumption and domestic water supply.

3.3.2.3 Department of Groundwater Resources

The Department of Groundwater Resources (DGR) under the Ministry of Environment and Natural Resources is charged with integrating the development and management of Thailand's groundwater resources so as to ensure that they are used in a way guaranteeing future sustainability and security. Part of this mandates serves to ensure equitable access across stakeholders, and monitoring of groundwater resources to ensure exploitation and the adverse impacts of overexploitation are mitigated and availability and groundwater quality maintained.

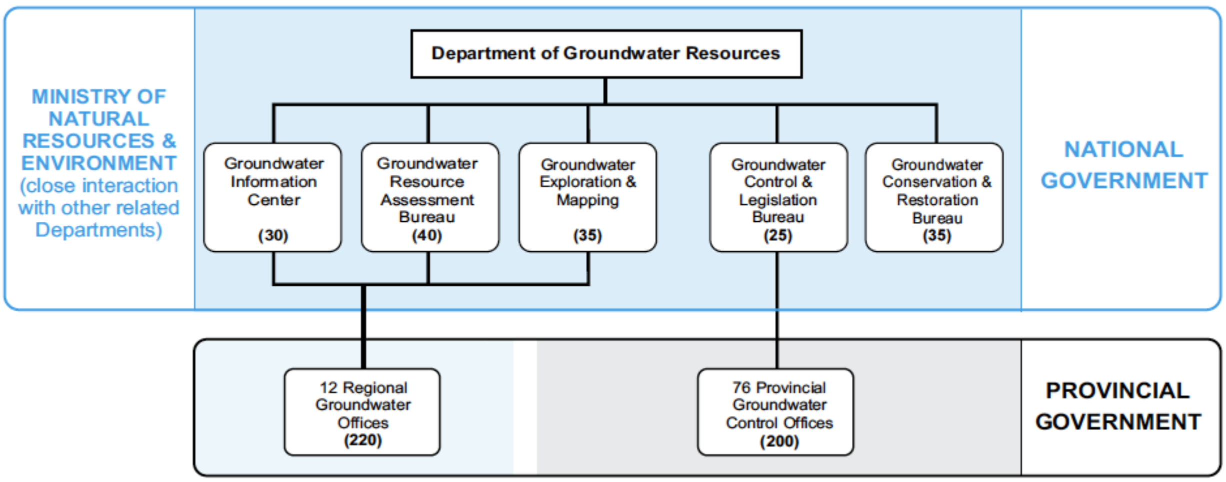


Figure 64: Organisational chart of the Department of Groundwater Resources (2007).

3.3.3 The Ministry of Agriculture and Cooperatives (MoAC)

In Thailand, the Ministry of Agriculture and Cooperatives is the major ministerial stakeholder in the agriculture sector. The Ministry of Agriculture and Cooperatives (MOAC) has more than twenty departments or offices, of which the Royal Irrigation Department (RID) is the most important and critical in terms of water management and provision. Within the Ministry of Agriculture and Cooperative (MoAC), there are 15 Departments, five state owned enterprises and three public organizations. Furthermore, the Bank for Agriculture and Agricultural Cooperatives (BAAC), under the auspices of the Ministry of Finance, reaches almost 90% of the farmers in Thailand and provides short and long-term credits. The National Economic and Social Development Board (NESDB) is responsible for agricultural and natural resource management and planning. Other relevant agencies involved in agriculture sector include Ministry of Natural Resources and Environment (MoNRE), Ministry of Science and Technology (MOST), Thai Research Funds (TRF) and National Research Council of Thailand (NRCT).

3.3.3.1 Royal Irrigation Department (RID)

The Royal Irrigation Department (RID) plays a vital role in water management in Thailand and is the most important and critical Department in terms of water management and provision. RID is the main agency involved in water project investment planning, design and construction in Thailand thus making it a key player as water resources manager. It also plays a principal role in flood mitigation issues as its canals and water regulation devices are utilised for flood protection and drainage during the wet season. The RID is responsible for development, operations and maintenance of Thailand's water management investments. RID, as the implementing government institution – holds an extensive team both nationally and at the project-Provincial levels, including a large team of hydrologist engineers and hydraulic engineers, whose expertise have driven the project and will continue to inform and implement its works – particularly for Output 2 of the proposal. The Department is responsible (under legislative regulation Ministerial Regulation of the Ministry of Agriculture and Cooperatives B.E. 2554) for 1) the implementation of activities aimed at achieving, collecting, storing, controlling, distributing, draining or allocating water for agricultural, energy, household consumption or industrial purposes under irrigation laws, ditch and dike laws and other related laws; 2) the implementation of activities related to prevention of damages from water; safety of dams and related structures; safety of navigation in commanded areas; 3) the implementation of land consolidation for agriculture under the Agricultural Land Consolidation Act, as well as the activities designated by laws or assigned by Cabinet or Ministers. RID, jointly with EGAT, plays a key role of allocating access to water resources, by determining total water demand requirements of all users and comparing this to overall seasonal water availability. RID is also responsible for maintenance of some river dikes.

RID is a member of the sub-committee on integrated policy and planning for climate change, which sits under the national climate change committee chaired by the Prime Minister, as well as the National water management and disaster risk management committees.

3.3.3.2 Land Development Department

The Land Development Department is responsible for soil survey and classification, soil analysis, land use planning, conducting experiments and carry various aspects of land development, assist farmers in soil and water conservation practices and soil improvement. The Department of Land Development is mandated with undertaking and managing land preservation through the prevention of soil erosion and land degradation. The Department undertakes landuse planning, sub-watershed landuse planning, sub-district landuse planning, and wetlands classification. In terms of agriculture – the Department promotes integrated form management, working to enact the Royal projects of vetiver soil erosion prevention as a natural engineering structure, as well as soil management activities for agricultural crops (i.e. corn, cassava, rice). The Department provides classification, mapping and education regarding Thailand’s soil types and distribution, as well as on soil preservation and restoration. The Department is responsible for Natural calamity and agricultural risk prevention (e.g. floods, droughts, and landslides impacting agriculture). The Department provides land development extension – such as facilitating farmers and those interested to receive various microbial catalytic substances for land development, vetiver tillers and seed for soil and water conservation. They provide analysis of soil, water and fertiliser for farmers, as well as maintain soil doctors to provide a network of support – and certification and licensing for agricultural inputs such as bio-fertilisers, organic fertilisers, soil improvement materials. Under the extension services are also a series of courses on how to improve and rehabilitate soils in agriculture. This Department is largely involved in the project, under Outputs 2 and 3, relating to the development of on-farm ponds. The Department is responsible for the construction (on request) of on farm ponds (of 1,260 cubic metres) for areas lying outside of the irrigation zone.

3.3.3.3 Department of Fisheries

The Department of Fisheries is charged with the promotion and control of fishing practices, including on land and aquaculture practices as they fall under Output 3. The Department of Fisheries is also responsible for promoting and developing all occupations relating to fisheries. This includes development of aquaculture with goals to increase fishery production from aquaculture from freshwater and coastal aquaculture respectively. It also includes mandate to increase the export of fishery products and to increase the value of fishery products and to increase consumption of fish per capita not less than 30 kilograms per year.

3.3.3.4 The Office of Agricultural Economics

The Office of Agricultural Economics monitors and provides essential information for determining the impacts of climate change to agricultural – in terms of providing information regarding crop adaptation, planning and assessments of implications. This Department also plays an essential role under Output 3. The Office of Agricultural Economics is the principal organisation for collecting vital statistical data and conducting research studies related to the economic situation of Thai agriculture. The Office generates statistics on production and marketing of crops, livestock and fisheries; it collects data on factors that would potentially affect crop, such as climate, ecology, and irrigation – which are vital for use in enabling development of recommendations and effective development plans in both market and sustainable uses of natural resources. The Office of Agricultural Economics comprises the Office of the Secretary; Bureau of Agricultural Development Policy and Planning; Bureau of Agricultural Economic Research; Centre for Agricultural Information; Centre for Project and Programme Evaluation, and; the Regional Offices of Agricultural Economics.

3.3.3.5 Department of Agriculture

The Department of Agriculture is responsible for agricultural production under the MoAC. The Department provides crop research and development, as well as farm mechanization – within principles of natural resource conservation and environmental protection. Overall, the Department is mandated to conduct research concerning crops and agricultural technology transfer, as well as provide certification and advice regarding soil, water, fertilizer, and agricultural input production and products. The Department is also responsive to urgent programs assigned under the Department of Agriculture by the Ministry of Agriculture and Cooperatives and the Cabinet Minister.

3.3.3.6 Department of Disaster Prevention and Mitigation

National disaster prevention and climate change mitigation and adaptation is undertaken by the Department of Disaster Prevention and Mitigation. The Department is responsible for formulating policy, guidelines and identifying criteria for disaster management; studying, analysing and conducting research and undertaking the development of disaster prevention and warning systems; developing information technology systems for disaster prevention, warning and mitigation; mobilizing public participation in engaging in disaster prevention and mitigation measures; creating awareness and preparedness amongst the general public; arranging training and preparation procedures for disaster prevention and mitigation, rehabilitation and in providing emergency and disaster relief to the victims as stated by law; promoting, supporting and carrying out disaster prevention and mitigation activities, providing assistance to victims and rehabilitating devastated areas; coordinating and directing relief operations for disaster victims and rehabilitating areas devastated by large scale disaster, and; coordinating with local and foreign organisations in providing technical assistance in disaster prevention, mitigation, rehabilitation and relief operation, and any other functions assigned under the Ministry of Interior.

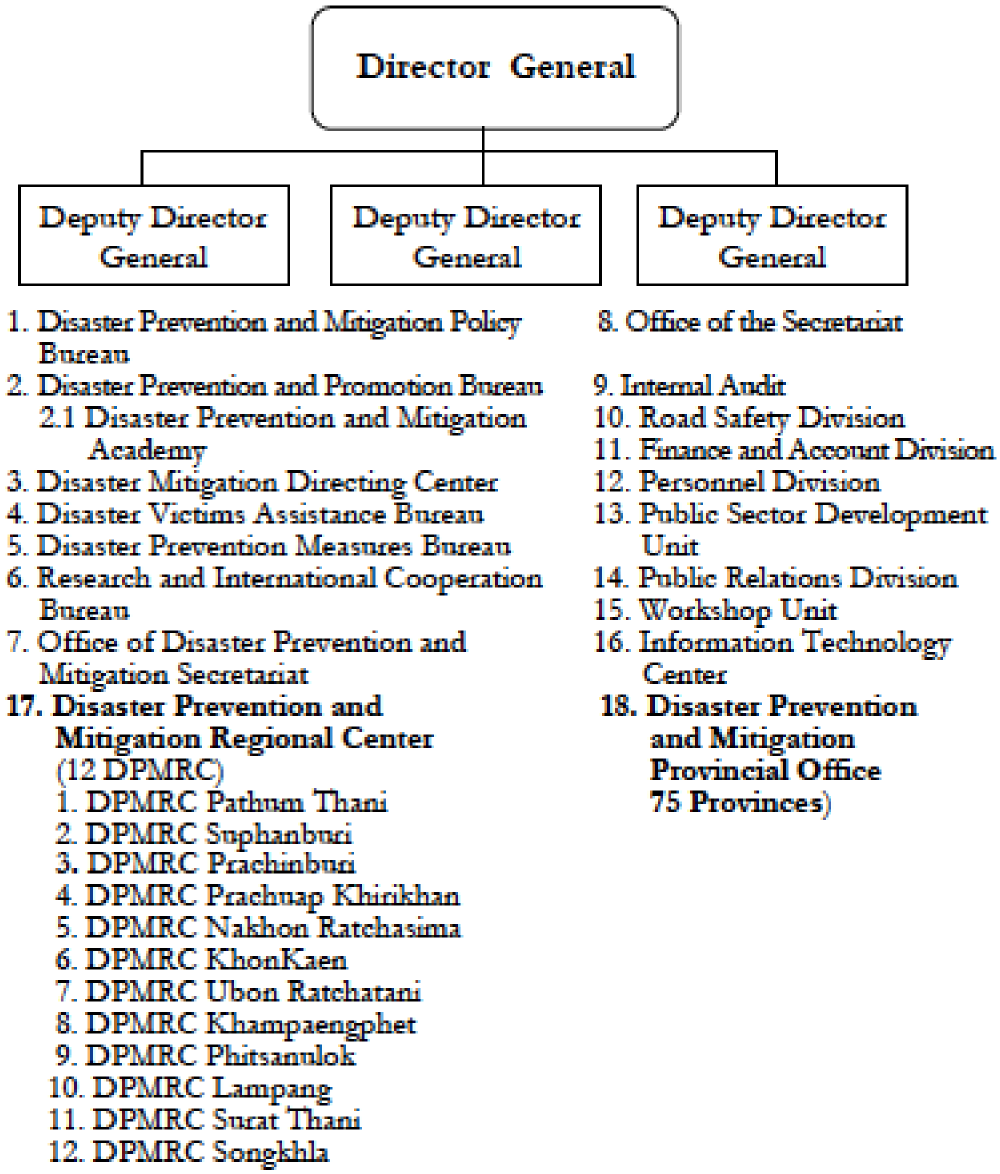


Figure 65: Organisational chart of the Department of Disaster Prevention and Mitigation (DDPM)

3.3.3.7 Disaster Management Centre

The Thai Government established a Flood Relief Operation Center (FROC) in October, 2011 in response to the flood. FROC's central office was located in Don Muang district of Bangkok. It previously served as the migrant center and shelter for flood victims. It also functioned with assistance from the military to repair irrigation facilities, evacuated flood victims from flooded areas, delivered survivor kits, etc. About USD 17.89 million were spent for flood relief activities.

3.3.4 Ministry of Social Development and Human Security

The Ministry of Social Development and Human Security is charged with the improvement and development of Thailand society, in a broad sense. This includes creating a social welfare system that enhances quality and security of human life, and protection from fluctuation and social change. It is also aimed at active social participation in social development aspects, and the development of knowledge management, capacity and administration of social development. Under this Ministry sites the Office of Women's affairs and family development; National Housing Authority; the Office of Promotion and Protection of Children, Youth, the Elderly and vulnerable groups; the National Office for empowerment of persons with disabilities, and; Community Organisations' Development Institute.

3.3.4.1 Office of Women's Affairs and Family Development (OWAFD)

The Office of Women's Affairs and Family Development OWAFD was established in 2002 under the Ministry of Social Development and Human Security. It serves as the focal point for the promotion of gender equality and the strength of the family institution. OWAFD implements policies, measures and mechanisms to support other public and private sector units in their own policy implementation promoting women's economic potential, their rights, and gender equality and equity. By hosting annual assemblies of provincial, regional, and national women's networks, OWAFD serves as a platform to review the problems and progress in women's affairs. This ultimately serves to develop measures for women's affairs economy-wide.

3.3.5 Ministry of Science and Technology

The Ministry of Science and Technology is responsible for the oversight of science and technology in Thailand. The Ministry is mandated with undertaking policy and strategic plans for science, technology and innovation as well as implementation, both in terms of research and development but also in establishing cooperative mechanisms between all sectors of society, with a view to promoting economic benefits and enhancing quality of life.

3.3.5.1 Ministry of Information, Communication and Technology

The Ministry of Information and Communication Technology (ICT) is responsible for the development and integration of ICT in Thailand, and incorporating the efficient and comprehensive development and usage of information and communication technology across all sectors in Thailand.

3.3.5.2 Department of Meteorology

At the national level, the Thai Metrological Department provides climate change/weather information on its website and via radio broadcast but systematic and institutional coordination, such as with the agricultural and irrigation departments, has not been effectively established. The Thai Meteorological Department is the main governmental body that has been carrying on meteorological administrations and managements for the sakes of two vital aims 1) the best economic, social, agricultural, and industrial benefits as well as 2) protection of human lives and properties possessed by public members, private sectors, and governmental units against natural disasters. TMD has been authorized to perform the following 5 duties:

1. To supply weather forecasts for the entire country and publicize disaster warnings to fulfill the requirement from administration and management in natural disaster mitigation

2. To build the people's awareness toward natural disasters, enabling them to perform correct surviving practices and reducing effects from natural disasters by using modern technologies together with IT services

3. To become the meteorological IT data and service center at the national level for users in any ventures

4. To improve and develop the Departments research works

5. To strengthen the Department's roles in international cooperation concerning meteorology and environment with the purpose of profound comprehension on changing world situation.

Since the year 2002 when the Thai Government reformed the government system, TMD was transferred to be under the Ministry of Information and Communication Technology. TMD has steadily involved in the international aspects of meteorology over the years since its adherence to the Convention of the World Meteorological Organization (WMO) in 1949. Its participation in many of the program of WMO and notably the World Weather Watch (WWW) and the Tropical Cyclone Program (TCP) has ensured its continuing development in keeping abreast of the latest technological advances.

3.3.5.3 Geo-informatics and Space Technology Development Agency (GISTDA)

The Geo-informatics and Space Technology Development Agency provides critical information for monitoring geographical changes, providing satellite imaging, GIS maps, and remote sensing – crucial to developing and monitoring effective climate change risk and forecasting under Output 1.

3.3.5.4 Climate Impact Science and Technology (CIST)

The Climate Impact Science and Technology organization under the Ministry of Science and Technology undertakes research on the impacts of climate change.

3.3.5.5 National Research Council of Thailand

The National Research Council of Thailand, provides research and development (R&D) for national interests and policy, including providing crucial R&D on climate change for Thailand. Research undertaken by the National Research Council of Thailand underpins all three outputs of the Project.

3.3.6 Relevant National and International-partnership Research Institutes

Thailand's policies, strategies and plans, regional partnerships and international commitments, are supported by a wide range of non-governmental national and international partnership research institutes, who support at different levels through research and development, information support and policy and planning development assistance in varying ways.

3.3.6.1 Thailand Research Fund

The Thailand Research Fund (the TRF) is one of the main domestic agencies dominant in providing continuous support for research projects on climate change and related issues in Thailand. The TRF has funded climate change research projects for Thailand across 7 key areas of: 1) future climate modeling, 2) the factors influencing climate variations and change, 3) impacts of climate change, 4) adaptation to climate change, 5), international climate change negotiations, 6) policy support tools for implementation in Thailand, 7) production and activity sectors in potential and readiness of reduction of greenhouse gas (GHG) emissions, as well as 8) the compilation of knowledge on climate change.

3.3.6.2 Southeast Asia START Centre

The Southeast Asia START Centre is one of the eight existing regions of the Global Change StsTem for Analysis, Research and Training (START) network – jointly initiated by the International Geosphere-Biosphere Programme (IGBP), International Human Dimension Programme (IHDP), and the World Climate Research Programme (WCRP). SEA START RC is aimed at strengthening adaptive capacity of local agricultural communities via the development of seasonal climate prediction system and the use of the Southeast Asia regional climate downscaling funded through the Pacific Network for Global Change Research (APN), as well as assessing international arrangements and adaptation options to improve building climate change adaptation capacity and management of climate change issues in coastal megacities and in improving Thailand's flood management plan. Researchers from Ramkhamhaeng University and Chulalongkorn University have taken part in the Southeast Asia Regional Climate Downscaling (SEACLID)[147] project funded under the Asia Pacific Network for Global Climate Change Research (APN). SEACLID is the first regional climate downscaling in Southeast Asia that has been undertaken in a regional cooperative approach – involving various countries in the task sharing

3.3.6.3 Asian Development Bank

The Asian Development Bank ran a project completed in 2016 'Thailand: Strengthening integrated water and flood management implementation'[148] in the area upstream area of the Yom River basin and upper Chao Phraya watershed on strengthening regulation, as well as implementing structural and non-structural water management and flood control measures. This project was primarily aimed at improving decision-making processes for IWRM with a focus on flood management through national strategic directions for overall water resource management: the implementation of the National Strategic Plan for Water Resources Management and the new draft Water Resource Act. Specifically, this project followed five output: (i) guidelines and checklist for water management programs and projects adopted; (ii) guidelines and management information system for monitoring implementation and evaluating impacts of water management programs and projects installed; (iii) guidelines for water resources assessment and systems analysis of the Yom River basin proposed; (iv) appropriate methodology and approach for a systems analysis study of surface and groundwater in the Yom River basin proposed; and (v) Yom River basin consultative process and participation mechanism strengthened.

3.3.6.4 Japan International Cooperation Agency (JICA)

The JICA - ADAP-T Project (2016 – 2021) is a technical cooperation project which Kasetsart University is continuing from its preceding project called Integrated Study Project on Hydro-Meteorological Prediction and Adaptation to Climate Change in Thailand (IMPAC-T). The ADAP-T Project stands for 'Advancing co-design of integrated strategies with adaptation to climate change in Thailand'. It seeks to develop resilient and sustainable solutions

[147] Southeast Asia Regional Downscaling (SEACLID}/CORDEX Southeast Asia: http://www.ukm.edu.my/seaclid-cordex/
[148] ADB. 2016, 'Thailand: Strengthening integrated water and flood management implementation', Completion Report, Asian Development Bank. https://www.adb.org/sites/default/files/project-document/185308/46231-001-tcr.pdf

for climate change, and incorporate plans into the Climate change Master Plan of Thailand in the 2020 revisal. ADAP-T is focused on undertaking research and studies in the freshwater, forest, sediment, and coastal, urban and rural sectors. Specifically, it sets out three outputs: 1) to establish a knowledge base for climate change (database); 2) to identify appropriate adaptation measures for coastal, forestry, water, urban, rural, and sediment sectors; 3) to co-design adaptation options for the Thai government to utilize for climate change response.

The IMPAC-T project started in 2009 and ran for five years, aiming to develop an integrated data system of the Project's counterpart agencies for water related research. Both Thai and Japanese researchers also developed several models and assessed the data for prediction of climate patterns in the future. The main IMPAC-T counterparts are Kasetsart University, Royal Irrigation Department (RID), and Thai Meteorological Department (TMD). Much of the research is included in the Feasibility Study undertaken by RID.

Establishment of a support system for resolving water-related issues caused by climate change: This project is working to propose effective techniques for management of water resources and models for water-related disaster mitigation, and to create support systems for policy implementation. The existing rainfall observation networks of the Thai Meteorological Department and the Royal Irrigation Department and local survey information enhances the accuracy of numerical simulations, thereby leading to an integrated system for hydrological information that can be used for the estimation of variability of the hydrological cycle accompanying climate change and land use change.

Exploring flood adaptation strategies through field surveys in the Chao Phraya River basin: A system for accumulating observational data and a system that integrates the observational data and water resource management models were developed. In 2011, an emergency survey of flooding in the Chao Phraya River basin was conducted, and contributed to the planning for adaptation. In January 2014, the integrated system for hydrological information, incorporating the monitoring systems, has been launched.

3.3.6.5 Other

Thailand has a leading network of academics in the region, conducting and publishing on climate change. This is including around 30 lead author experts and researchers in compiling data, publishing papers and technical reports – as well as relevant information, climate change knowledge synthesis and identification of knowledge gaps. It includes the publishing of more than 1,000 papers, and technical reports, dissertations cited in multiple volumes of assessment reports, as well as a numerous scientific peer-reviewed international journal publications, particularly on climate variability and extremes, as well as future climate projections.

3.3.7 Framework for an effective Early Warning System

Thailand has *Drought and flood Databases and Hazard Mapping* and various Early Warning Systems set-ups for Tsunami, tropical cyclone and storm, flood, extreme temperatures, drought – as well as a National Disaster Warning Centre (NDWC), and decision support tool Disaster AWARE platform. However, these are primarily focused on tsunami and earthquake warnings, rather than climate impact related information and warning – and do not have an overarching framework to date. The Thai Meteorological Department currently undertakes early warning, and integration of Early Warning System in climate impacts brudges multiple jurisdictions including the Thai Meteorological Department (TMD), National Disaster Warning Centre (NDWC), the Department of Mineral Resources (DMR), the Royal Irrigation Department (RID) and the Department of Water Resources (DWR). Support to farmers in terms of early warning information is currently mostly provided through local level support from development agencies and civil society organisations (CSOs) in which to inform agricultural practice. Further support is required in improving climate information dissemination, as well as tailored climate information to farmers to improve for preparedness to climate change and variability.

3.3.8 Community-based organizations, Civil Society Organisations

CSOs provide support to farmers on climate change information in which to inform agricultural practices. Support to farmers is mostly at the local level supported by development agencies and CSO's for use of climate change information to inform agricultural practices. Support is needed to improve dissemination of tailored climate information to farmers to improve preparedness to changing climatic conditions.

3.3.9 Supporting working groups and networks

A number of committees, networks and working groups have been established that have relevance to the project.

3.3.9.1 Yom River Basin Ad Hoc Sub-committee

Yom River Basin catchment area covers 23,618 square kilometers of 11 provinces comprising of Payao, Nan, Lampang, Phare, Tak, Kampangphet, Sukhothai, Uttaradit, Phitsanulok, Pichit and Nakhon Sawan. In the dry season residents have been confronted with drought following with flood in the rainy season almost every year for decades. In the process of the budget allocation for the 2009 fiscal year, the ac-hoc sub-committee, was set up to find out solutions to tackle water resource related problems in the northern region, commissioning a study in order to establish a sustainable solutions under people participation concept in accordance with Prime Minister Office Regulation on Public Hearing B.E.2548.

3.3.9.2 Royal Irrigation Department at the Provincial levels

The main source of water for the first dry season rice is the remaining water from flood plus the irrigated water. For the second dry season rice, approximately 30 percent of households use underground water. However, both dry season rice cultivation need irrigation water. Before the cultivation of the second dry season, the royal irrigation department will inform farmers the quantity of water that would be released for agriculture each season which usually less then farmers' need. Moreover, royal irrigation department (RID) normally provides forecasting information of rainfall to village's leaders, water usage group through application LINE.

3.3.9.3 Water usage group

The Water Usage Groups are set up under the advice of Royal Irrigation Department (RID). After receiving information about the quantity of water that would be released (from reservoirs) especially for the second dry season cropping, water is allocated to members according to the conclusion from the water usage group meeting. There are two ways of using the limited water allocated. The first way is that each member will make a cultivation plan of how to use the limited water separately. The second way is that all members will make a plan of using limited water together and make cultivation in the same reduced land. The "Joint Management Committee for Irrigation (JMC)" operates water management in a single-command irrigated area

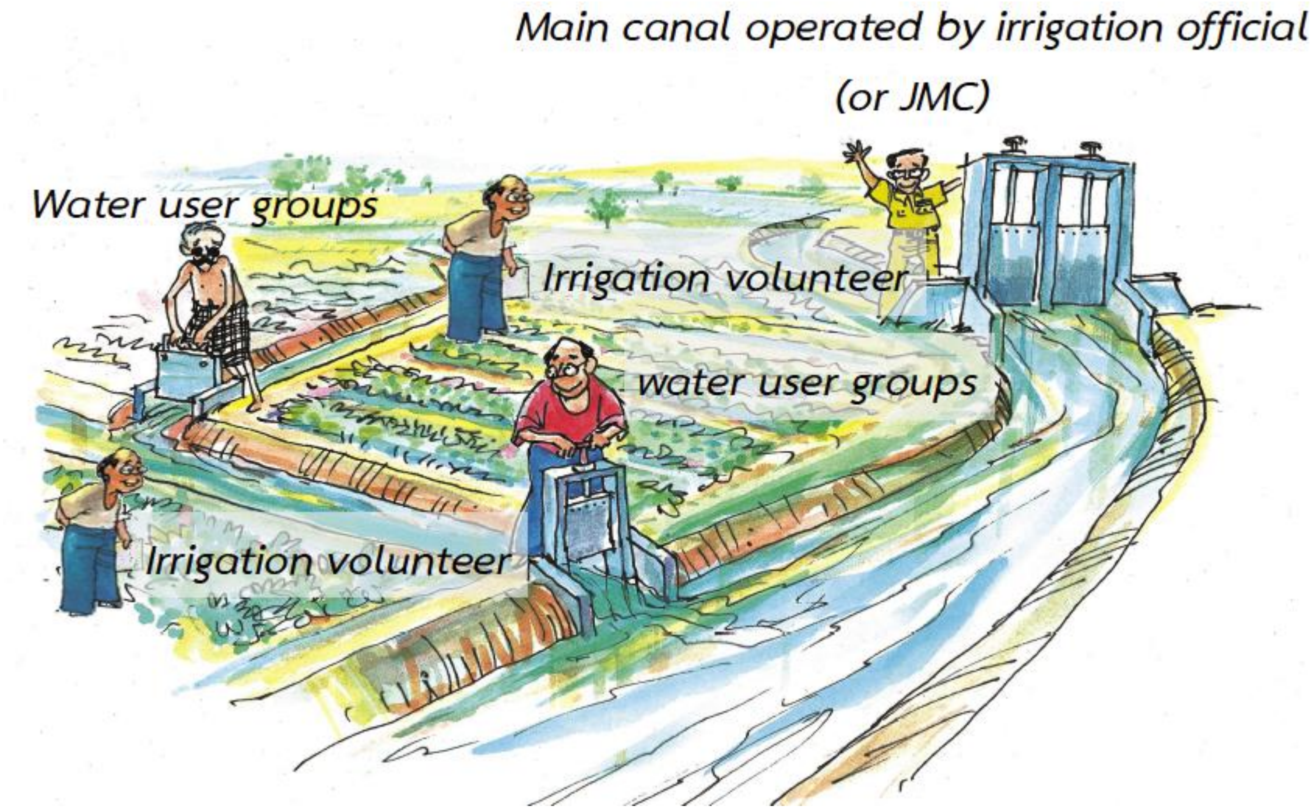


Figure 66: Operation of water allocation in a single-command irrigated area for dry-season management.

Source: Amnatsan, S. 2015, 'Dry season planning and management', Office of Water Management and Hydrology, Royal Irrigation Department

3.3.9.4 Agricultural and farmer support

Within the Yom-Nan River Basin area, several agricultural and farmer support networks and processes that operate for farmer support.

3.3.9.4.1 Village level information dissemination and support

Information received by farmers generally comes through village leaders who will usually distribute information received from civil organizations through village wire communication. Many civil organisations, and agricultural extension for instance, send information through the application LINE to village leaders. For information from RID, which consists of the forecast of rainfall, amount and time of water released are sent through application LINE too. Many civil organizations at provincial level always have various training programs such as the production of bio-fertilizer and hormone through the office of agricultural extension. Rural development officers do the training of household accounting and grouping, and the office of internal trading undertakes marketing strategy training. Each village usually has a number of groups that are active in providing agricultural and community support. These groups include savings groups, village fund groups (one million baht group), as well as the groups of the agricultural and cooperative banks (such as for loans, micro-credit and the like). Other groups that exist in a number of the villages include community business groups (e.g. community rice centre), but these mainly operate under government support and services.

4. Chapter 4: Past and ongoing efforts to improve resilience of the agricultural-based livelihoods and communities

4.1.1 Related sector projects that are ongoing with synergies to the GCF project:

Conserving Genetic Resources in Yom-Nan River / Centre for Building Capacity of Environmental CBO: The Centre for Building Capacity of Environmental CBO of Phitsanulok Province (CBO-PLK): Founded with accumulated experience of NGO active in lower northern region during the past six years, CBO-PLK is a centre for cooperation of multiple-sectors in rehabilitation of environment and community development with grass-root population as the main target. (Grant US$33,159, co-financing US$28,322, co-financing in-kind: US$426,736). It will be important to review and employ best practices of grass roots efforts in relation to the proposed project.

Sustainable management of biodiversity in Thailand's production landscape: This project between UNDP Thailand, and the Biodiversity-based Economy Development Office (BEDO) in the Ministry of Natural Resources and Environment (MoNRE) is intended to gain efficient community-based natural resources and environmental management in selected ecosystems with effective engagement of people's organisations in policy and decision-making processes affecting the environment and the use of local natural resources; increased capacity of national agencies to set policy priorities and remove barriers to pursuing sustainable management of biodiversity, renewable energy, and water resources in response to national priorities and in compliance with international treaties; promote community-based knowledge management by supporting formation of community networks and promote evidence-based policymaking at all levels. Given the role of communities in the proposed project, this project can help ensure effective engagement of people's organisations in policy and decision-making processes affecting the environment.

