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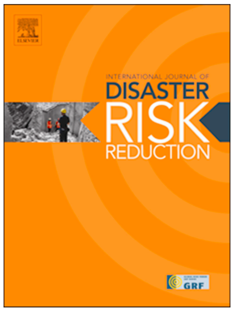

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Stakeholder Perceptions of Drought Resilience Using Government Drought Compensation in Thailand

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Abstract:

In the context of escalating climate challenges in Southeast Asia, this study investigates the dynamics of disaster budget allocation in Thailand and examines farmers' perceptions of drought compensation, focusing on the Ping catchment situated in the Northwest of the country. The main objective of the study was to gauge stakeholders' awareness and views on government drought compensation and evaluate its effectiveness. Using government budget data, drought indicators, and a comprehensive survey in Chiang Mai and Tak provinces, the study explores correlations between budget allocation, drought indicators, and farmers' experiences. A correlation analysis unveils stronger links between compensation and Vegetation Condition Index (VCI) as compared to Drought Severity Index (DSI), with regional variations and the impact of irrigation practices. Compensation shows positive correlations with drought severity, suggesting support to farmers occurs when they suffer severe crop damage. We investigate drought occurrences and their impacts along with farmer's awareness and experiences of drought compensation schemes to uncover disparities in awareness, application rates, and satisfaction levels, providing insights into farmers' views on compensation effectiveness. The study concludes by proposing policy adjustments, tailored regional approaches, and feedback mechanisms to enhance the effectiveness of drought compensation strategies. Despite limitations in sample size and potential biases, this study contributes valuable insights into the complex dynamics of disaster budget allocation, drought compensation, and farmers' perspectives in Thailand, laying a foundation for refining policies and fostering sustainable agricultural practices amidst increasing climate challenges.

Key words: Agricultural droughts, drought compensation, Thailand, survey, drought resilience.

1. Introduction

Changes in climatic conditions manifest through shifts in precipitation patterns, elevated temperatures, and intensified evapotranspiration [1,2]. These factors contribute to the increased instances of drought occurrences in different parts of the world on a global scale. Droughts, one of the costliest hazards globally, are expected to increase in frequency, severity, duration, and intensity for many parts of the world as a result of a changing climate [3]. This trend is set to intensify in Southeast Asia [4] because of several natural and anthropogenic drivers such as changes in monsoon trends, atmospheric circulation patterns, and human factors such as deforestation, land use land cover changes and change in water management practices [5–7]. In recent years, droughts in Thailand such as the 2010, 2015-2016 and 2018-2020 events [8], illustrate the increased frequency of droughts. Many areas in this region are already seeing an increase in drought impacts, for instance, an estimated $53 billion of damage has been caused in the Asia-Pacific area in the last 30 years as a result of drought events [9].

Droughts can have profound impact on the agriculture sector affecting crop yields, livestock, and overall food production [10]. Agriculture is affected by the intensification of droughts, in turn leading to economic losses and social impacts beyond the primary drought impacts [8]. Agricultural land makes up 46.5% of Thailand's 51 million ha land area [11]. Further, Thailand is the second largest economy in Southeast Asia [12], and the second largest exporter of rice in the world [13], contributing 40% of global rice exports [14]. 30% of the population in Thailand work within the agriculture sector [11] and agriculture contributes 11.64% of the total GDP [9]. Therefore, Thailand's agricultural resilience to droughts is critical in guarantying robust food supply and security both globally and locally, ensuring and maintaining long-term sustainability as well as economic stability. Further, droughts have negative impacts on crops grown in Thailand, particularly rice, corn and other cash crops [15], and with rice being the dominant crop in 63 of Thailand's 76 provinces, this demonstrates a particular vulnerability to drought impacts. However, the impacts of droughts are not uniform across Thailand, due to differences in land use, water storage and irrigation, amongst others [15].

Drought risk management strategies are of paramount importance for ensuring the agriculture sector's ability to withstand and recover from the above-mentioned challenges. Sedtha et al. [16] found that an overwhelming majority of farmers in Northeast Thailand have noticed changes in the climatic conditions, prompting the adoption of diverse adaptation strategies to mitigate the adverse effects of climate change. These strategies include agronomic adjustments, such as altering cropping patterns and increasing fertilizer usage, as well as non-agricultural adaptations like purchasing insurance, seeking financial support through loans and credits, and engaging in off-farm employment. In Thailand, drought risk and management is spread across multiple national government ministries or departments [8]. A government scheme is in place in Thailand, which is the subject of this study, through which farmers can get compensation paid following a drought event for short-term drought assistance. Whilst such compensation may help deal with short-term crisis management, it may unintentionally discourage longer-term adaptation and induce risk-taking, which leads to continued drought vulnerability. The Thai Government's Disaster Relief Programme is operated by the Ministry of Agriculture and provides compensation to farmers who meet certain criteria [9]. In addition to ex-post compensation, the Government supports farmers through a range of drought management interventions including artificial rainmaking, mobilising equipment like water pumps, budget allocation for drilling wells, encouraging changes to more drought-resistant crop varieties, subsidies, and limited insurance products [9,17]. Due to the importance of rice to both the economy and farmers' livelihood, rice farmers, in particular, have been subjected to a range of financial interventions, which have included the Government purchasing rice above market prices, deferred debt payments (to the Bank for Agriculture and Agricultural Cooperatives, BAAC), reduced interest rates on loans, and subsidised crop insurance premiums [18].

In this context of agricultural challenges, financial interventions target drought-affected farmers, aiming to provide support, though uncertainties persist about their effectiveness in enhancing resilience. Operating at micro (farm) and macro (e.g., national) levels, these interventions influence factors like household incomes and agricultural yields while challenging government resources and capabilities. This creates complex policy trade-offs for institutions navigating strategies to support farmers, foster economic growth, and address issues like environmental conservation and social stability [19].

In recent years, Thailand experienced a significant drought in the first quarter of 2020 which led to reduced off-season rice and corn production and reduced agricultural economic growth [20]. The drought conditions were brought about by a shorter monsoon season and below-average annual rainfall in 2019. News reports suggest that some farmers in drought affected areas in 2020 may have ignored government advice to stop off-season rice cultivation in exchange for monetary compensation, which has been part of the government's approach since 2017 [21]. Pak-Uthai [22] explains that farmers may be unwilling to cease rice cultivation in exchange for government support if they feel unable to market crops other than rice.

In this study, our primary objective was to understand the current levels of awareness and stakeholders' perceptions regarding Government drought compensation and assess its fitness for purpose. To achieve this, we integrated two complementary approaches: firstly, we examined the correlation between government compensation data and the severity of drought, measured by various drought indicators. This statistical analysis aimed to quantify the alignment between compensation distribution and drought impacts and prepare the basis of the study. Subsequently in the second part, we conducted a survey among farmers in Northern Thailand and interviewed Government officials to gain contextual insights into how stakeholders perceive the implementation, accessibility, and effectiveness of these compensation schemes. By combining the two quantitative and qualitative approaches, the study seeks to cultivate insights into how stakeholders (farmers and government officials) believe that drought management practices could be modified to enhance agricultural resilience in the long run. This dual approach provides a holistic perspective, bridging statistical trends with real-world stakeholder experiences, and offers valuable, real-world transferable insights into the tangible impact of drought compensation schemes, offering clues on potential improvements for optimising their effectiveness in the future.

2. Data and Method

The paper starts with an analysis of disaster budget allocation in Thailand, with emphasis on its relationship with drought indicators. This is followed by an assessment of stakeholders' (farmers and government officials) perceptions of drought compensation, using the Ping catchment as a case study. Together, these approaches provide complementary insights into policy effectiveness.

2.1. Study area

Thailand is located in the tropics, between 5°30′ N and 20°30′ N, and 97°30′ E and 105°30′ E. The country is commonly divided into 6 regions in scientific studies – Central, Eastern, Northeastern, Northern, Southern and Western – each of which can be further separated into provinces (Figure 1). There are a total of 76 provinces, plus a special administrative area for the capital, Bangkok. Thailand experiences a tropical climate influenced by seasonal monsoon winds. From May to October, the southwest monsoon brings warm, moist air from the Indian Ocean, resulting in substantial rainfall, particularly in mountainous regions. Starting in October, the northeast monsoon brings cold and dry air from the anticyclone in China, affecting mainly the northern and northeastern regions at higher latitudes [23]. In the south, the monsoon brings mild weather and abundant rain along the eastern coast. Mean annual rainfall is 1542 mm, with higher amounts on the eastern and southern areas [23]. The mean temperature is 26.3°C in the north and 27.5°C in the southern and coastal areas [24].

The study focuses on the Ping catchment as our case study, given its importance within the agricultural sector and vulnerability to drought. Within the Ping catchment, the study concentrated on two provinces, Chiang Mai which is in the Northern region and Tak situated in the Western region. Both regions are mountainous and largely forest-covered, although with a key difference that agricultural expansion has resulted in deforestation in the Northern region over the last few decades, whilst the forests in the Western region are less disturbed [11]. The Ping River is one of the four main tributaries into Thailand's largest river, the Chao Phraya, and has a catchment area of 36,018 km^2 [12].

