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Drought adaptations for agriculture in Northeast Thailand: a qualitative assessment of water-centric government projects

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Abstract

Droughts drastically constraint agricultural systems in Northeast Thailand. They have prompted a wide range of government-led projects aimed at improving water security and rural livelihoods. This study assesses their diversity and effectiveness through a review of national strategic documents, institutional surveys, and participatory field investigations conducted between 2024 and 2025. We first identified ten public agencies most actively involved in drought adaptation at national level, and then analysed six representative project sites implemented in the driest provinces of Northeast Thailand. These projects range from on-farm ponds to collective irrigation schemes. We evaluated adaptation outcomes through three interacting dimensions: (i) the biophysical fit between infrastructure and local environmental conditions, (ii) governance arrangements and the effectiveness of collective action, and (iii) the socio-economic and technical capacities of farmers. Results show that project performance depends less on infrastructure alone than on the alignment between these three dimensions. Projects that combine context-specific technical design, participatory governance, and strong local capacities generate more sustained improvements in water access, agricultural production, and resilience. Conversely, mismatches between infrastructure and environmental conditions, weak collective action, limited technical knowledge, and market constraints reduce effectiveness and may increase vulnerability. The analysed projects differ markedly in their degree of standardization, participation, and adaptability, leading to contrasting outcomes across sites. These findings highlight the need for more systemic, context-sensitive and socially embedded approaches to drought adaptation. Beyond Thailand, they provide insights for designing more resilient and inclusive adaptation policies in drought-prone agricultural regions facing increasing climate variability.

1- Introduction

Due to their multiple faces, droughts affect more people globally than any other natural hazards (FAO 2026). Meteorological droughts (low rainfall) induce hydrological droughts (depletion of natural water reserves), in turn inducing agricultural droughts (limited water availability for crops). In some instances, droughts may become a socio-ecological phenomena coproduced by the recursive engagement of human and non-human transformations (Savelli et al 2025). In the agricultural sector, droughts reduce yields via water scarcity and water quality decline, and indirectly through pests, diseases, and soil degradation (Arunrat et al 2022; Qadir et al 2008). Consecutive falling incomes and rising costs (e.g., pumping, transport) worsen the economic situation. In turn, the poorest face deteriorating health and well-being due to food shortage, degraded water supply, and, in severe cases, heat stress and dehydration (Amir Faisal et al 2014). At the community and household levels, droughts exacerbate inequality by disproportionately affecting those with limited income diversification, often compounded by uneven social aid (Lertamphainont and Sparrow 2016; UNDP 2019; WHO, 2014; IPCC 2022). Limited water availability leads to farmer disputes over water rights (FAO 2018) and can create tension between citizens and local governments (UNESCO 2019; IPCC 2022). Meanwhile, the need to focus on immediate personal needs disrupt cultural practices tied to agriculture and water and weakens the community identity (UNESCO 2018; Adger et al 2013). Outmigration of young adults and local leaders for work reduces

support for local activities, weakening community structure and cohesion (Aldrich 2012; Black et al 2011; FAO 2018). Added responsibilities for children and youth disrupt education and social development (UNCF 2017; World Bank 2018). Over time, repeated droughts cumulatively undermine socioecosystem and agricultural recovery (Reynolds 2007). From insufficient rainfall to livelihoods, Cavalcante et al (2025) demonstrate the cascading effect of drought impacts and the policy implications. Drought will worsen with climate change: rising mean temperature increasing evapotranspiration, more frequent heat waves and greater rainfall variability (Waqas et al 2025) are expected to reduce average yields for most crops, especially wet-season rice (Shrestha et al 2017). Some CO_2 fertilization benefits exist but do not offset heat and water stress.

Drought adaptation projects are interventions that aim to sustainably reduce these negative impacts, by deploying long-term strategies oriented to reduce vulnerability and enhance resilience. Thailand exemplifies their diversity, due to a long dry season whose severity is magnified by climate change and a growing water demand stimulated by a dynamic economy. About 80% of agriculture lands in Thailand are rainfed (RID 2024; Luangchosiri et al 2025) and concentrate such initiatives. Drought adaptations are manifold (ONEP 2015). They involve interventions on i/ the crops (e.g. planting drought-resistant varieties and annual species with shorter cycles (Waqas et al 2025)), ii/ the soils (e.g. amendment and agroforestry to improve infiltration and water holding capacity, mulching to reduce evaporation losses, rotations with leguminous to fix nitrogen), iii/ farming and irrigation practices (e.g. direct seedling and alternate wetting and drying to save water in rice fields, fertilization with potassium to improve water use efficiency), iv/ water storage, access and use efficiency at farm level (e.g. ponds, wells, land levelling, drip irrigation, irrigation canal maintenance to reduce leaks) and v/ catchments (e.g. land-use management to promote infiltration of runoff and groundwater recharge). Non-structural measures include food reserves, improved access to drought forecasts, allowing planning planting times and choosing crops suited for the anticipated climate. The diversification of incomes from additional non-agricultural activities also contribute to improved resilience of farmers (Bridhikitti 2019). Co-financing at community level can help afford expensive infrastructures such as collective ponds. Sedtha et al (2023) highlight the critical role of government support in strengthening farmers' adaptation capacity in Northeast Thailand, not only through financial assistance, but also by providing extension services, early warning systems, capacity building, and institutional support.