The Asian Development Bank's project in the river basins of Thailand is aimed at *Strengthening Integrated Water Resource Planning and Management at River Basin Level* (current), while the earlier project *Thailand: Strengthening Integrated Water and Flood Management Implementation*, provided support in developing planning and implementation procedures as well as guidelines for water project assessment, monitoring and evaluation. Where relevant, related measures can be guided work supported by ADB.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH Thailand and the Bureau of International Cooperation Department of Water Resources (DWR), Ministry of National Resources and Environment (MoNRE) - *Ecosystem-based Water Management in Upper River Basins in Thailand* project is aimed at improving the ecosystem of the upper River Basin area in 3 project sites (Tha Di Basin, Lam Pa Chi River Basin, Huai Sai Bat Basin) as well as contribute to climate protection and sustainable development by promoting green and grey measures in water management. As a partner to the proposed project, application of best practices and lessons learned can be ensured, as well as complementarity.

Cooling Earth by Families and Communities: is located in the lower portion of Nan River Basin in three districts of Phitsanuloke Province, with both wetlands and cultivated lands containing paddy fields and indigenous orchards. Several landraces and species are under threats from quick cash crop and energy crop promotion. Nan River and Yom River, which drains into Chao Phaya River, which are integrated ecosystems of the Gulf of Thailand. The project involves: Launching technical capacity building of target population through study tours and open forum; Demonstrating and putting into practice the built capacity through, i.e. carbon sequestration area, agro-ecology and community forest, low carbon technologies ;Conducting participatory evaluation, and; Disseminating project results to wider audiences (UNDP-GEF US$24,129).

Integrating Agriculture into NAPs (BMU/IKI), 2015-2019 (5 years), approximately 700,000 USD for country-specific technical support. Thailand is part of the global NAP-Ag Programme implemented by UNDP and FAO, which supports the development and implementation of a Climate Change Strategic Plan for the Agricultural Sector (2017-2021) in the Ministry of Agriculture and Cooperatives (MoAC) as well as horizontal integration in the NAP through the NAP pillar strategy for agriculture and food security. The NAP-Ag Programme provides technical knowledge and policy expertise to facilitate a participatory process engaging all departments of the MOAC and consulting relevant stakeholders. Collaboration between the NAP-Ag Programme, ONEP, the Risk-NAP project, and the Thailand NAP process includes participation in respective workshops, regular coordination meetings, and review and sharing of respective technical outputs.

As the two above projects are supported by UNDP, synergies and complementarity with the proposed project can be ensured.

4.2 Best practices and lessons learnt from implemented or on-going projects, as well as international best practices

This proposal includes a review of the best practices and lessons learnt both from implemented and on-going projects locally, nationally, regionally and internationally – in order to ensure that the project activities and approaches to achieving project outcomes are in accordance with the best available knowledge and practice that can be implemented to date.

4.2.1 Ecosystems based Adaptation

In comparison to 'grey' infrastructure, Ecosystem-based Adaptation (EbA) measures are often underestimated as efficient options for climate change adaptation. EbA measures can support several direct adaptation benefits related to the project, including mitigation of storms and flood damages (reduced loss and damage, incl downstream), ecosystem services (e.g. groundwater recharge), improved water retention/storage and more sustained farmland productivity during drought periods[149]. When complementing grey water management infrastructure, EbA measures can reduce soil erosion and sedimentation, which would otherwise affect the effectiveness and efficiency of the infrastructure.

The German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMU) supported the government of Thailand in its efforts to include the EbA approach into its water management system through the project Improved Management of Extreme Events through Ecosystem-based Adaptation in Watersheds (ECOSWat). The project started in 2013 with the 1st funding phase until mid-2016 and the 2nd phase until December 2017. Four main expected outputs were:

1) Water management institutions in the Chi and Tha Di catchment areas are using an information system for the development of the water management plans, which integrates data from DWR, RID, the respective River Basin Committee as well as of the local universities.
2) At least one ecosystem-based adaptation measure in the field of drought and flood prevention in the Chi and Tha Di catchment areas is implemented respectively.
3) Thailand's national adaptation strategy for the water sector includes ecosystem-based watershed management measures in the field of drought- and flood-prevention. Experiences from the pilot measures are integrated into national adaptation strategies.

[149] Valuing the Benefits, Costs and Impacts of Ecosystem-based Adaptation Measures A sourcebook of methods for decision-making; GIZ

4) DWR's and RID's responsible employees at national level are trained in the design of EbA measures.

An economic evaluation of EbA measures within the Huai Sai Bat and Tha Di river basin was conducted based on a Cost-Benefit-Analysis (CBA) of the proposed individual measures and of different scenarios representing varying combinations of the potential EbA measures identified in the report of Pre-Selection of Ecosystem-based Measures. Taking the example from Huai Sai Bat as a case study, four scenarios were developed to rank the identified potential measures in terms of their combined efficiency to counteract the water scarcity problem in the Huai Sai Bat Basin : Scenario 1 ("Engineering") consists only of dredging of the Nong Yai reservoir, Scenario 2 ("EbA") includes all EbA measures but no engineering measures, and Scenario 3 ("Hybrid") combines a reduced set of EbA measures with a dredging alternative of the reservoir. Scenario 4 is considered as the baseline scenario with ongoing regular dredging of the Nong Yai reservoir ("Business as usual") and no EbA measure. The study result showed that Scenario 3 ("Hybrid") with its measure combination that increases and secures the storage capacity of the Nong Yai reservoir appears to be the most promising alternative to safeguard the water security in the Huai Sai Bat river basin from considering total costs, BCR and the effectivity to secure high water storage capacity during the dry season.

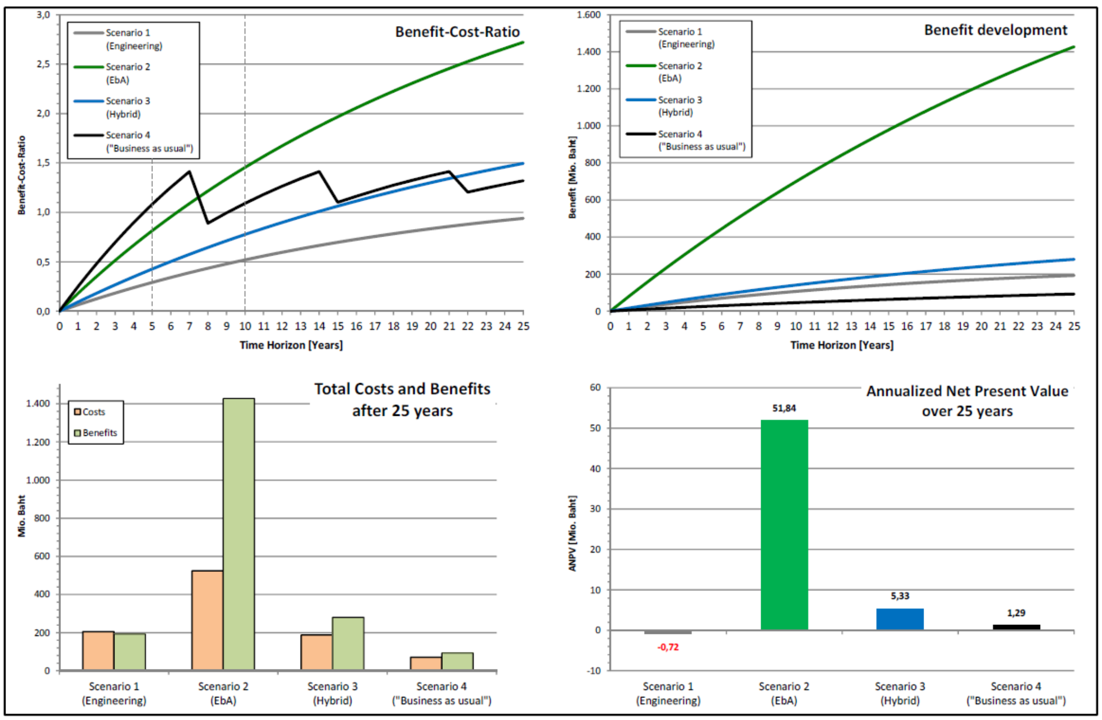


Figure 67: Results of economic evaluation for the Huai Sai Bat and Tha Di river basin.

It is also important to note challenges faced by ECOSWat. The project started in 2013 with the 1st funding phase until mid-2016 and the 2nd phase until December 2017. Four main expected outputs were:

1) Water management institutions in the Chi and Tha Di catchment areas are using an information system for the development of the water management plans, which integrates data from DWR, RID, the respective River Basin Committee as well as of the local universities.
2) At least one ecosystem-based adaptation measure in the field of drought and flood prevention in the Chi and Tha Di catchment areas is implemented respectively.
3) Thailand's national adaptation strategy for the water sector includes ecosystem-based watershed management measures in the field of drought- and flood-prevention. Experiences from the pilot measures are integrated into national adaptation strategies.

4) DWR's and RID's responsible employees at national level are trained in the design of EbA measures.

Evaluation of the ECOSWat project found that it was lacking participation, which partially led to a lack of ownership and unclear roles and responsibility of river basin committee. Lack of participation seemed to be caused by a combination of a top-down approach with technical analysis, and a disconnect between the project partner and its mandate (DWR – the main project partner – does not have the mandate to build these measures). At the regional level, River Basin Committees (RBC) was established by the government to help review activities and propose measures / projects and organize public hearings for the 25 river basins in Thailand. However, at the time, RBCs had a limited mandate and capacity. DWR assumes the role of the secretariat of RBCs. This has in part been resolved with the Thai Water Act adopted in 2018.

Water Resource Act, B.E. 2561 (2018) is bestowed by His Majesty King Maha Vajiralongkorn Bodindradebayavarangkun on 25th December B.E. 2561. This Act lies in putting forth efficiency and effectiveness of the administration of water resources in respect of the allocation, use, development, management, maintenance, rehabilitation and conservation thereof as well as rights in water, thereby benefiting the provision of public utility services and other public interests.

Under section 35 of the Water Resource Act B.E. 2561, a river basin committee has an important role for not only river basin level, but also national body. A river basin committee has the duties and powers in connection with water resources administration in the boundary of the river basin and shall also have the duties and powers including to prepare a master plan on the use, development, management, maintenance, rehabilitation and conservation of water resources in the boundary of the river basin and submit to the National Water Resources Committee (NWRC) for approval.

Incorporating lessons learned and to ensure sustainability of the new Thai German Climate Programme TGCP-Water component, it was recommended to focus specifically on the technical, on the institutional and on the operational level. Key recommendations included:

- Following-up with the training programme – strengthening capacity building
- Developing EbA guidelines focusing on methodologies and guidelines used by agencies will help ensure uptake and sustainability
- Making sure the project is aligned with national priorities and partners' mandates and frame it as a "value-added"
- Explicitly focusing on sustainability of the project from the start by for example having an exit strategy. Engaging other stakeholders especially on the "implementation" side including public & private stakeholders

In close cooperation with the Thai water sector, GIZ is currently in the process of developing an EbA Guidebook as a national standard for the systematic identification, prioritization and selection of EbA measures at river basin scale. The EbA Guidebook is to be complemented by a Code of Practice (CoP) for selected EbA measures that will cover specific design issues. The EbA Guidebook and CoP are to be finalized by end of 2021 and are planned to be published under the Thai Office of the National Water Resources (ONWR). RID and DWR are participating in the development of the EbA Guidebook and CoP. The national standard builds besides others on the Guidebook on Climate Risk Assessment for Ecosystem-based Adaptation and joint cause-impact chain analysis as key elements of a joint prioritization and selection process for effective EbA measures. https://www.adaptationcommunity.net/wp-content/uploads/2018/06/giz-eurac-unu-2018-en-guidebook-climate-risk-asessment-eba.pdf.
A more detailed review of the ECOSwat and TGCP-Water has been provided as document under Annex 18 of the funding proposal package.

Selected EbA measures should be integrated in a climate-sensitive River Basin Management approach (reflected in the River Basin Master Plan – RBMP) that builds on climate risk and vulnerability information and an integrated water resources management (IWRM) concept. Quantity & quality of societal benefits are to be reflected as well (in terms of impact on livelihoods e.g. source of income, reduced risks as well as in terms of ecosystem services e.g. reduced erosion, extreme event buffering for flood and drought situations).

Following consultation with government partners and key stakeholders, a number of EbA measures have been identified which could be suitable in the GCF project sites (particularly Pichai Srinakorn, Khonkairas, Sawankha Lok, Promphiram, Bangrakham and Muang Phitsahulok). These include: wetland / floodplain / oxbow lake restoration; living weir; riparian zone rehabilitation / bank stabilization by vetiver grass, buffer zones, sedimentation traps and/or an appropriate combination of measures. These measures are further explained below.

4.2.1.1 Restoration of riparian zones, buffer zones and sediment traps

Riparian zones act as the link between terrestrial and aquatic ecosystems and play a vital ecological function in both of these systems. Riparian land supports an array of biodiverse species, as well as playing a number of ecological service roles. In particular, riparian zones when restored and ecologically managed, provide ecological services in reducing pollutants, sediments, as well as trapping and retaining nutrients. Pollutants tend to be attached to sediment particles, and intact riparian vegetation will trap sediment in a process of biofilitration. Riparian buffer zones are the most effective in providing these ecological services of filtration and sediment trapping when they are wide (e.g. required usually at a minimum of 20m).

'Plants in riparian areas filter ground and surface water moving into streams' and are able to 'absorb, hold and use such of the water that flow off from these sources and able to chemically and biologically bind or detoxify contaminants contained.'[150] Healthy riparian vegetation also plays a dual role of cooling water temperatures by providing shade through vegetation cover, as well as producing tannin (the amber colour in water which then reduces light penetration of the water), as well as increasing dissolved oxygen levels. A healthy riparian zone, will, under healthy watershed conditions, filter water across the landscape and result in minimal runoff and erosion reaching to riparian zones. Healthy riparian buffers hold a diversity of vegetation that catches eroded sediments and prevents them from entering streams. Yet, the diversity of plants that they hold also facilitate water filtration and take up many nutrients otherwise carried into rivers by runoff and groundwater. As riparian areas have unique soil profiles of sediment and soil environment, they provide favourable conditions for the chemical and biological degradation of many soil pollutants and containments. However, in unhealthy watershed conditions – a healthy riparian zone will be unable to absorb and filter large volumes of water, nutrients and contaminants when land management practices across the watershed are not managed properly in terms of soil conservation and water resources.[151]

Riparian areas play a vital role in the functioning of the entire river system. Naturally vegetated riparian areas also can reduce the force, height and volume of floodwaters throughout particular points on river systems – as they can promote the spread of water horizontally along the floodway and across floodplains. Vegetation can also have the double-benefit of slowing and hence raising water levels in other areas (retention), so flood management

[150] Monteron, M. & Tampus, A. 'Discharge zones riparian vegetation: Domains and characteristics', *The Track on Internet Things of INRIT 2016, Impact Forum, Sapphire 118, Bangkok, Thailand, 6 July 2016*
[151] Monteron, M. & Tampus, A. 'Discharge zones riparian vegetation: Domains and characteristics', *The Track on Internet Things of INRIT 2016, Impact Forum, Sapphire 118, Bangkok, Thailand, 6 July 2016*

through vegetation should be carefully planned.[152]

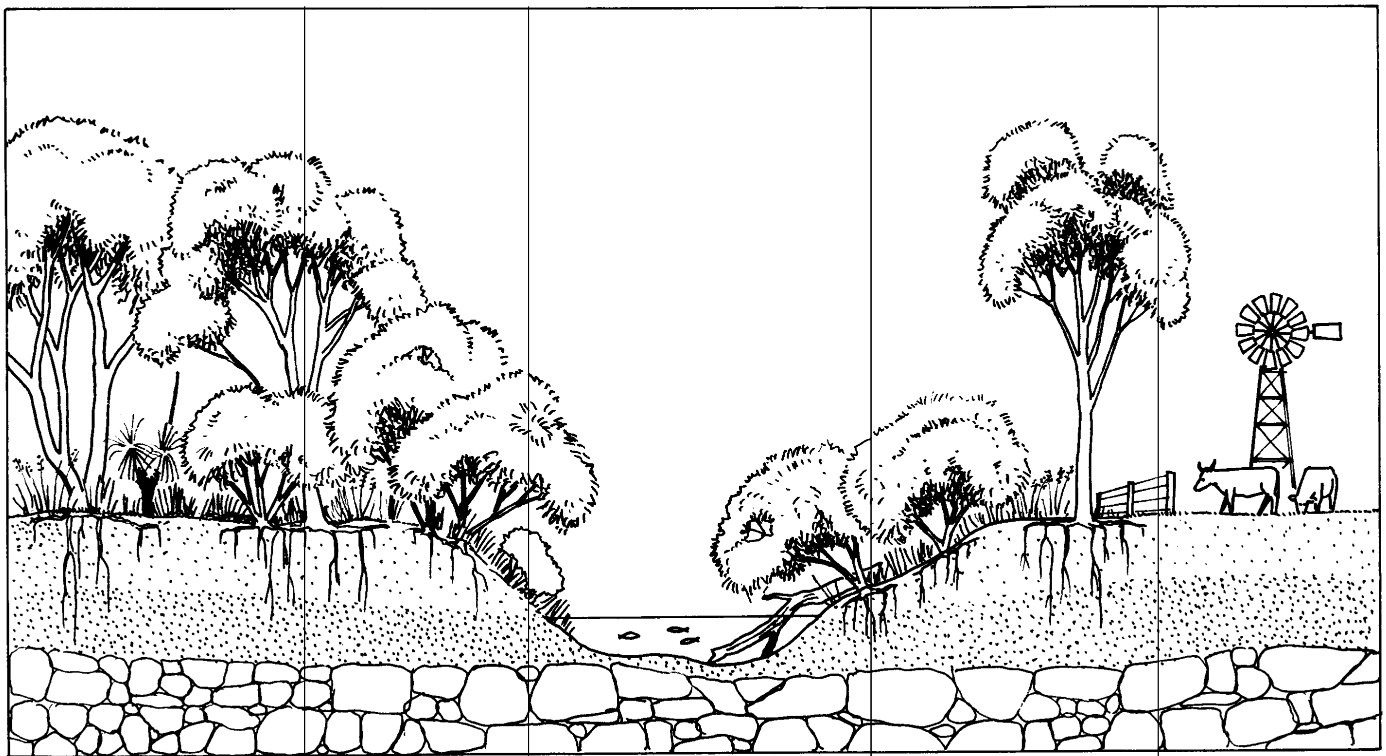


Figure 68: Some values of the riparian zone
Source: Water and rivers Commission, Western Australia. Waterways WA Program[153]

Changes that have occurred in hydrological systems – will most likely also reflect changes in riparian vegetation.

River restoration requires the results of the modeling (see point 4.3.9.1 and 4.3.9.2) to establish the duration of curves and depth-discharge to be shaped. Using results from hydrological, water needs, erosion and sediment flow modeling, the shape of cross-sections can be designed, and berms can be positioned at a height that allows plants to survive as well as for their selection according to expected number of days of inundation. Inundation ultimately should occur occasionally, but not permanently throughout the wet-season. Frequent flood levels should submerge the berms, while the mean conditions should remain beneath the berms.

[152] Natural Heritage Trust. 2000, 'Water notes: The values of the riparian zone', *Advisory notes for land managers on river and wetland restoration*, Water and rivers commission. https://www.water.wa.gov.au/__data/assets/pdf_file/0008/3113/11441.pdf
[153] Natural Heritage Trust. 2000, 'Water notes: The values of the riparian zone', *Advisory notes for land managers on river and wetland restoration*, Water and rivers commission. https://www.water.wa.gov.au/__data/assets/pdf_file/0008/3113/11441.pdf

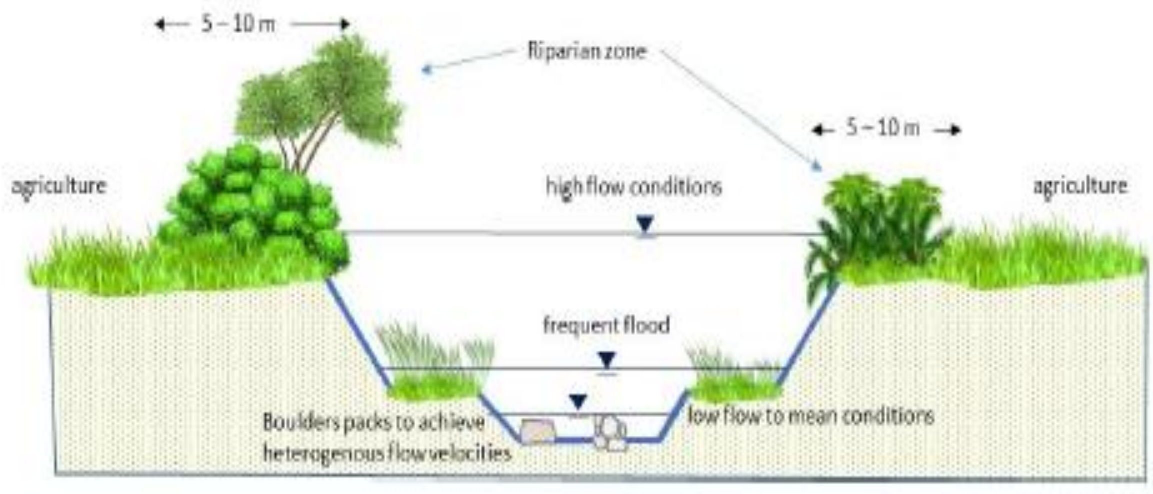


Figure 69: Example of a typical cross-section with berms and vegetation

Additionally, hydraulic calculations need to be adjusted in two ways for naturally shaped cross-sections with vegetation. Ideally, where weediness is common and unavoidable (as in most cases), it should be considered in regard to the hydraulic calculations, in terms of the coefficients that need to be adjusted. Secondly, vegetation within cross-sections is exposed to the flow velocity, and the strength of the vegetation to resist the force of the flow should be taken into consideration and assessed.

Critical flow velocities for various vegetation can be obtained according to guidelines.[154] The higher the elasticity of plants is the higher the resistance itself against force of flow – so flexible plants would be the best to use in flood exposed sections for vegetation. Vegetation planning for river restoration requires information on the velocities of the water flow, as well as careful consideration regarding localization. Attention should be paid to properly locate vegetation in zones with reduced velocities where possible.

Cross-sections should also be widened regularly within a river reach, in order to create pools with lower flow velocities and to allow for the development of rich habitats and generate additional water storage. However, this will rely on long term negotiations and effective engagement for balancing resource land allocation and use between water, agricultural and ecosystem requirements.

4.2.1.2 Bank stabilization by vetiver grass

Vetiver grass, known as the living barrier, assists in preventing erosion and maintaining topsoils. Soil degradation problems are an additional impact of climate change due to the increased intensity of the heavier rainfall pattern, cyclone, flooding, and landslides. Growing Vetiver grass as part of soil conservation system reduces run-off and soil loss and an increase in nitrogen levels for fertile soil, whilst also promoting good water holding capacity. Vetiver hedges are feasible to control flood flow and erosion on cropped flood plains and land slopes between 0.5-2 percent.

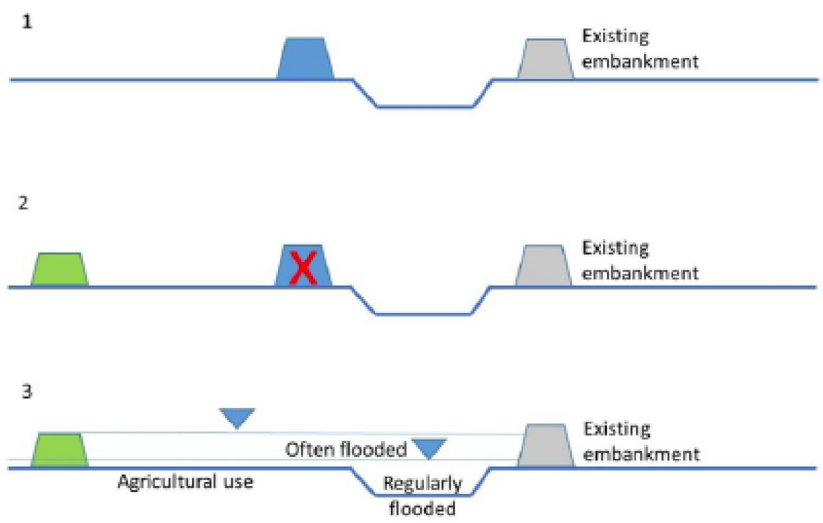
4.2.1.3 Floodplain restoration

Floodplains tend to provide a ‘win-win’ example for delaying excess water from causing significant inundation and

[154] Fischenich, C. 2001, Stability Thresholds for Stream Restoration Materials. U.S. Army Corps of Engineers Ecosystem Management and Restoration Research Program

flood damage to agricultural, residential, urban or industrial areas. By being set up as target zones to receive water the establishment of flood plains as an adaptation measures, also has bonus benefits of creating and maintaining aquatic, riparian and terrestrial habitats, as well as in increasing groundwater recharge. Flood plains benefit from being regularly inundated.

As part of improvements to the restoring the flood plain of the Old Yom River, the large areas of still ecologically sound riverbanks and floodplains should be enhanced. Infrastructure designs (6.4.2. – Technical designs) will need to alter design from the standard (business as usual) approach where by embankments are enacted along both sides of the river bank, in order to control the flooding process. The concept for erecting embankments on two sides of the river banks is to be able to control keeping water at the beginning of the rainy season inside the embankments, and to open the gates to flood the hinterland when harvests are finished. In this way, inundation of agricultural land is delayed by means of retaining water volumes in the cross sections, as shown in the comparison below. The diagram below demonstrates possible ecologically-based adaptive design that promotes the restoration of the floodplain through dyke setbacks. Point one shows the business as usual approach to designing flood embankments and the current setting for river enhancement infrastructure pre-ecosystem based adaptation transformative design. Point 2 and 3 then show the positioning of the dyke setback to allow greater volumes of water to enter the plains.



The dyke can be setback at greater distance from the river to allow for the existing floodplains and assist in both restoring and conserving their ecological service functions. The volume of water gained in the floodplain should outstrip the water that can be stored in the riverbed with high embankments, and should in turn, result also in a longer time for preventing the hinterland from flooding.

The figures below show as example, two sections of the Yom-Nan area where natural floodplains exist and can be preserved in this way. Natural floodplains such as these examples, should be preserved as a cut-off from the main riverbed by heightened embankments or dykes – as such embankments would destroy these ecosystems, and subsequently, these areas would lose their ability to regulate water flows and provide complete ecological services in terms of water storage and flood protection.

Figure 70: Floodplain area in the Yom-Nan River System area

Figure 71: Floodplain incursion for agricultural use in the floodplain area in the Yom-Nan River system area

Farmers adjacent to the river systems have long lived with flooding regimes, and have adjusted to frequent flooding and farmed with methods reflecting this. However, in certain sections, farmers have also encroached on the existing floodplains within the Yom-Nan project area. In the example above, for example, farmers have encroached on RID river adjacent land to make use of the fertile soil for selling. This demonstrates some of the uses competing with the natural ecological needs of the river system in terms of space for the river.

River system restoration

Trapezoidal forms with berms on both sides will be renewed and reshaped in order to facilitate low flow in mean flow conditions. The berms on the outer sides of the river, become submerged when flow conditions exceed the mean water level.

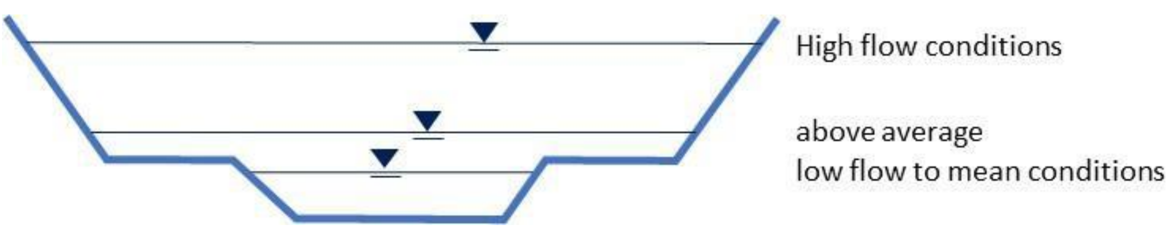


Figure 72: Standard cross-section with berms

4.2.2 Monkey cheek

Monkey Cheek is a flood-control concept initiated by His Majesty King Bhumiphol, who observed that most monkeys, when they obtain bananas, usually store them in their mouths, and then gradually chew and swallow them. The concept of water detention is to temporarily store excessive water during flooding period and afterwards gradually drain it, once the floods recede. However, in natural canals or lowland areas, there are no hydraulic structures to control and retard the floodwater as in irrigation project. Therefore, use of irrigation project areas to store excessive floodwater is a solution to alleviate downstream flooding. The Monkey Cheek concept is also useful, as stated by King Bhumibol Adulyadej in 2003, the "...Monkey Cheek reservoirs are needed in order to retain water when the sea water rises, and water excess cannot be drained. During the flooding season between September and November, the seawater will push water in rivers until it reaches Ayuthaya province, which will make it impossible to drain excessive rainwater into the sea. As a result, the areas along the Chao Phraya River in the lower Central Plains will remain flooded. Therefore, we need Monkey Cheek reservoirs" to receive water excess during the flooding season[155]. An example of successful 'Monkey Cheek' project is the Mahachai-Sanamchai Canal Monkey Cheek Project (Royal Initiative Project). This project was studied by using the developed mathematical model to simulate flooding condition in 2011 in cases of with-and without-project. The result revealed effectiveness of floodwater detention to reduce flood depth and inundated area. The Monkey cheek in this section was developed in order to alleviate some of the flooding problem in the West Bank of the Chao Phraya River – and including the west of Bangkok. The monkey cheek works to alleviate some of the wastewater problem, to protect from saltwater intrusion, and to store water for other activities such as agriculture, fisheries, and so forth. The Monkey Cheek can store 6 million cubic metres of water. This concept will be applied to lowland and irrigation project areas in the Yom and Nan River Basins tributaries of the Chao Phraya River Basin, north of Nakhon Sawan province in Thailand.

Building on lessons learned of previous efforts, investments in monkey cheeks for the Yom-Nan area must follow a consultative process with farmers, with adequate awareness raising and knowledge sharing about the project, as well as with measures in place for financial compensation for farmers where necessary (http://agritrop.cirad.fr/594430/1/DifficultEncountersAroundMonkeyCheeks2019.pdf).

4.2.3 Other adaptation measures applied in Thailand

- The 'living weir' concept is in practice already in Thailand, and falls into line with the Sufficiency Economy principle in its application of applied technology combined with local knowledge and local community practices. By constructing bamboo grids in rivers in which biodegradable sand bags are placed, an initial structure is made. These sand bags contain a combination of manure, coconut coir, and sand – on which vegetation can be established to stabilise soils. Usually using Banyan trees (ficus bengalensis) and legume plants; the Banyan trees have formed roots that over decades re-structure strong, living, river banks as they mature. These 'living weirs' then assist to improve the groundwater recharge, as well as increasing fish habitat and their ability to move along the river (e.g. climb upstream) and the development of surrounding species (plant and animal) biodiversity. Local communities can also undertake any ongoing maintenance that is needed.
- For drought protection, the Royal project for drought protection focuses on forest rehabilitation using temporary weirs, to prevent deforestation and the resulting desertification caused by deforestation through parts of Thailand. This technique renews forest by using a technique that traps water with numerous small temporary checkdams built out of earth and stone, or even bamboo. The areas using this process have been promoted under the late HM the King's initiatives through the programme 'Village that learn' of Royal Development Study Centre.

[155] Suppaisarn, C. (2011) 'Medium and Heavy Flood Management in Chao Phraya River Basin Following the Royal Initiative'. TRF Seminar, 2 Dec. 2011.