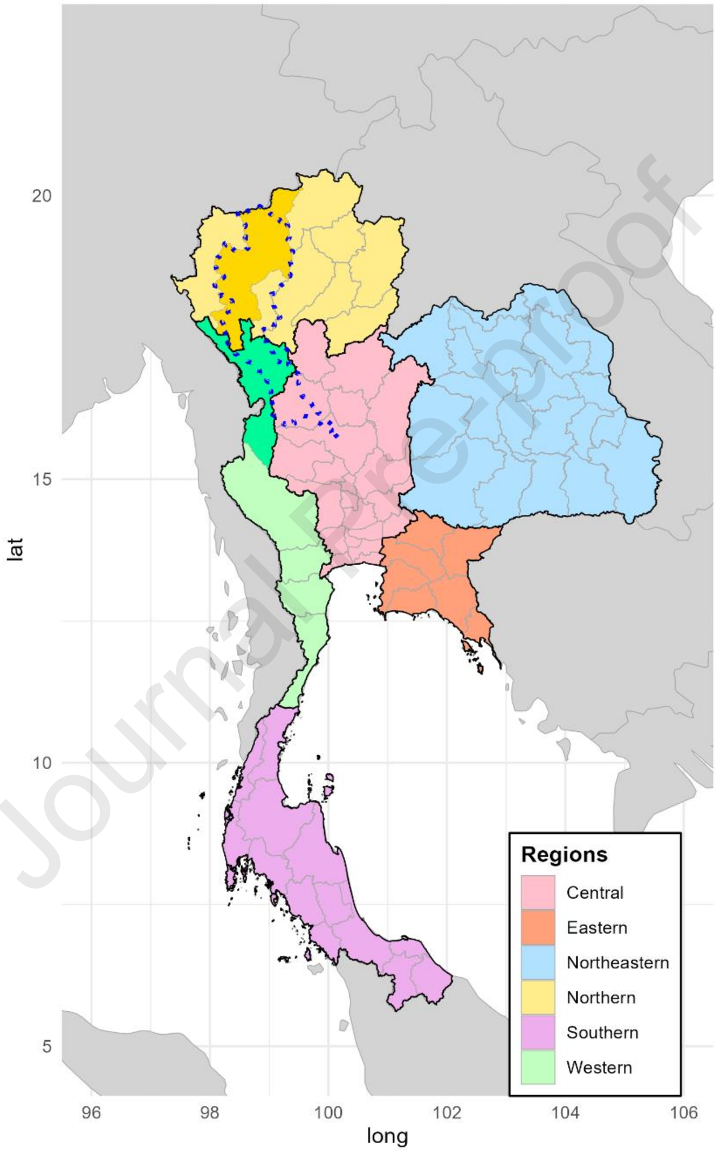

Figure 1: *Map of Thailand showing regions and provinces used in this study. The Ping catchment is denoted by the dotted blue line and the two case study provinces, Chiang Mai and Tak, are shown in darker colours than their corresponding region (Northern and Western, respectively).*

2.2. Analysis of government disaster budget allocation

2.2.1. National Drought Compensation dataset

We used government budget allocation data (2010-2020) by province produced by the Disaster Victim Relief Division within the Department of Disaster Prevention and Mitigation, Ministry of Interior, categorised by type of disaster and purpose, and focused on the drought compensation data. It should be noted, for later reference, that the budget is allocated after the occurrence of disaster events and includes compensation for farmers as well as post-disaster infrastructure restoration expenses. Unfortunately, the dataset does not provide a breakdown between these two components, but this does not affect the analysis.

2.2.2. Drought indicators

We selected two drought indicators commonly used in drought monitoring systems to analyse the relationship between these and the drought compensations, using a simple correlation analysis for each province. Table 1 shows the temporal and spatial resolution of the data used in this analysis (drought indicators and compensation data). The aim of this analysis was to establish whether compensation was received in the provinces which suffered the most from drought, based on these indicators, with the caveat that the dataset for drought compensation combines both farmers' compensation and post-disaster infrastructure restoration expenses. Consequently, the exact allocation to farmers cannot be discerned from the available data.

The Drought Severity Index (DSI) provides a measure of meteorological drought and its impacts on vegetation. Using data sourced from MODIS-TERRA and AQUA satellite products, DSI is calculated from evapotranspiration, potential evapotranspiration (MOD16A2 product [25]), and Normalised Vegetation Index (NDVI, MOD13A1 and MYD13A1 products [26,27]) and comparing current values against the long-term means [28] as follows:

$$RT_i = \frac{ET_i}{PET_i} \quad (1)$$

$$Z_i = \frac{(RT_i - \overline{RT})}{\sigma_{RT}} + \frac{(NDVI_i - \overline{NDVI})}{\sigma_{NDVI}} \quad (2)$$

$$DSI_i = \frac{(Z_i - \overline{Z})}{\sigma_z} \quad (3)$$

where $\overline{RT}$ and $\overline{NDVI}$ are the mean values of the monthly RT and NDVI, respectively; σ_{RT} σ_{NDVI} are the standard deviations of the monthly RT and NDVI, respectively; Z denotes the summation of the monthly standardized ratios of RT and NDVI; and $\overline{Z}$ and σ_Z are the mean and standard deviation of Z, respectively.

Negative DSI indicates drier than normal conditions whereas positive DSI indicates wetter than normal conditions.

The Vegetation Condition Index (VCI) compares the current NDVI to the range of values observed in the same period in previous years. It was calculated on a monthly time step, using satellite data from MODIS-TERRA and AQUA as in Bachmair et al. [29] using the following equation:

$$VCI = \frac{(NDVI - NDVI_{min})}{(NDVI_{max} - NDVI_{min})} X\, 100 \quad (4)$$

Where $NDVI_{min}$ and $NDVI_{\max}$ represent the minimum and maximum NDVI values observed in the same time period over a historical baseline

A lower VCI value indicates poorer vegetation state conditions whilst higher VCI values indicate good vegetation conditions. Strong correlations between VCI and crop yield data have been shown by Tanguy et al. [11] in their study for Thailand. The drought indicators were first derived at pixel level for the entire country and then a land cover map (MCD12Q1 product from MODIS [30]) was used to extract crop-covered pixels only. We then calculated province-level drought indicator averages for cropland, using the corresponding land cover mask.

Figure S1 in the supplementary material shows map of VCI, DSI and government compensation for an example drought year.

Table 1: *Data used in analysis of government compensations.*

Data	Temporal Resolution	Start	End	Spatial Resolution
Compensation – Drought	Yearly	2010	2021	Province
Compensation – Agriculture (crop)	Yearly	2010	2021	Province
Vegetation Condition Index (VCI)	Monthly	Feb. 2000	Jun. 2020	Province
Drought Severity Index (DSI)	Monthly	Feb. 2000	Dec. 2019	Province

2.2.3. Correlation analysis

A correlation analysis was carried out to assess the relationship between drought severity and drought compensation paid at province level. We use two distinct drought indices, DSI and VCI, as a measure of drought severity. Whilst the drought indices and compensation data have the same spatial resolution, they have differing temporal resolutions (Table 1). Therefore, in order to calculate the monthly correlations shown in Figure 2, the monthly drought indices data was subset into a yearly series per calendar month. The correlation analysis was then conducted between the yearly series of drought compensation data and the yearly series of drought indicator data for a given calendar month, employing the Pearson correlation coefficient, which estimates the strength of normalised covariance between two variables, allowing for insight into how closely related the two variables are.

The correlation analysis was conducted to quantify the alignment between drought severity and compensation distribution, identify potential anomalies or gaps in the compensation system, support policy decisions, and contextualise farmers' perceptions. While it is generally expected that government compensation would correlate with the severity of drought impacts, the analysis aims to assess whether compensation is consistently allocated to regions most affected by drought, as measured by the drought indicators. Additionally, the analysis seeks to identify instances where the relationship between drought indicators and compensation may be unexpected, such as areas receiving compensation despite better vegetation conditions, which could indicate systemic issues or other influencing factors. By clearly establishing the relationship between drought severity and compensation, this analysis aims to provide insights that could inform policy decisions, helping to improve the allocation of resources to the areas most in need. Furthermore, the correlation analysis serves to complement the questionnaire data by providing a broader context for understanding farmers' reported experiences, helping to verify whether their perceptions of drought impacts align with official compensation data and drought indicators.

2.3. Farmers' survey and government officials' interviews

Data collection included a survey of farmers in Chiang Mai and Tak provinces using a questionnaire and interviews with government representatives. These methods were used to examine the experiences and perceptions of drought impacts, and the use of government compensation by the farmers. In this study, the questionnaires and interviews were administered to independent respondents. Therefore, the responses reflect independent perspectives without any overlap between interviewees.

2.3.1. Data Collection

Villages in the Ping catchment with a history of drought were selected to represent typical agricultural production typologies. In each, the village headperson selected farm household heads to participate, and trained enumerators undertook data collection after obtaining informed consent. Enumerators were trained by a member of the research team, and the first set of survey responses was reviewed by the research team to ensure the quality of the data being collected. In total, 48 questionnaires were completed in July 2021 with 18 and 30 respondents coming from the provinces of Chiang Mai and Tak respectively. Government officials (n = 8) were purposively recruited and interviewed by phone after giving informed consent. Participants were invited to interview to represent a range of organisations and roles across central government, district, and sub-district government offices.