About 30 public agencies are involved in water and disaster governance in Thailand. In response to recurrent droughts, the Thai government has implemented a range of programs aimed at strengthening water security and supporting rural livelihoods in drought-prone areas (DGR 2024; Dhammahaso 2022; HII 2021; Luangchosiri 2025; ONWR 2019; Panyasing 2021; RID 2024). These initiatives target either individual farmers or communities. They include the expansion of small-scale irrigation infrastructure, groundwater development, and farmer support programs designed to enhance agricultural resilience. Several studies emphasize that the effectiveness of such projects depends not only on infrastructure investments but also on the capacity of local institutions and communities to cooperate, manage water resources and adapt agricultural practices under increasingly variable climatic conditions (Babel et al 2024; Dhammahaso 2022; HII 2021; ONEP 2015; Pak-Uthai and Faysse 2018; Suwanmontri et al 2018).

Despite these numerous government-led drought adaptation programs and a growing body of literature on water management in Thailand, little is known about how these projects perform at the local level or how farmers perceive their effectiveness. Addressing this gap, this study examines how government-supported water and agricultural programs contribute to drought adaptation in rural communities. Section 2 describes the study site located in Northeast Thailand, the most drought-prone region of the country. Section 3 presents the methodology, considering that adaptation success is conditioned by three interacting dimensions: (i) biophysical fit between infrastructure and the local environment, (ii) governance arrangements and the effectiveness of collective action, and (iii) the socio-economic and knowledge capacity of farmers. Drawing on a set of diverse projects implemented by six agencies, section 4 presents our results, detailing the farmers' perceptions on government interventions. We identify the socio-technical, environmental and governance factors shaping outcomes. Section 5 discusses the results by comparing them with previous studies and highlights remaining challenges in the face of climatic and market uncertainties.

2- Study site

Northeast Thailand is the driest and poorest region of the country due to a combination of biophysical and socioeconomic factors. First, this region experiences high interannual rainfall variability driven by monsoon dynamics and climate oscillations (Lacombe et al 2017). This translates for farmers into irregular rainfall, delayed monsoon onset, prolonged dry spells during the cropping season and insufficient water for rice cultivation (Amir Faisal et al 2014). These detrimental climatic conditions are aggravated by sandy and saline soils with low water holding capacity. Second, irrigation infrastructure remains relatively limited compared to central Thailand, resulting in a strong dependence on rainfed agriculture. Third, rural livelihoods are still characterized by relatively high levels of poverty and limited adaptive capacity, increasing vulnerability to climatic shocks. Together, these factors make Northeast Thailand a particularly relevant case for examining how government-supported drought adaptation measures are implemented at the local level and how they influence the resilience of farming communities (Panyasing et al 2021; Suwanmontri et al 2018). Our study targets the most drought-prone provinces of the region, namely Nakhon Ratchasima and Buriram, that were previously selected to conduct a drought vulnerability analysis (Babel et al 2024) (Fig. 1). These areas correspond to the upstream half of the Mun River Basin which is the main tributary of the Mekong River in Thailand.

3- Method

The performance of drought adaptation projects is shaped by the interaction of three interdependent dimensions: (i) biophysical fit between infrastructure and local environmental conditions, (ii) governance arrangements and the effectiveness of collective action, and (iii) the socio-economic and knowledge capacity of farmers. This framework builds on insights from social-ecological systems (Ostrom 2009), institutional fit theory (Young 2002), and climate change adaptation literature (IPCC 2022). These dimensions are often discussed separately in the literature, but they are closely intertwined in practice.

Relevant information on these 3 pillars were collected through a series of activities involving literature review, participatory approaches and surveys, that took place between October 2024 and July 2025.

An inception workshop was organized in October 2024, gathering 40 individuals from eight government agencies involved in drought adaptation, three regional operating offices based in the two targeted provinces (Nakhon Ratchasima Rice Research Center, Office of the National Water Resources 3, Royal Irrigation Department, RO 8), faculties from two Thai universities (Chulalongkorn and Kasetsart) and from the authors' institutions. The aim was to reflect on the specific challenges to be addressed and produce a common understanding to be deepened during the following surveys. Two questions were addressed and discussed during this workshop: i/ how droughts affect populations? ii/ what adaptations have already been implemented? A stakeholder mapping exercise, performed between February and March 2025, combined literature review, analysis of government strategic documents and institutional surveys among national agencies. It aimed to identify which public agencies support farmers in adapting to droughts at National level, and how they operate. It also aimed to gather recommendations on which project sites, where agencies are implementing structural projects in the 2 targeted provinces, to focus our analysis. In April and May 2025, preliminary field surveys were conducted in these recommended project sites to verify their relevance for in-depth surveys to follow. The selection of these sites was performed so as to obtain a sample representing the diversity of projects in terms of infrastructures and modalities of collaborations between the leading agencies and the benefiting local communities. In June and July 2025, in each of the selected sites, a semi-structured questionnaire, adapted from Babel et al (2024), UNECE (2008) and Visessri (2023), was submitted to a gender-balanced group of 18 farmers to capture their individual perception of droughts, their level of satisfaction regarding the adaptation commodities subsidized by the government, their understanding of the causes of failure or success of the government projects and their suggestion for improvements. Interviews were analyzed using thematic coding structured around recurring themes related to technical performance, governance, and adaptive capacity. One full day was spent on each project site. The morning was allocated to the filling of the questionnaire. During the afternoon, focus group discussions co-facilitated by the authors of this paper and by the responsible agency of the project site, enabled the morning respondents to interact directly on main issues and benefits from the government projects, and their factors of success.