- Between 1984 and 1987, H.M. King Bhumipol suggested the use of good quality water to dilute polluted water and also water hyacinth as well as aquatic plants to filter the water. The development of waste water treatment using techniques, including: 1) The Lagoon Treatment System, 2) The Artificially Constructed Wetland System, 3) The Grass Filtration System 4) The Red and White Mangrove System and Ornamental species plant appearance[156] and 5) Chaipattana technology, which is a low speed surface aerator paddle-wheel machine in the form of a floating buoy that helps add oxygen to water and can be operated in tidal polluted water treating waste water - particularly as it sucks water from the bottom to mix with air, in the process improving the movement and circulation below the water surface and improving the overall water quality.[157]
- Traditional houses in the flood plain and river basin areas fared better during flood events than non-traditionally constructed houses and structures.[158] In flood plain areas, Thai houses are structured as stilt houses in the central region. Long overhanging eaves can protect from sun or rain, while the wide terrace outside the house is suitable for summer use. Additionally, there is the high open space under the house for use as storage of tools or agricultural equipment, parking, eating meals and other activities.[159]

4.2.4 Soil Conservation and Conservation Agriculture Practices

2.

Soil conservation and biodiversity was formalized in the United Nations Convention on Biological Diversity (UNCBD) in 1992, in order to ensure ecosystem function, and resect for organisms of every size in the role that they play within ecosystem function. The World Soil Charter (2015) states, that 'soils are a key reservoir of global biodiversity, which ranges from micro-organisms to flora and fauna. This biodiversity has a fundamental role in supporting soil functions and therefore ecosystem goods and services associated with soils. Therefore, it is necessary to maintain soil biodiversity to safeguard these functions' (FAO, 2015:2-3).[160] Global soil carbon stocks in agricultural land have significantly decline and continue to do so. [161] Soil erosion associated with conventional agricultural practices can occur at rates up to 100 times greater than the rate at which natural soil formation takes place. [162] Soils and therefore soil conservation play a key role in pooling active carbon and in the global carbon cycle. The intensification of agricultural production has played a key role in altering the relationship and influence of greenhouse gas emissions particularly through intensive tillage and soil carbon loss. A 1 percent reduction of soil organic carbon in the top (30cm) topsoil layer results roughly losses of 45 tons of carbon per hectare, equivalent to 166 tons of Co2 per hectare to the atmosphere. [163]

Conservation agriculture not only restores some of the lost soil organic carbon, but also increases soil fertility and the long-term sustainability of agriculture and food security.

[156] D. Konnerup, T. Koottatep, and H. Brix, "Treatment of domestic wastewater in tropical, subsurface flow constructed wetlands planted with Canna and Heliconia," Ecological Engineering, vol. 35, no. 2, pp. 248–257, 2009.
[157] Aruninta, A.2009, 'WiMBY: A comparative interests analysis of the heterogeneity of redevelopment of publicly owned vacant land', *Landscape and Urban Planning*, Vol. 93, Iss. 1. Pp 38-45
[158] *World Bank Rapid Assessment*
[159] National Identity Office, Office of the Permanent Secretary, the Prime Minister's Office (1993). Ruen Thai. Thailand: National Identity Office, Office of the Permanent Secretary, the Prime Minister's Office.
[160] FAO. 2015. Revised World Soil Charter. Rome: Food and Agriculture Organization of the United Nations.
[161] Gattinger, A., Muller, A., Haeni, M. Skinner, C., Fliessbach, A., Buchmann, N., Mader, P., Stolze, M., Smith, P., El-Hage Scialabba, N. & Niggli, U. 2012, 'Enhanced top soil carbon stocks under organic farming', *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 109, No. 44.
[162] Montgomery, D.R. (2007). Soil erosion and agricultural sustainability. Proceedings of the National Academy of Sciences, 104, 13268-13272
[163] ECAF. 2012, *Conservation Agriculture and the CAP 2020,* Position Paper 2011/2012, European Conservation Agriculture Federation

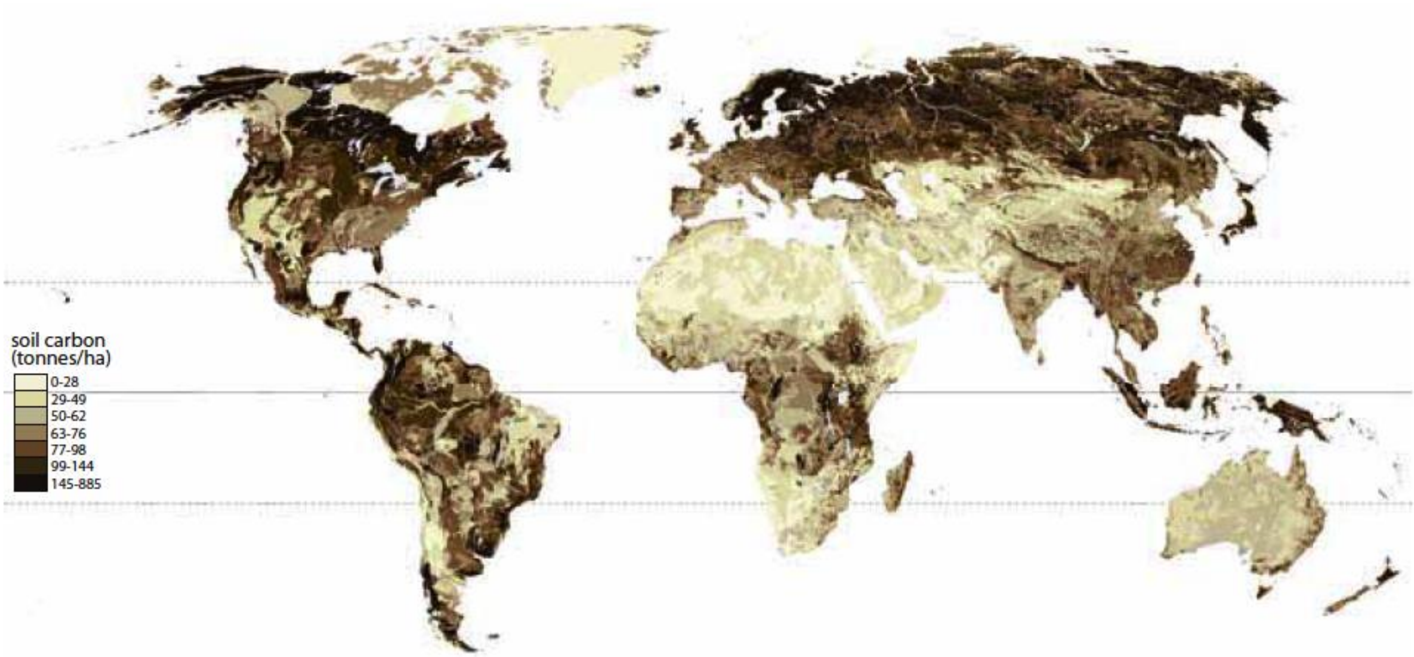


Figure 73 Organic soil carbon to a depth of 1 metre in tonnes per hectare from Harmonised World Soil Database V1.1 data.

Source: UNEP-WCMC, 2009 UNEP-WCMC (2009). Updated global carbon map. Poster presented at the UNFCCC COP, Copenhagen.: Scharlemann et al. on methodology in preparation (2012)

Soil organic carbon stocks are estimated to be around 1500 Petagrams (Pg) of carbon in the first top metre of soil[164]. Although this estimate varies significantly depending on spatial distributions and temporal variability – the level of carbon is more than is contained in the atmosphere (which is roughly 800 PgC), and in terrestrial vegetation (500 PgC), even when the two are combined.[165] This reservoir of soil carbon is not static but constantly cycles. Sequestration occurring through soil organic carbon runs in three stages – 1) the removal of carbon from the atmosphere via plant photosynthesis, followed by 2) the transfer of carbon from carbon to plant biomass, and then 3) the transfer of carbon from the plant biomass into the soil where it becomes stored.[166].

Carbon on local scales can be lost or gained through soil erosion or deposition, leading to the redistribution of soil carbon on either local, landscape or regional scales. In turn, storage of soil organic carbon is controlled by managing the levels of organic residues that enter the soil, and minimizing the losses (FAO, 2016). Managing soil organic carbon, by enhancing ecosystem function – inadvertently supports food security, water resources, biodiversity, and increased levels of resilience in buffering climate change impacts, and climate change mitigation. According to FAO (2016), research indicates that soil biodiversity can be maintained as well as partially restored if it is managed sustainably – through improved restorative practices that promote ecological complexity and robust soil biodiversity. The diagram below provides an overview to the relationships between soil biodiversity and carbon cycling.

[164] FAO 2017. Soil Organic Carbon: the hidden potential. Food and Agriculture Organization of the United Nations, Rome, Italy
[165] FAO 2017. Soil Organic Carbon: the hidden potential. Food and Agriculture Organization of the United Nations, Rome, Italy
[166] FAO 2017. Soil Organic Carbon: the hidden potential. Food and Agriculture Organization of the United Nations, Rome, Italy

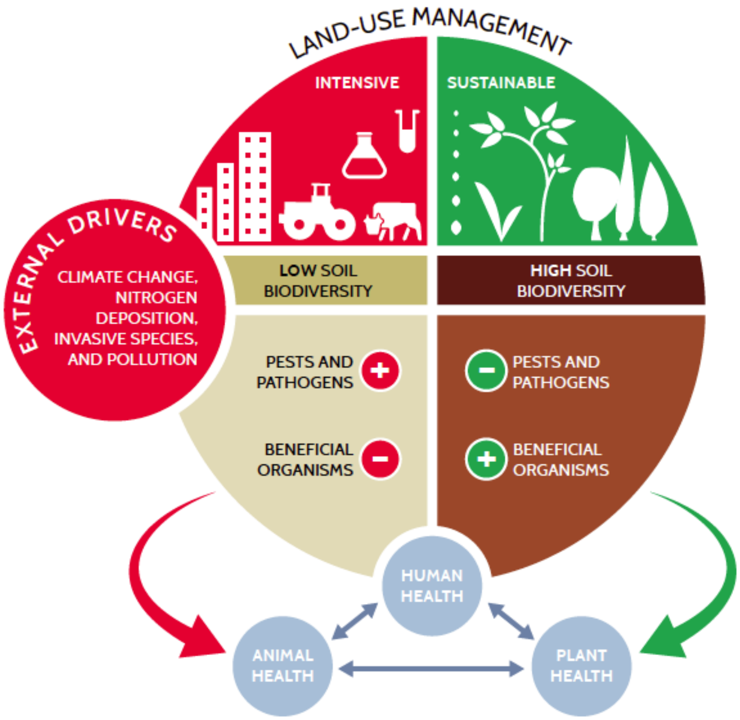


Figure 74 Impact of land use decisions on soil biodiversity

Source: Modified from Wall et al. 2015[167], in FAO, 2016.

Benefits of maintaining healthy soils: [168]

- Plant growth and surface mulches can help protect the soil surface, as well as provide stable, well-aggregated soil structure that resists surface sealing and continues to infiltrate water during intense rainfall events. This in turn will decrease the potential for downstream flooding.
- Porosity determines the capacity of the soil to retain water and controls transmission of water through the soil. In addition to total porosity, the continuity and structure of the pore network are important to these functions and also to the further function of filtering out contaminants in flow (see FAO and ITPS, 2015).
- Water stored in soil serves as the source for 90 percent of the world's agricultural production and represents about 65 percent of global fresh water (see Amundson et al., 2015).[169]

Maintaining healthy soils is assisted also by improving crop varieties, extending crop rotations (notably those with grass-clover or forage legume leys that allocate more carbon below-ground), avoiding or reducing use of bare (unplanted) fallow, and the application of organic fertilizer such as compost or waste products from livestock husbandry in the form of slurry or stacked manure. Core agricultural practices where crop production relies in large part on closed nutrient cycles by returning plant residues and manures from livestock back to the land and/or

[167] Wall, D. H., Nielson, U. N. & Six, J. 2015. Soil biodiversity and human health. Nature, 528: 69-76.
[168] FAO 2017. Soil Organic Carbon: the hidden potential. Food and Agriculture Organization of the United Nations, Rome, Italy
[169] Amundson, R., Berhe, A. A., Hopmans, J. W., Olson, C., Sztein, A. E. & Sparks, D. L. 2015. Soil and human security in the 21st century. Science, 348(6235).

by integrating perennial plants are all of benefit.[170] Sustainable Agriculture, agro-ecology, organic farming, conservation agriculture and integrated practices – are therefore thought to lead to a reduction in soil carbon losses and potentially higher soil carbon concentrations over time, whilst also providing several co-benefits of assisting agricultural resilience to climate change, enhancing biodiversity, and soil conservation – in turn also leading to improved, and more climate resilient livelihoods and food security outcomes. For a typical farming system with 100kg N/ha applied, the equivalent of around 465kg of CO2 per hectare (or 127 kg Co2-C/ha) is emitted.[171] Sequestering soil organic carbon from plant biomass offers some emissions offsetting for agricultural emissions. When soil and conservation agriculture is practiced with soil fertility built in at the farm level, along with soil protected from compaction, and the soil biodiversity is enhanced and/or nurtured; then not only is soil organic carbon sequestered, but stream, lakes and rivers are more protected from sediment and nutrient runoff from agricultural fields. Similarly, increasing cropping system complexity holds additional benefits of diversity of crop root depths and patterns (retaining soil), crop residue qualities and greater carbon inputs. [172] Soils store more carbon (1500Pg) than vegetation (650Pg) and the atmosphere (750Pg) does. A study in 2012[173] found that at conservative estimates, in reviewing 74 studies reporting on soil organic carbon stocks – that organic soil carbon stocks were 3.50 ± 1.08 Mg C ha^{-1} higher, and sequestration rates were 0.45 ± 0.21 Mg C ha^{-1} y^{-1} higher than in nonorganically managed soils: that organic farming practice lead to Soil Organic Carbon (SOC) stocks in the upper 20 cm of soil over a period of ca. 14 years that are 3.50 ± 1.08 Mg C ha^{-1} higher in organic than in nonorganic systems. One way to reduce soil carbon release is to stop burning straw in the rice paddies (Reeves, 1997; Bird et al., 2001; Follett et al., 2005). The burning of this organic matter obstructs the increasing levels of carbon accumulation in soil because the organic matter is lost during the burning process.[174]

[170] Gattinger, A., Muller, A., Haeni, M. Skinner, C., Fliessbach, A., Buchmann, N., Mader, P., Stolze, M., Smith, P., El-Hage Scialabba, N. & Niggli, U. 2012, 'Enhanced top soil carbon stocks under organic farming', *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 109, No. 44.

[171] Franzluebbers, A. 2009, 'Soil organic carbon sequestration with conservation agriculture in the Southeastern USA: Potential and limitation', USAD Agricultural Research Service and Food and Agriculture Organisation (FAO).

[172] Franzluebbers, A. 2009, 'Soil organic carbon sequestration with conservation agriculture in the Southeastern USA: Potential and limitation', USAD Agricultural Research Service and Food and Agriculture Organisation (FAO).

[173] Gattinger, A., Muller, A., Haeni, M. Skinner, C., Fliessbach, A., Buchmann, N., Mader, P., Stolze, M., Smith, P., El-Hage Scialabba, N. & Niggli, U. 2012, 'Enhanced top soil carbon stocks under organic farming', *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 109, No. 44.

[174] Arunrat, N., Pumijumnong, N. & Phinchongsakuldit, A. 2014, 'Estimating soil carbon sequestration in rice paddies as influenced by climate change under scenario A2 and B2 of an i-EPIC model in Thailand', *Environment Asia*, 7:1, Pp65-80.

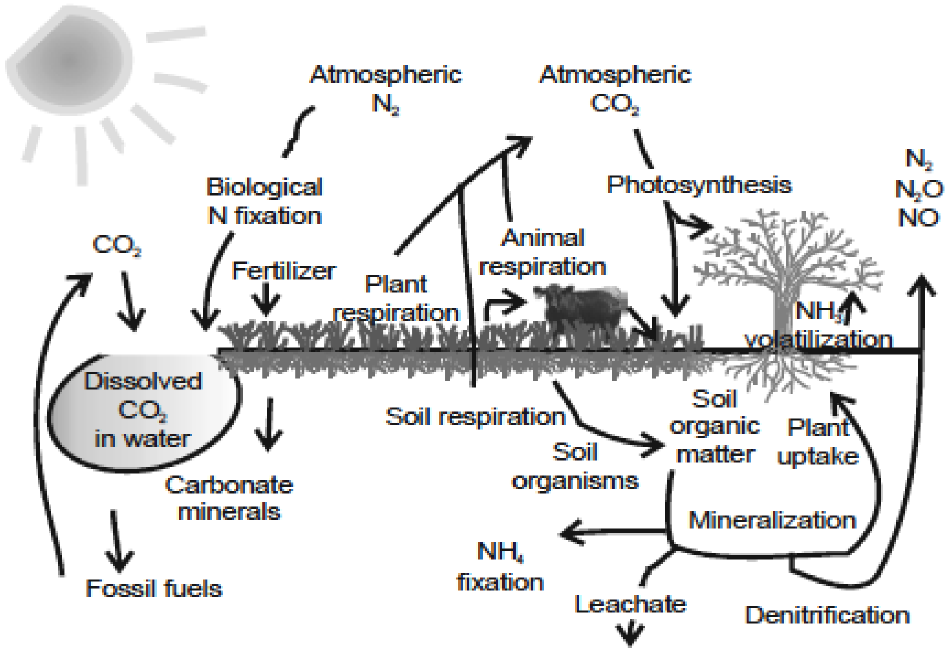


Figure 75: Illustration of the terrestrial carbon cycle

Source: FAO: Franzluebbers, A. 2009, 'Soil organic carbon sequestration with conservation agriculture in the Southeastern USA: Potential and limitation', USAD Agricultural Research Service and Food and Agriculture Organisation (FAO).

A considerable part of the depleted soil organic carbon (SOC) pool can be restored through conversion of marginal lands into restorative land uses, adoption of conservation tillage with cover crops and crop residue mulch, nutrient cycling including the use of compost and manure, and other systems of sustainable management of soil and water resources. Ensuring that carbon inputs to the soil are greater than carbon losses from the soil can enhance carbon stocks. Different strategies are required to achieve this objective, depending on land use, soil properties, and climate and land area.[175] Measured rates of soil carbon sequestration through adoption of recommended management practices range from 50 to 1000 kg/ha/year.[176] Estimates are also given that in tropical climates, organic composting use can add around 30 percent to the soil organic carbon[177] While estimates for Italy suggests that additional uptake of organic soil carbon through appropriate soil management can be gained by a minimum reduction of 12.8 tonnes of CO2 per hectare.[178] Evaluation tools for measuring carbon sequestration and GHG reductions from conservation agriculture practices are available online, such as the USDA Comet-Planner.[179] For example, when all the conservation agriculture practices are implemented on 1 acre, the total CO2 equivalent greenhouse gas emissions per year sequestered or reduced are 24 tons, when applied in the south east of the US.

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[175] Reynaldo, R. et al., 2012, 'The Benefits of Soil Carbon: Managing soils for multiple economic, societal and environmental benefits', UNEP Year Book 2012

[176] Lal, R. 2004, 'Soil carbon sequestration to mitigate climate change', *Geoderma 123, Pp 1-22*

[177] Binder, C. & Patzel, N. 2001, 'Preserving tropical soil organic matter at watershed level. A possible contribution of urban organic wastes', *Nutrient cycling in Agroecosystems*, Vol. 61., Iss. 1. Pp 171-181

[178] Brenna, S., Acutis, M., Tabaglio, V. & Grandi, M. 2014, 'Conservation Agriculture as a driver for Carbon Credit market', Green Carbon Conference

[179] http://comet-planner.com/

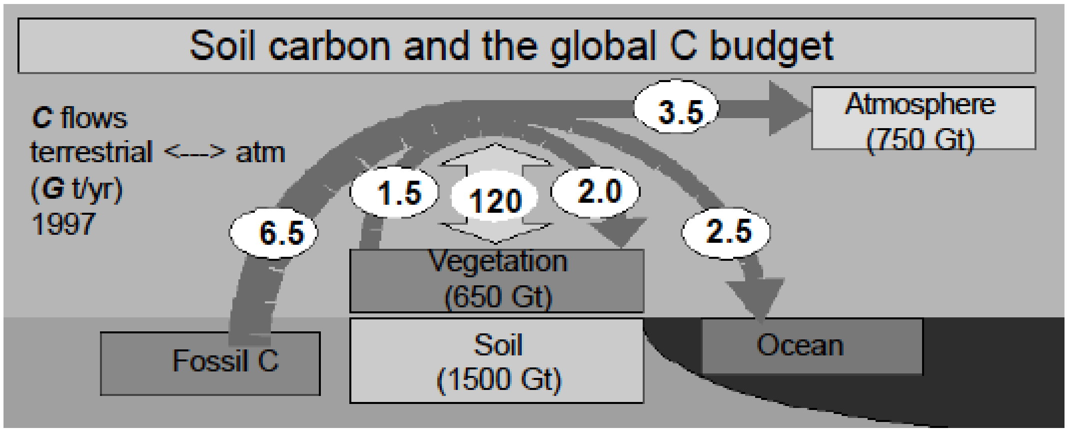

Figure 76: the terrestrial carbon cycle: soil carbon and the global carbon budget after the International Geosphere Biosphere Programme 1998

Source: Robert, M. 2001. 'Soil carbon sequestration for improved land management', World Soil Resources Reports No. 96, Food and Agriculture Organisation of the United Nations (FAO).

In Thailand, the estimation of the distributions of organic carbon content in country showed that most of the soils at depth 0-25cm contain the amount of soil organic carbon, (SOC) 40-80 ton ha-1 covering an area of 2,222 ×106 ha (43.3% of country area). The SOC contents of 20-40 ton ha-1 covered an area of 1,710 ×106 ha (33.3% of country area) and < 20 ton ha-1 covering an area of 361 ×106 ha (7.03% of country area). At depth 0-100 cm, covering the area of 2065 ×106 ha (40.25% of country area) contains the soil organic carbon of 40-80 ton ha-1. Most of the remainder contains the amount of organic carbon over 80 ton ha-1 and a small amount under 40 ton ha-1. In 2008, the data of organic carbon (OC) contents were reported that the OC contents were classified as low soil OC (OC < 0.29-0.86%) covered in 38% of the total soil survey area.[180]

Stopping erosion by implementing a system of surface mulching is an effective way to retain soil carbon, as the carbon content is found to be 2-3 times higher in the eroded sediment than in the undisturbed soil. Tillage practices adapted to maintain top reside on the soil surface (minimum tillage, surface mulching, tillage by chisel and disc plough) can then return 5-30 percent of the top residues (500-1000 kg/ha) leading to a stabilization of soil carbon content. In addition, the management of wetlands has also a largely unknown potential for carbon sequestration. All of Thailand has been surveyed and mapped at the scale of 1/50 000 by the Land Development Department over the last decades. This unique effort in Southeast Asia has provided the basic data about soil organic and inorganic carbon for most soil series. At the depth of 25 cm soil organic carbon (SOC) was 4-8 kg/m2 in the central, northern and southern regions and 2-4 kg/m2 in the other regions, except in the mountains still under forest where soil organic carbon ranged from 8 to 9 kg/m2. [181] The gravity of deforestation, drought and flooding has become a major issue, affecting soil fertility and top production. Recent farmers' practices in some cultivated areas, particularly orchards; fruit trees and vegetable gardens, often use too many chemical fertilisers, pesticides, fungicides and other chemicals to increase trop yields. In general, the soil organic carbon content in agricultural areas is lower than 0.5 percent. In this regard, soil organic carbon recycling and organic fertilizer utilization play a prominent role in soil conservation and improvement of the soil organic carbon (SOC) content.[182]

Estimates on the rate of soil loss in the north of Thailand are around 42.24 kilograms per hectare per year due to

[180] Jaiarree, S. 2010, 'Soil management for maximizing carbon sequestration in Thailand', Research and Development for Degraded Soil Division, Office of Research and Development for Land Management, Land Development Department, Ministry of Agriculture and Cooperatives, *Proceeding of the International Workshop on Evaluation and Sustainable Management of Soil Carbon Sequestration in Asian Countries*, Bogor, Indonesia. Sept 28-29, 2010.
[181] Limtong, P. & Srikhajon, M. 2002, 'Soil organic carbon and carbon sequestration. Present situation and research needs in Thailand', Land Development Department, Ministry of Agriculture and Cooperatives.
[182] Limtong, P. & Srikhajon, M. 2002, 'Soil organic carbon and carbon sequestration. Present situation and research needs in Thailand', Land Development Department, Ministry of Agriculture and Cooperatives.

erosion. [183]

Region	Watershed area (mha)	Annual runoff (mcm/yr)	Suspended sediment (t/yr)	OC in sediment (t/yr)
North	1.16	48.2	10.4	0.44
Northeast	0.74	29.8	4.2	0.14
Central/East	0.77	45.1	13,3	0.15
South	0.53	75.6	3.1	0.62

Table 45: The amount of suspended organic carbon of sediment in runoff is also high

Source: Source: Limtong, P. & Srikhajon, M. 2002, 'Soil organic carbon and carbon sequestration. Present situation and research needs in Thailand', Land Development Department, Ministry of Agriculture and Cooperatives.

Type	Amount (mt/yr)	Application/mass rate (t/ha)	OC content	OC sequestrated (t/ha)
Crotalaria juncea	N/A	20.67	47.04	9.72
Canavalia	N/A	11.53	49.51	5.71
Vigna ssp.	N/A	14.92	46.47	6.93
Sesbania rostrata	N/A	11	48.70	5.36
Vetiver grass	N/A	4.41	53.90	2.38
Ruzi grass	N/A	14.01	51.62	7.23
Cattle manure	15.81	25	20.89	5.22
Pig manure	3.61	25	25.56	6.39
Poultry manure	3.12	25	24.55	6.14
Bagasse	100,000	25	15.98	3.99
Eucalyptus chips	50,000	25	17.12	4.28
Rice husk and straw	30,000	25	17.12	4.28

Table 46: Potential carbon sequestration by adding/incorporating crop residues, compost and/or manure

Source: Limtong, P. & Srikhajon, M. 2002, 'Soil organic carbon and carbon sequestration. Present situation and research needs in Thailand', Land Development Department, Ministry of Agriculture and Cooperatives.

Soil organic carbon content showed a decreasing trend under B2 and A2 climate scenarios (average 0.87 percent and 0.85 percent, respectively) compared to the reference from 2007 (average 0.92 percent).[184] Increasing the soil carbon content in agricultural lands is likely to result in a significant improvement of soil and water quality, a decrease in nutrient loss, a decrease in soil erosion, an increase in water conservation and soil moisture, and an increase in crop production. [185] The total pool of initial carbon (TPIC) of soil illustrates that the average TPIC of both the major and second rice production during the growing season was 0.81 percent and 0.77 percent, respectively, whereas the soil organic carbon level averaged 0.77 percent and 0.73 percent during the major rice growing season and the second rice growing season, respectively.[186]

[183] Limtong, P. & Srikhajon, M. 2002, 'Soil organic carbon and carbon sequestration. Present situation and research needs in Thailand', Land Development Department, Ministry of Agriculture and Cooperatives.
[184] Arunrat, N., Pumijumnong, N. & Phinchongsakuldit, A. 2014, 'Estimating soil carbon sequestration in rice paddies as influenced by climate change under scenario A2 and B2 of an i-EPIC model in Thailand', *Environment Asia*, 7:1, Pp65-80.
[185] Arunrat, N., Pumijumnong, N. & Phinchongsakuldit, A. 2014, 'Estimating soil carbon sequestration in rice paddies as influenced by climate change under scenario A2 and B2 of an i-EPIC model in Thailand', *Environment Asia*, 7:1, Pp65-80.
[186] Arunrat, N., Pumijumnong, N. & Phinchongsakuldit, A. 2014, 'Estimating soil carbon sequestration in rice paddies as influenced by climate change under scenario A2 and B2 of an i-EPIC model in Thailand', *Environment Asia*, 7:1, Pp65-80.

In general, the soil organic carbon level in the rice paddy in the central region of Thailand was found to be at a medium level. Provinces with high soil organic carbon levels included Nakhon Pathom, Pathum Thani, Nonthaburi,

Region	Major rice				Second rice			
	Soil organic carbon (%)	Soil temperature (°C)	Carbon loss with residue decomposition (%)	Biomass pool carbon (%)	Soil organic carbon (%)	Soil temperature (°C)	Carbon loss with residue decomposition (%)	Biomass pool carbon (%)
2007 (REF scenario)								
Central	0.848	26.68	0.035	0.0195	0.797	26.64	0.036	0.0172
Eastern	1.246	26.97	0.031	0.0367	1.057	26.87	0.040	0.0265
Northern	0.725	26.32	0.039	0.0137	0.728	26.30	0.039	0.0140
Northeastern	0.554	26.78	0.029	0.0098	0.558	26.78	0.030	0.0097
Southern	0.775	26.68	0.050	0.0110	0.779	26.66	0.050	0.0111
Western	0.477	26.37	0.030	0.0067	0.479	26.36	0.030	0.0068
A2 scenario								
Central	0.852	28.80	0.033	0.0198	0.800	28.76	0.034	0.0177
Eastern	1.247	29.26	0.031	0.0368	1.060	29.21	0.039	0.0270
Northern	0.731	26.70	0.036	0.0141	0.733	26.68	0.035	0.0145
Northeastern	0.556	27.91	0.027	0.0102	0.560	27.89	0.028	0.0103
Southern	0.779	29.32	0.048	0.0110	0.780	29.29	0.052	0.0113
Western	0.482	29.53	0.029	0.0072	0.487	29.48	0.030	0.0073
B2 scenario								
Central	0.853	27.78	0.032	0.0199	0.800	27.74	0.033	0.0177
Eastern	1.248	28.55	0.030	0.0371	1.060	28.50	0.039	0.0268
Northern	0.732	26.21	0.035	0.0141	0.732	26.21	0.035	0.0145
Northeastern	0.558	26.99	0.026	0.0102	0.559	26.97	0.027	0.0103
Southern	0.777	30.17	0.048	0.0109	0.779	30.13	0.051	0.0111
Western	0.482	29.55	0.029	0.0071	0.486	29.48	0.029	0.0073

Phra Nakhon Si Ayutthaya, Nakhon Nayok, Suphanburi, Ang Thong, Singburi, and Saraburi, respectively. Provinces with a medium level of soil organic carbon were Phitsanulok, Lop Buri, Phetchabun, ChaiNat, Phichit, Sukhothai, Nakhon Sawan, and Bangkok. Areas with low soil organic carbon levels included Uthai Thani, and Samut Prakan[187]

Table 47: Simulation results of major and second rice dived according to regions across Thailand.

Source: Arunrat, N., Pumijumnong, N. & Phinchongsakuldit, A. 2014, 'Estimating soil carbon sequestration in rice paddies as influenced by climate change under scenario A2 and B2 of an i-EPIC model in Thailand', *Environment Asia*, 7:1, Pp65-80.

[187] Arunrat, N., Pumijumnong, N. & Phinchongsakuldit, A. 2014, 'Estimating soil carbon sequestration in rice paddies as influenced by climate change under scenario A2 and B2 of an i-EPIC model in Thailand', Environment Asia, 7:1, Pp65-80.