Table 2: *List of data collected from farmers' surveys.*

Category	Questions
Demographic	Gender
	Age
	Educational background
	Years of farming experience
Farm characteristics	Size
	Land ownership
	Registration status with the Ministry of Agriculture and Cooperatives
	Water sources
	Irrigation practices
	Farm production type
Drought impacts in the past	Frequency and timing of drought occurrences
	Impact on farming activities: crop failure, water shortage, reduced production, or complete cessation of production.
Farmers' experience and perceptions of compensation	Awareness of compensation scheme (including eligibility)
	Compensation amounts, eligible crops, and the farmers' perception of the adequacy of compensation
	Past experiences with applying for and receiving compensation payments, and their levels of satisfaction
Investment for drought resilience	Investment Strategies: investments made by farmers to increase their resilience to future droughts. Categories: increasing water availability, reducing water needs, income diversification and others.
	Farmer's intentions to use compensation amounts for future drought resilience investments.

The structured questionnaire (summarised in Table 2) collected: (i) farmers' demographic information (e.g. age, gender, annual income, highest level of education), (ii) details of farm characteristics (e.g. crops grown, farm size, irrigation methods), (iii) engagement with government compensation (whether they were aware of government compensation, had applied in the past and had receive it, were satisfied with the level of compensation and whether they thought it was effective), and (iv) perceptions of resilience (including what farmers and governments could do). For 'receipt of compensation' we also drew on results from the STAR survey (n = 176) undertaken in the Ping catchment with farmers in January 2020 [31]. Note that this survey included respondents from two additional provinces (Lamphun and Kamphaeng Phet) in the Ping catchment. Government interviews followed similar themes, asking about (i) participant's role and background, (ii) knowledge of, involvement with and perceptions of drought compensation, (iii) perceptions of drought resilience including factors enabling or constraining progress towards a more drought resilient agricultural sector. The questionnaires were originally written in English, translated into Thai and administered before translation back to English for analysis. The study gained ethical approval through the Cranfield University Research Ethics System (CURES) CURES/13334/2021.The full version of both survey questionnaire and interview questions can be found in the supplementary information (S1, S2), along with the full survey questionnaire results (S3).

2.3.2. Statistical Analysis

Statistical analysis of the survey data was undertaken using the statistical software package SPSS (v26). Survey responses were numerically coded and, for the purposes of statistical analysis, Likert-type responses scales were assumed to approximate continuous data under the assumption that the statistic tests were robust to these data [32] and that the results would be interpreted with caution. We used Chi-squared when comparing two categorical variables, t-test and ANOVA for comparing means for different groups, and logistic regression for investigating the extent to which determinants predicted outcome variables. To examine the relationships between demographic and farm variables and the experience of receiving compensation in the past, a logistic regression model was applied. This model was constructed using data from this study and previous surveys [31] to analyse factors affecting compensation reception.

Analysis of the qualitative interview data was undertaken following the principles of thematic analysis, with the coding of transcripts and the sorting and classification of themes facilitated through the NVivo (v12) qualitative data analysis software package.

3. Drought and budget allocation in Thailand

Figure 2 shows heatmaps illustrating the correlations between the drought indices and compensation data for drought. These correlations were calculated for each province over the common period shared by compensation and indicator data. The calculations were conducted individually for each month across all years within the common period. For instance, we correlated the annual compensation data for Chiang Mai from 2010 to 2020 with the series of January VCIs in Chiang Mai from the same period, and so on. Note that since small values of drought indices indicate the severity of drought, a higher negative correlation (depicted in red in Figure 2) suggests a strong correlation between compensations and drought severity.

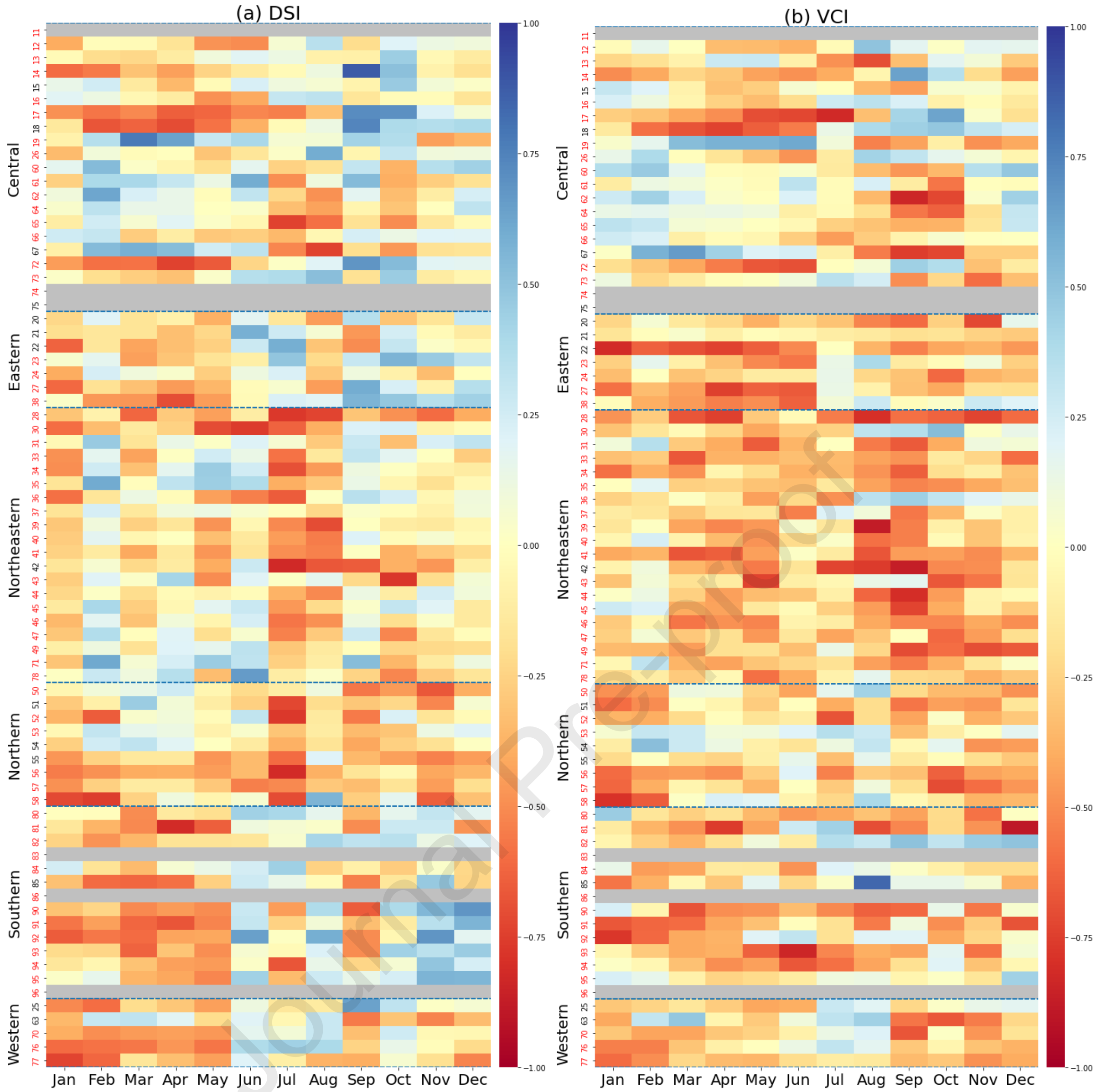

__Figure 2:__ Correlation between budget allocation for drought and drought indices (a) DSI and (b) VCI. Months are displayed on the X-axis and provinces on the Y-axis (represented using an abbreviated version of the province admin code, e.g., Chiang Mai = TH50 = 50; Tak = TH63 = 63). For the full list of province codes, please see supplementary information S4. The provinces highlighted in red on the Y-axis are the ones for which rice is the dominant crop, either Paddy Rice or Second Rice. The provinces have been grouped into the six regions of Thailand (Central, Eastern, Northeastern, Northern, Southern, Western). A grey row in the figure indicates that no compensation data was recorded for that province across all years. Note that since a small value of drought indices indicates the severity of drought, a higher negative correlation (depicted in red in the figure) suggests a strong correlation between compensations and drought severity.

In general, the drought severity represented by VCI is more strongly correlated to government drought compensation than with DSI (more red in the heatmaps). This discrepancy may arise because the VCI is solely based on vegetation health status, whereas the DSI combines both vegetation status and evaporative demand. The latter factor can be partially alleviated through irrigation, potentially leading to a less direct association with the actual impact of drought on crops – especially in regions with widespread irrigation practices, such as the Central region [11]. The Southern region, being considerably wetter than the rest of the country, exhibits a reversed correlation between compensation and DSI values for part of the year, as indicated by the blue on the heatmap in Figure 2a. This trend is particularly evident from June to November, corresponding to the wettest months in that region. Tanguy et al. [11] highlighted that short droughts in the Southern region can have a positive impact on crop yield, possibly due to increased solar radiation and reduced damage from floods. Hence, VCI likely serves as a more objective representation of the severity of drought's impact on crops than DSI. The critical phases for drought stress affecting paddy rice, with significant repercussions on crop yield, include the initial germination and seedling stage, as well as the flowering period [33–36]. However, the extent of this impact varies among different rice varieties, and the growing acceptance of drought-resistant strains serves to alleviate these adverse effects. Figure 2b reveals no distinct or consistent seasonal pattern in correlations between VCI and compensations, except in some provinces in the NE and central regions where the strongest correlations occur in September-October, corresponding to the growing and flowering seasons for the main rice crop. Additionally, numerous provinces across the country exhibit their highest correlations around March-May, aligning with the growing and flowering seasons for rice cultivated as the second crop [37].