4- Results

4 – 1 Ten agencies supporting farmers' drought adaptation

Three strategic documents published by the government of Thailand were reviewed to identify institutional actors involved in drought adaptation and understand their mandate: the 2023-updated versions of the 20-year national strategy (NSC 2018), the 20-year water master plan (ONWR 2019) and the 2024–2025 dry season water management plan (RID 2024). Three of the 23 master plans described in the 20-year national strategy were scrutinized. They are related to Agriculture (#3), Sustainable Growth (#18) and Integrated Water Management (#19). Out of their sub-master plan goals, 24 were found to be related to droughts and involved predominantly 10 departments or institute listed in Table 1. These 10

agencies were found to be the ones primarily involved in drought management according to ONWR (2019) and RID (2024), thus confirming their relevance for further analysis.

Table 1
The 10 public agencies mostly engaged in drought alleviation and adaptation in Thailand

Ministry	Department or Institute	Acronym
Agriculture and Cooperatives	Department of Agriculture	DOA
	Royal Irrigation Department	RID
	Land Development Department	LDD
	Department of Agricultural Extension	DOAE
	Rice Department	RD
Natural Resources and Environment	Department of Climate Change and Environment	DCCE
	Department of Water Resources	DWR
	Department of Groundwater Resources	DGR
Higher Education, Science, Research and Innovation	Hydro-Information Institute	HII
Interior	Community Development Department	CDD

Institutional surveys conducted among these 10 agencies (cf. section 3), consisting in a semi-directive interview that aimed to clarify their involvements in drought adaptations, allowed identifying 6 project sites (localized on Fig. 1) illustrating different types of interventions. Their characteristics are summarized in Table 2 and illustrated in Fig. 2. Four agencies from Table 1 (DOA, DOAE, RD and DCCE) did not implement any drought adaptation sites in Northeast Thailand and were therefore not studied further in this analysis.

Table 2
The six studied project sites

Province	DGR	RID	DWR	HII	LDD	CDD
	Nakhon Ratchasima		**Buriram**			
District	Phimai	Khon Buri	Phutthaisong	Nang Rong	Prakhon Chai	Satuek
Sub-district	Bot	Chorakhe Hin	Mafueang	Nong Bot	Tako Tapi	Don Mon & Ron Thong
Village	Moo 24	Moo 3 (Mun Bon Project 8)	Moo 6	Ban Lim Thong	Tako Tapi and Khok Krachai	Several villages
Scale	Village	Irrigation scheme	Sub-district	Community	Farm	Farm
Partnering beneficiaries	Community	Community	Community	Community	Single farm	Single farm
Project	Solar-powered groundwater pump system for collective irrigation	Climate-smart technologies for irrigated rice	Increase storage capacity of wetland for irrigation	Participatorily designed water storage system	On-farm pond	Khok Nong Na Model

4 – 2 Descriptions of the six selected agencies and their respective drought adaptation project

Since 2021, **CDD** is implementing the *Khok Nong Na* model under the project “Model area for quality of life”. This model divides a private farm into three zones: *Khok* designates an elevated area where excavated soil is piled up to grow perennial crops and trees above flood-prone areas. *Nong* designates a soil excavation to store year-round water from surface runoff and groundwater, to irrigate nearby crops. *Na* designates rice plots benefiting from improved water moisture and enhanced soil fertility. By promoting agroecology, this model encourages crop diversification and reduced dependence on purchased inputs. It is rooted in Thailand’s new theory Agriculture and Sufficiency Economy Philosophy (SEP) developed by the King (Dhammahaso et al 2022). Tens of thousands of households were targeted by this project (PAGE 2023), based on their engagement to adopt SEP. More than 2000 learning centres were created in the Buriram and Nakhon Ratchasima provinces, serving as field schools and collective learning space to promote the *Khok Nong Na* model and SEP.

DGR is implementing the “groundwater development project for agriculture using solar energy” (DGR 2024). This project provides collective groundwater infrastructures to irrigate contiguous agricultural areas of at least 60, 300 or 500 rai of farmed areas, depending on the selected investment, with the objectives to benefit multiple farmers (> 8, > 10 or > 15 households, respectively) and to generate substantial agricultural output. Applicants must demonstrate willingness to collectively manage the irrigation system. Typical infrastructure components include 1 to 3 wells (80 to 120 m-deep and 6 inches diameter), submersible pumps powered by 4800 Watt-solar panels, one 120 m^3 storage tank and a piped irrigation water distribution system. Before implementation, DGR conducts groundwater surveys, aquifer testing and environmental assessments. Between 2011 and 2024, this project was implemented over 10 295 sites across 68 provinces, benefiting 270 000 farmers.

Nationally, **RID** has implemented about 200 large (> 80 000 ha), 1700 medium (between 8 000 and 80 000 ha), and 3000 small irrigation projects (< 8 000 ha) (ONWR 2019). Project planning and design have historically been highly centralized, with limited involvement of local communities, particularly in large-scale schemes. However, since the 1990s, participatory approaches have been increasingly promoted, notably through the establishment of water user associations, especially in medium- and small-scale systems (Mentaem et al 2024). The Mun Bon Project #8 (Table 2) is a small project with a command area of about 7 300 ha (RID 2024). It includes experimental plots where climate-smart technologies are evaluated by the management unit (e.g., alternate wetting and drying, non-rice crop diversification, smart irrigation system such as SCADA, drip irrigation). So far, its management by RID remains highly centralized (Mentaem et al 2024).