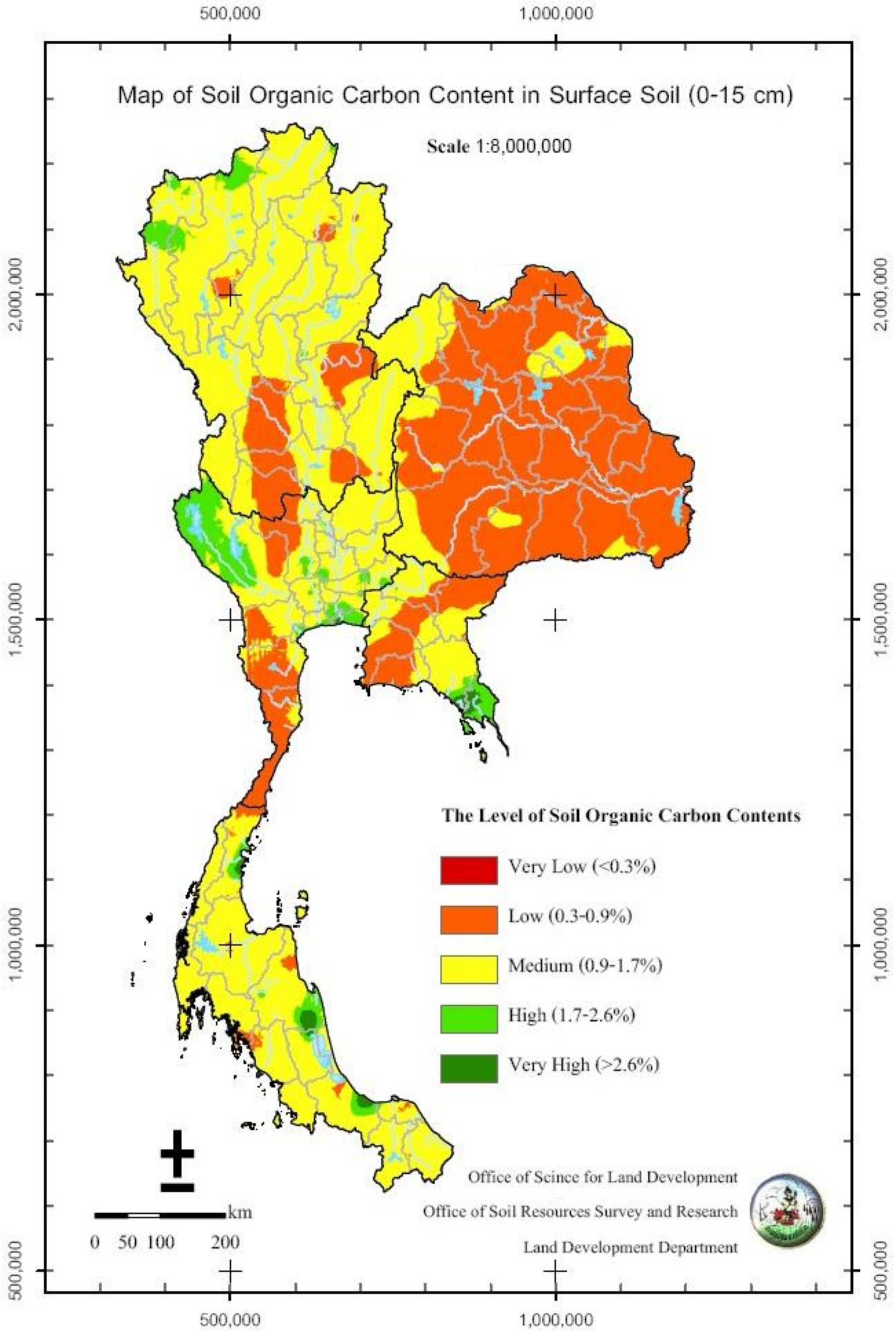

Figure 77: Soil Organic Carbon levels in Thailand, 2008

Source: Jaiarree, S. 2010, 'Soil management for maximizing carbon sequestration in Thailand', Research and Development for Degraded Soil Division, Office of Research and Development for Land Management[188]

Estimates for the application of crop residue alone, are at an application of 12.5 tons per hectare, which will accumulate 5.88-7.29 tons per hectare of soil organic carbon. No-tillage is a key principle under conservation agriculture, and works on the basis of increasing soil organic carbon and soil organic matter and mircobes in soil conservation. Conservation agriculture systems have three guiding principles that can be globally applied: minimizing soil disturbance, consistent with sustainable production; maximizing soil surface cover by managing crops, pastures and crop residues; and stimulating biological activity through crop rotations, cover crops and integrated nutrient and pest management.[189]

4.2.5 Climate resilient ecological/climate resilient agriculture

A significant number of best practice irrigation techniques and options are available for utilisation. A number of these have already been implemented, while some, such as integrated rice-fish management have a traditional basis in the Yom and Nam River Basin area, that has been significantly loss of recent decades and can be strengthened for a 'resurgence' given the level of resilience it bolsters to agricultural livelihoods.

Best practice irrigation techniques (see, for example, FAO, 2013[190]), are not limited to, but include the following:

- The cleaning (and maintenance) of irrigation canals and drainage channels.
- Lining of canals.
- Construction and rehabilitation of canal structures, as well as pumping stations, and small water storage facilities.
- Implementation of efficient irrigation systems, including low pressure pipeline water delivery systems, sprinklers, and micro and drip irrigation systems.
- Water monitoring, measurement and management.
- Changed design of irrigation channels to prevent risks from increased peak flows.
- The downscaling of Global Climate Model (GCM) output data for processing, and hydrological model development for irrigation water resources estimation.
- Design of new infrastructure with consideration of climate change impacts.
- Designs based on increased flood protection levels (i.e. beyond the 100 year flood estimate).
- Modification of design standards for water infrastructure such as new dams and levees in order to accommodate increases in flooding and extreme storm events, including updating of modeling protocols and precipitation data for use in all design work and analysis.
- Inclusion of climate change projection in both water supply and water quality planning to enhance reliability, as well as to improve stream flows, fish passage, as well as water quality.

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[188] Jaiarree, S. 2010, 'Soil management for maximizing carbon sequestration in Thailand', Research and Development for Degraded Soil Division, Office of Research and Development for Land Management, Land Development Department, Ministry of Agriculture and Cooperatives, Proceeding of the International Workshop on Evaluation and Sustainable Management of Soil Carbon Sequestration in Asian Countries, Bogor, Indonesia. Sept 28-29, 2010.
[189] FAO. 2008, 'Soil carbon sequestration in conservation agriculture: A Framework for valuing soil carbon as a critical ecosystem service', United Nations Food and Agriculture Organization.
[190] FAO. 2013, *Climate Smart Agriculture Sourcebook*, Food and Agriculture Organisation of the United Nations (FAO).

- Adoption of a range of water harvesting techniques such as low-cost groundwater recharge methods, climate proofed medium reservoirs, water use efficient irrigation systems and so forth.
- Efficient management of water via canals, lakes and ponds, in combination with soil conservation (e.g. through swales, terraces, platforms), crop type use – and water harvesting techniques through dams, percolation tanks and agricultural practices using contour bunding, and gully plugging.
- On farm storage for improved access and retention of on farm water management.
- Wetting front detectors.
- Rehabilitation of existing irrigation systems to reduce water loss and allow for the expansion of the storage capacity of ponds to cope with longer dry seasons due to climate change.
- Introduction or 're'introduction of aquaculture along irrigation system canals. Maintaining aquaculture systems separate from natural water bodies will allow a reduction of impacts to the natural systems – as well as reducing the aquaculture's exposure to climate-driven vulnerabilities.
- In the case of rice agriculture: alternating wet and dry (AWD) irrigation.
- Installing innovative climate-smart irrigation program (CSIP) based on a computerized regional network of agro-meteorological stations, which provides farmers with daily climatic data information necessary to tend crops in terms of water, and to take into consideration the specific and microclimatic conditions of where their crops are located.
- The renovation of community ponds and adoption of micro-irrigation facilities.
- Installation of water efficient irrigation systems through technologies such as drip irrigation and grey water recycling practices.
- The expansion of storage capacity of existing irrigation systems in order to be able to manage more frequent extreme weather events.
- The maintenance and repair of existing irrigation systems to reduce water loss.
- The harvesting and storing of rainwater for agricultural use, capturing the runoff from on-farm buildings for reuse.
- Support aquifer storage by capturing runoff, and enhance groundwater recharge, considering adequate environmental protections.
- Limit groundwater extraction, in order to avoid groundwater depletion.
- The integration of surface water diversions and groundwater pumping in order to prevent groundwater overdraft and the related environmental impact, whilst also reducing pressure on surface water resources at times of low flow, and high environmental sensitivity.
- Implement measures to reduce erosion and polluted runoff.
- Use riparian vegetation and vegetated swales to slow bank erosion and filter drainage water from rice fields and other agricultural areas.
- Employ slow-forming terraces, constructed from a combination of infiltration ditches, hedgerows and earth or stonewalls, to decrease runoff and increase infilitration.
- Employ conservation tillage and cover crops in order to reduce erosion and improve water quality.
- Use runoff containment in reservoirs.

- Undertake the restoration of wetlands in order to filter pollutants and sediment.
- Provide assistance and incentive to farmers and landowners to restore wetlands, both upland and in riparian zones in order to increase the capacity for natural water storage.
- Installation or development of an automated gauging or reporting network, for water in rivers across public supply reservoirs and in aquifers – in order to provide the basis of a statewide early-warning system for recognizing supply shortages.
- Implement asset management planning (AMP) that identifies asset stock such as canals, drains, structures and forth, and assesses its performance and condition quantitatively in terms of providing an estimate of the investment required to maintain the system performance, or improve the condition through upgrade, to improve or extend its performance.
- Identification of lead times for adaptive construction so that time frames for infrastructure rehabilitation and replacement can be considered and factored into budget planning timeframes accordingly.

4.2.5.1 Agroecology,

Agroecology is the process of integrating ecological principles into agricultural practices – as the name agro-ecology suggests. Interpretations range across types of farming practice. Agroecology relies substantially on indigenous agricultural knowledge processes, and shares similarities that blend with sustainable agriculture and integrated farming systems. The principles of agroecology are based on nutrient recycling, energy recycling – rather than reliance on external inputs, and include the integration of crops and livestock, diversification of species and genetic resources, over land and time, and a focus on the interactivity and productivity across the agricultural system –rather than on individual species (e.g. monoculture approach).

Examples of options under agroecology,[191] include:

- Ducks and rice – integrated farming: 2-3 weeks following rice planting, ducks patrol rice paddies to feed on unwanted pests, whilst fertilizing and enhancing the soil (aeration/soil oxygenation and nutrients), weeding service and additional incomes.

- Ancient and modern aquaponics combined – a combination of aquaculture and soiless plants (hydroponics); crops grow in the bodies of water which contain fish – so that chemical fertilisers are not needed, as fertilisers come from fish waste. The plants in turn filter and cleanse the water and render the appropriate conditions for the fish.

- Integrated micro-organisms systems – a system originating also in Thailand which uses minimal interference, e.g. no tillage, no chemical pesticides or fertilisers, however, instead rely on the use of effective microorganisms (Ems). By enriching soils with EMs, soil activity and fertility is increased, plant growth is stimulated, and crop yields are increased with the ecological balance retained in the system.

- Polyculture farming – which attempts to replicate the diversity of a natural ecosystem within an agricultural system, using multicropping, multiple animals species and so forth in a closed loop system to produce more fertility, more biodiversity and more productivity as a result.

[191] Worldwatch Institute: Agrcolecology at its best http://blogs.worldwatch.org/nourishingtheplanet/five-holistic-alternative-farming-methods-agroecology-at-its-best/

Agricultural production, including rice farming, relies on ecosystem management in order to be able to cultivate output. In the case of the Chao Phraya River Basin area, as is also the case in much of Thailand, application of agricultural science has increased output to be extracted from limited resources.[192] Increased yields however, also threaten the sustainability of the system with a narrowed focus on individual nutrients, pests or genetic materials.[193] The problems of the Thai rice industry are several and severe. Thai rice farmers have operated under what is essentially a command economy for generations and have worked increasingly marginal land. This has involved an increasingly risky relationship with water, despite the development of Thailand's dams and irrigation networks, and global climate change will only make matters worse. [194] The government in response is now pushing for the incorporation of sustainable agricultural practices, in line with the Philosophy of Sufficiency Economy, to diversify and manage risk, particularly in the face of increasing drought and climate change impacts. Agro-ecology focuses on the entire food system, from all aspects – social, economic and ecological and interacts closely with climate-smart agriculture.

4.2.5.2 Integrated farming

Integrated farming systems, are agricultural systems based on whole farm management and sustainable agriculture principles. Crop diversification in integrated farming practices has been so effective in rice growing areas – growing flowering crops between and beside rice fields that it has reduced insecticide spraying by 70 percent (by attracting and supporting parasitoids and predators by providing flower nectar), as well as increasing yields by 5 percent. [195]

4.2.5.3 Precision Agriculture

Precision agriculture refers to the use of technology to assess exact needs of the soil and crops. Sensors and drones are used to collect data and release only the needed amount of water or pesticide. As a result, it is water efficient and could be a viable adaptation option for some farmers. Other benefits include reduced crop loss, increased yield and savings from reduced pesticide and water use. Generally, precision agriculture is applied by larger farms. For individual small holder farmers, the cost of the technology may be prohibitive, and the small size of the plots may not merit the investment. However, combining adjacent farm plots and sharing costs across a number of smallholder farmers can help reduce financial risk – bridging the technology gap between large and small farms.

Applying the Internet of Things concept (see figure below), data can also be collected and analyzed by authorities to prepare for, assess risk or respond to extreme events, as well as for water management and agriculture planning. This is consistent with the Ministry of Digital Economy and Society's vision to promote and support the digital economy in line with national policies "Thailand 4.0". There is therefore an incentive for public investment to support uptake of this technology on a broader scale, which should be further explored.

[192] Rerkasem, B. 2015, 'The Agroecosystem of Thai Rice: a Review', *Plant Genetic Resource and Nutrition Laboratory, Chiang Mai University*
[193] Rerkasem, B. 2015, 'The Agroecosystem of Thai Rice: a Review', *Plant Genetic Resource and Nutrition Laboratory, Chiang Mai University*
[194] Draper, J. 2014, 'Can Thailand's rice industry go organic?', Bangkok Post, http://www.bangkokpost.com/opinion/opinion/436494/can-thailand-s-rice-industry-go-organic

[195] Gurr, G., Zhongxian, L., Zheng, X., Xu, H., Zhu, P., Chen, G., Yao, X., Cheng, J., Zhu, Z., Catindig, J., Villareal, S., Chien, H., Cuong, L., Channoo, C., Chengwattana, N., Lan, L., Hai, L., Chaiwong, J., Nicol, H., Perovic, D., Wratten, S. & Heong, K. 2016, 'Multi-country evidence that crop diversification promotes ecological intensification of agriculture', *Nature Plants 2,* No. 16014

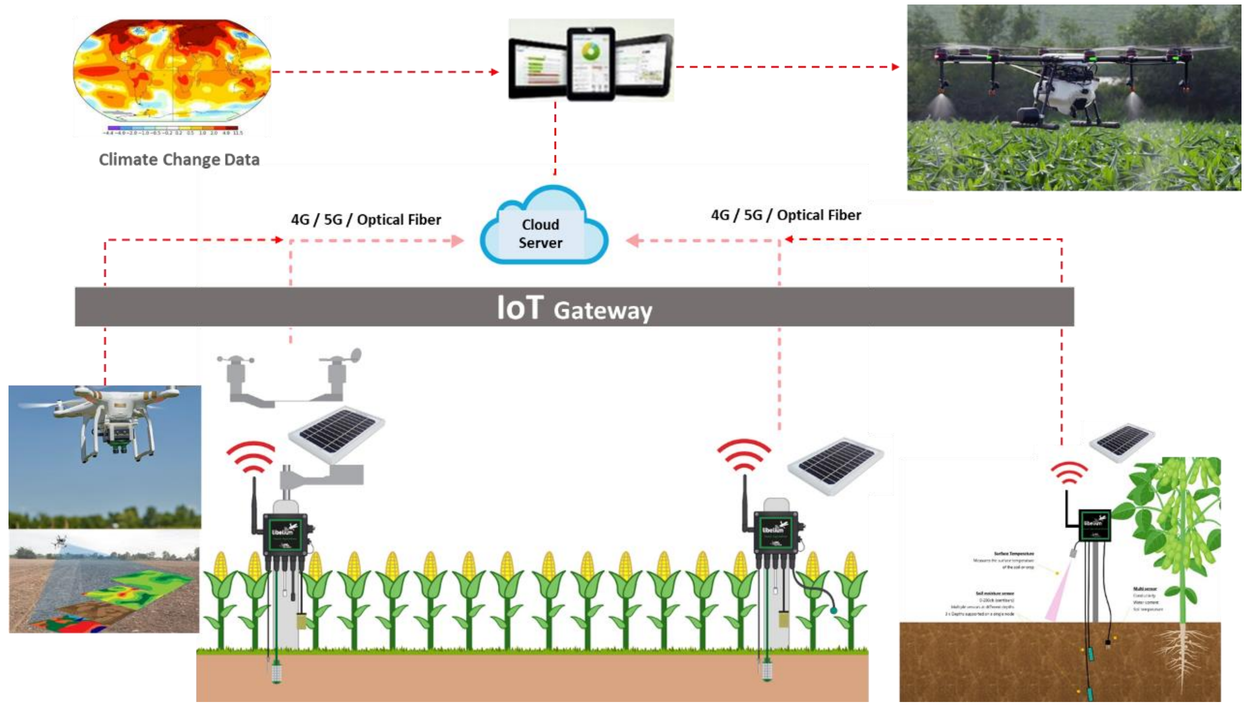


Figure 78: Concept of IoT framework for Smart farming

4.2.5.4 System of rice intensification (SRI)/Alternate Wetting and Drying (AWD)

AWD applies simple and low costs tube to monitor the depth of the water table in the field. Once the water level reaches 15cm below the surface of the soil, water is added to 5cm at the time of flowering, from 1 week before to 1 week after the maximum flowering. The water in the rice field needs to be kept at 5cm depth to avoid any water stress that would result in severe loss in rice grain yield. A cost benefit analysis conducted showed significant reductions in water use from conventional methods to SRI, while showing increases in yield.

	Conventional system		SRI	
Soil types	Min.	Max.	Min.	Max.
Clay soil	15,054.50	16,844.50	9,932.50	13,057.50
Sandy loam	15,054.50	17,033.70	9,932.50	13,134.50

Table 48: Total amount of water use under conventional and SRI system for 1 season (m3/ha). [196]

	Conventional system		SRI	
Soil types	Min.	Max.	Min.	Max.
Clay soil	7,280.00	12,137.50	6,000.00	12,275.00
Sandy loam	5,625.00	7,400.00	4,502.11	11,391.84

Table 49: Total amount of yield gain under conventional and SRI system (kg/ha/cropping year). [197]

While SRI/AWD is promising as an adaptation measure to cope with challenges in water supply/rainfall, the

[196] Arayaphong, Supisra (2012) Cost – Benefit Analysis of Different Rice Cropping systems in Thailand
[197] Arayaphong, Supisra (2012) Cost – Benefit Analysis of Different Rice Cropping systems in Thailand

approach has had mixed results in Thailand. Per consultations, RID had initiated the Alternate Wetting Drying (AWD) promotion programme for rice farming in Thailand in 2017. It was found that this technology did not work well with rice farming in lowland with shallow ground water levels. Suitability of the sites to the approach should be assessed as well as further review of the lessons learned and best practices to the AWD promotion programme.

4.2.5.5 Aquaculture

Small-scale freshwater aquaculture in Thailand has been reduced over recent decades, as a result of diminished spawning and nursing grounds for fish and environmental pollutants such as agricultural fertilizers and pesticides. The freshwater fisheries decline has provided stimulus for recent development of aquaculture in the country. The diversity of freshwater fish in Thailand is rich due to the network of rivers and canals, reservoirs and water storage, particularly located in the Central plains. In areas where there is intensive chemical usage in farming practices, water holds low concentrations of pesticide contamination.[198] Measurements taken in Nan, and Yom rivers tend to remain with lower than average concentrations due to the upstream flow diluting concentrations.[199] However, in rice-paddy aquaculture amounts are much higher due to proximity. Four farming systems are recognized officially: fishponds, which make up 89 percent of the total inland aquaculture production; and fish culture in rice fields (7 percent), in ditches (2 percent), and in cages (1 percent). Most freshwater production takes place in the central plains (58 percent) and the least takes place in the south (6 percent) where marine fish are readily available. The two regions where poverty-focused aquaculture has greatest relevance are Northern and Northeastern Thailand with 19 percent and 18 percent of the total inland aquaculture production, respectively, but with 22 percent and 50 percent, respectively, of the total number of farms in the country. The Northeastern region has the largest number of small-scale fish farms according to official statistics.[200]

It assumed also that these statistics are largely underestimated due to the difficulty in identifying small and widely scattered aquaculture farms in the area.

Freshwater aquaculture in Thailand is comprised of the following:

Types	No. of Holdings (person)	Having Product (kg)	Buying Price (baht) per kg	Selling Price per kg	Income per year	Place	Period
1. Nile Tilapia	10	740	15	52	26,833	Pond culture	6 month, 1 year
2. Walking Catfish (Pla Duk)	12	1,277	13	45	12,142	Pond culture	4, and 6 month
3. Striped Catfish (Pla Sawai)	3	20,100	9	37	26,666	Paddy-field culture	1 year
4. Others	7						
Total	32						

*Note: others Common Silver Barb, Common Climbimg Perch, iant Gourami

Accessibility via the removal of technical constraints for new entrant small-scale farmers have been largely resolved through research partnerships and development between the Asia Institute of Technology (AIT) and the

[198] *ADB. 2005, 'Overview of small-scale freshwater aquaculture in Thailand', Case Study 7,* An Evaluation of small-scale freshwater rural aquaculture development for poverty reduction*, Asian Development Bank*
[199] ADB. 2005, 'Overview of small-scale freshwater aquaculture in Thailand', Case Study 7, *An Evaluation of small-scale freshwater rural aquaculture development for poverty reduction*, Asian Development Bank
[200] ADB. 2005, 'Overview of small-scale freshwater aquaculture in Thailand', Case Study 7, *An Evaluation of small-scale freshwater rural aquaculture development for poverty reduction*, Asian Development Bank

Department of Fisheries.

Access to markets in fisheries:

According to a study undertaken by the Asian Development Bank[201], the domestic fish market involves a complexity of channels and types of markets and parties that sits primarily in the hands of private sector, with the exception of some state enterprises such as the Fish Marketing Organisation and the associated assembly market in Bangkok. Several private assembly markets have been established over the last few years around production areas and Bangkok and neighbouring provinces. Fish trading is done through auctions and negotiations in assembly markets, - and overall the distribution and marketing of freshwater fish is not a constraint to small-scale producers, as it provides efficient marketing and market access for fish farmers.

The findings the study[202] on small-scale freshwater aquaculture in Thailand also determined prices at farm gate, as well as in wholesale and retail markets – to be very competitive, with a large number of buyers and sellers intermediating in the market chain. Similarly, resources post-harvest, in terms of processing facilities and transport logistics were found to be adequate. Farmers have options to sell their fish on to wholesalers, processers, retailers, and collecting agencies according to quantities. Fish processers buy fish directly from fish farmers, assembly markets, wholesalers and other types of processors; wholesalers purchase fish from markets or directly from farmers to sell on to retailers; fish retailers sell directly to consumers; but also in the intermediary are fish collectors who act between farmers and fish traders – and who also gather and grade fish in price and size categories from various farms postharvest, and fish agents who take commissions in the transactions between assembly market buyers and sellers.[203]

The Department of Fisheries and Aquaculture extension:

Aquaculture has been long promoted in Thailand through extension services for small-scale rural aquaculture, and including inputs and incentives (e.g. free advisory services, technologies, pond construction inputs, feed, seed and so forth); although interlinkages with farmers organisations (agricultural), and farmer organization marketing have not been made. Community-based aquaculture also exists in Thailand (e.g. self-driven, localized initiative and ownership) with varying levels of success. [204] Promotion of rural fish production is also done through other initiatives such as Her Royal Highness Princess Maha Chakri Sirindhorn School Fishpond Program – which integrates fish-poultry farming. Promotion of small-scale freshwater aquaculture is supported under the National Economic and Social Development Plan (NESDP) goals; Thailand's National Fisheries Policy which seeks to increase production for domestic demand, increase farmer incomes and livelihood values. Integrated aquaculture-agriculture has been practiced for around a Century in Thailand, through livestock-aquaculture farming systems (which rely on the livestock manure waste for fishpond organic fertilizer and vice versa act as waste stabilization ponds). Rice-fish integrated farming is also widely practiced, as also poultry-fish-rice.

4.2.6 Ecosystem-based Adaptation

Part of this project seeks to retrofit ecosystem-based adaptation processes into the area, through the re-introduction and/or strengthening of integrated farming practices (such as rice-fish management), as well as the

[201] ADB. 2005, 'Overview of small-scale freshwater aquaculture in Thailand', Case Study 7, *An Evaluation of small-scale freshwater rural aquaculture development for poverty reduction*, Asian Development Bank
[202] ADB. 2005, 'Overview of small-scale freshwater aquaculture in Thailand', Case Study 7, *An Evaluation of small-scale freshwater rural aquaculture development for poverty reduction*, Asian Development Bank
[203] ADB. 2005, 'Overview of small-scale freshwater aquaculture in Thailand', Case Study 7, *An Evaluation of small-scale freshwater rural aquaculture development for poverty reduction*, Asian Development Bank
[204] ADB. 2004, 'Overview of small-scale freshwater aquaculture in Thailand', Case Study 7, Asian Development Bank.

re-introduction and strengthening of vegetation and waterflow systems, within the reinforcement of the existing canal channels and large irrigation system structures already in place. Given that much of the project is focused on the retention of water in the upper tracts of the project area – some areas will have water areas increased (e.g. monkey cheek) whereby wetlands management techniques can be employed, and the re-introduction of some of the original fauna and flora can take place. The 'greening' of reservoirs and canals is likely to take place through use in part of riparian vegetation sections – to act in combination with sediment filtration systems for more effective soil management and anti-topsoil runoff loss solutions. More recently, farmers have moved onto a de-intensification of their practices, moving from green revolution to good agriculture practices, best practice or organic farming.[205] However, the project area is already well established as a predominately rice-based agricultural area, with little existing other vegetation cover, or intact natural river and wetland systems. As part of the green revolution, this area took on irrigation and farming systems thought of best practice at the time. The issue of competing land uses between Ecosystem-based Adaptation (EbA) uses and agriculture is well understood – and as a result draws attention in particular to three EbA measures that complement existing planning. These are floodplain development and floodplain conservation, river restoration, and fish migration.

Overall, a holistic approach should be undertaken to integrating ecosystem-based approaches to climate change adaptation. An integrated approach to managing ecosystem as part of natural resource management pays attention to the interactions both within and from outside of that ecosystem. In the case of water resources management and agriculture for the Yom-Nan project area, in building a future climate resilient set of measures to reduce vulnerability within the area – inclusions covering hydrology and water resources management, agriculture, biodiversity, urbanization and water related EbA have been considered in this proposal.

4.2.6.1 Supporting ecosystem based adaptation (EbA) institutionally

Overlapping roles and authority in water management, and ecological systems, means that institutional support that is cross-cutting needs to be gained in order for any ecosystem based adaptation measures or approaches to be well integrated and interventions effectively implemented. This project provides the opportunity to unite information sharing and prevent overlap across mandates and responsibilities, with emphasis on using the mechanisms established (steering committees and management committees) to streamline decision making across the agencies and stakeholder groups, as well as monitoring, data management and overall natural resource and water management decisions relating to the area and ecosystem.

4.2.6.1.1 Capacity building for EbA

A capacity building programme to support the implementation of ecosystem based adaptation measures, would assist in ensuring that any EbA measures are effective in implementation and sustainability. Various options for enacting this exist, potentially – regular courses including a 'Training of Trainers' (ToT) approach, in order to support RID and other parties in replicating and effectively implementing the EbA approaches at broader scales, and within the project area directly. With the project serving to role model ecosystem based adaptation approaches to water resources, trainings undertaken to support these activities would also serve to assist any future applications of the approach to other areas, environment types and sectors. Community and stakeholder level engagement around the ecosystem-based measures being utilized, would assist in ensuring the longevity and sustainability of the measures, and their overall success.

4.2.6.2 Integration of hydrology and water resources management in Ecosystem based Adaptation

[205] Vandergeest P. 2006

Modeling serves as a structured way in which to describe the river basin and its features – in order to apply scenarios (such as climate futures). Major features of the river basin and the river basin attributes are assessed incorporating the river stretches, sub-basins, water infrastructures and geometry properties into the model, along with long frame time series climate data, and water discharge volumes – in order to address the elements for the data management of the system. This also incorporates an inventory of water demand needs, and the projected future water demand needs. Within this, agricultural timings are factored in to the water demand needs, in terms of cropping patterns, current irrigation practices and levels of efficiency/inefficiency, alongside quota flows to and from the project area boundaries. Boundary flow requirements (both ways) to and out of the project area become requirements in the model. Each tradeoff between water availability, agricultural yields and boundary conditions thereby form part of the modeling analysis. The water modeling developed is used to provide a strategic analysis of the project area water resources – to inform the water resource master planning.

Within the modeling, scenario generation plays a vital role, with two specific stages taking place – 1) the generation of the scenarios, and 2) the evaluation of the scenarios. The first part, generating scenarios relies on a participatory instrument to set out the plausible development strategies identified by stakeholders as desirable, feasible, preferable and/or economical. Each of which is then evaluated against a baseline scenario representing the current (BAU) situation. Ideally, this process follows scenario development of: baseline scenario (current situation, benchmark for all other scenarios); water supply management scenario (provision of water to meet water demand); water demand management scenario (adaptation of water demand to the fluctuations of the hydrological regime); agricultural scenarios;[206] and incorporation of EbA measures.

This modeling process requires delineation of the area of interest and delineation of sub-catchments; identification and localization of all hydrological relevant features; assessment of parameters and characteristics; assessment of agricultural water demand (e.g. using guidance from FAO[207]). This is followed by the generation of a flow network, assessment of operating rules and generation of a control and rule network with cause-effect relationships, and; checking of external links like subsidies, market structures, defined rules on how these external links will affect water management and implementation into the model, and finally; creation of projections for the external links as a time series. The time series setup should be managed according to a compilation of available time series within the metadata, with gaps checked for and outliers filled and corrected, and then the longest time period derived for which all driving time series are available.

Calibration procedures should select time periods that show corresponding observations for precipitation and discharge and water levels, followed by calibration of parametres for soil characteristics, storage coefficients, river roughness and so forth. The verification process should select time periods that correspond observations for precipitation, discharge and water levels but haven't been used for calibration, and then run the model and compare the simulation with the observed discharge. Overall, results should be generated into a time series of flow and duration curves at all model nodes, high flow conditions associated with return periods, low flow conditions associated with return periods and duration, water consumption based on various agricultural patterns and supply safety respectively, impact of operation rules and impact of various allocation concepts, and groundwater recharge for all sub-basins in the model.

The process of the scenario generation also provides a participatory stakeholder process in which awareness of the opportunities and limitations can be raised and engagement generated on deciding ways of planning for the future. This process factors in to evaluating early on the plausibility of certain scenarios in both containing unrealistic expectations and in demonstrating possible achievements.

[206] Agricultural scenarios for the Yom-Nan project area will factor largely – with specific attention needing to be paid to alterative crops, and alternative cropping patterns; organic and sustainable agriculture practices; and the avoidance of dependence on pesticide and fertilizer usage.
[207] Doorenbos and Pruitt (1977): Crop water requirements, FAO Irrigation and Drainage Paper No 24, FAO, Rome.

Continuous long-term simulation enables identification of all effects of water management strategies including all water consumer needs being incorporated. Based on principles for modeling hydrological elements, it is also able to integrate elements such as atmosphere-vegetation-soil interfaces, river stretches, hydraulic elements, storage facilities and so forth. Each element (sub catchment, including hydrological unit and soil column, river stretch, hydraulic element, storage facility and so on) is calculated in its various states in time, by considering the current boundary conditions (rain, temperature, abstraction, diversion, position of gates and so on) based on previous states. This ensures that at any tie during the calculation all hydrological components are continuously known, with results available in a time series, which can be evaluated subsequently.

4.2.6.3 Vulnerability and Risk Assessment

Hazards emerging from both natural and human-induced impacts can be assessed within the modeling generated – in relation to flood and drought. Modeling is able to provide in these instances an indication of potential hydrological flows determining flood and drought occurrences. At the same time – early indications of these occurrences can mean that flows are controlled to assist in retaining or reducing water flows and determining risk zones and offset zones. Indications of these risk zones provide the entry point in determining both crop selection and ecosystem-based measures like floodplains.