The dominance of red hues in the heatmap in Figure 2b implies that compensation is allocated during years characterised by more pronounced crop damage, aligning with our expectations and providing reassurance. This finding is corroborated by farmers' reports of significant crop damage during droughts, as reported in section 4.2 below (Figure 4b). However, discerning the proportion of this compensation allocated to farmers is not possible due to the dataset's amalgamation of both farmers' compensation and expenses for post-disaster infrastructure restoration, with no available breakdown.

4. Farmers' perceptions of government drought compensation: Survey and interview analysis

4.1. Farmer and farm characteristics

From the 48 participants (18 from Chiang Mai and 30 from Tak province), there were slightly more female respondents (58%). The majority were aged between 40 and 59 years (71%), followed by respondents between 60 and 80 years (23%), with 6% in the younger age group of between 20 and 39 years of age. The majority of respondents had completed the highest level of primary school (71%), while 15% had completed secondary and 10% completed high school. A small proportion of the respondents indicated having no schooling (4.0%). On average, the respondents reported having around 27.7 years of farming experience. Most farmers (87.5%) stated that their household earned less than 120,000 THB (£2,600) per year (46% earned less than 32,000 THB (£700) per year).

The average farm size was 25 rai (4 ha) and three-quarters of the farmers owned all of their land (all but one farmer owned at least some part of their land). All of the farmers were registered with the Ministry of Agriculture and Cooperatives. None of the farmers said that their farm was located within a government irrigation zone and the most common source of water was rain (rain-fed 77%) supported by farm ponds and water tanks. Active irrigation (i.e. not simply rain-fed) was practised by 56% of farmers and their method was surface or flood irrigation.

Farmers responding to the survey had a mix of production types, with the main inter-relationships illustrated in Figure 3. Farms mostly had: Animals (n = 36, including cows, pigs, chickens and fish), Fruit (n = 30, mostly mango and longan), rice (n =28), short-season crops (n = 23, mostly maize), long-season crops (n = 21, mostly cassava but also tea). Some farmers also produced vegetables (n = 8) and pastures (n = 5). Farmers on average had 3.5 different production types (with livestock, poultry and fish counted as separate production categories).

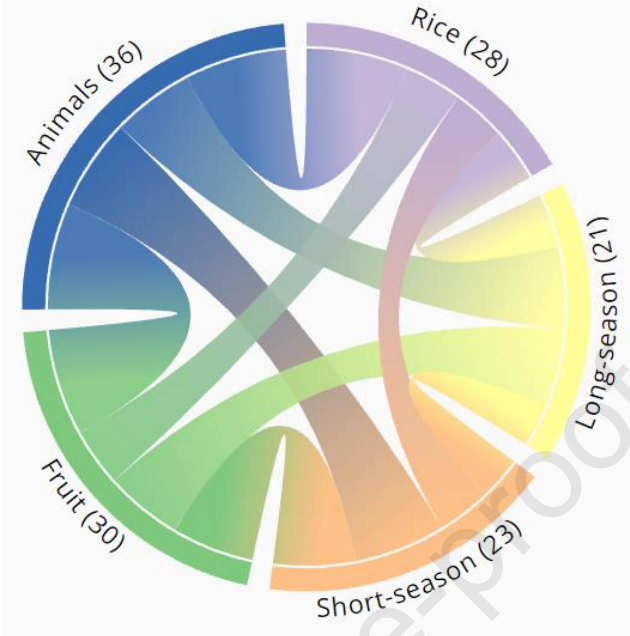

Figure 3: *Chord diagram illustrating the inter-relating main production types of the surveyed farmers*

4.2. Drought impacts in the past

The farmers were asked about the drought impacts on their farms in the past. Nearly 32% of the farmers surveyed (n = 15) said their farm was exposed to droughts every year since 2015. The impact of drought was more pronounced in recent years and 75% of farmers reported experiencing drought during the years 2019-2021 (Figure 4a).

The impacts of drought in the past indicated by the farmers (Figure 4b) included: crop damage or failure (crops such as longan, cassava, maize, rice were damaged or died), water shortage (not enough water, no water for longan, no water for cows, tank water brought to the village, had to carry water), less production (price drop linked to poorer quality of the product, loss of profit, nothing to feed cows, mango flowers not blooming, production affected by insects, had to buy rice for household consumption) and no production (nothing to sell, land can't grow anything). The majority of farmers in Tak reported crop failure as the main drought impact, followed by less production, no production and water shortage. In Chiang Mai, 44% of farmers reported less production and 22% reported water shortage as their major drought impacts.

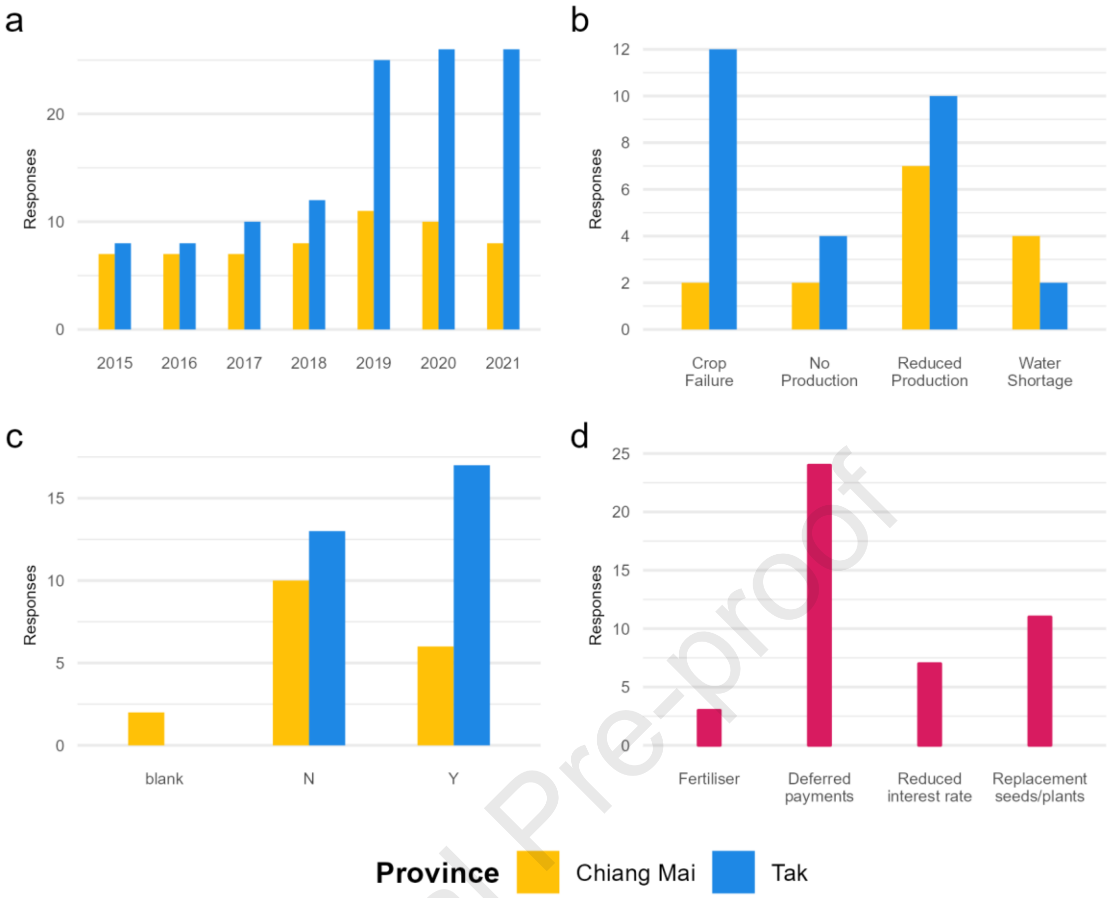

Figure 4: *Survey responses regarding (a) Number of farmers that identify each year as a drought year; (b) The reported drought impacts; (c) Farmers' awareness on the Government's current drought compensation scheme (N=not aware, Y=aware); and (d) Other forms of government support that the farmers received*

4.3. Experiences and perceptions of compensation

Nearly half of the farmers surveyed (48%, n = 23) said they were aware of the government's current drought compensation scheme (Figure 4c). Notably, a higher proportion of farmers in Tak province were aware of the scheme compared to those in Chiang Mai. This disparity may be attributed to Tak province's suffering more impacts from recent droughts, resulting in farmers having greater exposure to and familiarity with the compensation scheme. Of those farmers aware of the scheme, 17 said they were aware of the criteria for getting compensation. For farmers, the commonly understood rules for receiving compensation were being registered (with district agricultural office, and having a BAAC account), growing rice, and experiencing 100% damage. Although some farmers thought that compensation was only available for rice, other farmers reported being compensated for maize, cassava, longan and livestock losses (Figure S2). Farmers reported compensation levels of between 500-1,000 THB (£11-22) and generally thought compensation was available for a maximum of 10 rai or 1.6 ha (one farmer say 20 rai or 3.2 ha). However, government officials reported higher levels of compensation, *"rice damage will get about 1,200 THB* (£26) *per rai"*, possibly available for up to 30 rai (4.8 ha), with the money being transferred to BAAC accounts. Government officials confirmed that damage needed to be 100% and some officials stated the need for an official drought declaration to be made. Government officials recognised limitations to the current compensation scheme, including: not all farmers were registered; the need for 100% damage means that substantial levels of damage were not compensated; and the amount not being enough to compensate losses.