Through its division “Water resources conservation and rehabilitation”, **DWR** is implementing wetland restoration projects to increase water storage capacity supporting domestic use and irrigation while reducing flood risks. A few projects have been implemented in five provinces, consisting in physical modifications of water bodies: dredging sediments in degraded reservoirs or wetlands, removing invasive aquatic plants, installing solar-powered water distribution systems, constructing small check dams. They are primarily infrastructural with limited social and governance components. Community participation usually occurs after site selection, mainly through consultation and validation, and after project completion, for maintenance and/or local water governance, in coordination with local administrative organizations. The studied site (Table 2) has a storage capacity of nine million cubic meters, potentially benefiting 652 households from 5 villages, through 640 ha of irrigated land during the dry season. It also supplies domestic water for about 2500 people in 2 villages. Another 300 households could benefit from additional 320 ha of dry season irrigation after system improvement.

The “Community Water Management Program” of **HII** promotes community-led water planning supported by scientific data and hydro-informatics technologies. Its funding includes local and private contributions. This program considers the different and possibly interconnected components of the water system including man-made (e.g., canal, reservoirs) and natural structures (e.g., rivers, groundwater) with the aim to balance water supply and demand. Water allocation rules, cropping calendars and drought preparedness strategies are participatorily co-designed. Since 2003, about 60 community projects have

been implemented in 19 river basins, benefiting about 1600 villages. In the studied site (cf. Table 2), the main technical innovations include i/ a hydraulic system made of 70 interconnected ponds to store excess water during floods and reuse it in dry season, ii/ a “canal street” system consisting of an improvement of the main road of the village so that it collects surface runoff from both sides of the road during rain events, and channels this flood water into connected ponds. These simple hydraulic infrastructures with trust-based participatory governance are replicated by neighbouring communities through local networks (HII 2021).

The “Soil and Water Conservation System Project in Agricultural Risk Areas” is the principal **LDD** initiative targeting drought-prone areas. It implements infrastructures (contour bunds, terraces, check dams, ponds, drainage systems) and land management interventions (grass strips, vegetative barriers, agroforestry) in rainfed farming systems to reduce soil erosion, improve runoff infiltration and soil water storage capacity. It also includes capacity building on soil conservation and land-use planning, to promote long-term adoption of such practices. On-farm ponds (1200 m^3 < storage capacity < 1600 m^3), built on individual farms, aim to collect rainfall and harvest local runoff to supplement irrigation during dry spells and contribute to groundwater recharge. These ponds also aim to support the implementation of the SEP through integrated farming.

4 – 3 Factors ensuring project success

Our assessment of the six projects described in section 4 – 2 indicates that they generate multiple benefits. The most obvious ones are increased yields and farm income due to improved dry-season water availability, as well as enhanced knowledge and skills through training programs and learning centres, ultimately supporting improved livelihoods (as clearly observed on CDD site). These projects also strengthen connectivity through new infrastructure (e.g., roads facilitating market access on RID and DWR sites), closer linkages with donors and service providers, and greater engagement with neighbouring communities (as observed on HII site), enabling the dissemination of innovations and improved access to advanced technologies (e.g., solar pumps, alternate wetting and drying). In addition, these projects enhance flood protection through water infrastructure such as canals (RID site) and reservoirs (DWR site), and contribute to a safer environment by reducing the use of chemical inputs (CDD site).

The analysis of the survey questionnaire and output from the focus group discussions reveal that the performance of these projects is shaped by the interaction of three interdependent dimensions: (i) the biophysical fit between infrastructure and local environmental conditions, (ii) the governance arrangements and the effectiveness of collective action, and (iii) the socio-economic and knowledge capacity of the benefiting farmers. Rather than acting independently, these dimensions interact to determine whether interventions lead to sustained improvements in water access and resilience or, conversely, to limited effectiveness and unintended outcomes.

4-3-1 Biophysical fit

Project performance depends on the degree of biophysical fit between technical design and local environmental conditions. Soil characteristics (fertility, water-holding capacity, depth), water availability and access, land characteristics (topography, plot configuration, and tenure) and groundwater properties determine whether infrastructures (e.g., ponds, canals, or wells) and irrigation facilitates (e.g., pumps and pressurized water distribution system) can function effectively. Although certain limitations can be alleviated (e.g., through soil amendments), others constitute binding constraints, especially water availability. Effective infrastructure design and management should be tailored to site-specific conditions. Mismatches—such as pond construction in highly permeable sandy soils as observed in one Khok Nong Na site managed by CDD, or poorly graded canals, as observed in the main RID project site — lead to significant efficiency losses. More broadly, projects targeting a single component of the water–soil–crop system without accounting for system interactions tend to underperform.

4-3-2 Governance & collective action

Governance arrangements and collective action play a critical role, particularly in community-based systems. Effective performance relies on several factors:

- Social cohesion and collective commitment. In practice, it is manifested through mutual assistance and the sharing of tools, equipment, and information among farmers (as observed in RID, DWR, DGR and HII sites)
- Leadership. The presence of a farmer leader capable of coordinating collective decision-making, community actions, mutual assistance and liaison with local authorities, strengthens the effectiveness of project planning, design, implementation, and management. This was well illustrated on the DGR site owned by a farmer who generously attributed his land to a group of neighbours who started growing various vegetables on his land, hence becoming eligible in terms of number of potential beneficiaries, to request the government support.
- Transparent, fair and sensed rules for water allocation and financial management of collective water infrastructure, including the collection of fees. Where these conditions are met, communities are able to coordinate equitable water access and use, and maintain infrastructure. This regulation helps prevent resource overexploitation, and supports the long-term sustainability of the system through effective cost recovery mechanisms. Conversely, weak participation, unclear rules, or limited institutional support can lead to misunderstandings, frustration, coordination failures, conflicts, inefficient water distribution, and reduced system sustainability
- Accessible information on institutional financial support. In particular, procedures for applying for government subsidies should be clearly defined and readily available to communities seeking to benefit from them.