4.2.6.4 Integration of erosion and sediment transport

Integrated into the hydrological modeling process, is erosion and sediment transport modeling – which is necessary to identify erosion prone and sediment deposition prone river reaches. Erosion and sediment calculation should be directly combined with hydraulic modeling, as a vital aspect of river engineering works as well as the considerations regarding the river morphology and river restoration. Additional inputs used in the incorporation of the erosion and sediment transport integration include the grain size distribution, sediment load at the inflow cross sections, and critical flow velocities triggering sediment transport, critical shear stress, river reaches with erosion and sediment transport, and aggregation with annual erosion/sediment deposition.

4.2.6.5 Integration of agriculture in Ecosystem based Adaptation

Given that the project area sits within a predominately agricultural-use area, mainly used for rice production, areas that previously formed the natural flood plains of the water catchment, are now used as agricultural lands. This means that within the area, natural water resources and floodplains with significant wetland tracts, have been drastically reduced, with canal embankments established for flood protection of farming areas, consequently preventing inundation onto the original floodplains, and in course, abstracting huge tracts of the natural water resources for funneling to downstream areas. As the agricultural use is prioritized, the regulating ecosystem services for the water resources are significantly reduced. For example, increasing crop production through the use of fertilisers, and growing crops in seasonal wetlands using increasingly larger water quantities for irrigation – has a negative impact on the level of ecosystem regulating service of the water system. In addition, agricultural uses have contributed widely to accumulated pesticide and nutrient residues (e.g. from fertilizer usage) – altering the natural ecosystems and aquatic life of the area, and interactive functions, such as reducing fish production, aquatic and terrestrial wildlife habitat loss, and the loss of natural pest control systems within the watershed system – as well as accumulating to concentrated levels within groundwater systems.

Ecosystem based approaches to managing water – call for recognition of the impacts of heightened and controlled canal embankments, in increasing water flow velocity, decreasing water permeability and groundwater recharge through floodplain inundation, and natural nutrient and sediment cycling systems.

4.2.6.6 Integration of biodiversity in Ecosystem based Adaptation

The remnant terrestrial and aquatic habitats present within the project area, retain much of the biodiversity present in agricultural landscapes.[208] These include the habitats in canals and the water bodies of the Yom-Nan area, as well as the pockets between paddy fields, and in some parts of the paddy fields forming irrigated wetlands. In the case of agricultural biodiversity – irrigated and rice wetland systems provide a great diversity of birds when compared with other types of agriculture.

Biodiverse floodplains and wetlands provide unique ecosystem services of flood control, groundwater replenishment, sediment and nutrient retention, control and export, water purification services, and highly biodiverse plant and animal habitants. In integrating biodiverse habitats in ecosystem based adaptation measures, areas prone to frequent flooding, should be excluded from intensive agriculture uses. In the case of the Yom-Nan project area, such flood prone areas, along with the planned water retention ponds and reservoirs (e.g. monkey cheeks), should integrated the following:

- Re-connection using ecologically enhanced irrigation canals.
- Construction of floodplains and wetlands, undertaken in specific ways, whereby riverbeds are widened in order to facilitate the creation of diverse river channels, and inhomogeneous flow conditions through cross-sections as well as in river stretches to recreate and enable a meandering process for slowing water flow.
- Landscaping and river rehabilitation should ensure that connectivity of the floodplain and river is retained (or reconnected), ensuring that the system maintains a cycle of regular flooding.

Increasing levels of biodiversity poses several challenges, as it overarching requires a shift in values and broad public understanding and willingness to accept biodiversity and ecosystem benefits. 'Trade-offs' are required between agricultural uses, that need to be well consulted with the users in the landscape and watershed area. Engagement with stakeholders regarding these tradeoffs need to highlight the regulating services of catchment ecosystems, and their potential limits where ecosystem services will no longer be met – leading to drastic consequences. In other words, consultation regarding the implementation of ecosystem based adaptation measures – need to draw close attention to the potential unsustainability of the current agricultural and food system of practices, and what the expected outcomes may be in the near future if a business as usual approach to agricultural and water resource management practices is continued. Numerous examples can be drawn upon that highlight these futures. Similarly, beneficial futures under the tradeoffs can also be demonstrated widely. In Thailand already, as well as in sites in China and Vietnam – multisite field studies have replicated the plantation of nectar producing plants around rice fields, resulting in significant benefits – in reducing the populations of two key pests, reducing insecticide use applications by around 70 percent, increasing yield gains by around 5 percent, and delivering economic advantage by 7.5 percent. Additional field studies have shown that predators and parasitoids of the major rice crop pests – have increased in abundance.[209]

4.2.6.7 Integration of water- related Ecosystem based Adaptation measures

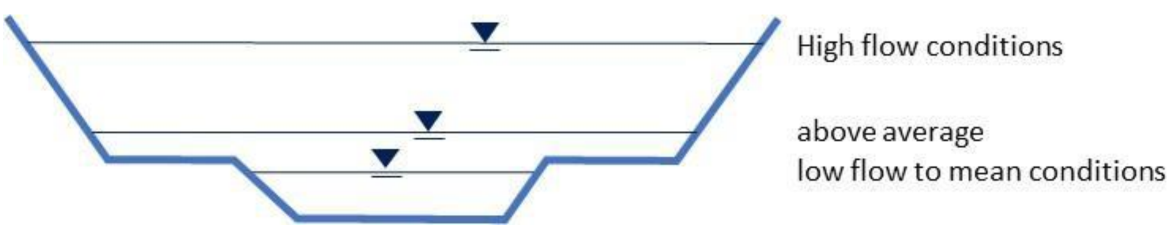
[208] Blann 2006: Habitat in agricultural landscapes: How much is enough? A State oft he Science literature review, *Defenders of Wildlife*, 2006
[209] Gurr et al. 2016: Multi-country evidence that crop diversification promotes ecological intensification of agriculture, Nature Plants, 2016

Management of water resources, with river restoration, fish migration and floodplains – should be undertaken in accord, utilizing an integrated approach. In the case of this proposal, the Yom-Nan area poses several problems to river restoration, namely in terms of the implementation of instream habitat structures in high-energy streams during peak flows. However, fish-passable flow paths can most likely be restored along the Old Yom River, without large hydraulic measures. This is technically feasible, with bypasses able to be constructed around the weirs and hydraulic structures of the Old Yom River, with exception to the large weir at the confluence of the Yom River.

Fish migration

The longitudinal connectivity of a river has a determining impact on the character and quality of river ecosystems. In the project area between the Yom River and the Nan River hydraulic structures – which includes the weirs and dams of the irrigation system; large obstacles are posed by these structures in terms of interrupting the connectivity of aquatic ecosystems, and in turn, causing ecological damage to fish stocks by decreasing breeding behaviours and reducing population sizes, not only to all resident fish species, but also to all aquatic organisms that perform migrations in the area.

The construction of fish passes, would enable fish migration in these areas. Although fish passes do not eliminate the basic ecological damage done, it would increase their ecological compatibility by re-linking waterbodies and potential spawning waters to facilitate the re-colonisation of rivers by endangered fish species and all aquatic organisms. Initial feasibility of the removal of fish migration barriers have been largely garnered from the work of investigations along the Lower Mekong Basin. Along the main stream of the Mekong River and its tributaries, a remarkable number of dams and weirs will be built by 2030. These dams and weirs will constitute barriers for fish migration. Investigation into impacts to fish by these structures, estimated a loss of 58% to fish production in the river-floodplain wetland habitats across Lao PDR, Cambodia, Thailand and Vietnam.[210] In the reverse, when applied to the Yom River System, removing the existing barriers to fish migration – is estimated to highly increase fish populations in the system, of up to 58%, although the figure for increase remains assumed rather than a given.



4.2.6.8 Fish migration

One of the major factors is facilitating fish migration, is as a first step – identification of the fish species present through a fish survey. Once the fish species composition of the river and water resources has been identified, then the individual fish species requirements will determine how connectivity of the fish habitat should be managed. Fish species categories can be made according to the behaviours and needs – including whether fish are 1) spawning, 2) intra-annual migratory – and therefore inhabiting different parts of the river over their life cycle with different conditions required during the different development phases, 3) downstream migratory, and 4) diadromous migratory (fish that spend portions of their life cycles partially in fresh water and partially in

[210] MRC (2011): Assessment of Basin-wide Development Scenarios. Cumulative impact assessment of the riparian countries water resources development plans, including mainstream dams and diversions. Main Report April 2011. Vientiane, Lao PDR.

salt water).

Fish passes

Fish species types found will largely determine the types of fish passes that should be used, particularly regarding wether fish are spawning types seasonally migrating, as well as the shape and body type of the fish. Where migratory species have been identified, then migration obstacles will need to be removed – although how this is done may take significant consideration. Fish passes include planning around the different aspects according to fish species requirements and local conditions – this will include some of the following considerations.

Fish have a tendency to follow the strongest current, so fish passes should therefore be placed within the strongest points, such as at the entrance to a lake or dam, in order to ensure effectiveness. The positioning should be where fish most largely congregate in their upstream movements. The positioning of the fish pass exit along with the exit conditions, must also be well considered in the planning phase. The dimensions of the fish way, such as length, slopes, resting pools or the discharge – require optimum conditions for migration and need to be individually defined depending on prevailing circumstances at each migration obstacle. Such factors should be included in any in-depth pre-planning assessment about the requirements in the project area. On the basis of designing the optimum fish pass type for each migration obstacle, three general types for consideration include:

- close to nature fish pass (e.g. bottom ramps and slopes, bypass channels, fish ramps)
- technical structures (e.g. slot passes, pool passes, denil passes)
- special constructions (e.g. eal ladders, fish locks, fish lifts).

Each have advantages and disadvantages according to the migratory needs, spawning habits, discharge, boundary conditions, and spatial constraints individually-specific for each locations.

4.2.6.9 Longitudinal connectivity of the Yom River

Re-establishing longitudinal connectivity of the Yom River, serves to achieve a number of ecological-resilience enhancing outcomes that in turn will boost the resilience of the water resources and livelihood options of the area to climate change impacts. Namely, re-connecting the river system longitudinally will involve several planning activities that build on from 4.3.10.3 for achieving these outcomes:

- Establishment of a fish species inventory and the types of migration patterns and periods of the fish species in the area;
- Identification of the potential spawning grounds of the identified fish species, throughout the Old Yom River and Khlong Nam Lai River, and areas upstream of these;
- Establishment of an inventory locating all obstacles to fish migration within the project area water systems;
- An assessment undertaken on the longitudinal connectivity including design, dimensions and positioning of fish pass construction types (e.g. natural based options versus technical), according to each migration obstacle, and the elements to be incorporated (discharge rates, attraction flow, conditions of entrance and exit, length, slope, resting pools, and so on), and it’s integration into the landscape;
- Maintenance plan – including budgeting, roles and responsibilities, and monitoring of the longitudinal connectivity.

For longitudinal connectivity of the Yom River, above the Had Sapham Chan Floodgate through to the weir at the confluence of the Old Yom River and with the Yom River, there are two options possible, according to a viability study undertaken by Sydro Consulting and Gesellschaft_für_Internationale Zusammenarbeit (2016-7). These options include a Yom-Nan alignment canal at the site of the Old Yom River, or along the Khlong Nam Lai River.

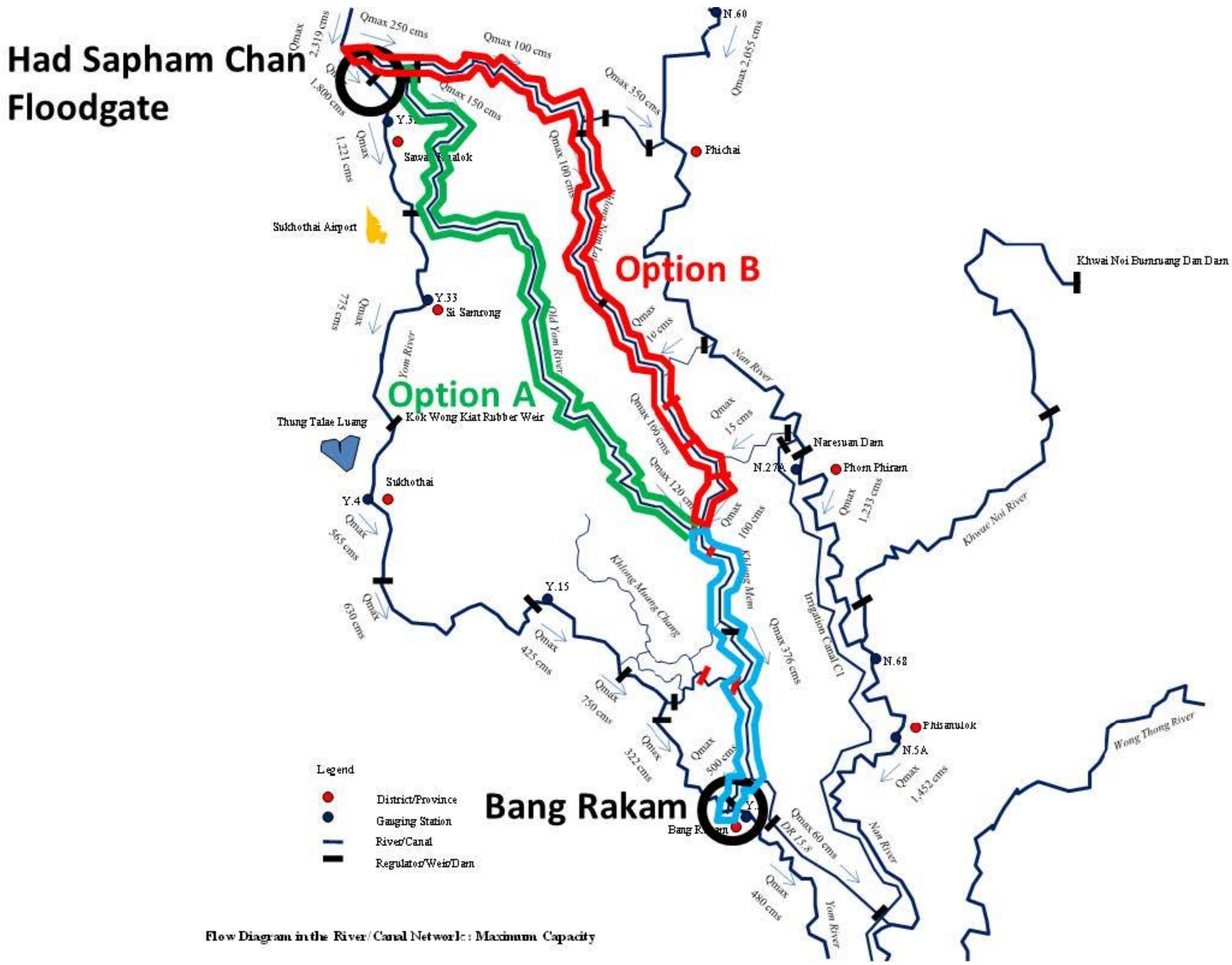


Figure 79: Longitudinal connectivity in the Yom River – option A and B.

The two options illustrated in Figure 79 should be evaluated in the course of the initial assessments. However, in both options, Khlong Mem River is part of the planning.

Option A – considers the utilization of the Old Yom River to relink the upper part of the Yom River above the Had Sapham Chan Floodgate with the lower part of the Yom River in the areas of Bang Rakam. The advantages posed in re-linking the upper part of the Yom River with the lower part of the Yom River in these places, is that less anthropocentric change would be generated to the river systems, and therefore also less fish migration obstacles would present challenges, when compared with Option B.

Option B, as the second option offered, has advantage given that it is retained within the project site area, and the Yom-Nan Operation and Maintenance area of RID. However, given the number of hydraulic structures in place within this system, including weirs and dams along the Khlong Nam Lai River, there are a number of fish migration obstacles to overcome – which will pose significantly higher cost in the connecting the Yom River.

Both Options A and B use the same point of the weir immediately upstream of the confluence of the Old Yom River with the Yom River, in setting the main point for connecting the river longitudinally upstream. The weir at this point currently has leakage which provides unintended environmental flows, and which could also act to provide a fish bypass connecting the Old Yom with the Yom River.

In reconnecting the river flow systems – through the longitudinal connectivity of the Yom River, by re-linking the waterbodies through the Khlong Mem River and the Old Yom River (Option A) or through the Khlong Nam Lai River (Option B) to the Yom River upstream of the Had Sapham Chan floodgate, the confluence shown in Figure 80 is critical. At this weir, a fish pass needs to fulfill a wide range of hydraulic and hydrological requirements, including appealing to migrating fish species downstream and upstream through optimum positioning and dimensions to attract the migrating fish into the Khlong Mem River.

Figure 80: Weir upstream of the confluence of the Old Yom River with the Yom River.

4.2.7 Groundwater recharge

Various artificial recharge schemes have been explored for the area in response to increasing groundwater decline – with several feasibility studies conducted[211] (groundwater recharge). In Ban Nong Na, Bang Rakam district of Phitsanulok, for example, 25,000 cubic metres of water have been artificially recharged to the groundwater

[211] Uppasit, S., Silaratana, N., Fuangswasdi, A., Chusanatus, S., Pavelic, P. & Kriengsak, S. 2013, 'Managed aquifer recharge using infiltration pond: Case study of Ban Nong Na, Phitsanulok, Thailand', *Journal of Earth Science and Engineering*, 1. Pp 14-22

subsurface supply, to be continued at around 935 million cubic metres per annum; in order to ensure a continued water supply can be maintained throughout the dry season.[212] Pilots have been instigated throughout Phichit, Phitsanulok and Sukhothai in response to the depletion of groundwater reserves in these areas. On average, the Department of Groundwater Resources expects that where farmers invest in artificial recharging systems with more than 5 rai of surface area, an investment would 'break even' within four years via the savings associated with costs incurred in extracting otherwise hard-to-reach groundwater.[213] Another study recently looked into the potential of groundwater as climate change adaptation to the 2015 drought situation for farmers in adapting to climate change in the Phitsanulok Irrigation Development Project area.[214] The study investigated the relationship between recharge rates against climate change data in terms of precipitation, evapotranspiration, temperature and soil type, according to a month-by-month time series. The study found that farmers in Phitsanulok tended to rely on groundwater supplements when irrigation water was scarce such as in dry season. In turn, this has caused groundwater to be draw down in the area (groundwater height sitting much lower), not only forcing farmers to dig deeper wells at a higher cost, but also having more serious environmental implications, such as land subsidence. Overall, the study found that recharge to groundwater is likely to decrease by around 58 percent due to climate changes within the near future, and by 50 percent in the longer-term future, when compared with current (2015) rates. This case of groundwater recharge reduction, combined with their findings of overall groundwater level reduction (approximately 0.23 metres per year in the short term future, and 0.16 metres per year in the long term future);[215] presents a serious case not only for artificial recharge efforts to the groundwater storage – but for more efficient use and management of water resources in agriculture for the area.

Items	Season 1	
	Plot 1	Plot 2
1st Rank	Irrigated canal	Irrigated canal
2nd Rank	Artesian well	Artesian well
3rd Rank	Rain	Rain
Surface water-Cost of power for irrigation pumping (THB/rai/year)	556	609
Surface water-Cost of electricity for irrigation pumping (THB/rai/year)	364	571
Surface water- Maintenance and repairing cost (THB/rai/year)	383	599
Ground water-Cost of power for irrigation (THB/rai/year)	602	679
Ground water-Cost of electricity for irrigation pumping (THB/rai/year)	319	350
Ground water-Maintenance and repairing cost (THB/rai/year)	386	564

Table 50: Surface Water and Ground Water Quantity Applied

Source: Siripornpipul, C. 2014, 'Technological demand of water management in urban development in Thailand, ASEM Seminar on Sustainable Management of Water Resources in the Context of Urbanisation, Department of Water Resources, MoNRE, Thailand

4.2.8 Impact to aquifers

The aquifers of the Yom and Nam River Basins have been mapped and monitored. It is expected that the retaining of water through retention options such as monkeys cheeks, and on farm storage/longer duration rice irrigation

212 NNT. 2013, 'Artificial recharge of groundwater pilot project to be expanded', *Pattaya Mail*, October 1, 2013
213 NNT. 2013, 'Artificial recharge of groundwater pilot project to be expanded', *Pattaya Mail*, October 1, 2013
214 Koontanakulvong, S., & Suthidhummajit, C. 2015. 'The Role of Groundwater to mitigate the drought and as an adaptation to climate change in the Phitsanulok Irrigation Project, in the Nan Basin, Thailand', *Jurnal Teknologi*, 76:15, Pp 89-95
215 Koontanakulvong, S., & Suthidhummajit, C. 2015. 'The Role of Groundwater to mitigate the drought and as an adaptation to climate change in the Phitsanulok Irrigation Project, in the Nan Basin, Thailand', *Jurnal Teknologi*, 76:15, Pp 89-95

– will have a positive influence on groundwater recharge, by allowing waters to be retained long enough to permeate to groundwater levels.

A study undertaken catchment wide on the upper parts of the Chao Phraya River Basin by Prattomchai (et al., 2014) looked at projected groundwater recharge under changing climate scenarios during the period of 2026 – 2040, based on GCMs (MIROC, ESM, CHEM, HadGEM2, ES HadGEM and GFDK ESM2M) under scenarios RCP2.6, RCP4.5, RCP6.0 and RCP8.5. The study found that annual groundwater recharge (storage) is likely to reduce by 12.9% as a result of the significant decrease in rainfall volumes in the April to June annual periods.[216] It is likely therefore that water security for farmers to rely upon drawing from groundwater will reduce. It is widely documented globally the correlation between groundwater reliance in flood plain areas, and groundwater-related subsidence (sinking), as a result of the extraction of groundwater – with groundwater extraction being attributed to an estimated 80% of serious land subsidence problems[217], and including the Chao Phraya River Basin[218]. Options that seek to restore groundwater recharge rather than shift reliance to groundwater use to supply agricultural water use – should therefore be pursued.

4.2.9 Integrated Water Resources Management (IWRM)

A concept largely based on the Dublin Principles presented at the World Summit in Rio de Janeiro in 1992, Integrated Water Resources Management (IWRM) seeks to manage water resources in a coordinated and integrated manner by strengthening flood management through integrated water resources management. It essentially builds steps towards integrating water management for different uses – consumption, production, or disaster risk management of droughts, floods and tropical storms. Providing principles and a framework in which to enact a coordinated and integrated approach to managing water across landscapes and sectors – it looks to bring together the management of water, land and the related resources to maximize economic and social outcomes, without compromising vital ecosystems. The framework outlines three key principles, of: 1) social equity – ensuring that all users are given equal access to water resources, with particular assurance to marginalised peoples, in order to guarantee that an adequate quality and quantity of water necessary to sustain human well-being is accessible; 2) ensure economic efficiency in addressing the greatest benefit to the greatest number of users possible with the financial and water resources available, and; 3) ensure ecological sustainability in addressing aquatic ecosystems and maintaining their ecological functions are sustained and allocated for.

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[216] Masud, M., Soni, P., Shrestha, S. & Tripathi, N. 2016, 'Changes in Climate Extremes over North Thailand, 1960 – 2099', *Journal of Climatology,* Research Article, 206:4289454, Pp 1-18
[217] USGC. 2000, 'Groundwater Resources for the Future', *US Geological Survey (USGS)* http://water.usgs.gov/ogw/pubs/fs00165/
[218] Phantumvanit, D. & Liengcharernsit, W. 1989 Coming to terms with Bangkok's environmental problems. Environment and Urbanization 1: 31–39

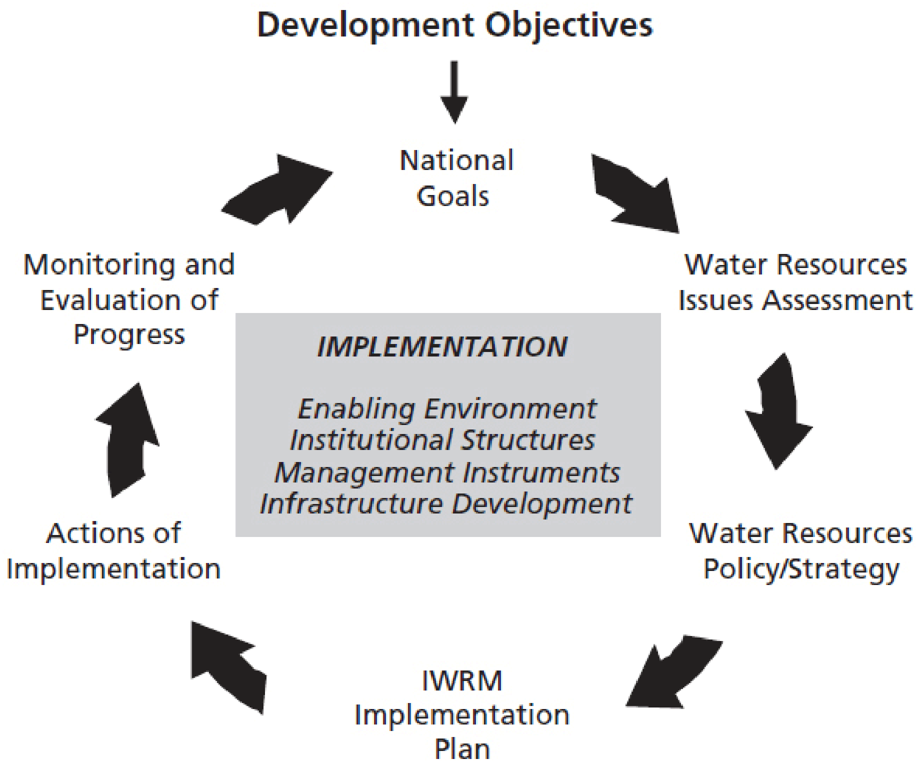


Figure 81: Stages in IWRM planning and implementation

Source: http://www.un.org/waterforlifedecade/iwrm.shtml

The concept of integrated water resources management (IWRM) based on the river basin model, is contained within Thailand's water policies and management. However, as found by a study by the World Bank (2012), the Thailand framework would benefit from a number of improvements – particularly in regards to strengthening and streamlining the IWRM approach through sectoral planning and programming. A broader (National) expert review ideally should take place, reviewing and analyzing the 2011 flood to provide further lessons and recommendations to the Strategic Committee on Water Management for integration into any future strategic plans. This Rapid Assessment also found that reviewing and passing the water bill, would benefit from high level championing of the IWRM model in instituting the political clout required to institute IWRM throughout sectoral development planning long term. Institutions need to strengthen their roles in coordinating to ensure that IWRM can take place, with focus on management instruments and an enabling environment being established to engage inter-agency and widely with stakeholders.

4.2.10 Room for the River

Room for the River (Ruimte voor de Rivier in Dutch), is an approach that has become well-known through its implementation in the Netherlands, where the River Rheine, the Meuse, the Waal and Ijssel (at more than 30 locations), were given an allowance of space or 'room' to manage higher water levels and allow flood within those spaces. The measures were implemented to also improve the quality of the 'rooming locations' and while following the main objective of flood protection, follow also principles of master landscaping and environmental conditions. Essentially it includes works of reallocating dykes further from river shores, lowering floodplain heights, riverbed excavation, water storage, allowing further drainage channels and removal of obstructions and so forth. In the case of 'room for the river', the strengthening of dikes becomes a last option to be considered if other interventions are technically or financially unfeasible. The measures included in 'room for the river' policy generally is considered to have significant consequences at the regional and local spatial planning level – which stress public participation as being a crucial element in the planning of flood management strategies that is vitally important.[219].

4.2.11 International Best Practice in Flood Management

Natural retention of flood water: As the damage caused by floods increases around the world, many communities and regions are considering investing in costly dams, dikes and other technical measures to avoid a repetition of this damage. Because of the high costs associated with technical measures, another approach has been gaining popularity, namely to put aside parts of the river flood plain that can be flooded under high water conditions and serve as a temporary storage basin for flood flows. Many countries including Denmark, Germany, the Netherlands, and Sweden, are already setting aside riparian areas (side channels and wetlands) for this purpose. These are mainly recreational, farming, or undeveloped areas that can be inundated without great risk to human populations or their structures.

Example: Temporary flood water storage in agricultural areas in the Middle Tisza river basin – Hungry

The Hungarian Government has been pursuing a new flood defence strategy for the Tisza based on temporary reservoirs where peak flood-water can be released. A plan to build six reservoirs was adopted, with the option to build an additional five. This case study is based on the analysis of operational scenarios of the reservoir schemes, while some of the detailed assessment took place specifically in one of the polders, the Hanyi-Tiszasülyi reservoir.

The designed flood protection strategies were planned so as to be integrated into a wider process of regional development that projected large scale landscape and social rehabilitation efforts in combination with the restoration of the natural ecosystem of the region characterised by a complex system of wetlands. The project was shown to be extremely effective in terms of flood risk mitigation. The retention of flood waters in the identified temporary reservoirs in the agricultural areas is crucial for the reduction of flood frequency and magnitude in the downstream areas, with considerable benefits for the cities located along the river. In normal conditions the retention areas are used for agricultural production. In case of emergency these areas are flooded and the farmers compensated for the losses. Unfortunately, as frequently happens in these cases, not all the stakeholders are enthusiastic about the solution adopted. Farmers claim inadequate consideration of their views and perspectives in the process that brought the government to use their land for temporary flood-water storage. Landowners are called to use their property for providing an important service, but they have not been involved in the design of the flood management strategy and the associated operating rules. In general, they are not enthusiastic about the reservoir concept[220]

Example: Lower Danube green corridor: floodplain restoration for flood protection

In 2000, the governments of Bulgaria, Romania, Ukraine and Moldova pledged to work together – with the signing of the Lower Danube Green Corridor Agreement - to establish a green corridor along the entire length of the Lower Danube River (~1,000 km). All partners recognized a need and shared responsibility to protect and manage the Lower Danube in a sustainable way. The Lower Danube Green Corridor Agreement aims to protect and restore wetlands along the river and reconnect the river to its natural flooding areas, reducing the risks of major flooding in areas with human

[219] Deltaris, 2016

[220] 'Temporary flood water storage in agricultural areas in the Middle Tisza river basin – Hungary (2014)', European Climate Adaptation Platform, Case studies: http://climate-adapt.eea.europa.eu/metadata/case-studies/temporary-flood-water-storage-in-agricultural-areas-in-the-middle-tisza-river-basin-hungary

settlements and offering benefits both for local economies – e.g. through fisheries, tourism – and for the ecosystems along the river. To achieve this, sections of dikes have been removed and isolated river meanders have been reconnected to the river.[221]

4.2.12 Technical Flood protection

Technical flood protection involves the Rre-enforcement of dikes and dams to increase their stability and resistance against breaching (e.g. overtopping of resistant dikes, re-enforcement through heightening, integrated functions/developments and combinations) [222, 223]; the restoration of dikes and dams as wetlands and other habitats; the compartmentalization of the region into protected zones (e.g. dike ring areas), and; consultative design through stakeholder participation

4.3 Efforts for the improvement and upgrading water infrastructure in the Yom and Nam River Basin

Working towards a more effective water retention model – that considers an ecosystem approach – of inclusion of the roles and complex interactions between precipitation, upper watersheds, reservoirs, wetlands, canals, farm ponds, rivers and stream, floodplains, soils and aquifers.

Water storage plays an integral role in Integrated Water Management - a diversity of storage types should be considered, in order to maximise the short and long term benefits and level of resiliency of the system. If the types of water storage work within the natural watershed and ecoshed dynamics to maintain water supply and healthy ecosystem – they will also be more resilient.

Increasing water retention in soil profiles - particularly in upper watersheds, along the watershed spreads, as well as on farms – assists the natural function in the watershed, as well as giving benefit to ecosystem functions such maintaining topsoil/reducing sedimentation and runoff, maintaining soil fertility – allowing seepage/recharge of groundwater, and maintaining flow and function of rivers, creeks, lakes and so forth. Capturing water across many sites also reduces costs (in terms of farmer access, for example), benefits farms and food security options, as well as contributing to reduced flood impacts, and securing water during drought or dry periods. These can range from engineer underground storage, on-farm ponds, seasonal wetlands, soils, larger reservoirs and ponds[224]

Slowing down water flow through capture and retention – reduces the impact/intensity of big rain events (as is increasing under climate change) – allowing filtering, sediment removal and the capturing of excess water for later use (in drought periods, for example).