Two-thirds of the farmers (n = 32) had applied for and received compensation payments in the past (Figure 5). Four farmers from Tak had applied in the past but didn't receive compensation, as they didn't meet the criteria. The remaining farmers (n = 12) had not applied for compensation. Other forms of support that farmers received included debt repayment delays, reduced interest rates, free seeds and seedlings, and free fertiliser (Figure 4d). Other farmers mentioned support with digging a pond, acquiring a community rice mill, and dredging the river. During previous years of drought, just under half (47%) of the surveyed farmers had received information about drought compensation from an agricultural district officer (Figure S3 of supplementary material). Of the farmers that received compensation, 66% (n = 21) said they were satisfied with the level of compensation they received.

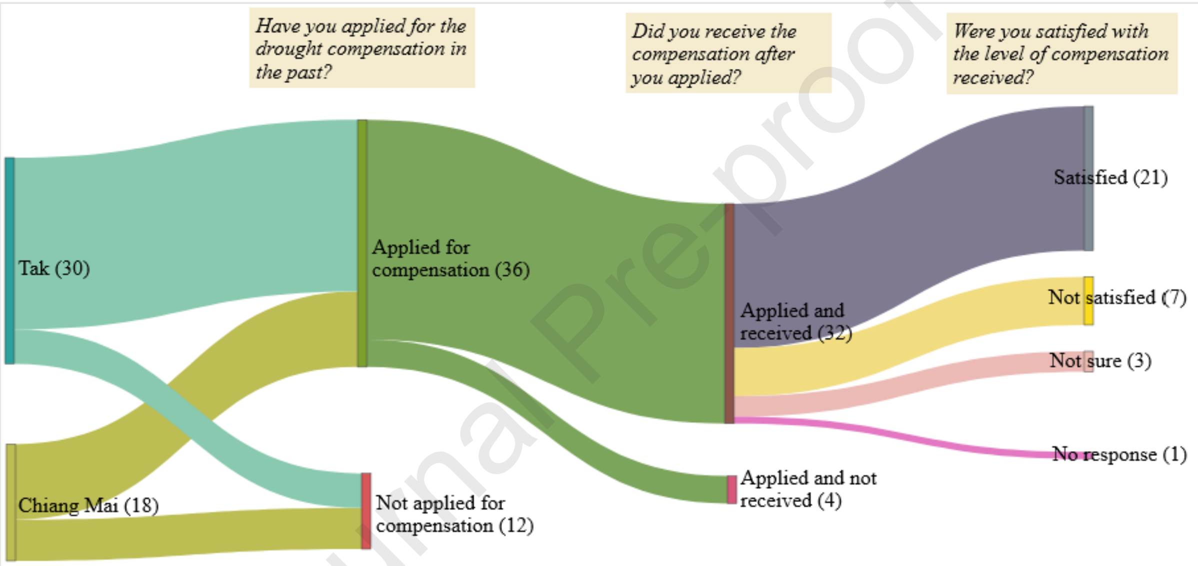

Figure 5: *Farmers' experience of drought compensation in the past (values in brackets indicates number of responses)*

We explored interactions of 'demographic and farm variables' and 'received compensation in the past' using logistic regression model (Table S1 of supplementary material). For this analysis, we used data from this study along with survey data from a related survey completed in January 2020 [31], which surveyed farmers across the Ping catchment (from four provinces: Tak, Chiang Mai, Lamphun and Kamphaeng Phet). The two datasets combined gave a sample size of 221 responses. Using this model, receiving compensation was predicted by being a rice farmer and being from Tak province. Neither age nor education predicted the receipt of compensation. However, being a farmer with lower income predicted the receipt of compensation.

There were some differences in the perceptions of compensation across the two provinces. Farmers from Tak were more likely to say that compensation was enough to cover their losses (although average fell towards 'somewhat disagree'). Farmers from Chiang Mai were more likely to feel that the compensation helps with drought resilience and with reducing worries about drought impacts (Table 3). While these differences were detected, we note that the analysis was limited by the small sample size and the sensitivity of the statistic tests based on the characteristics of the data.

Table 3: *Perceptions of government compensation*

	Mean response value*		Comparison of means	
	Chiang Mai	**Tak**	**t-test**	**Sig(p)**
The compensation is enough to cover the financial losses from the drought	2.28	2.73	2.139	0.038
The compensation arrives early enough	2.78	3.07	1.111	0.272
The compensation system is equally fair to all farmers	3.22	3.37	0.533	0.597
The compensation scheme helps farmers like me become more resilient to droughts	4.06	3.30	-3.075	0.004
Government compensation reduces my worries about drought impact	4.00	3.30	-2.802	0.007

*1=strongly disagree, 3 = neither agree nor disagree, 5 = strongly agree.

The actual government drought compensation amounts given out in both provinces can be seen in Figure S4 in the supplementary information.

4.4. Farmers' perceptions on drought resilience using drought compensation

Around 77% farmers (n = 37) reported that they have made investments in their household farm to increase their resilience to future droughts. However, 11 farmers had not made any investments. It is stated that, after the last drought, the investments were mostly made related to increasing the availability of water (n = 27, e.g., digging wells and borehole, constructing microdams), income diversification (n=20; e.g., livestock, other agricultural activities, non-agricultural activities) and reducing the water needs in the farm (n=15; e.g., changing crops, cultivation periods, crop varieties, reducing irrigation amounts, changing irrigation system) (Figure 6). About 43% of the farmers made a single type of investment whereas the majority (57%) have made more than one type of investment. About 38% of respondents invested in at least two types of investments, whereas 18% invested in more than two types.

Out of 37 farmers who made investments for future drought resilience, 17 of them used the drought compensation received to fund investments in their household farm, whereas 18 famers used some other sources to make investments (Figure 7).

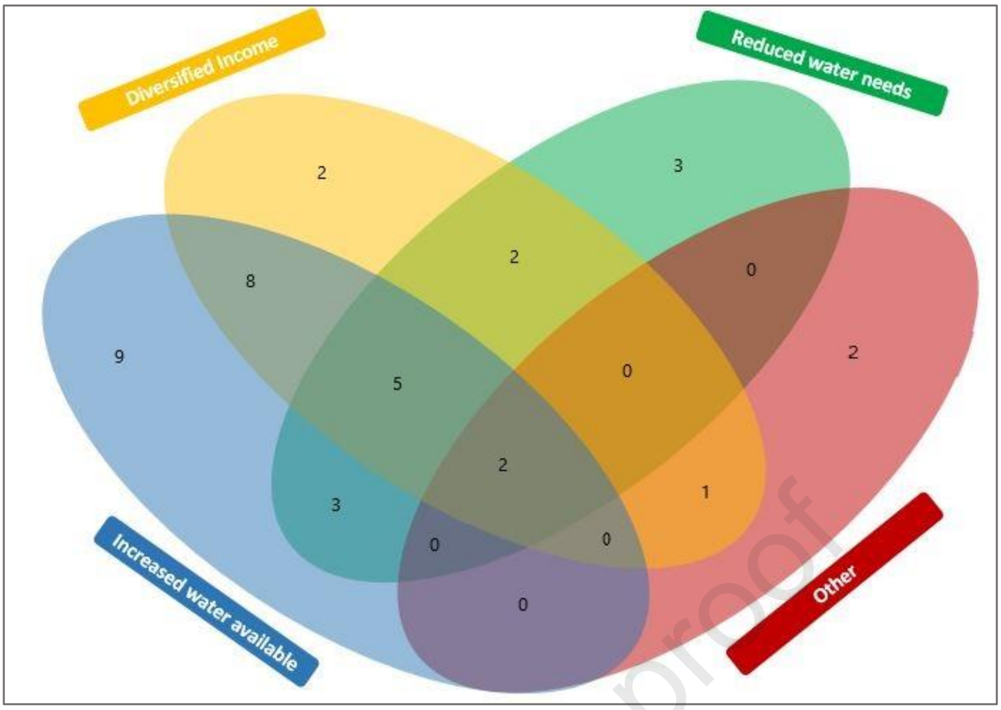

__Figure 6:__ Number of respondents for each type of investments in their household for future drought resilience (values indicate the total number of responses (both Chiang Mai and Tak))

__Figure 7:__ Farmers' experience of using compensation amount for future drought resilience (values indicate the total number of responses from both Chiang Mai and Tak)

The farmers were asked their views on using compensation amount for drought resilience in future. Around 90% of the farmers from Tak and 94% farmers from Chiang Mai are planning to use compensations in future to increase drought resilience. Some of the farmers didn't respond to the question. Only a few farmers (7%) in Tak province clearly answered that they are not going to use the future compensation amount for drought resilience (Figure 8a).