4-3-3 Socio-economic and technical capacity of farmers

The capacities of farmers strongly influence the adoption and effective use of the projects implemented by the agencies. Conversely, effective infrastructure design and management should be tailored to local needs and socio-cultural practices. This requires participatory approaches to integrate local knowledge, combined with reliable field data to assess constraints and opportunities. Technical knowledge on soil, water, and crops, understanding of the market conditions, access to financial resources and the ability to invest in complementary infrastructure (e.g., pumps, wells) are key determinants. For example, the adoption of drought-tolerant crops should be aligned with local market conditions, including demand and price stability. Likewise, technologies such as pumps should be based on affordable components that are locally available and supported by accessible maintenance and repair services. Farmer commitment, reflected in co-investment mechanisms such as financial contributions, allocation of privately owned land for infrastructure development (e.g., ponds, canals), and provision of labour for operation and maintenance, is a key determinant of success. In some cases, such co-investment is even requested by the service provider: in some instances, LDD informally requested that the pond's beneficiary would invest in digging a pond and purchasing a pump to fill the pond when it becomes dry. In general, these farmers' contributions strengthen local ownership and contribute to the long-term sustainability of interventions. Beneficiaries must demonstrate motivation, openness, and an entrepreneurial mindset for government investments to be effective (unless the site governance is predominantly top-down and doesn't require pro-activeness as in RID site). They should also be convinced of, and committed to adopting, the approach promoted by the project (e.g., the SEP promoted by CDD). Key factors of project resilience include crop diversification, the use of farm-saved seeds to reduce dependence on commercial seed suppliers, diversification of funding sources to ensure financial sustainability (as observed in DGR site where farmers received funds from LDD and CDD to dig ponds and in HII site where farmers were found to receive support from a wide range of other agencies listed in Table 1 while HII did not intervene in sites managed by other agencies), and long-term engagement (3-year and 5-year monitoring and evaluation by farmers, as requested by HII and LDD, respectively). These findings illustrate how project outcomes depend on the interaction between technical design, institutional coordination, and user capacities.

4–4 Constraints and remaining adaptation needs

Constraints usually emerge from misalignments between biophysical conditions, water infrastructure design, governance arrangements, and farmers' adaptive capacities.

4-4-1 Biophysical and local water management constraints

First of all, adverse environmental conditions are primary constraints. For example, regions with sandy or saline soils, in upland settings characterized by limited natural water storage and deep groundwater, while being drought-prone, are among the most inconvenient locations in Northeast Thailand to implement drought adaptations. In addition, remote areas are unfavorable because of difficult access to materials and equipment. Second, the effectiveness of drought adaptation projects is strongly conditioned by their alignment with local environmental conditions and inadequate infrastructure design reduces project

performance. For example, ponds excavated in sandy soils with deep groundwater tables experienced high percolation losses (as observed in one of the CDD site), while irrigation canals with irregular slopes failed to adequately convey water to downstream areas (as observed in RID site). More broadly, projects targeting a single component of the water–soil–crop system often proved suboptimal. For instance, efforts to improve irrigation access without simultaneously enhancing soil water-holding capacity in sandy environments frequently resulted in limited gains in water productivity.

Water mismanagement also emerged as a major constraint. Inadequate irrigation scheduling and limited knowledge of crop water requirements contributed to evaporation and percolation losses, leading to crop stress and reduced yields. In RID-managed irrigation schemes, irrigable areas are annually defined according to actual reservoir storage amount, yet these recommendations were not always respected. Cultivation beyond recommended areas generated water shortages, inequitable distribution, and conflicts among users. Constraints further differed across project types: individual farm-based systems were primarily limited by insufficient water availability, whereas community-based systems more often faced water access limitations due to inadequate pumping and conveyance infrastructure despite adequate storage capacity.

4-4-2 Governance and collective-action constraints

Collective projects frequently encountered governance-related challenges affecting the long-term sustainability of water management systems. Weak participation in collective action sometimes resulted in individualistic behaviours, including non-compliance with water allocation rules, which undermined equitable water distribution and reduced system efficiency. In several cases, insufficient transparency in decision-making and financial management weakened trust among users and complicated collective coordination. The sense of belonging to a common project, like on the RID site, was found, in some specific situations, to exacerbate inequalities between farmers, in terms of land sizes and access to water. More generally, the effectiveness of community-based systems depended heavily on pre-existing social cohesion, leadership capacity, and the ability of local institutions to enforce agreed management rules.