Water retention at the landscape level – the principles of which include that healthy soils store water; the least disturbance level of land surface will allow increased filtration and slow runoff; surface reservoirs and ponds assist in capturing peak flows to reduce downstream flooding and offset groundwater withdrawals in dry periods.

[221] 'Lower Danube green corridor: floodplain restoration for flood protection', European Climate Adaptation Platform, Case studies: http://climate-adapt.eea.europa.eu/metadata/case-studies/lower-danube-green-corridor-floodplain-restoration-for-flood-protection
[222] 'Adaptation or improvement of dikes and dams (2015)', European Climate Adaptation Platform: http://climate-adapt.eea.europa.eu/metadata/adaptation-options/adaptation-or-improvement-of-dikes-and-dams
[223] DG ENV project ClimWatAdapt, DG CLIMA project Adaptation Strategy of European Cities and Ourcoast II http://dtvirt35.deltares.nl/products/30043http://www.climatechangesspatialplanning.nl/media/default.aspx/emma/org/10354094/34-44+Adaptation+cost+in+the+Netherlands+-+Climate+Change+and+flood+risk+management.pdfhttp://www.ice.org.uk/disciplines-and-resources/case-studies/rotterdam-adapting-to-climate-change
[224] See for example: 'From storage to retention: Expanding California's Options for meeting its water needs', California Roundtable on Water and Food Supply, November 2012: http://www.aginnovations.org/uploads/result/1431288789-f294220a8a403e34f/CRWFS_Storage_to_Retention.pdf

Floodplain restoration where possible will assist these conditions.

4.4 Traditional agricultural practices and integrated management practices in the Yom and Nam River Basin

To date, agricultural-livelihood based households throughout the Yom and Nam River Basin areas, have been adapting to climate change autonomously. Long existing strategies for dealing with flood, for example, can be seen in the architecture characteristic of northern Thailand flood plain areas – whereby houses are raised on stilts. While more ongoing, and recent adaptations to climate change include the shifting of copping patterns and calendars, and the move to diversify incomes and (re) integrate non-rice incomes. The changes to date do not consider the increased pressure on water resources from climate change. Classical house construction of farmers in northern Thailand tends to be long adapted to flooding (including climate-driven floods) as they are raised.

Farmers, during consultations undertaken throughout September and October 2016, noted (with discrepancies according to access to irrigated water) that rice crops can be grown 2 to 3 times a year, if access to water supply is ensured. Fish however, tended to be used as a supplementary income. However, variability in climate – and limited access to climate information in tune with usefulness for crop planning cycles; had resulted in losses to crops, or inertia in not knowing whether to invest in the second and/or third crop cycles. These losses result in significant impact not only to farmer earning capacity – but also investment losses. Access to effective and useful climate information through the project is imperative in supporting farmers in the area not only to continue farming, but to maintain livelihoods that are climate resilient. The beneficial areas of the 13 projects are all repetitive flood areas. Flood period is normally between August to October each year. However, farmers in these areas are still growing rice twice a year by modifying the calendar of rice production. Instead of cultivating rice in the usual rainy season (June – October), their main season for rice production starts at November to February in which water from the rainy season is still remaining in the fields and the second crop is between March or April to July. Livelihood of communities in the repetitive flood areas is then related to flood. One of the supplementary incomes from individual household is fishing. Integrated fish-rice farming was traditionally undertaken until around the 1970s when it gradually became less common as fertiliser-pesticide intensive farming methods became more dominant. Most of households have various kinds of local fishing instruments under their houses. The related community business taking place in the areas are fish, preserved fish products; fermented fishes and fish sauce.

5. Chapter 5: Current needs, gaps and barriers; constraints to improve the resilience of vulnerable communities

Thailand's Technology Needs Assessment (TNA) undertaken in 2012, identified three sectors in urgent need of climate change adaptation technologies. These being:

1. Agriculture: urgent requirement for established network of early warning system technologies; crop improvement and precision farming technologies;
2. Water resource management: networking (pipes and canals), infrastructure management (inclusive of zoning), climate predictions (specifically seasonal variation), and sensor web which utilizes climate modeling and data, and;
3. Modeling: an integrated national data centre, which drives national data transfer and management, including advanced research, weather and forecasting (WRF – ARW) model, as well as employing an integrated model in which to address water hydrology needs/water resource management and the agricultural sector.

5.1 Limited technical and financial capacity for climate-informed upgrade of existing infrastructure

The last improvement of irrigation project in these areas was in 1994-1995. However, climate change induced extreme rainfall and drought are growing challenges of these areas. Upgrading of infrastructure must be informed by climate For drought damage alleviation, enlarging the storage capacity of irrigation or natural canals or monkey cheeks for keeping irrigated water for the second dry season rice would be needed.

Recommendations from the World Bank Rapid Assessment (2012), indicated that key areas for works to take place for flood management – should include:

- The immediate rehabilitation of hydraulic assets to increase drainage capacity.
- Regular maintenance of water management assets to ensure that they remain efficient and extend the life and effectiveness of water infrastructure over time
- A review of critical flood embankments.

Dikes, dams, and other structures regularly and successfully protect low-lying areas from flood – and it is likely that they will continue to provide an important level of protection and coping with flood into the future, within the context of increasingly frequent and high river flows from climate change. Though alone insufficient, infrastructure of this type plays a vital role in managing the impacts, and lowering climate change vulnerabilities as a result. Thailand already practices water management techniques in the critical Chao Phraya River basin to stave off flooding during the wet season and to ensure water availability during the dry season, using canals and regulators, including reservoir operations. In the upper section (upland area), dams and reservoirs are used to store and regulate the flow of water. In the middle section (low lying area), water is drawn into designated low lying area to store the water for certain periods for release when the rainy season ends, preventing flooding in the lower (urban) part. In the lower section of the basin (the urban and industrial area), canals divert excess water to the Gulf of Thailand, while dams are used to regulate the distribution of water for industrial and agricultural use. Yet, the existing water management infrastructure is no longer able to effectively respond the changing rainfall patterns impacted by climate change. Greater intensity of flooding and longer periods of drought are putting vulnerable agriculture households at increasing risk. A recent feasibility study commissioned by RID have confirmed this. The canals and regulators currently in place in the Yom and Nan river basins can no longer cope with the increased pressures of climate change. A recent feasibility study of the Yom and Nan river basins explored ways to better manage water resources in order to support communities for a better quality of life, to make use of excess water, and to reduce impact from flooding in the lower area of the basin. The study, which took into consideration engineering, social, environmental and economic aspects, identified strategic upgrades to flood gates and canals, which would best support flood and drought mitigation efforts.

Support is needed to ensure that the necessary upgrades of infrastructure are suitable to the landscape and informed by climate change. Given the significant investment needed to upgrade infrastructure in the Chao Phraya River Basin, as well as other river basins, designs must also consider the best design for effective and efficient use of funds. Already the investments are planned over a 20 year period.

5.2 Limited use of EbA measures to complement grey infrastructure for water management

Thailand generally uses grey infrastructure (e.g. regulators) for water management. Existing plans and designs for the Yom-Nan project area and the Greater Chao Phraya River Basin Area do not include EbA measures. RID seeks to complement grey infrastructure with ecosystem-based adaptation (EbA) measures however RID experience in this area is limited. Combining grey infrastructure with EbA measures would not only support critical ecosystem services, but also reduce overall costs (i.e. lower upfront investment and long-term O&M, compared to a purely grey infrastructure investment).

The project area is heavily altered by small settlements, farms, and cultivation; villages are scattered throughout the catchment area with many irrigation canals cutting through the area. While the area is significantly utilized, there are still different ecological habitats present. Lines of bushes and trees can be found quite often in between paddy fields or other farmland areas. As existing water management systems must be enhanced to be more climate-resilient, there is an opportunity to also introduce EbA measures to complement planned grey infrastructure investments by RID. An assessment on the possibility to integrate EbA measures was conducted during the development of this proposal (see Annex 22). The assessment concluded that there is a high potential to integrate EbA approaches in the project area, with specific recommendations include:

- Application of modeling comprising of three different methodologies each of which build on each other: hydrological river basin and water allocation modelling, hydraulic modelling, and erosion and sediment transport;
- River restoration, with duration curves and depth-discharge curves informed by the above models; and
- And the conduct of a fish survey to inform fish passes.

With targeted support to RID in planning and implementing EbA measures in the GCF project site area, RID can then replicate or expand on use of EbA, to complement grey infrastructure, in their plans for the Greater Chao Phraya River Basin Area.

Further, greater application of EbA principles to complement grey infrastructure could benefit functionality of the grey infrastructure. Urban settlements and intensive agricultural use put high pressure on still existing natural habitats. The network of irrigation canals, weirs and diversion structures block and disrupt flow and migration pathways for aquatic life, and numerous stretches or the irrigation canals do not have natural cross sections, vegetated banks and varied morphologic bend structures. Several parts of the irrigation canals are also overgrown with water hyacinths, which are considered to be a weed responsible for both a reduction of storage volume for irrigation purposes, during the dry season. A high usage of fertilizer and pesticide in agricultural practices permeates the area, with high residues causing significant water pollution, and deteriorated water quality – as well as also presenting significant risk of soil toxic accumulation affecting not only and directly fish, but the entire ecological-aquatic food chain.


Pressure on natural habitats


Flow blocking structure


Water hyacinths within an irrigation canal


Straightened canal with bare embankements

5.3 Lack of reliable data and risk information on localized climate change impacts

The inability for water canal and regulator infrastructure to cope under climate change pressures is partly informed by the level (or lack thereof) for climate projections to inform infrastructure at the planning stage. Further, an Early Warning System (EWS) for farmers has not yet been systematically implemented – and only fragmented cases of climate information have been applied for agricultural planning. The current climate information systems allow for medium term forecasts to be more accurate within downscaled localities. Effective flood forecasting and early warning systems for flood and drought forecasts and information communication, relevant to farmers and relevant to the public – are essential. Best practice availability around river basins and early warning systems globally – have combined meteorological forecasts with local hydrology details and topography, in order to provide the best information able regarding the occurrence of floods, several days in advance. The project has already downscaled climate information relevant to the project area, and combined with hydrological modeling of the area, as the preliminary work to be further developed and refined for the development of an early warning system. Loss and damage to some of the hydro-meteorological network infrastructure has occurred, partially in response to the planning stage not being informed by climate change projections. As the network has not been fully implemented to process and disseminate information for farmers – the application of climate information for agricultural planning remains fragmented. Further investment and support is required to improve the dissemination of farmer-tailored climate information, to improve preparedness to changing climatic conditions

5.4 Insufficient coordination between water and agriculture sectors for effective integrated water resources management

As detailed in its NDC, a top adaptation priority for Thailand is to promote and strengthen of IWRM practices to achieve water security, effective water resource management to mitigate flood and drought. To achieve this, greater coordination is needed across sectors, in particular water and agriculture as the most vulnerable to climate change.

5.5 Farmers lack of access to climate information and support to adapt to climate change

Closely related to the lack of localized climate information, there is currently a constrained access to information and support about climate change and adaptation measures to communities and farmers. While communities are already experiencing flood and drought related impacts, without information and support there is a risk for maladaptive measures (e.g. such as ground water extraction for water intensive crops). Diversification to climate-resilient agricultural practices (e.g. adapting drought tolerant crop varieties, techniques using short cycle crops) and water saving technologies (e.g. on farm ponds) requires specific knowledge, skills, and technology transfer that is limited, as communities lack the technical assistance and support owing to limited capacities among peers and local extension staff.

Importantly, with adaptation or change comes uncertainty. Farmers lack sufficient information on markets, and training on accessing new markets, to make informed decisions on changes in crops, agriculture practices and related risk mitigation measures.

Below are a number of preferences/concerns raised by farmers, where additional information, support and coordination could guide them in making sustainable, climate informed decisions:

- Farmers were unfamiliar with markets for non-rice crops, and were uncertain on how to set prices. Without adequate knowledge of markets, potential cash crops like garden vegetables, lemon tree and fruit trees such as mango, guava are grown for household consumption only.
- According to interviews with farmers undertaken during consultation -it is not that farmers prefer to grow rice, but rather that the opportunity/potential for growing other crops is less known than rice in terms of the suitability of soil, the context of flood, the knowledge relating to techniques of production, market and marketing.
- It is found that there are fishes and animals raising. Fishes are raising in soil ponds. Fish raised come from buying fish breeds and/or come with flood. However, fishes could not be raised in rice field because farmers used many kinds of chemical substances in rice production.
- It should be noted that the following factors are cited as being the reasons given by farmers in the Chao Phraya River Basin area for 'not' adapting to flood (after the 2011 flood): 'the perception that floods that took place were rare events; the perception that it is not worthwhile to invest in / implement adaptation strategies; and the lack of knowledge, information and knowhow about adaptation strategies'[225].
- Reasons were given ahead of the 2015-2016 drought, as reasons for 'not' adapting to flood: 'droughts that took place are rare events and lack of capital are main factors that hinder adaptation to drought

[225] Thampanishvong, K. 2014, *Farmers' Adaptation to Extreme Weather Events in the Chao Phraya River Basin*, Thailand Development Research Institute, October 15 2014

among the farm households.[226] Instead, they rely on the short-term strategies to cope with droughts such as finding temporary jobs. A large number of farmers reported that they lack capital to implement adaptation strategies

- Lack of knowledge about adaptation options and markets serve to be barriers to adaptation to severe droughts in the Chao Phraya River Basin[227]

[226] Thampanishvong, K. 2014, *Farmers' Adaptation to Extreme Weather Events in the Chao Phraya River Basin*, Thailand Development Research Institute, October 15 2014

[227] Thampanishvong, K. 2014, *Farmers' Adaptation to Extreme Weather Events in the Chao Phraya River Basin*, Thailand Development Research Institute, October 15 2014

6. Chapter 6: Recommendations for the project interventions

Climate change has shifted rainfall patterns and changed the intensity of the rainfall during the wet season. These changes have forced adjustments to which are more responsive in nature and but of which are not yet systemically applied at the planning stage. These changes have not yet been adequately analysed and reflected in public water management, nor have they been tailored to the needs of farmers and disseminated to inform agriculture practices. The Project's direct beneficiaries (those who reside in the Project area) are estimated to be 20,000 households or 62,000 people and indirect beneficiaries (those who reside outside the Project area but will indirectly benefit from the intervention) will be approximately 25 million people – who reside in the Greater Chao Phraya river basin area.

6.1 Climate-smart investments to improve resilience and upgrade lives and livelihood of small holders farmers in targeted areas

During a series of questionnaires and surveying undertaken during 2016-2017 with farmers across four of the districts within the Yom-Nan project area, farmers gave preferences and suggestions that they would like to see implemented in the area in order to better cope with climate change impacts such as flood and drought.

Structural measures	Percentage
Digging canals for storage water	16.2
Constructing detention areas	10.5
Constructing aquifer wells	10.3
Constructing reservoirs	2.9
Constructing/repairing the drainage doors	2.9
Building a soil ridge to prevent flooding	1.5

Table 51: Recommendation on coping with flooding and drought, structural measures

Non-Structural measures	Percentage
Technical areas	
Releasing water to farms during cultivation period	20.6
Monitoring current's weather condition	8.8
Providing weather information for cultivation preparation	2.9
Changing the dates of growing plants	1.5
Economical, social areas	
Requesting for government cultivation financial support	7.4
Improving drainage system, especially during the rainy period	5.9
Providing supplementary works for farmers to get revenue in a short period of time.	2.9
Monitoring the water system continuously.	2.9
Reducing rice straw burning instead for use as organic fertiliser	1.5

Table 52: Recommendation on coping with flooding and drought, non-structural measures

6.1.1 Ecosystem-based Adaptation (EbA) measures and related capacity building

As part of this feasibility study, the Royal Irrigation Department (RID) and United Nations Development Programme (UNDP) Thailand, requested additional assistance from Gesellschaft fur Internationale Zusammenarbeit (GIZ) to propose Ecosystem-based Adaptation approaches for responding to the risks and impacts of the Yom-Nan area, and for integration into the proposed intervention measures included for this proposal. By nature, Ecosystem-based Adaptation measures are responsive and flexible in nature. Given the level of uncertainty in predicting future climate outcomes this is also imperative. Such measures are linked across sectors, operating in a landscape – e.g. agriculture, urban land use, water management, ecosystem settings – and in order to have a future-proof approach should be integrated in all future planning stages, consisting of integrated adaptation measures encompassing all of the relevant sectors.

In order to establish such a holistic approach in integrating all the relevant aspects into future-responsive measures, the Ecosystem based Adaptation measures assessed:

- Available modeling for the area: including hydrologic modeling for the hydrological regime and the probabilities of occurrence; hydraulic modeling for water levels, flow velocities, inundation maps and risk zones.
- Ecosystem-based Adaptation as a basis for sustainable climate-responsive measures, using agricultural, biodiversity, urban and water related Ecosystem based Adaptation approaches, on principles of balancing provisional, regulatory and cultural ecosystem services, and a systemic approach to utilise the interplay of all components and their effects/impacts.
- An overall integration of data management and dissemination, the infrastructure development and enhanced operation and capacity building – in developing a set of measures for intervention.

6.1.2 Climate resilient agricultural practices and marketable alternatives

While further development of climate adaptive agricultural interventions is to be established through a consultative process during the project phase with farmers in the Yom and Nan River Basin, a number of key activities were identified in the feasibility phase:

- Climate-informed ecological adaptation processes
- Integrated agriculture practices and training
- Conservation agriculture practices and training
- Support for additional on-farm water storage to assist with drought impacts
- Diversification of crop options appropriate to the locality
- Support in appropriate market development and linkages for farmers of the diversified crops.
- Promotion of interspersing of trees on farms to assist on farm water retention in soil and assisting temperature stabilisation and protection against temperature increases.
- Habitat enhancement for fish: re-stocking of irrigation canals with habitat for fish and non-fish species (increasing of food security options).
- Diversified options with ‘back up’ of less water-intensive crop choices.

6.2.3 Agricultural extension and community-based training on climate-smart agricultural practices and climate information incorporation

Interventions will support awareness raising, informed adaptation measures, and training to communities, such as agricultural practices that are less water-intensive. In addition, to allow for effective climate-responsive water management planning to take place – improving climate risk-informed planning information will enable farmers to respond and integrate appropriately climate-informed climate-smart agricultural practices appropriate to their specific location, and assist to build greater climate resilience of the agricultural sector and livelihoods of households within the Yom and Nan River Basin area. Knowledge sharing to extension officers and agricultural households on climate change impacts on agriculture in the Yom and Nan River basins needs to be undertaken that strengthens and works with existing practices and mechanisms.

From the section above 6.2.2 and 6.2.4, the integrated platform of climate resilience and smart farming is included to build greater climate resilience of the agricultural sector and livelihoods of households within the Yom and Nan River Basin area.

6.1.3 Water Management in terms of agricultural practices, and greater intersectoral coordination

The efficient management of water will increase water supplies for the project area in Tung Bang Rakam Floodplain and also be able to help in retaining water flow to the lower Yom River and the Chao Phraya River Basins at a certain level. However, the storage of runoffs within the area would definitely increase the water supply but also would have adverse impacts on farmlands and farming patterns. Therefore it is necessary to set up the appropriate level of water storage in accordance with the cultivating timeline of farmers.

During the middle of rainy season with heavy rains and runoffs draining from the upper area, all water regulator facilities should be opened in order to drain water out of the area. This is to be prepared for a large volume of runoffs in the mid-season till the end of the rainy season. During the end of the rainy season when water level in the Yom River and the flooding water over the lowland subside and get close to the planned storage level, the existing water regulator facilities should be closed to store water then the farming activities can be started (the period around mid-October to late-October). The storage water volume would cover the large area of farmlands in Tung Bang Rakam floodplain at the level of less than 1.20 meters from the ground level. It would be difficult to drain the entire area before the cultivation of the second rice crops and it would cause the loss of storage water. A recommendation for the farmers is that the farming should begin in the area inundated for less than 0.20 meter. The preparations for rice cultivation with transplanting rice seedlings technique are possible to be done in the area inundated with low level of water. Farmers should prepare the farmlands and nurse the seedlings at the same time. The preparation for the seedlings nursery should be in small pieces of land equipped with water pumps to drain those submerged pieces of land. Otherwise farmers should pool up to utilize the land on the high ground as their nursery. Two weeks after the preparation activities on the least flooded farmlands (of less than 0.20 meter of inundation), when water from the surroundings would be drawn for the farming activities, flood level is expected to be subsided. Then the preparation works can be done in the next less flooded farmlands and such this step can be continued until covering the entire project area. The more farmland is cultivated, the less pieces of land submerged. Farms located at the lowest elevation level of this planned flood retention area could be used for farming eight weeks after the first plots of farmlands were cultivated.

According to a graph of relationship between the volume of water demand and the decreased flood volume, the water demand in the area was found to be higher than the amount of flood water retained by about 58.63 million cubic meters. This shortage amount of water should be delivered from outside sources that would be from the Yom River (possibly flow from the Ping River Basin) and Khlong Bang Kaeo Canal (possibly flow from the Nan River

Basin through Khlong Wang Khon, Khlong Mem Canals under operation of the Plai Chum Pol Project). The water flow should be started at the ninth week of the farming season around the end of December till early January. The in-season rice cultivation would start from the mid of April. The rainfed cultivation techniques would be applied. The harvesting should be done before the mid of August when a large amount of runoff would flow into the area.

Further, recharge to groundwater is likely to decrease by around 58 percent due to climate changes within the near future, and by 50 percent in the longer-term future, when compared with current (2015) rates. This case of groundwater recharge reduction, combined with their findings of overall groundwater level reduction (approximately 0.23 metres per year in the short term future, and 0.16 metres per year in the long term future).[228] presents a serious case not only for artificial recharge efforts to the groundwater storage – but for more efficient use and management of water resources in agriculture for the area, including on farm retention measures and farms system artificial recharge configurations to wells and systems that allow slow permeability of water into the soil. Systems such as artificial groundwater recharge, through farmer installations -rainwater capture and onsite water retention filtration to underground pockets, would assist in returning supply during oversaturation times in wet periods, for use in dry periods.

Given the vulnerability of the agriculture sector to climate change, and the impact of climate change on temperature and water, ensuring greater intersectoral coordination between agriculture and water planning is of critical importance. And this integration should be evident in support provided to communities and households.

6.2 Strengthened water management infrastructure for greater resilience to projected climate change

The proposed measures in the project seek to support more effective water management and an increase in the number of irrigated farmlands. Overall, in terms of recommended proposed improvement measures, the interventions primarily consist of measure for increased water storage within the irrigation network, and the use of water retention ponds for irrigation purposes within the dry season; enhancements to manage flood events by responding to higher return periods in agricultural land flood prevention; and increased protection of farmland against flooding and enabling two harvests per year. Specifically – activities to achieve this fall under the: dredging of canals, maintenance and improvement of existing weirs and diversion structures, heightening embankments and damns, and constructing new retention ponds within the project area. The climate analysis of Output 1 will inform the necessary upgrades to existing infrastructure, namely the canal and regulator network in the Yom and Nan river basins. Per the recently-conducted feasibility study undertaken by the Royal Irrigation Department, in order to adequately regulate water during wet and dry season, four water gates need to be upgraded and three existing canals need to be enlarged to ensure greater climate resilience. Specifically, the recommended interventions, per the feasibility study include the following:

[228] Koontanakulvong, S., & Suthidhummajit, C. 2015. 'The Role of Groundwater to mitigate the drought and as an adaptation to climate change in the Phitsanulok Irrigation Project, in the Nan Basin, Thailand', *Jurnal Teknologi*, 76:15, Pp 89-95

6.2.1 Selection of the water infrastructure types and improvements (for all 13 targeted sites, including the two proposed to be implemented under outcome 2 of this project)

No.	Component	Dimension		Discharge Capacity		Construction Cost		Detailed Design Drawings
		Existing	Improvement	Existing (cms)	Improve (cms)	(M Baht)	(M $US)	
1	Khlong Nam Lai Improvement,			100	150	60.00	1.71	Completed
	including embankment (12 km)							
2	Khlong Wang Khon Improvement,			100	150	135.00	3.86	Completed
	including embankment (27 km)							
3	The Old Yom River Improvement (11 km)			120	200	85.00	2.43	Completed
4	Khlong Muang Chang Improvement,	No.1 2 @ 2.0 x 2.0 m	No.1 2 @ 6.0 x 5.0 m	30	100	200.00	5.71	Completed
	including appurtenance structures	No.2 2 @ 2.0 x 2.0 m	No.2 2 @ 6.0 x 5.0 m	30	100			
5	Wang Khon Regulator Reconstruction	3 @ 2.9 x 3.0 m	3 @ 6.0 x 5.0 m	100	150	60.00	1.71	Completed
6	Wang Won Regulator Reconstruction	3 @ 2.9 x 3.0 m	3 @ 6.0 x 5.0 m	70	150	60.00	1.71	Completed
		+ 2 @ 2.0 x 2.0 m		30				
7	Wang Makham Regulator Reconstruction	3 @ 2.9 x 3.0 m	4 @ 6.0 x 5.0 m	70	200	90.00	2.57	Completed
		+ 2 @ 2.0 x 2.0 m		30				
8	Ta Kay Regulator Reconstruction	3 @ 2.9 x 3.0 m	4 @ 6.0 x 5.0 m	70	200	90.00	2.57	Completed
		+ 2 @ 2.0 x 2.0 m		30				
9	Khlong Rahan Improvement (11.6 km),		3 @ 6.0 x 5.0 m		150	100.00	2.86	Completed
	including reconstruction of a regulator							
10	Khlong Kate Improvement (7.5 km)		2 @ 6.0 x 5.0 m		100	60.00	1.71	On going
	including reconstruction of a regulator							
11	Khlong Kram Improvement,				50	30.00	0.86	On going
	including embankment (12 km)							
12	Khlong Bang Kaew Drainage Improvement,				500	400.00	11.43	On going
	including embankment (60 km)							
13	Khlong Nam Lai Drainage Improvement,				150	85.00	2.43	On going
	including embankment (17.5 km)							
	Total					**1,455.00**	**41.57**	

Table 53: *Proposed component to be improved and cost*

**Currency exchange rate: THB35 = US$1*

Total construction and improvement cost is 1,455 million THB

Project section:	Province	District	Subdistrict	Villages
1. Improving Khlong Nam Lai and improving the left and right banks project	Uttaradit, Sukhothai	Phichai, Srinakorn	Thamafuang, Korrum, Klongmaplup, Nongbuo	Village 8 : Baan Log 17 Village 4 : Baan Paataew Village 9 : Baan Klongnamlai Village 7 : Baanbangna Village 8 : Baan klongmaplup Village 1 : Baanpaakratum
2. Improving Khlong Wang Khon and Improving the left and right banks	Phitsanulok,	Promphiram	Nongkham, Wangwoon, Sriphirom, Thaloktiem	Village 8 : Baanklongtan Village 4 : Baanwangsatoe Village 1 Baanwangwoon Village 2 Baanklang Village 8 Baanwangmaikhan Village 10 Baanwangmaikhan

Project section:	Province	District	Subdistrict	Villages
				Village 10 Baanbungthammaroong Village 2 Baanthangam Village 3 Baansong Village 6 BaanPhrayabundan
3. Improving Old Yom river and improving the left bank	Phitsanulok, Sukhothai	Promphiram, Khongkairas	Nongkham, Wangwoon, Promphiram, Kokrat	Village 9 Baanwangmakham Village 7 Baanwangnamboe Village 5 Baan klongthakha Village 11 Baanwangnamyen Village 4 baankokrat Village 6 Baankangluang Village 10 Baanthaplai
4. Improving Khlong Muang Chang and building	Sukhothai	Khongkairas	Kainok, Dongdoei	Village 8 baanwangpaisoong Village 4 Baandongyang Village 7 Baandonsamrong
5. Improving Wangkhon water and drainage system	Phitsanulok	Promphiram	Sriphirom, Wangwoon,	Village 10 Baanbungthammaroong Village 10 Baanbunghai Village Village 9 BaannongThan
6. Improving Wangwoon water draining system	Phitsanulok	Promphiram	Wangwoon	Village 1 Baanwangwoon Village 2 Baanklang Village 3 Baannonghang Village 4 Baanwangsatoe Village 5 Baandongmakrud Village 6 Baanklong Thamnaeb Village 8 Baanwangmaikhen Village 8 Baanwangmaikhen
7. Improving Wangmakham water draining system	Phitsanulok	Promphiram	Wangwoon, Promphiram	Village 9 Baanklong wangmakham Village Baanklongtan Village 11 Baanwangnamyen
8. Improving Klongthakae water draining system	Phitsanulok, Sukhothai	Promphiram, Khongkairas	Wangwoon, Promphiram, Kokrat	Village 7 Baanwangboe Village 9 Baanklong wangmakham Village 5 Baanklongthakha Village 11 Baanwangnamyen Village 6 Baankangluang
9. Improving Klongrahan and building	Phitsanulok	Bangrakham	Thanangngam, Choomsaeng songklam, Baankrang	Village 5 Baanhuoachan Village 3 Baanwangrae Village 10 Baanmaerahan

Project section:	Province	District	Subdistrict	Villages
10. Improving Klong Ked and building	Phitsanulok	Bangrakham	Choomsaeng songklam, Baankrang	Village 3 Baanwangrae Village.9 BaanThabagngam Village 10 Baanmaerahan
11. Improving Klongklum and building	Phitsanulok	Bangrakham	Choomsaeng songklam	Village 3 Baanwangrae Village.9 BaanThabagngam
12. Improving Klong bangkaew water and drainage system	Phitsanulok	Bangrakham, Muang, Promphiram	Thanangngam, Baankrang, Thachang	Village 3 Baanbangkaew Village 5 Baanhuochan Village 8 Baanyanyai Village 10 Baanmaerahan Village 10 Baanwangkhileg Village 12 Baanmaisuksumran
13. Improving Klong Namlai water drainage system	Sukhothai, Uttaradit, Phitsanulok	Srinakhon, Phichai, Promphiram	Klongmaplup, Korrum, Thamafuang, Phrayaman, Thaloktiem, Sriphirom, Wangwoon, Nong Kham	Village 8 Baanklongmapulp Village 9 Baanklongnamlai Village 8 Baanlog 17 Village 6 Baanphrayapandan Village 10 Baannongfugkhoon Village 2 Baanthangam Village 3 Baandansong Village 10 Baanwangmaikhen Village 8 Baanklongtan

Table 54: Villages in the project area that receive direct impact from upgrades to water infrastructure, according to project section

Khlong Improvement:

1. Improvement of Khlong Nam Lai (its width) to strengthen water distribution and diversion capacity from 100 to 150 cms and build the concrete river bank on the left and right sides. The distance is 12 km and the cost is 60 M baht. The design capacity by using the rational formula method in 25 years of annual occurrences is 150 cms.

2. Improvement of Khlong Wang Khon (its width) to strengthen water distribution and diversion capacity from 100 to 150 cms and build the concrete river bank on the left and right sides. The distance is 27 km and the cost is 135 M baht. The design capacity by using the rational formula method in 25 years of annual occurrences is 150 cms and the regulator size is 3 @ 6.00 x 5.00 m.

3. The Old Yom River Improvement: Improvement of the Old Yom River (its width) to strengthen water distribution and diversion capacity from 120 to 200 cms and build the concrete river bank on the left and right sides. The distance is 11 km and the cost is 85 M baht.

4. Khlong Muang Change Improvement: Improvement of Khlong Muang Change, including appurtenance structures, to strengthen water distribution and diversion capacity from 30 to 100 cms and build the concrete river bank on the left and right sides. The cost is 200 M baht.

5. Wang Khon Regulator Reconstruction: Build Wang Khon Regulator to replace the old water diversion pipeline which had limited capacity and to regulate the flow (divert flood and distribute water). The cost of

construction is 60 M baht.

6. Wang Won Regulator Reconstruction: Build Wang Won Regulator to replace the old water diversion pipeline which had limited capacity and to regulate the flow (divert flood and distribute water). The cost of construction is 60 M baht.