The survey also asked farmers if they thought their farm would benefit from being more resilient to drought in the future and nearly half of the farmers said no (48%, Figure 8b). More farmers from Tak received compensation (the sample was also bigger and proportionally there was little difference to Chiang Mai), but farmers from Tak were less likely to perceive benefits to being resilient compared to farmers from Chiang Mai. Most farmers in Chiang Mai who received compensation also perceived benefits to being more resilient (n = 7, 64% of those that received compensation perceived benefits to being more resilient).

Those who received compensation were more likely to say there were benefits to being resilient to drought (47%), compared to 30% who said there were benefits but didn't receive compensation (Figure 8c). Rice farmers were more likely to say they had made investments to increase resilience after the last drought compared to farmers not cultivating rice ($\chi2$ (1) = 4.172, p = 0.041). This factor could, to some extent, help explain why many farmers did not see any benefit to becoming more resilient – that is, they had already made investments to increase their resilience.

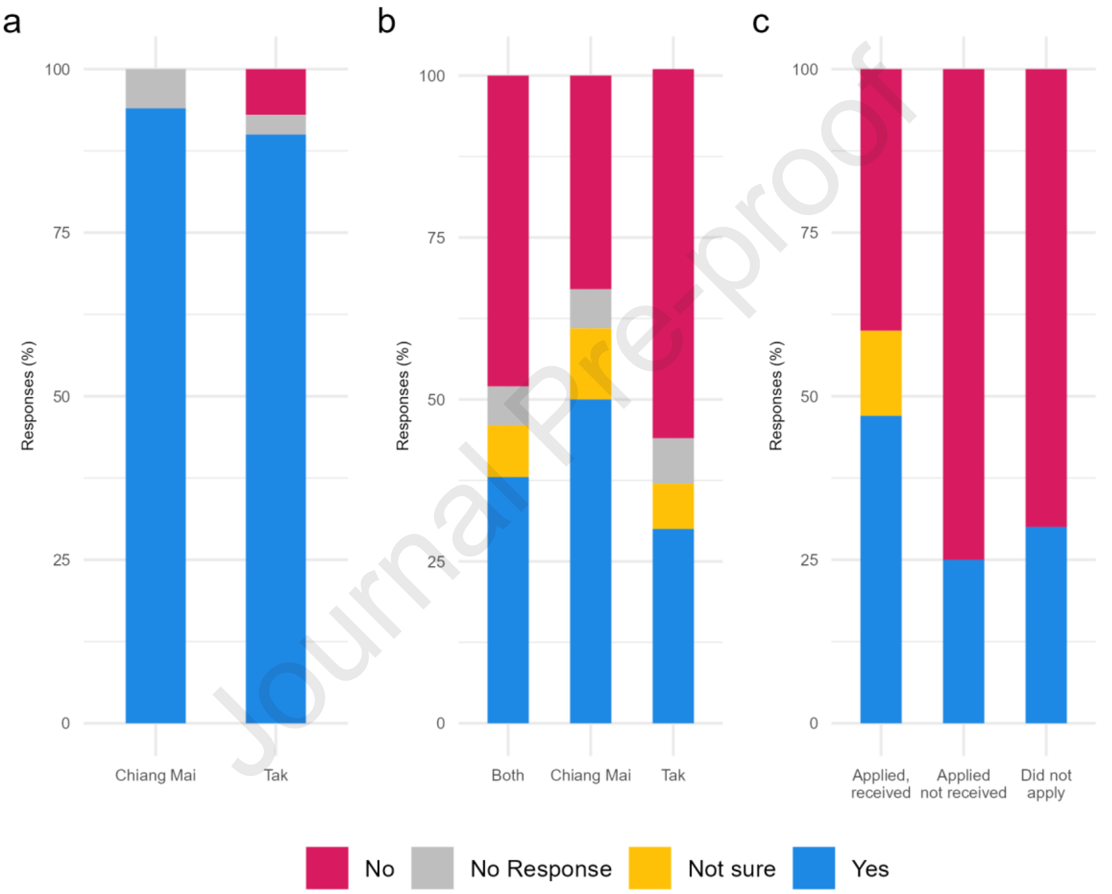

Figure 8: *Survey responses regarding famers' perception on drought resilience, more specifically (a) Farmers' perception on drought compensation for future drought resilience, (b) Perceived benefit to being more resilient to drought in the future summarised by province, (c) Perceived benefit to being more resilient to drought in the future depending on whether the respondent had received compensation.*

Farmers and government officials were asked what they thought governments could do to support farmers to be more resilient to drought. These qualitative responses were thematically coded and are summarised in Figure 9a. The main themes were suggested by both farmers and government officials and related to increasing water supply, other practical forms of support for farms (such as providing seedlings, fertiliser or technology), providing advice and training, and financial support. Government officials were concerned about the availability of budgets and saw limited budgets as constraining effective drought responses. Improving regulations was also suggested by government officials, who suggested that "*the supporting laws and regulations has many limitations*".

Stakeholders were also asked what they thought farmers could do to be more resilient to drought (thematically coded responses summarised in Figure 9b). Both farmers and government officials thought farmers could be better prepared, should diversify their crops and incomes and should look for ways to increase their water supply. Some farmers couldn't think of anything and others felt that they just had to "*fight to survive*". Thus, these themes highlight the link between financial barriers and planning for drought, such that although farmers recognise they need to act, they do not have the resources to carry out their desired actions.

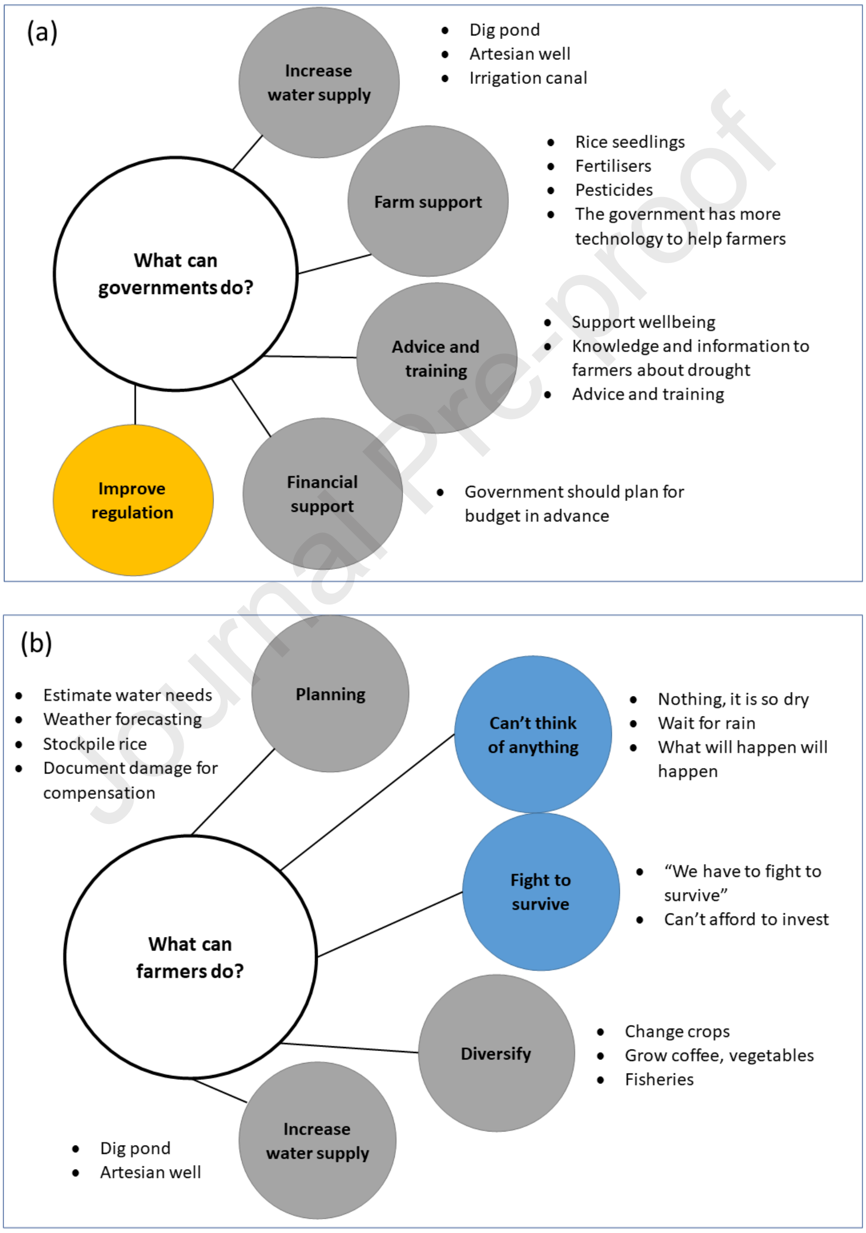

Figure 9: *Thematic responses to (a) what governments could do to increase resilience, and (b) what farmers could do to increase resilience. Blue= farmer response, yellow = response from government officials, grey = response from both farmers and government officials.*

5. Discussion

5.1. Farmers' awareness, perception and experience of compensation

The study finds that only about half of the surveyed farmers were aware of the compensation scheme which highlights the potential limitations in current government outreach and communication strategies. This aligns with findings from Goodwin et al. [8], who, in their study on agricultural drought adaptation in Northern Thailand, emphasised the positive association between the perceived efficacy of communications and farmers' adaptations. Strengthening information networks, as suggested by Goodwin et al. [8], could be pivotal in enhancing awareness and understanding of compensation schemes, especially among less networked farmers. By drawing parallels with the importance of effective communication in adaptive capacity, our study emphasises the need for improved outreach strategies to ensure that compensation information reaches a larger proportion of the farming population.