4-4-3 Socio-economic and knowledge constraints

Farmers also identified significant socio-economic and knowledge-related barriers limiting their adaptive capacity. Economically, increased water demand during the dry season raised pumping costs, while unstable or low market prices for alternative crops reduced incentives for diversification (as observed on CDD an LDD sites whose farmers are missing economic information from markets, likely resulting from excessively enforced SEP). Limited financial resources further constrained farmers' ability to invest in complementary infrastructure and long-term soil and water conservation measures. Important knowledge gaps were reported across technical, agronomic, and institutional domains. Farmers emphasized the need for improved understanding of soil management, water-holding capacity, drought-tolerant crops,

irrigation scheduling, pest and disease management, and water budgeting, especially those owning a pond subsidized by LDD, often exposed to crop water stresses, hence the need to save water during the crop development stages requiring less water This water budgeting would also aim to adjust the size of the pond to the local context of water supply and demand, thus reducing the risk of over- or under-sizing that often result from a standardized and decontextualized engineering approach. Farmers also expressed the need for improved access to market information and clearer information regarding government support schemes. This is particularly pregnant on the RID site where more abundant water could allow crop diversification at the condition that market prices are attractive. These findings highlight that effective drought adaptation requires not only infrastructure investments, but also sustained capacity-building and institutional support.

5- Discussion

While our study remains limited by the relatively small sample size and the focus on selected case studies, which may not fully represent the diversity of drought adaptation projects in Thailand, our analysis has highlighted the diversity of government projects across geographic scales, ranging from on-farm or individual storage systems (e.g., ponds and the *Khok Nong Na* model implemented by LDD and CDD, respectively), to community-based systems of reservoirs, implemented by HII and DGR, and larger-scale schemes relying on single water bodies serving hundreds of farmers (e.g. the projects implemented by DWR and RID). While some projects follow predominantly top-down approaches (e.g., DWR and RID), others rely on collective action, either emerging spontaneously (DGR) or facilitated through institutional support (HII). Furthermore, whereas certain agencies promote standardized, pre-conceived models (e.g., the *Khok Nong Na* model by CDD and solar-powered groundwater irrigation systems by DGR), HII adopts a more adaptive approach tailored to local socio-technical specificities.

Some of our findings are consistent with previous studies showing that limited technical knowledge and restricted access to relevant information, advisory services, credit, and labour are major constraint to project adoption (Waqas et al., 2025; Luangchosiri et al., 2025). Landlessness and indebtedness further disadvantage smallholders, who are less able to invest in long-term soil and water conservation practices compared to landowners with better access to irrigation systems and water storage infrastructure (Lertamphainont and Sparrow, 2016; Amir Faisal et al., 2014; Waqas et al., 2025). In addition, socio-cultural factors—such as limited motivation, weak collective engagement, and resistance to change and innovation—can constrain farmers' proactiveness in decision-making, often in relation to education levels and social roles. Chaiyason et al (2023) emphasized the importance of participatory and locally grounded approaches to drought adaptation. They demonstrated that locally accepted water budgeting can serve as an effective decision-support tool to mitigate drought impacts and improve preparedness in Northeast Thailand. By systematically accounting for water inflows, outflows, and storage, such approaches enable communities to anticipate shortages, allocate water more equitably, and adjust cropping patterns to seasonal availability, thereby reducing crop failure risks and economic losses. However, their effectiveness depends critically on farmer participation in data collection and interpretation, as well as the involvement of local administrative organizations. In this context, stakeholder acceptance appears

more important than technical sophistication. Similarly, Panyasing et al (2021) highlight that successful adaptation relies on collaborative, multi-stakeholder processes that integrate local knowledge and reflect the diversity of socio-environmental contexts. Communities characterized by strong leadership (as observed on the DWR site), active farmer groups (well-illustrated by the HII site), and cooperative water governance tend to achieve better adaptation outcomes. Conversely, top-down approaches are often less suited to local conditions and therefore less sustainable in the long term (as observed in one of the CDD sites where high soil filtration and deep groundwater prevent any surface storage). Our analysis broadens these previous findings by showing that the success of government projects is shaped by the interaction of three interdependent dimensions: (i) biophysical fit between infrastructure and local environmental conditions, (ii) governance arrangements and the effectiveness of collective action, and (iii) the socio-economic and knowledge capacity of the benefiting farmers. These findings support institutional fit theory by showing that projects poorly aligned with local environmental and social conditions tend to underperform despite substantial infrastructure investments.

The constraints to drought adaptation may themselves be exacerbated by drought impacts, creating self-reinforcing feedback loops. For instance, drought-induced losses of soil organic matter reduce soil water-holding capacity, while declining yields limit farmers' financial resources and thus their ability to invest in adaptive measures. Similarly, drought-driven soil erosion can accelerate reservoir siltation, reducing storage capacity over time. Social dynamics may also reinforce vulnerability, as more innovative or better-resourced farmers are more likely to migrate, leaving behind households with lower adaptive capacity and reduced motivation. In addition, drought conditions can weaken collective action, further undermining effective water management. In some cases, adaptation measures may even increase vulnerability, for example when improved water access creates a false perception of abundance and encourages higher water consumption, potentially leading to unsustainable use. Farmers often rely on short-term coping strategies rather than more effective and proactive long-term adaptation measures in order to minimize immediate losses. However, such responses can increase long-term vulnerability by locking households into suboptimal production systems and generating risks of maladaptation. Common examples include unsustainable groundwater abstraction, reliance on high-interest loans, and the sale of productive assets. Although farmers are often aware of more sustainable long-term options, limited access to capital and insecure land tenure constrain their ability to adopt them, leading them to favour short-term, low-risk "no-regret" strategies. This tendency is further reinforced by climatic and market uncertainties, which incentivize conservative, low-return decision-making (Pak-Uthai and Faysse, 2018). These dynamics highlight the critical role of the state in regulating water use, supporting collective action, and ensuring that adaptation strategies remain sustainable over the long term.