7. Wang Makham Regulator Reconstruction: Build Wang Makham Regulator to replace the old water diversion pipeline which had limited capacity and to regulate the flow of water (divert flood and distribute water). The cost of construction is 90 M baht.

8. Ta Kay Regulator Reconstruction: Build Ta Kay Regulator to replace the old water diversion pipeline which had limited capacity and to regulate the flow of water (divert flood and distribute water). The cost of construction is 90 M baht.

9. Khlong Rahan Improvement: Improvement of Khlong Rahan, including a regulator, to strengthen water distribution and diversion capacity. The distance is 11.6 km and the cost is 100M baht.

10. Khlong Kate Improvement: Improvement of Khlong Kate, including a regulator, to strengthen water distribution and diversion capacity. The distance is 7.5 km and the cost is 60 M baht.

11. Khlong Kram Improvement: Improvement of Khlong Kram to strengthen water distribution and diversion capacity. The distance is 12 km and the cost is 30 M baht.

12. Khlong Bang Kaew Improvement: Improvement of Khlong Bang Kaew to strengthen water distribution and diversion capacity. The distance is 60 km and the cost is 400 M baht.

13. Khlong Nam Lai Drainage Improvement: Improvement of Khlong Nam Lai drainage to strengthen water distribution and diversion capacity. The distance is 17.5 km and the cost is 85M baht.

The total construction and improvement cost is 1,455 M baht.

Stream System and Drainage System

The planned water retention area is the lowland between two main waterways that lay in the Yom River on the west and Khlong Mem or Khlong Bang Kaeo canal on the east. These two waterways converge at Bang Rakam's Bang Rakam sub-district. The conclusions are these followings;

1. The upper part of the designated retention area (north of Ban Krand-Ban Bang Kaeo route and the north of Khlong Wang Rae canal) contains a number of stream and river systems including:

- Khlong Muang Chang Canal (Khlong Nong Luang Canal), Khlong Ban Mai Canal and Khlong Bung Kok Canal are flowing through Highway No.12 (Sukhothai-Phitsanulok) and entering the area from the north.
- Khlong Kod Canal (Khlong Tung Koo or Khlong Khi Lek Canal) splits from Khlong Mem
- Canal (Khlong Bang Kaeo) on the east side of the area. This canal empties into the end course of Khlong Klam Canal then joining Khlong Mem Canal (Khlong Bang Kaeo).
- Khlong Samrong Canal connects to the Yom River on the west. A part of the canal also connects to Khlong

Klam Canal and another part flows southward emptying into Khlong Wang Rae (Khlong Lahan) Canal.

- Khlong Klam Canal receives water supply from several canals such as Khlong Samrong, Khlong Muand Change (Khlong Nong Luang) Khlong Ban Mai, Khlong Bung Kok and Khlong Kod (Khlong Tung Koo or Khlong Khi Lek) Canals and empties into Khlong Mem Canal on the east.Khlong Wang Rae or Khlong Lahan Canal is considered the main waterway in the mid of the planned retention area. It connects to the Yom River on the west and also receives water supply from Khlong Samrong and Khlong Ket Canals. Khlong Klum canal empties into Khlong Ket Canal on north-south axis then joining Khlong Wang rae Canal, after that merging into Khlong Mem or Khlong Bang Kaeo Canal on the east part of the area.

2. The lower part of the planned retention area (south of Ban Krang-Ban Bang Kaeo Road and south of Khlong Wang Rae Canal) contains these following water systems,

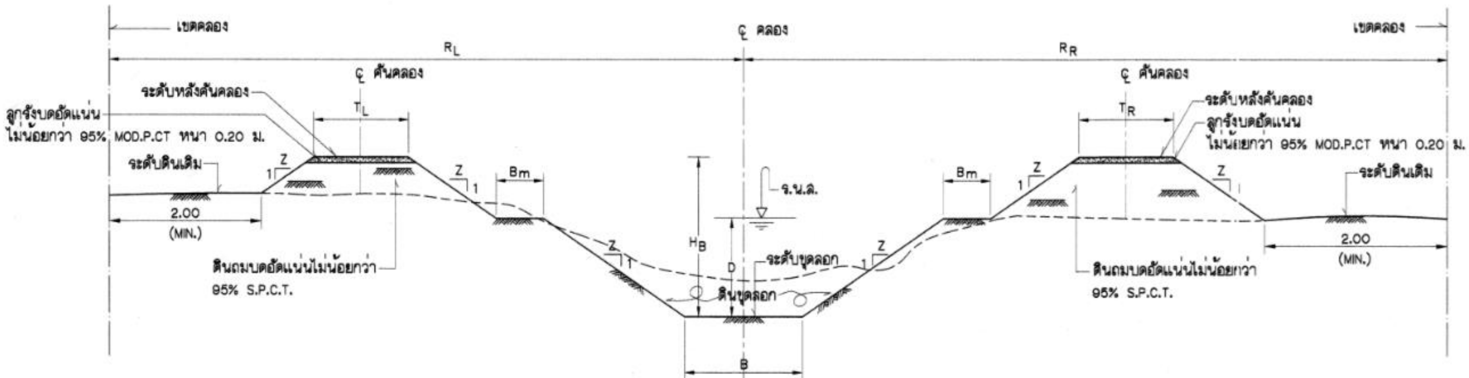
- Nong Krao is only large lake in the planned retention area project with its length of about 3 kilometers and the width of 100 meters at the widest part. A dike has been built across the end part of the lake in order to collect water for consumption. Nong Krao Lake receives water supply from Khlong Lahan or Khlong Wang Rae Canal from the north and flows southward through the low-lying area in Chum Saeng Songkram sub-district. Then this canal separates into two streams,
- The first stream runs to join Khlong Dai Cha Lued and Khlong Huay Yai Canals before emptying into the Yom River at Ban Yan Yao Village.
- The second stream runs to join Khlong Pla Krai Canal then emptying into Khlong Bang Kaeo Canal.
- Khlong Nong Suang Canal receives water supply from Khlong Wang Rae and flows southward. A branch of Khlong Nong Suang Canal flows southward joining Khlong Cha Dai Lued Canal which emptying into the Yom River. Another branch joins Khlong Pla Krai Canal then emptying into Khlong Bang Kaeo Canal.
- Khlong Kra Kok and Khlong Tha Mo Canals are splitting from Khlong Nong Suang Canal and flow eastward to join Khlong Mem Canal.
- Khlong Huay Yai Canal collectes run-off water from the lowland located near the part of Nong Krao Lake and flows into Khlond Dai Cha Lued Canal then emptying into the Yom River.

Project elements being recommended in terms of hard infrastructure:

1. Hydraulic structures to be utilized for control of water flow. It would manage the water inputs and outputs between the project area and main waterways outside as well as to manage the circulations and drainage of water within the project area. Details are including;

- Drainage tunnels equipped with gates, nine facilities in total
- Floodgates, three facilities in total

2. The construction of levees to assist the hydraulic structures in controlling and maintaining water to be within the particular waterways. This element has been planning in the lowlands and the lower part of the project area (not for preventing the runoff or flood water flowing into the area) with total length of 15.60 kilometers.



S Longitudinal	1:Z	B (m)	D (m)	H_B (m)	B_m (m)	T_L (m)	T_R (m)	R_L (m)	R_R (m)
1:10,000	1:1.5	30.00	4.00	6.00 (MAX.)	2.00 (MIN.)	6.00 (MIN.)	6.00 (MIN.)	–	–

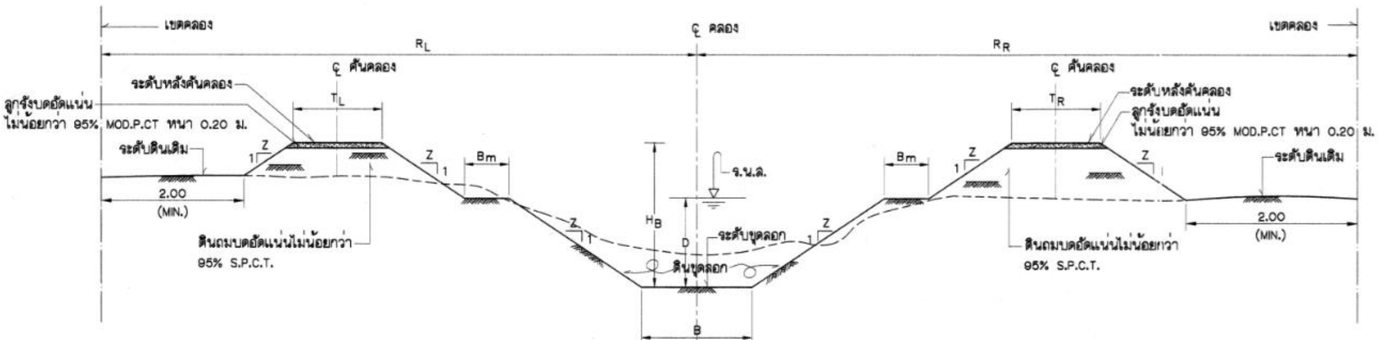
Khlong Nam Lai

Left Bank Drainage Culvert

Right Bank Drainage Culvert

Figure 82: Khlong Nam Lai Improvement

Source: Royal Irrigation Department



S Longitu	1:Z	B (m)	D (m)	H_B (m)	B_m (m)	T_L (m)	T_R (m)	R_L (m)	R_R (m)
1:10,000	1:1.5	30.00	4.00	6.00 (MAX.)	2.00 (MIN.)	6.00 (MIN.)	6.00 (MIN.)	–	–

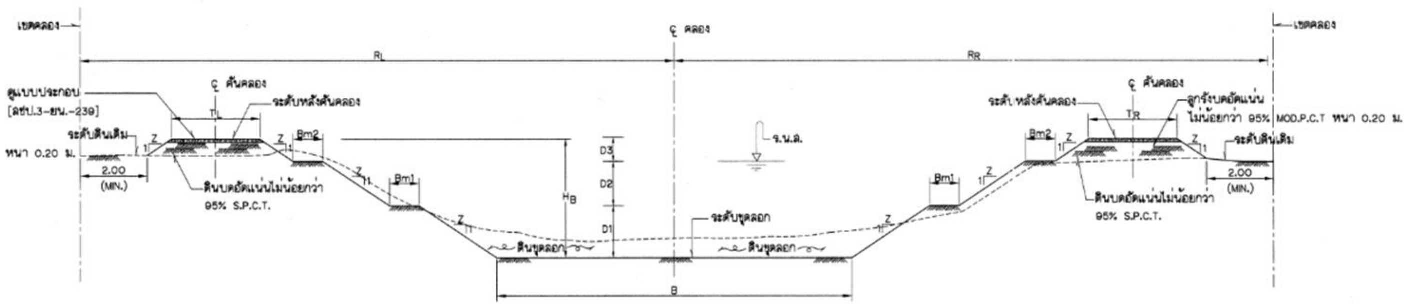

Khlong Wang Khon near Ban Khom


Khlong Wang Khon near Wang Khon Culvert


Khlong Wang Khon near Wang Won Culvert

Figure 83: Khlong Wang Khon Improvement

Source: Royal Irrigation Department



S Longitudinal Slope	1:Z	B (m)	D1 (m)	D2 (m)	D3 (m)	H_B (m)	B_{m1} (m)	B_{m2} (m)	T_L (m)	T_R (m)	R_L (m)	R_R (m)
1:10,000	1:1.5	40.00	4.00	3.50	3.00	10.50 (MAX.)	2.00 (MIN.)	2.00 (MIN.)	6.00 (MIN.)	6.00 (MIN.)	–	–

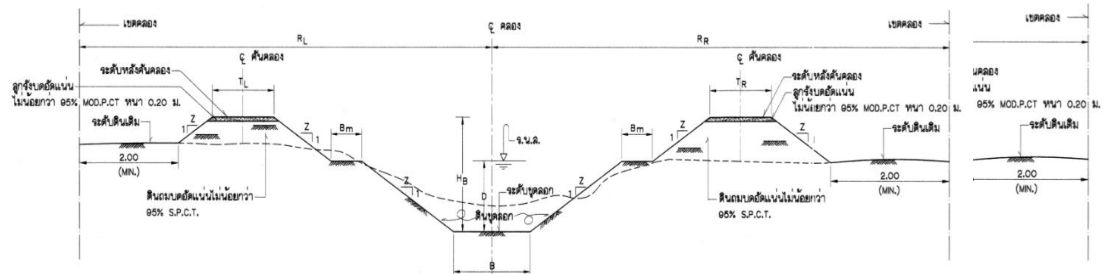

The Old Yom River near Khlong Ta Kay Cul.


The Old Yom River


Beneficiary Areas

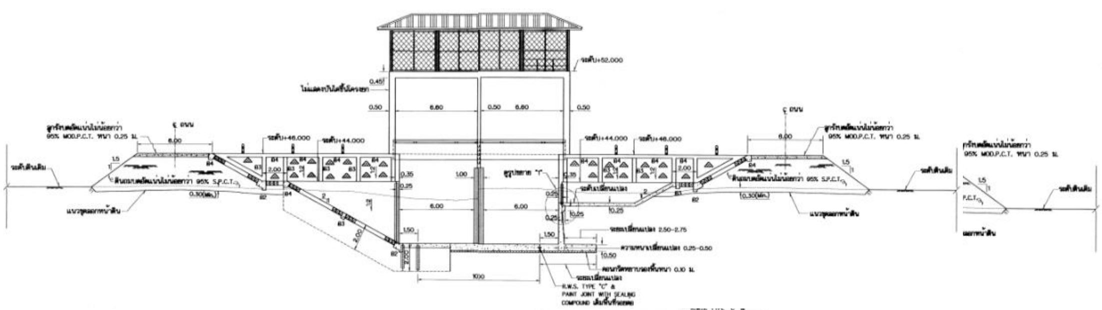
Figure 84: The Old Yom River Improvement

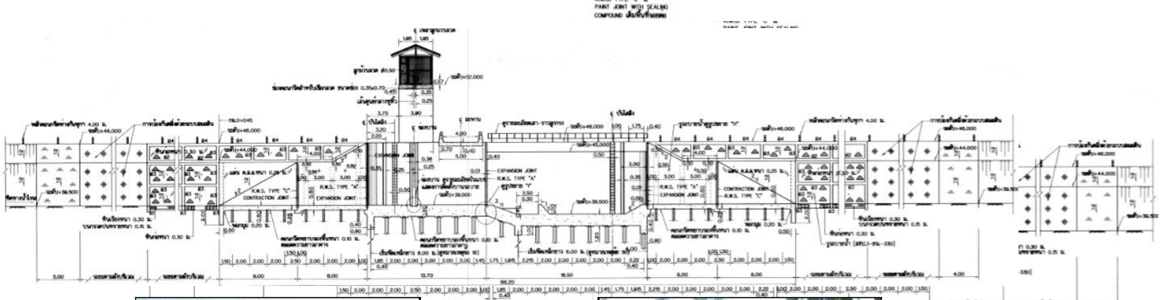
Source: Royal Irrigation Department

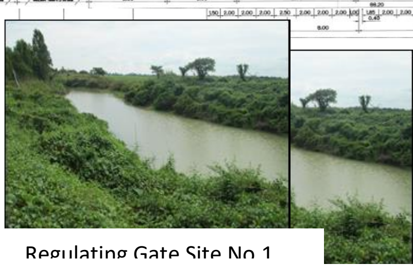


S Lon	1:Z	B (m)	D (m)	H_B (m)	B_m (m)	T_L (m)	T_R (m)	R_L (m)	R_R (m)	R_L (m)	R_R (m)
1:10,000	1:1.5	30.00	4.00	6.00 (MAX.)	2.00 (MIN.)	6.00 (MIN.)	6.00 (MIN.)	–	–	–	–

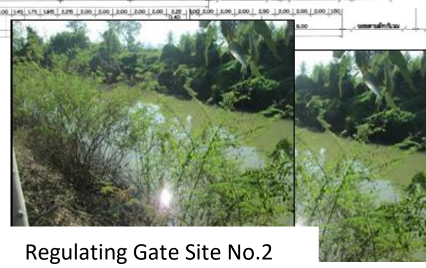
Khlong Muang g Cha Khlong Muang ng Ch Beneficiary Areas ary Areas







Regulating Gate Site No.1

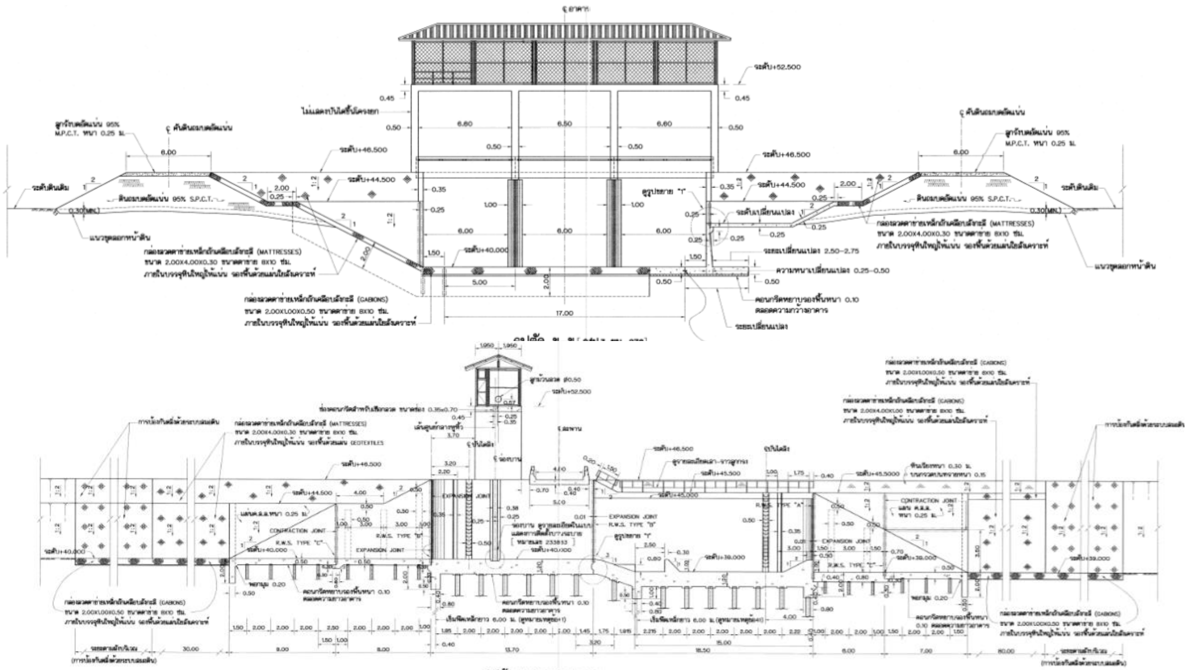


Regulating Gate Site No.2

Regulating Gate Site No.1 Regulating Gate Site No.2 Downstream

Figure 85: Khlong Muang Change Improvement

Source: Royal Irrigation Department

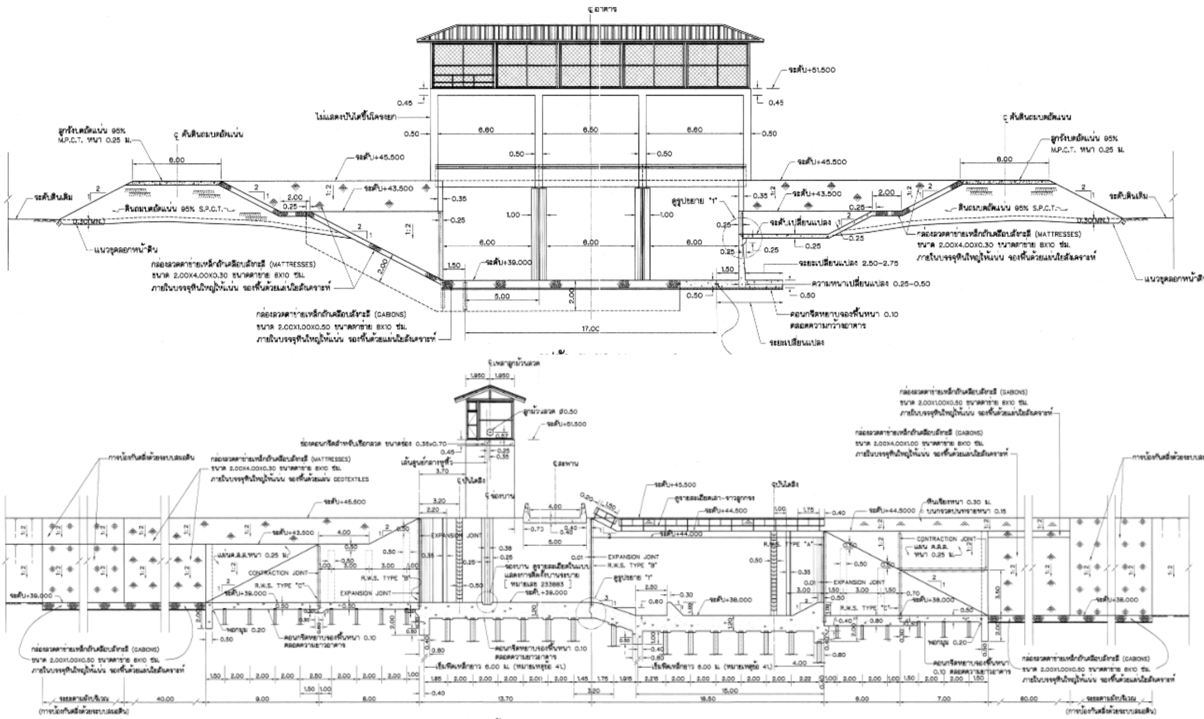


Existing Wang Khon Culvert 3 @ 2.90 x 3.00 m (looking upstream)

Existing Wang Khon Culvert 3 @ 2.90 x 3.00 m (looking downstream)

Figure 86: Wang Khon Culvert Reconstruction

Source: Royal Irrigation Department



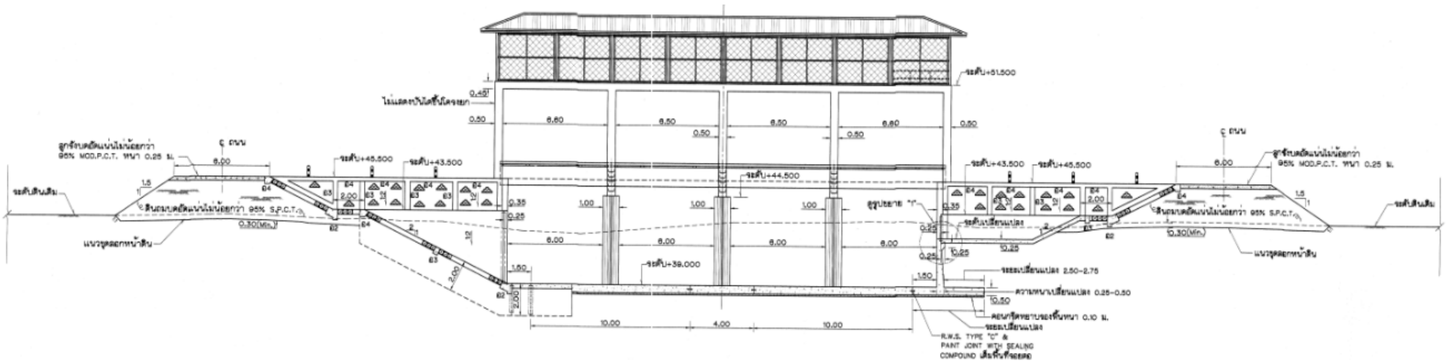
Existing Wang Won Culvert 3 @ 2.90 x 3.00 m (looking upstream)

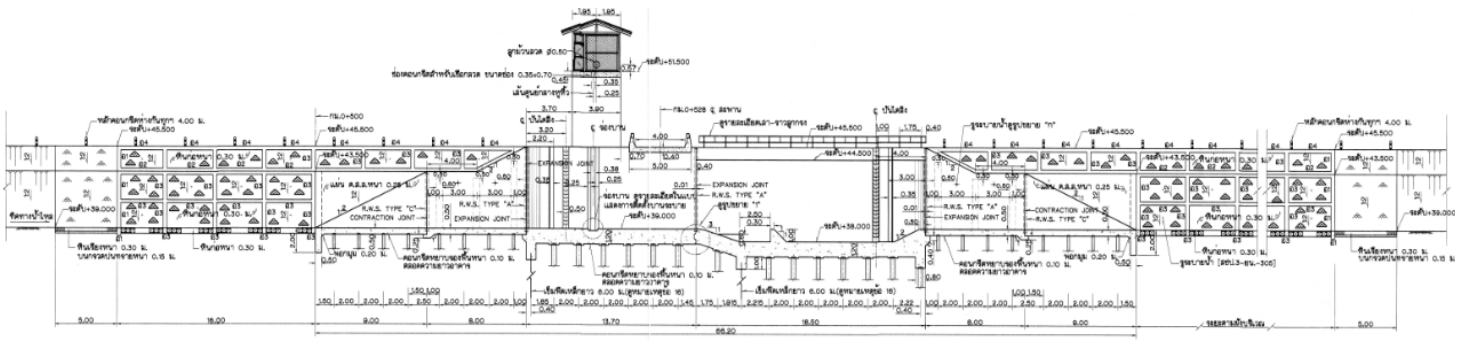
Existing Wang Won Culvert 3 @ 2.90 x 3.00 m (looking downstream)

Existing Culvert 2 @ 2.00 x 2.00 m nearby (looking downstream)

Figure 87: Wang Won Culvert Reconstruction

Source: Royal Irrigation Department





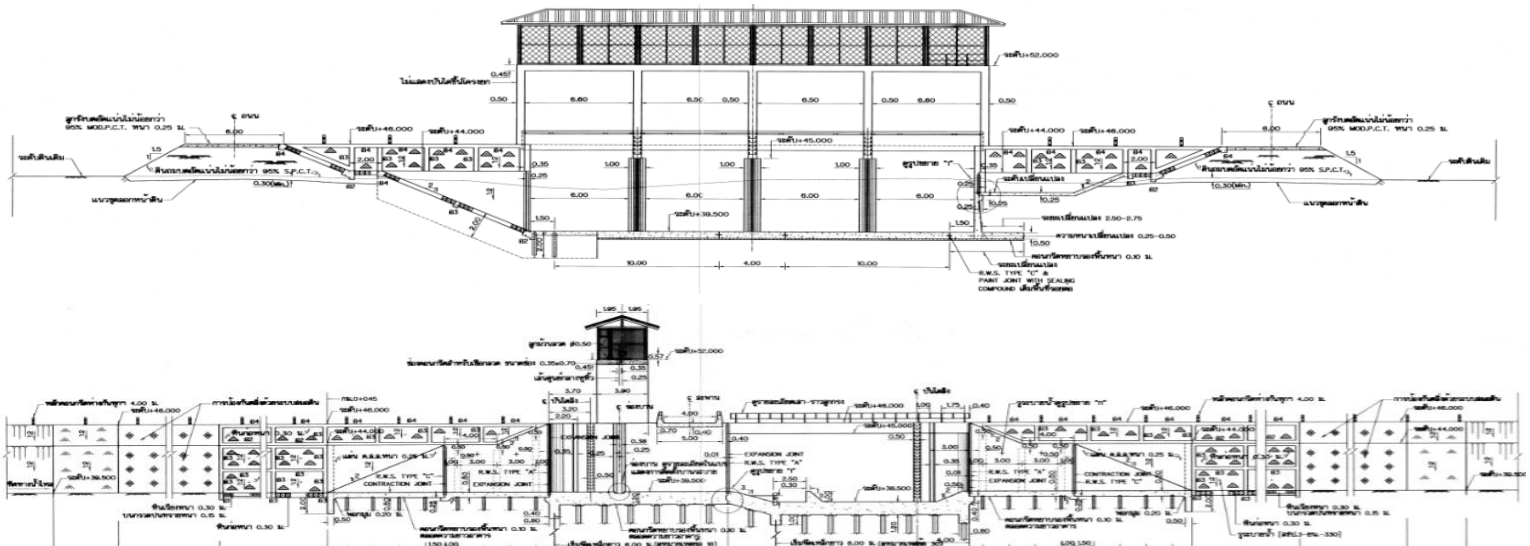
Existing Wang Makham Culvert 3 @ 3.00 x 3.00 m
(looking upstream)

Existing Wang Makham Culvert 3 @ 3.00 x 3.00
(looking downstream)

Existing Culvert 3 @ 2.00 x 2.00 m
nearby (looking upstream)

Figure 88: Wang Makham Culvert Reconstruction

Source: Royal Irrigation Department



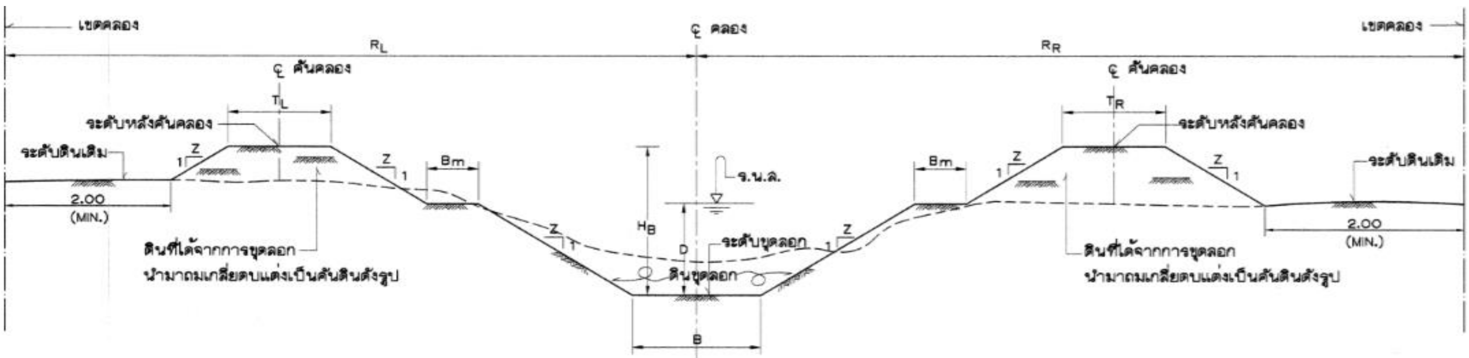
Existing Khlong Ta Kay Culvert 3 @ 2.90 x 3.00 m with Culvert 2 @ 2.00 x 2.00 m at both sides

Existing Khlong Ta Kay Culvert (looking upstream)

Existing Khlong Ta Kay Culvert (looking downstream)