A significant proportion of farmers did not apply for compensation, partly from lack of awareness, but also potentially due to other barriers including complex application procedures, lack of understanding of eligibility criteria, or doubts about the likelihood of approval. Among those who applied for compensation, the study found varying levels of satisfaction. Some farmers were content with the compensation they received, while others expressed dissatisfaction. The dissatisfaction could stem from discrepancies between their expectations and the actual compensation received. Some of these disparities could be attributed to the compensation criteria, such as the need for 100% damage, which might not align with the actual losses incurred during droughts. Expectations may be influenced by the perceived extent of damage and the effectiveness of compensation in covering their losses. The Organisation for Economic Co-operation and Development (OECD) shed light on certain deficiencies in the Thai National Rice Insurance Scheme [38]. This included the scheme's dependence on the government's declaration of a disaster for the entire area which resulted in some farmers not receiving pay-outs despite suffering losses, while others received payments they did not necessarily need. This might contribute partly to the dissatisfaction reported by some farmers in our survey.

5.2. Effectiveness of compensation policies and drought resilience strategies

The study highlights some discrepancies between farmers' perceived needs and the provisions made by existing compensation policies:

- *Eligible crops:* most compensations focus on rice. However, farmers reported crop failure in crops such as longan, cassava, maize, and others. As a result, farmers who suffered losses in non-traditional crops can be left without support. This might also discourage diversification of crops.

- *Compensation amounts:* The study indicates that compensation amounts may not align with the actual losses incurred by farmers. Some farmers reported that the free seeds/seedlings and fertilisers distributed by the government did not equal to the amount lost from their damaged crops.

- *Conditions required for compensation:* criteria such as the need for 100% damage or drought officially declared for a whole region, means that some farmers who have suffered loss are not eligible for compensation. The need for 100% damage as a prerequisite for compensation introduces challenges to the seamless integration of remote sensing and other indirect assessments into drought management and related financial instruments. Specifically, this stringent criterion complicates the adoption of technologies like remote sensing, which excel at identifying variations in crop health across landscapes but may struggle to discern whether an individual farm has suffered complete devastation.

However, despite these discrepancies, the complementary nature of our analyses becomes clear. The correlation analysis between drought severity (as estimated through drought indicators) and compensation levels suggests that, in general, compensation tends to increase during years of severe crop damage caused by drought, especially in the NE and E regions (section 3). This aligns with findings from Tanguy et al. [11], who showed that drought indicators such as VCI were highly correlated to crop yields, indicating that compensations are more likely to occur when the damage is extensive. On the other hand, our survey findings provide valuable insights into the subjective experience of farmers, offering a human-centred perspective on how compensation is perceived, applied for, and distributed. This combination of the objective, data-driven insights from the correlation analysis and the subjective insights from farmers' personal experiences underscores the complex nature of drought compensation. In line with this, Thavorntam et al. [39] found a strong link between farmers' self-reported life satisfaction and drought indicators (including VCI used as proxy for drought severity) in drought-prone areas of NE Thailand, suggesting that help also goes to those struggling the most.

To the best of our knowledge, no previous study in the region has provided such a comprehensive analysis that integrates both quantitative data and farmers' qualitative experiences on government support for drought, effectively bridging the gap between official drought monitoring systems and their real-world impacts. This unique approach offers unprecedented insights into farmers' experiences, revealing both the strengths and weaknesses of the current drought compensation scheme and providing valuable guidance for the enhancement of future drought compensation policies.

A number of studies have documented advantages and disadvantages to ex post drought compensation, whereby we refer to compensation to typically signify government payments to farmers for losses caused by drought (or other climate related events). Post event compensation can also extend to emergency investments in critical infrastructure damaged by the event or subsidies that help farmers to recover some of their losses. Drawbacks to centrally funded state compensation include constrained government budgets where funds may be diverted away from other resilience building contingencies like ongoing maintenance and repair of irrigation infrastructure or that eligibility or administration factors lead to low and inequal scheme uptake where few farmers benefit [19].

The fully subsidised Thai National Rice Insurance Scheme, launched in 2014, significantly increased the number of covered farmers by overcoming low willingness to pay for insurance, however, it showed limitations in raising awareness and incentivising risk reduction [38]. The transactional passivity of farmers resulted in limited transfer of risk information. The one-size-fits-all approach of offering payments to farms of all sizes makes the scheme financially burdensome, particularly for larger farms that could afford alternative risk management strategies.

While there may be some benefits to governments providing ex post crisis management support funds, such stimulus is unlikely to facilitate longer-term resilience particularly if farmers become dependent on compensation or where prioritising short-term needs does not facilitate the building of capacity to adapt away from existing vulnerabilities [19].

Despite these limitations in compensation mechanisms, a large proportion of surveyed farmers (77%) have reported the adoption of several strategies to increase their resilience to droughts, including (i) increasing water availability (wells, boreholes, microdams); (ii) reducing water needs (altering crop varieties, shifting cultivation periods, more efficient irrigation) and (iii) income diversification (livestock farming, non-agricultural activities).

This aligns with the conclusions of earlier studies in the region, such as those by Wai [40], Pak-Uthai and Faysse [41], and Sedtha et al. [16]. These studies report that farmers in Thailand recognise the impact of climate change and have adopted diverse measures to adapt to these evolving conditions. Liao et al. [42] found that farmers in Thailand identified increasing droughts as one of the major perceived environmental changes.

These investments not only serve as immediate measures to combat the impacts of drought but also play a crucial role in achieving long-term agricultural sustainability. They contribute to resource preservation (efficient water resource management), economic stability (diversified income make farms more resilient to various shocks), climate adaptation (farms able to cope to increasingly unpredictable weather extremes) and sustainable agriculture (resource efficient practices). However, a large proportion of respondents did not know what to do increase their resilience to drought (Figure 9b), highlighting the crucial role of educating and disseminating knowledge.

The proactive adoption of strategies to increase resilience for many of the surveyed farmers constitutes an interesting contrast to responses reported by Holman et al. [43] for temperate agriculture, where drought responses were dominated by reactive and crisis-driven actions to cope with, or enhance the recovery from, drought; but which contributed little to increased resilience to future droughts. These divergent behaviours in different parts of the world could be attributed to a combination of multiple contextual, environmental, and socio-economic factors (e.g., climatic differences with Thailand being more prone to droughts, risk perceptions, government policies). This highlights the importance of tailoring interventions regionally, as effective strategies for enhancing resilience to drought must consider the unique interplay of socio-economic, cultural, and climatic circumstances that shape agricultural practices in diverse environments.

5.3. Implication for policy

The results from our survey suggest that there are a series of potential policy adjustments that could be worth exploring.

These include:

- *Enhance compensation scheme awareness and clarity*: Less than half of the surveyed farmers had received information about drought compensation from an agricultural district officer in previous years, highlighting the need to improve outreach programs to enhance farmers' awareness of existing schemes. Goodwin et al. [8] identified a catchment-scale advice network as an efficient means to improve knowledge exchange.

- *Revise compensation criteria and amounts* so that the help is more flexible, more consistent and fairer. This could involve evaluating the feasibility of adjusting damage thresholds or exploring a tiered compensation system that accounts for varying degrees of loss. Ensuring that compensation amounts align with the actual impact of drought on different crops and farming practices could contribute to a fairer and more effective scheme. Additionally, this flexibility can facilitate the integration of novel technologies like remote sensing into the framework of drought management and compensation instruments, thereby advancing the overall efficacy of the system.

- *Support drought-resilient farming practices*. Need for training and knowledge exchange is evidenced by the response of nearly half of the respondents who didn't know what to do in situation of droughts (Figure 9b).

Where there are discrepancies between government officials and farmers, we suggest opportunities to improve drought management advice and governance networks [8]. Bringing together the views of farmers with their local knowledge and experience with the overarching strategic ambitions of institutions can help to facilitate shared learning and to devise policy interventions to support more resilient agricultural systems [8]. OECD [38] also reports that farmer awareness remains low due to limited technical assistance on risk management. Thai extension services provide farmers with information on select practices that reduce risk, but these focus primarily on helping farmers reduce their costs of production in an effort to boost productivity. Such advice could include measures that reduce vulnerability (e.g. promoting efficient water use in drought-prone areas).