One limitation of our study is that we deliberately focused our analysis on government-led adaptation projects. Local initiatives also exist and interact with public interventions. In some instances, local users are not merely recipients of public interventions: they may modify and adapt infrastructures, technologies, rules and institutional arrangements to better fit their local circumstances, through processes sometimes described as "bricolage"; see Ould Rebai et al (2017, 2024) in Algeria, and Mayaux et al (2023) in Algeria and Syria. Such processes have also been documented in Brazil where smallholders have translated and

locally adapted irrigation technologies introduced through public irrigation schemes (Mateos et al 2018; dos Santos Almeida et al 2023). We did not systematically investigate these incremental processes of local appropriation and adaptation, nor how they interact with government-led interventions. Further research in our study site in Thailand should therefore examine how local bricolage can complement, transform or constrain public adaptation interventions, and under which conditions such interactions contribute to more context-specific and sustainable adaptation outcomes.

6- Conclusions

This study highlights the diversity and complexity of drought adaptation strategies implemented by the government in Northeast Thailand, emphasizing that no single solution can effectively address the range of biophysical, socio-economic, and institutional challenges faced by farming systems. Government projects span multiple spatial scales—from individual farm-level storage systems to large-scale irrigation schemes—and reflect varying degrees of standardization, participation, and adaptability. While these projects have contributed to improving water access and reducing vulnerability in some contexts, their effectiveness remains highly dependent on local conditions and governance arrangements. The role of collective action emerges as a critical determinant of success. Future policies should therefore prioritize flexibility and local engagement to enhance resilience in the face of increasing climatic variability.

Beyond Thailand, the findings of this study are relevant to many drought-prone regions across the world where adaptation policies continue to prioritize infrastructure development while insufficiently addressing governance and farmer capacity-building. By highlighting the importance of socio-technical alignment and context-specific adaptation strategies, this study provides transferable insights for the design of more resilient and inclusive drought adaptation policies in vulnerable rural areas worldwide. Future research should assess which policy and governance arrangements are most effective in scaling up context-sensitive drought adaptation while maintaining local ownership and sustainability.

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declaration

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Author Contribution

GL: Conceptualization, Formal analysis, Funding acquisition, Investigation, Project administration, Software, Supervision, Validation, Visualization, Writing – original draft.PP: Data curation, Formal analysis, Investigation, Writing – review and editing.TP: Conceptualization, Formal analysis, Investigation,

Methodology, Project administration, Supervision, Validation.TB: Data curation, Methodology, Visualization.MB: Conceptualization, Methodology, Project administration, Writing – review and editing.SM: Investigation.SP: Software, Writing – review and editing.

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Data Availability

The data that support the findings of this study are available from CIRAD, but restrictions apply to the availability of these data, which were used under licence for the current study and so are not publicly available. The data are, however, available from the authors upon reasonable request and with the permission of CIRAD

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Figures

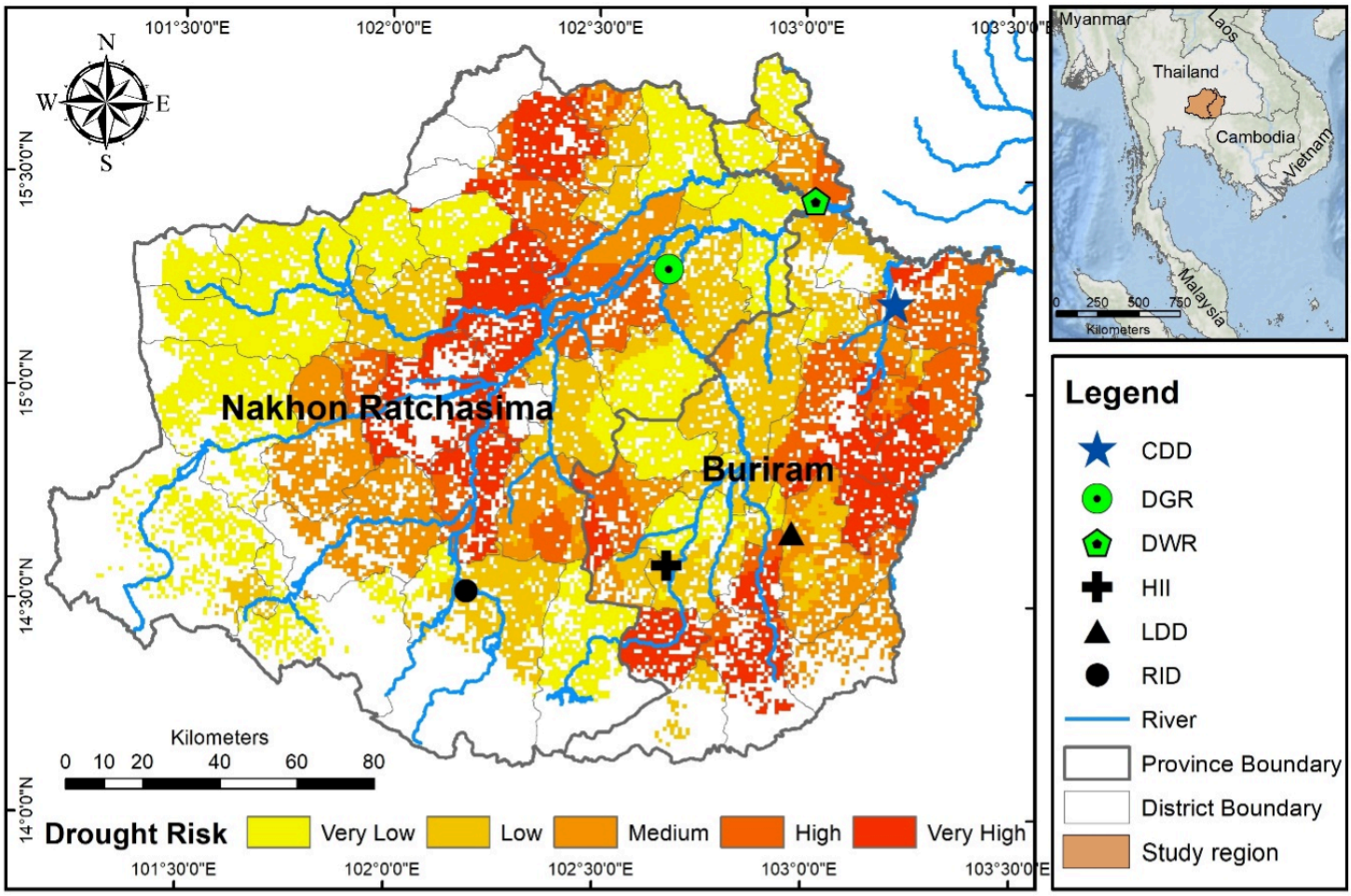


Figure 1

Location of the selected project sites and drought risk levels assessed by Babel et al (2024)

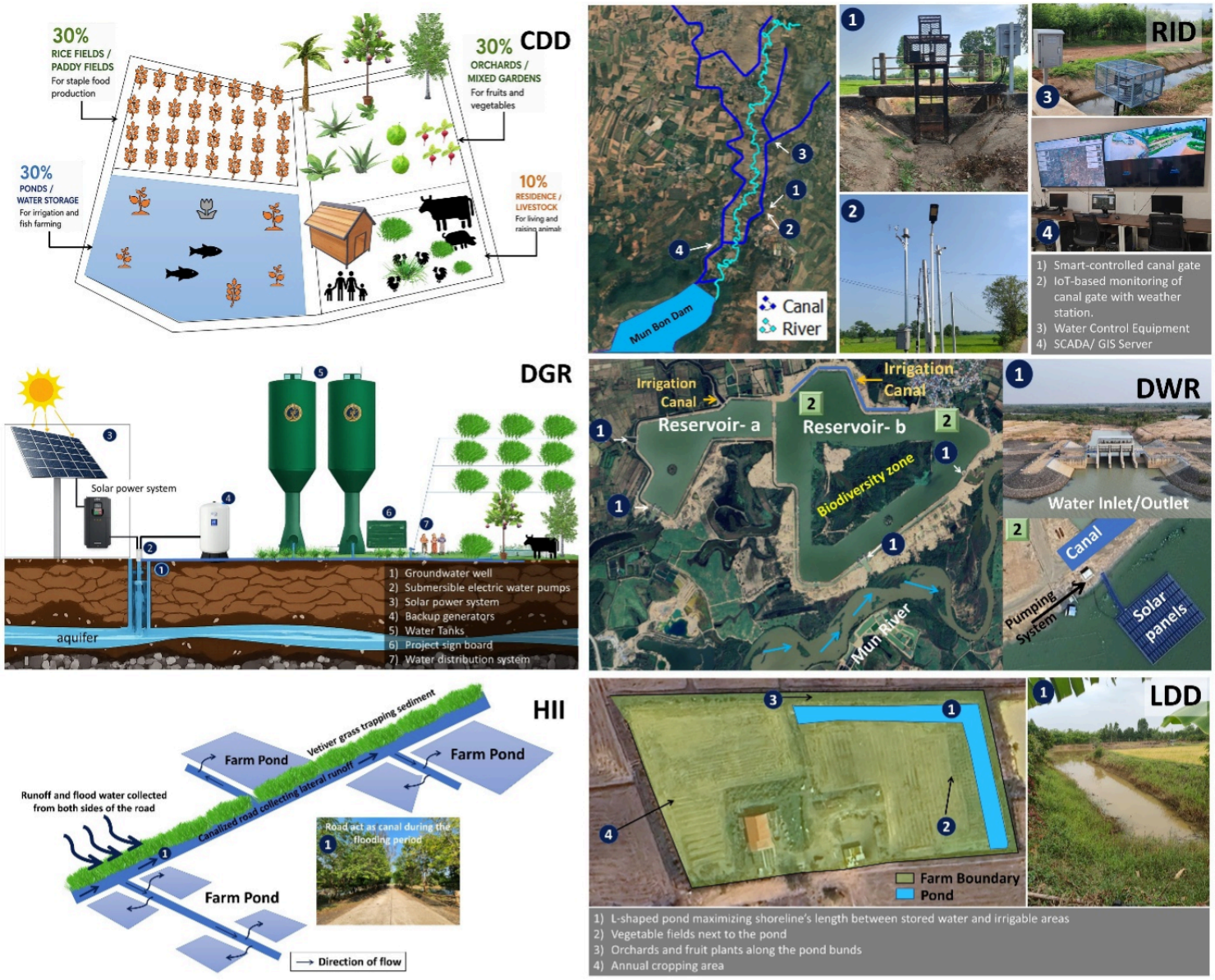


Figure 2

The six selected project sites. Acronyms are defined in Table 1