Figure 89: Khlong Ta Kay Culvert Reconstruction

Source: Royal Irrigation Department



S Longitud	1:Z	B (m)	D (m)	H_B (m)	B_m (m)	T_L (m)	T_R (m)	R_L (m)	R_R (m)
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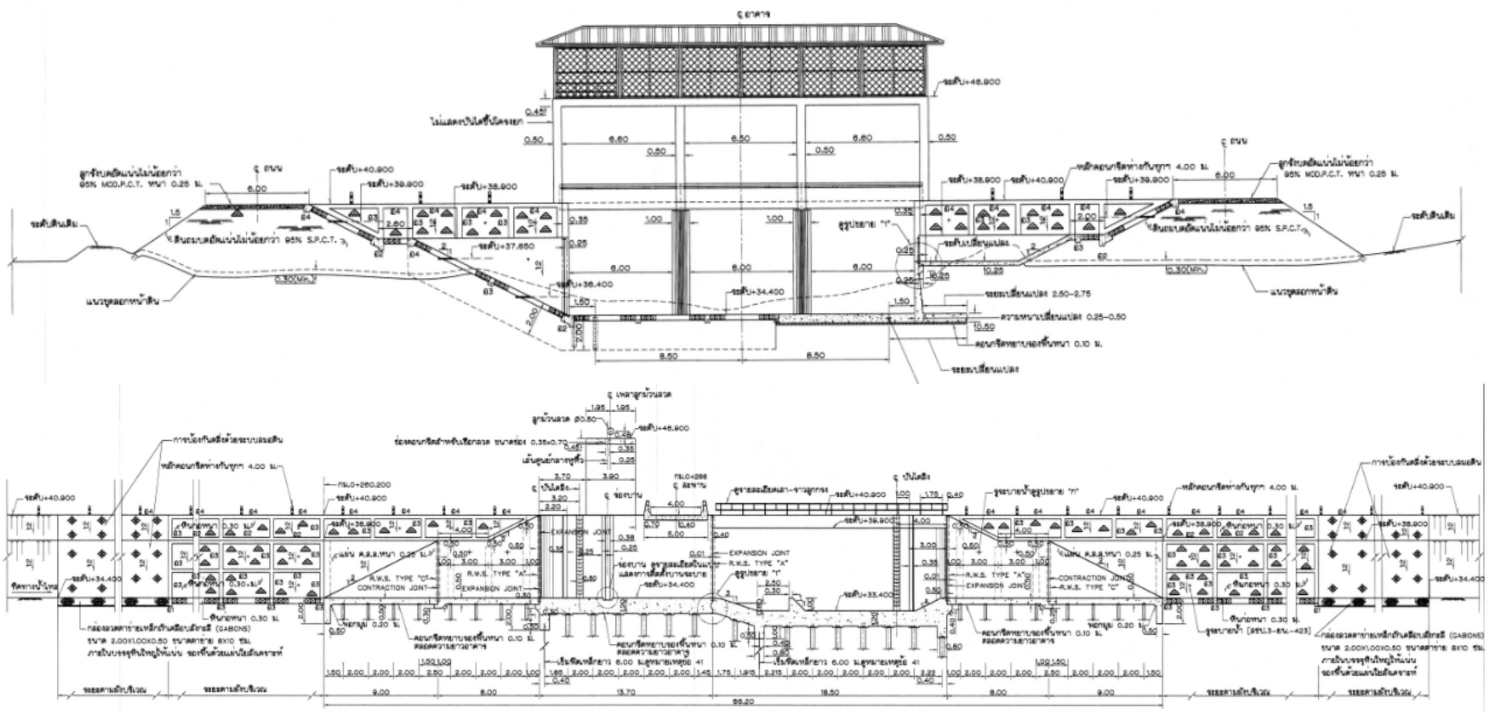
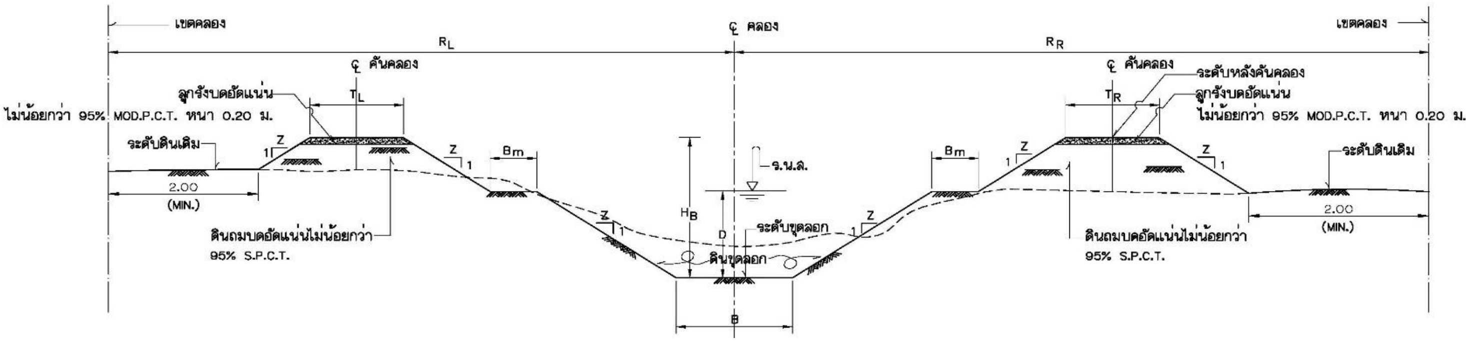


Figure 90: Khlong Rahan Improvement

Source: Royal Irrigation Department



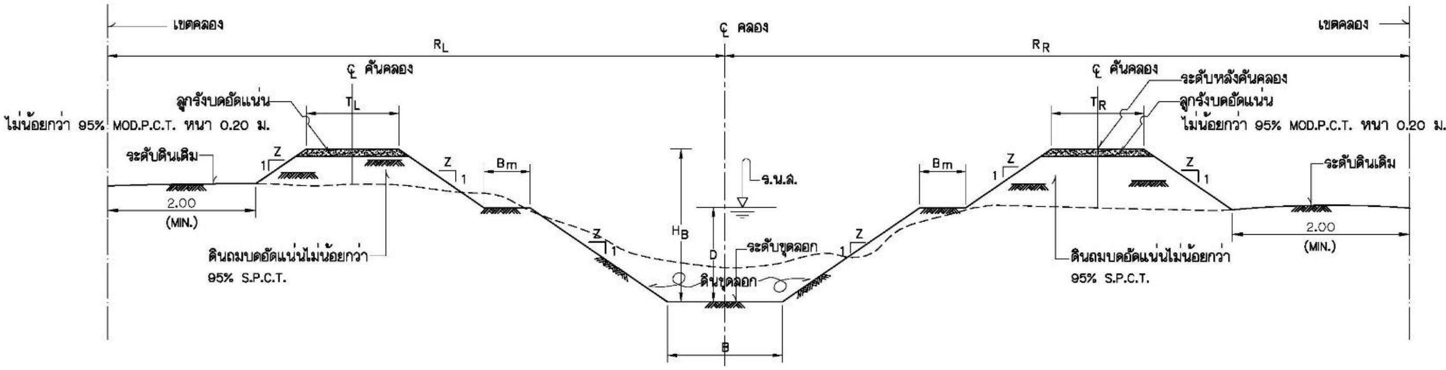
S Longituinal Slope	1:Z	B (m)	D (m)	H_B (m)	B_m (m)	T_L (m)	T_R (m)	R_L (m)	R_R (m)
1:10,000	1:1.5	25.00	4.00	5.50 (MAX.)	2.00 (MIN.)	6.00 (MIN.)	6.00 (MIN.)	–	–


Khlong Kate


Khlong Kate

Figure 91: Khlong Kate Improvement

Source: Royal Irrigation Department



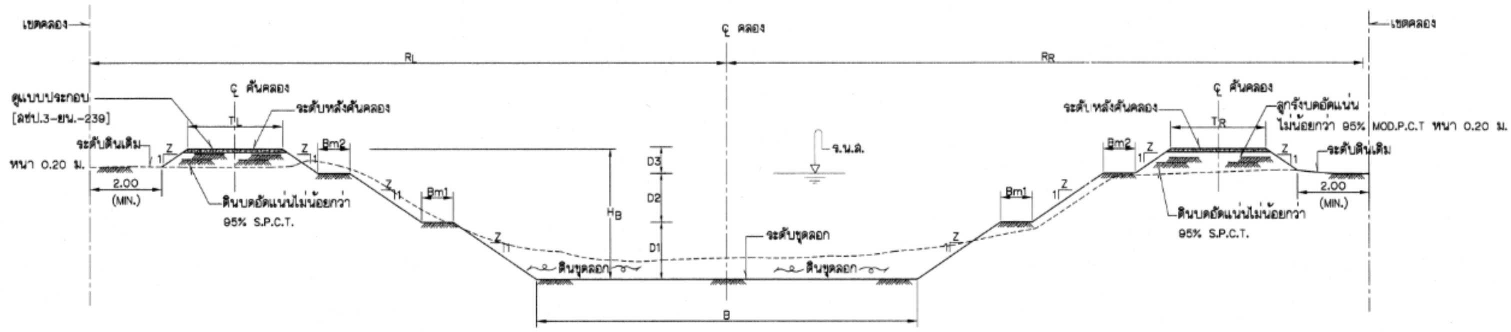
S Longituinal Slope	1:Z	B (m)	D (m)	H_B (m)	B_m (m)	T_L (m)	T_R (m)	R_L (m)	R_R (m)
1:10,000	1:1.5	18.00	3.50	4.50 (MAX.)	2.00 (MIN.)	6.00 (MAX.)	6.00 (MIN.)	–	–


Khlong Kram


Khlong Kram

Figure 92: Khlong Kram Improvement

Source: Royal Irrigation Department



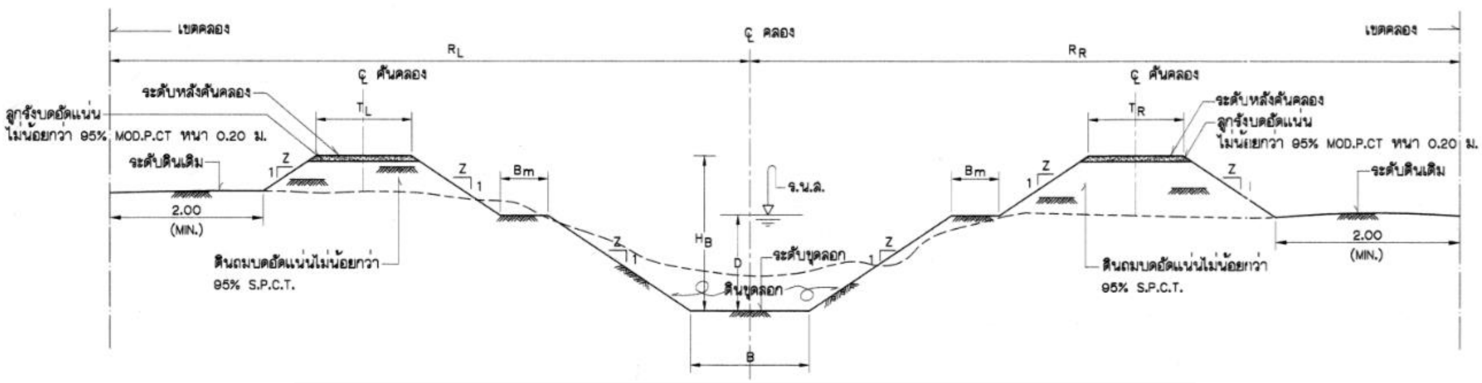
S Longituinal Slope	1:Z	B (m)	D_1 (m)	D_2 (m)	D_3 (m)	H_B (m)	B_{m1} (m)	B_{m2} (m)	T_L (m)	T_R (m)	R_L (m)	R_R (m)
1:10,000	1:1.5	50.00	4.00	3.50	3.00	10.50 (MAX.)	2.00 (MIN.)	2.00 (MIN.)	6.00 (MIN.)	6.00 (MIN.)	–	–

Khlong Bang Kaew

Beneficiary Areas

Figure 93: Khlong Bang Kaew Improvement

Source: Royal Irrigation Department



S Longitud...	1:Z	B (m)	D (m)	H_B (m)	B_m (m)	T_L (m)	T_R (m)	R_L (m)	R_R (m)
1:10,000	1:1.5	30.00	4.00	6.00 (MAX.)	2.00 (MIN.)	6.00 (MIN.)	6.00 (MIN.)	–	–


Khlong Nam Lai


Khlong Nam Lai


Beneficiary Areas

Figure 94: Khlong Nam Lai Drainage Improvement

Source: Royal Irrigation Department

6.3 Improving climate risk-informed planning in the water and agriculture sectors

A number of activities to take place will improve climate risk-informed planning capacity within the water and agriculture sectors. These include training, dialogue and forums to improve climate risk-informed planning in the water and agriculture sectors. The proposed interventions will support tailored climate information for both enhanced water management and agricultural planning. Some risk mapping has already been undertaken, as well as, for this feasibility study preliminary assessments of climate projections and climate-risk hydrological modeling. Additionally, under Output 1, detailed comprehensive risk mapping will be undertaken across the Yom and Nan River Basin area using a hydrological model with catchment characteristic data; in this case, Yom and Nan River Basins, together with the forecasted climate data, future runoff/discharges can be simulated. The volume of water can be estimated and used for water management planning.

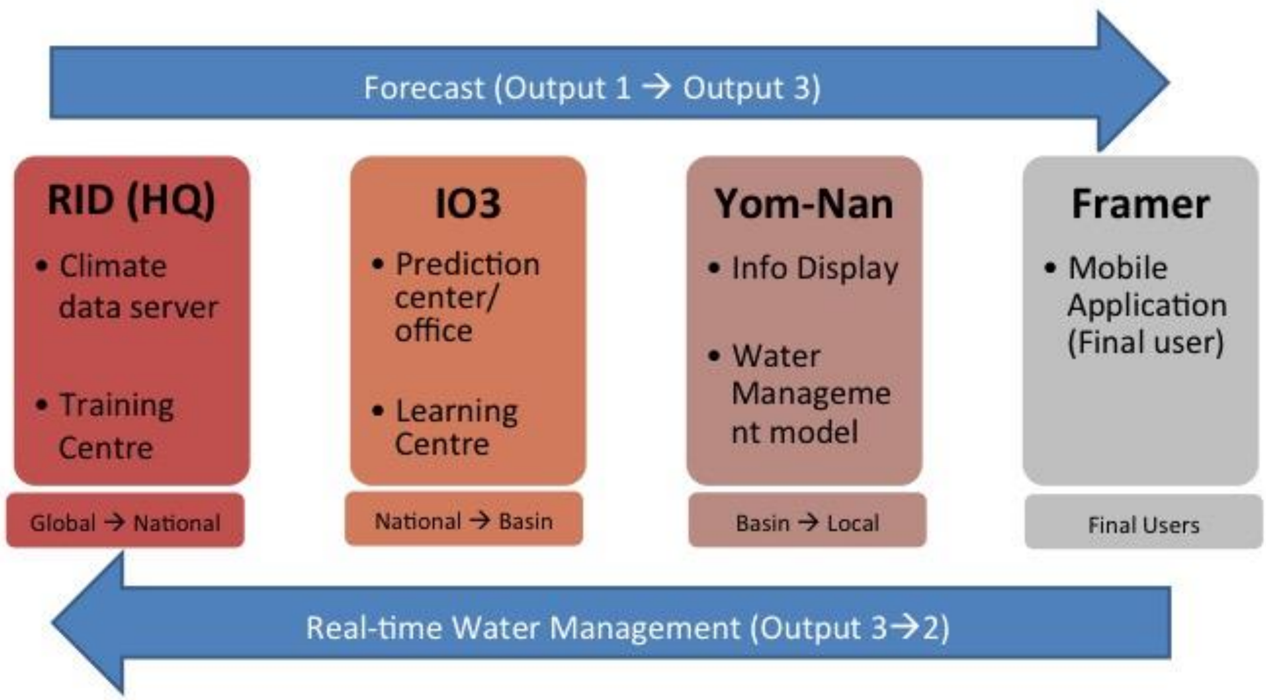
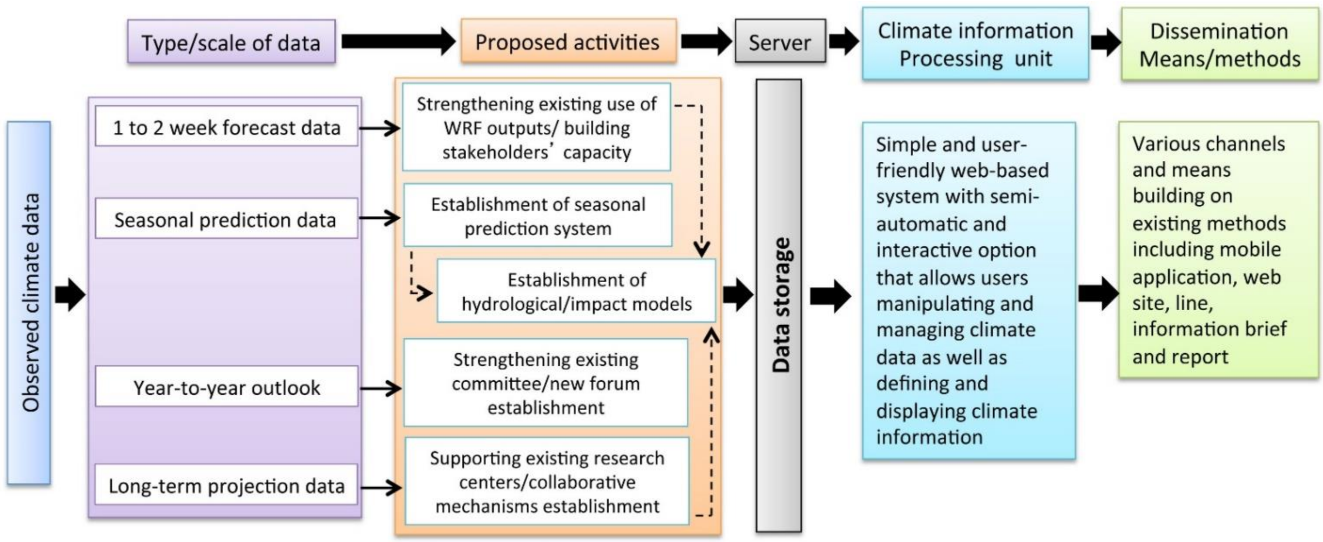


Figure 95: Proposed climate data information centre



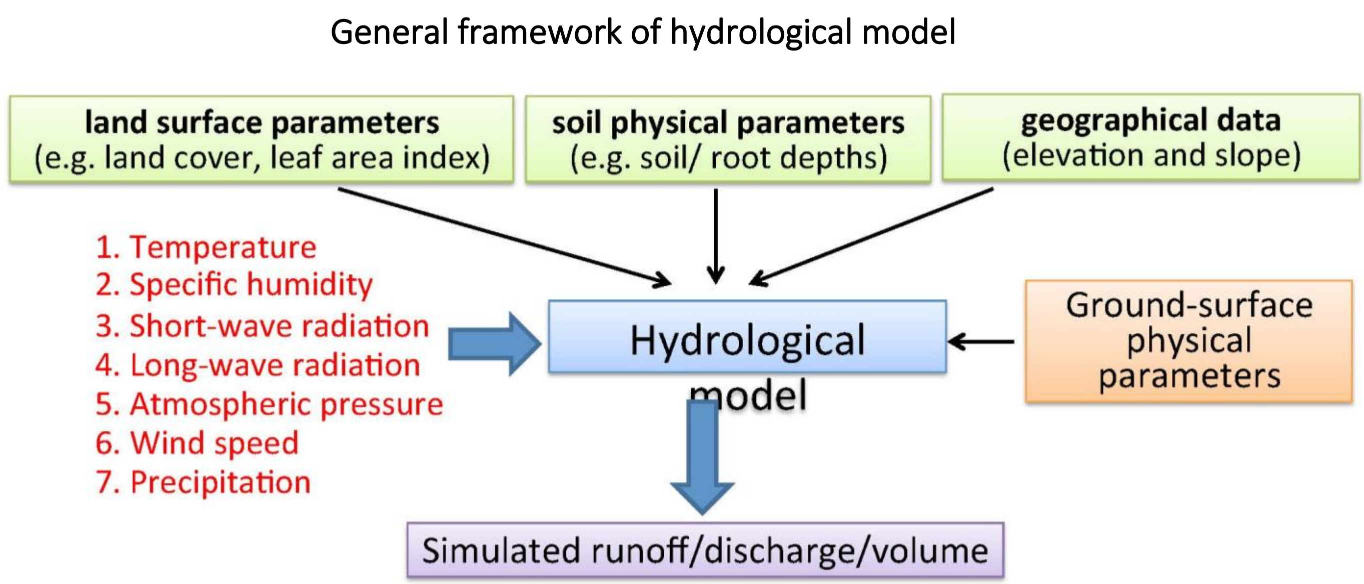


Figure 96: Proposed approach to hydrological modelling

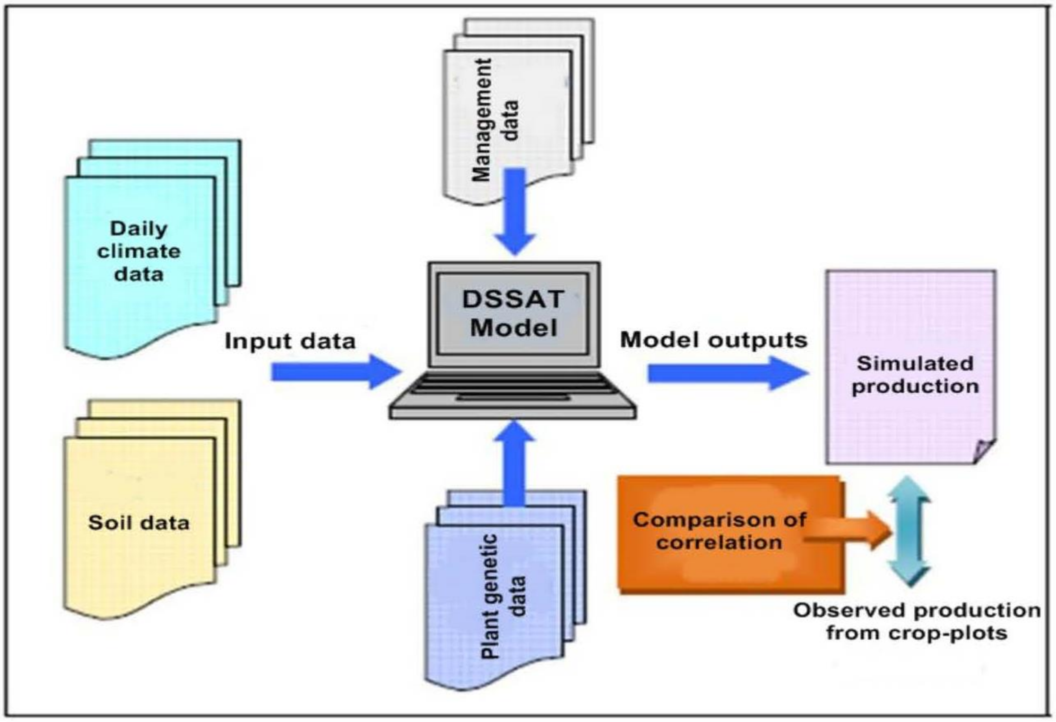


Figure 97: General framework of DSSAT4 Crop model for assessing climate impact on agricultural crops

6.3.1 Agro-meteorological stations

An existing hydro-meteorological network is in place, although the data collected is not analyzed, tailored or disseminated for use in managing water and agriculture. Damages to some of the hydro-meteorological network infrastructure has occurred, partially because the location and civil works associated with these installations did not take into account likely increases in climate-induced flooding and intense rainfall.

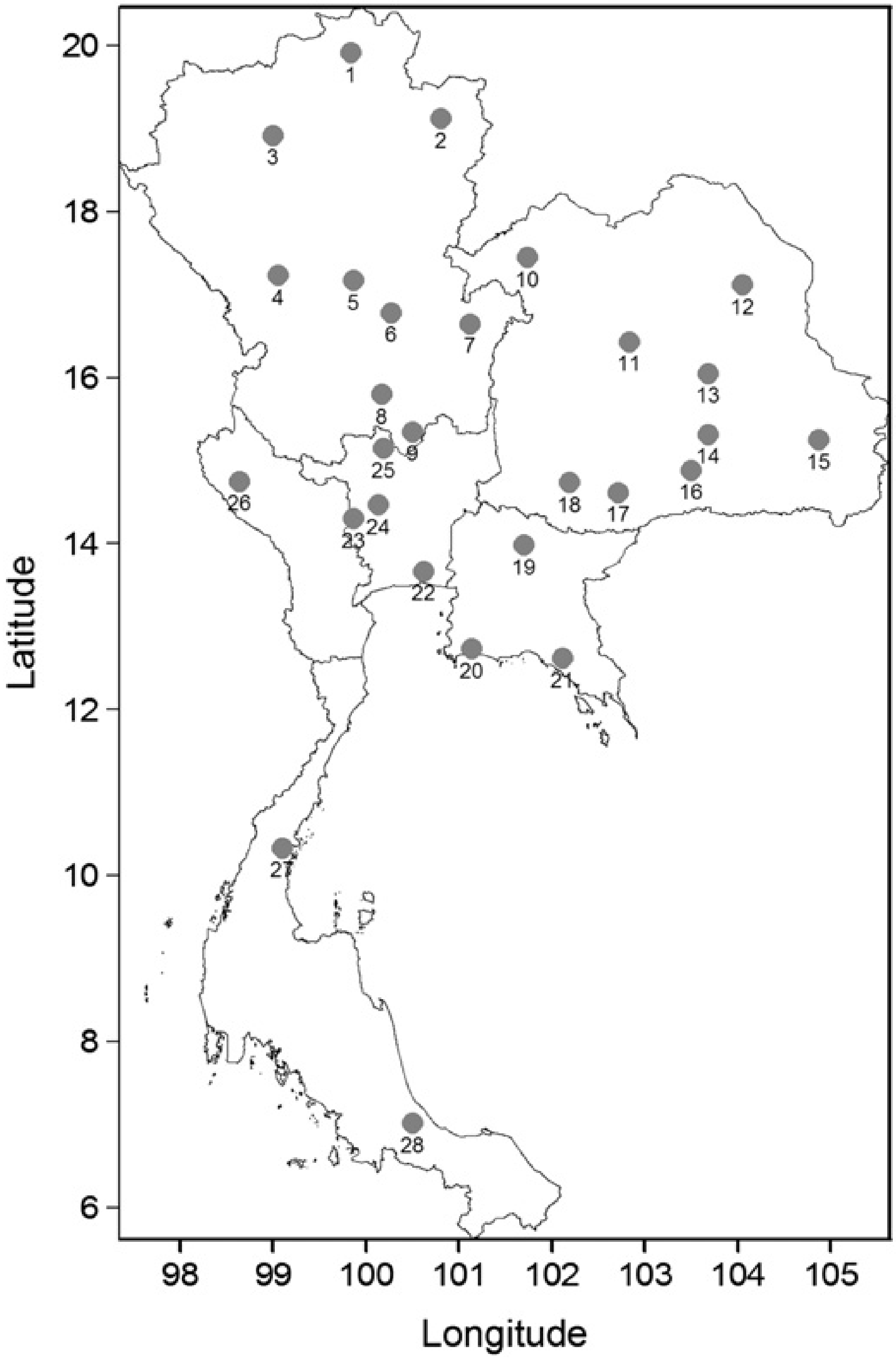


Figure 98: Locations of weather stations; all stations for panevaporation and mean air temperature, 19 stations for humidity (1, 3–6, 8–13, 15–16, 20–21, 23–25, 27), 18 stations for sunshine duration (1, 3, 5– 6, 8–13, 15, 20–23, 25, 27–28) and 11 stations for wind speed (1, 4, 6, 8, 10–11, 13, 15–16,21,24).

Source: Limjirakan, S & Limsakul, A. 2012. 'Trends in Thailand pan evaporation from 1970 to 2007', *Atmospheric research*, 108, Pp 122-127

6.3.2 Dissemination and the use of the data

Integration and effective dissemination of climate and risk data, will depend primarily on inter-agency coordination being undertaken at the local, provincial, and central levels – in order to support agricultural households' responsiveness and adaptive capacities to climate change.

In order to support the effective use of this information, related training to government staff on climate scenarios projecting predicted rainfall, runoff, temperature, and evaporation rates, in order to incorporate a greater accuracy of incidence of flooding and drought, will need to take place. This should involve:

Government level capacity building:

Interventions will facilitate inter-ministerial coordination across other sectors (outside of exclusively water management) in order to ensure that climate projections are analysed, tailored, and disseminated in a way that can support policy integration and cross-sectoral planning; with particular attention to the water and agricultural sectors). This will allow for comparison of supply to use with demand, and adjustments to be made within the framing of the sufficiency economy philosophy. Cross-sectoral coordination will allow for budget planning, infrastructure and communications to follow – that consider the necessary upgrades for ensuring climate change adaptive measures in water planning following the IWRM approach.

Farmer level capacity building and training:

As agriculture is responsible for 75% of water use, the proposed GCF project also includes capacity building for farmers – providing tailored climate information which can be applied to agriculture planning, as well as training to support the government policy emphasizing less water-intensive crops.

6.3.3 Context for targeting of women and gender-focused interventions

Gender of the household head impacts on adaptation outcomes – in the Chao Phraya River Basin, households with male household head have lower probability of up take of the drought adaptation strategies.[229] From the farmer consultations: women generally do the same activities in agricultural cultivation as men do and may be more. For managing water usage group, the leaders are usually men. However, roles and responsibilities of women in these groups include vice president, financing and accounting and any position related of many document such as secretary. In general female farmers in Thailand have predominant economic roles in the agricultural sector, particularly in terms of investment, harvesting, marketing and trading. Male farmers make decisions on major farm investments. Women play a key role in local seed systems throughout the role, and in Thailand. Farming households have tended to become more individualised in terms of decision-making and knowledge use and transfer, inputs, seeds and capital. Gender roles are normally well defined in the agricultural sector – with a clear division of labour between male and female family member.[230] In Thai society/Chao Phraya area, the family relationships are matrilineal as lands are inherited to daughters. This is consistent with anthropological literature in Thailand. When asked about the costs and revenues of farming related activities, the responses mainly came

[229] Thampanishvong, K. 2014, *Farmers' Adaptation to Extreme Weather Events in the Chao Phraya River Basin*, Thailand Development Research Institute, October 15 2014
[230] Thampanishvong, K. 2014, *Farmers' Adaptation to Extreme Weather Events in the Chao Phraya River Basin*, Thailand Development Research Institute, October 15 2014

from the female farmers, who articulately responded to the practical questions on agriculture production, investment, marketing and trade.[231]

A new element of the Human Development Index was introduced in 2014 – which provides a breakdown of gender-disaggregated Human Development Index, defined as a ration of female to made HDIs. The Gender Development Index (GDI) factors gender in health/life expectancy, education, and control over economic resources. The measure is then calculated and compared across 161 countries. The overall HDI value for Thailand is 0.726. Which can be compared to neighbouring countries in the table below:

	Life expectancy at birth		Expected years of schooling		Mean years of schooling		GNI per capita		HDI values		F-M ratio
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	GDI value
Thailand	77.9	71.1	13.9	13.1	7.1	7.5	11,820	14,888	0.726	0.726	1.000
Philippines	71.8	64.9	11.5	11.1	8.4	7.9	5,382	10,439	0.649	0.664	0.977
East Asia and the Pacific	76.0	72.2	13.0	12.8	6.9	8.0	9,017	13,780	0.692	0.730	0.948
High HDI	77.4	72.8	13.8	13.4	7.7	8.5	10,407	17,443	0.724	0.758	0.954

Table 55: Thailand's GDI value for 2014 relative to selected countries and groups

Source: UNDP. 2015, Work for Human development: Briefing note for countries on the 2015 Human Development Report, Human Development Report 2015.

In 2010, the HDI introduced the Gender Inequality Index (GII), which reflects the gender-based inequalities of reproductive health (maternal mortality and adolescent birth rates), empowerment (share of parliamentary seats and secondary and higher education attainment), and economic activity (labour market participation rate for men and women). The GII is then interpreted as the equality lacking between genders. Thailand overall ranks as 76 out of 155 countries in the 2014 index, and holds a GII value of 0.38.

	GII value	GII Rank	Maternal mortality ratio	Adolescent birth rate	Female seats in parliament (%)	Population with at least some secondary education (%)		Labour force participation rate (%)	
						Female	Male	Female	Male
Thailand	0.380	76	26	41.0	6.1	35.7	40.8	64.3	80.7
Viet Nam	0.308	60	49	29.0	24.3	59.4	71.2	73.0	82.2
Philippines	0.420	89	120	46.8	27.1	65.9	63.7	51.1	79.7
East Asia and the Pacific	0.328	—	72	21.2	18.7	54.7	66.3	62.6	79.4
High HDI	0.310	—	41	28.8	20.6	60.6	69.5	57.0	77.2

Maternal mortality ratio is expressed in number of deaths per 100,000 live births and adolescent birth rate is expressed in number of births per 1,000 women ages 15-19.

Table 56: Thailand's GII for 2014 relative to selected countries and groups.

Source: UNDP. 2015, Work for Human development: Briefing note for countries on the 2015 Human Development Report, Human Development Report 2015.

[231] Thampanishvong, K. 2014, *Farmers' Adaptation to Extreme Weather Events in the Chao Phraya River Basin*, Thailand Development Research Institute, October 15 2014