- *Tailored Regional Approaches*: The disaster Prevention and Mitigation Act (2007) authorises local government to co-ordinate local Disaster Risk Management (DRM) activities. However, in practice, the line departments at the provincial level are often confined to their silos and cross-sectoral co-ordination is less than optimal. Most decisions on national and even local DRM requiring interministerial collaboration are sent back to the Ministry of the Interior or the Prime Minister's Office [38]. To enhance the effectiveness of regional approaches, fostering a culture of interdepartmental collaboration and empowering local authorities with decision-making autonomy could be essential steps forward. This may require fundamental changes involving revisiting bureaucratic structures, streamlining communication channels, and promoting a more integrated and collaborative approach to disaster management at both regional and national levels.

- *Support investment in infrastructure* (see Figure 9b) *and long-term planning/adaptation*. Planning large infrastructure projects needs increased stakeholder consultations and risk analysis. Potential irrigated area accounts for 20% of total agricultural land in Thailand. However, only 1/3 of that area is effectively irrigated. For example, for the country to cope with the 2016-17 drought season, the government has estimated that an additional 17,661 cubic meters of reservoir water was needed, of which 54% would go to agricultural irrigation [38]. The Strategic Plan on Thailand's Water Resources Management (The Policy Committee for Water Resources Management, 2015) is addressing this shortfall through its key targets which are: to increase the efficient water management of the 5 million ha in existing irrigation areas, to increase the efficiency of existing water-resource projects by at least 10% for existing irrigation areas, and to develop new water-resource projects to achieve a volume of 9500 million m^3 and thereby increase irrigation to cover 1.4 million ha in 25 river basins [12].

- *Regular feedback and evaluation mechanisms*: to monitor the effectiveness of compensation schemes and to incorporate farmers' perspectives in policy development and improvement. OECD [38] highlights the importance of taking into account indigenous knowledge to DRM policies to foster the participation and leadership of local communities and their members in Disaster Risk Reduction (DRR) activities, and also to improve knowledge transfer efficiency and feedback mechanisms.

Longer-term planning to build resilience and adaptive capacity may be a preferable response than ex post crisis management support funds, albeit one requiring more intensive and extensive planning and coordination. However, the main limitation for the adoption of these suggested policy adjustments is the financial burden for the government. The availability of funds, competing with other spending priorities, is needed for sustaining an efficient scheme. Nonetheless, there are many low-regret interventions that integrate existing community adaptive practices, engage with farmers' needs and prioritise extension support which may encourage more desirable counteractions to drought [19].

5.4. Limitations of the study

A key limitation of this study is the relatively small sample size of 48 participants. While the responses provide valuable insights into stakeholder perceptions of drought resilience and government compensation, the limited number of participants restricts the generalisability of the findings. A larger sample size could have captured a broader spectrum of views, potentially uncovering regional or demographic variations in perceptions. For instance, expanding the sample could have provided a more nuanced understanding of how factors such as farming practices, access to water resources, or reliance on compensation programs differ among distinct stakeholder groups.

Moreover, the small sample size amplifies the risk of statistical outliers disproportionately influencing the results [44]. While we applied appropriate methods to analyse and interpret the data, the inherent limitations of such a small dataset mean that caution is required when extrapolating these findings to a wider population. This highlights the importance of larger, longitudinal surveys in future research to improve representativeness and statistical reliability [45].

In addition to the sample size, potential biases arising from the survey methodology merit attention. Self-reporting, for example, may lead to overestimation or underestimation of certain experiences or attitudes, as participants may respond in ways they perceive to be socially desirable or aligned with expected outcomes [46]. Selection bias is another concern [47], as the participants may not fully represent the diversity of stakeholders in the Ping catchment area. Factors such as ease of access to respondents, willingness to participate, and familiarity with government compensation programs may have influenced the composition of the sample.

Despite its limitations, the use of small sample sizes in exploratory studies such as this is not uncommon and has been shown to provide meaningful insights, particularly in contexts where data collection is constrained by logistical or resource limitations. For instance, studies on disaster resilience and farmers' perceptions on disaster management often rely on small, targeted samples to explore stakeholder perceptions in depth (e.g. Wandera et al., [48], Hoque [49]; Theron et al. [50]). These approaches allow for a focused investigation into specific phenomena that might otherwise remain underexplored. Additionally, small-scale surveys can effectively highlight patterns and generate hypotheses for further, larger-scale research. In the absence of broader datasets, such studies are invaluable for initiating dialogue and shaping preliminary policy recommendations. Hubbard [51] introduces the principles of the "Rule of Five" and the "Mystery of the Urn", based on statistical theory, demonstrating how even small samples can yield statistically meaningful insights about a population. Similarly, Patton [52], Gelman and Hill [53], and King et al. [54] underscore the ability of small datasets to uncover key trends, test hypotheses, and provide probabilistic insights in both qualitative and quantitative research. These perspectives underscore that while larger samples may enhance generalisability, well-designed small-scale studies remain invaluable in exploring complex socio-environmental phenomena, where logistical challenges often necessitate reliance on small, targeted samples.

To mitigate the biases deriving from small sample size in future studies, incorporating mixed methods approaches – such as complementing survey data with focus groups or in-depth interviews – can provide richer, more context-specific insights. Additionally, employing stratified sampling techniques [55] to ensure proportional representation across regions, genders, and socio-economic groups could enhance the inclusivity and reliability of findings. Finally, using alternative data sources, such as anonymised administrative records, could help validate or triangulate self-reported perceptions, reducing reliance on subjective responses.

In addition, only 10 years of data were available for the correlation analysis, which is very short to infer any robust relationship. Despite this temporal constraint, the decade under consideration was marked by notable drought events (2010, 2015-2016, and 2018-2020). Consequently, while acknowledging the brevity of the dataset, we believe that the results retain value as a general indication of the existing relationship between drought severity and government compensation.

Finally, while the correlation analysis in this study focuses on the Vegetation Condition Index (VCI) and Drought Severity Index (DSI) as drought indicators, we acknowledge that soil moisture is a critical factor in assessing agricultural drought and its impacts. Soil moisture-based indices, which provide direct insights into water availability for crops, were not included in our analysis due to limitations in data resolution and availability. Future research should consider incorporating soil moisture indices, particularly those derived from high-resolution remote sensing or reanalysis datasets, to enhance the accuracy of drought impact assessments.

6. Conclusion

Thailand has been experiencing an increase in frequency and severity of droughts over the recent years. This study explores drought compensation dynamics in Thailand, particularly within the context of farmers' experiences and perceptions of governmental policies, and sheds light on the complex interplay between budget allocation and farmers' satisfaction. The correlation analysis between drought severity and drought compensation provides nuanced insights, indicating that compensation distribution often aligns with the severity of impact on crop. In contrast, the farmer survey offers a deeper understanding of the subjective experiences of those affected, revealing significant gaps in awareness and access to compensation. Together, these two analyses provide a more holistic view of the challenges in drought compensation, with the correlation analysis offering objective, data-driven insights and the survey capturing the human, on-the-ground perspective of farmers. The study uncovers a significant gap in farmers' awareness and application for compensation, highlighting potential barriers such as insufficient outreach and understanding of eligibility criteria.

The varying levels of satisfaction among those who did apply underscore the need for a more transparent and adaptable compensation framework. Discrepancies in eligible crops, compensation amounts, and stringent conditions reveal challenges in the current policy landscape. Despite these, positive correlations between drought severity and compensations, especially in the Northeast and East regions, suggest that compensation tends to increase during severe drought years, aligning with the struggle of those most affected. By integrating both the correlation analysis and farmers' feedback, we gain a more comprehensive understanding of how the compensation system is perceived and how it operates in practice, revealing areas for improvement.

To increase their resilience, farmers employ diverse strategies to mitigate drought impacts, as evidenced by practices such as increasing water availability, reducing water needs, and income diversification. This aligns with broader regional studies indicating a proactive response to climate change. Such strategies not only address immediate challenges but contribute to long-term agricultural sustainability.

Implications for policy include the necessity for tailored regional approaches, improved awareness campaigns, and a reconsideration of compensation criteria to better meet the evolving needs of farmers. A multi-faceted approach, including infrastructure investment and long-term planning, emerges as crucial for bolstering agricultural resilience. Regular feedback mechanisms and evaluations are recommended to refine policies continually and ensure their efficacy in addressing farmers' evolving needs.

While the study provides valuable insights, acknowledging the limitations of a small sample size and potential biases in data collection methods is crucial. Future research endeavours might consider expanding the scope for a more robust understanding. Overall, this study contributes to the ongoing discourse on effective drought compensation policies, emphasising the need for adaptive and farmer-centric approaches in the face of evolving climatic challenges.

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Declaration of generative AI in scientific writing

During the preparation of this work the authors used ChatGPT with the exclusive aim of enhancing readability and language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Authors' contribution

Rishma Chengot: Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing - original draft; Writing - review & editing

Daniel Goodwin: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Software; Supervision; Validation; Visualization; Writing - original draft; Writing - review & editing

Maliko Tanguy: Conceptualization; Investigation; Funding acquisition; Project administration; Resources; Supervision; Validation; Visualization; Writing - original draft; Writing - review & editing

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: