Mitig Adapt Strateg Glob Change (2024) 29:6
https://doi.org/10.1007/s11027-023-10099-w

ORIGINAL ARTICLE

# Which factors determine adaptation to drought amongst farmers in Northern Thailand? Investigating farmers' appraisals of risk and adaptation and their exposure to drought information communications as determinants of their adaptive responses

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Received: 3 February 2022 / Accepted: 19 December 2023


**Abstract**
Drought communications constitute an important source of learning about climate risks and responses that can assist adaptation decision-making amongst those whose livelihoods are threatened by drought. This paper applies Protection Motivation Theory to explore associations between drought communications and attitudes towards drought risk and adaptation amongst farmers in Northern Thailand. The analysis reveals links between drought communications, farmers' adaptation appraisal, and their adaptation decisions, whilst links with risk appraisal are minimal. The results highlight positive feedbacks between adaptation experience and appraisal and reveal a weak negative relationship between risk appraisal and adaptation appraisal. The findings imply benefits to framing drought communications in terms of the efficacy and attainability of suitable adaptations, rather than simply highlighting drought risks or providing drought warnings, to best enable farmers to build drought resilience.

**Keywords** Protection Motivation Theory · Drought risk perceptions · Climate change resilience · Thailand

## 1 Introduction

Agriculture is sensitive to water availability, with climatic extremes leading to substantial yield losses (Lesk et al. 2016). Droughts constrain crop productivity and pose an ongoing threat to global food production which is likely to increase due to climate change, population growth and pressure on water resources (Daryanto et al. 2017; Leng and Hall 2019). Building agricultural drought resilience is of crucial importance to global food security and human well-being (Carrão et al. 2016; Challinor et al. 2014). However, many factors limit effective adaptation, including informational, attitudinal and behavioural barriers (Howden et al. 2007). Understanding how to overcome these barriers and increase the adaptive

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Published online: 11 January 2024

capacity of farmers must be prioritised to support agricultural development, crisis prevention and vulnerability reduction (Lipper et al. 2014). As such, research has increasingly focused on how farmers' understandings and perceptions of climate change determine their adaptation decisions (Deressa et al. 2011; Mertz et al. 2009; Sutcliffe et al. 2016), with studies addressing the cognitive processes that link climate perceptions with decisions to implement action (Grothmann and Patt 2005; Truelove et al. 2015).

The attitudinal factors that determine decisions to employ a protective measure in response to a threat (i.e. adaptation) have been modelled using the Protection Motivation Theory (PMT) conceptual framework. The PMT framework identifies two cognitive pathways which are believed to determine whether individuals decide to employ protective behaviour. These pathways are risk appraisal and adaptation appraisal. Risk appraisal combines an assessment of the potential severity of a negative impact with the likelihood that such an impact will occur. Adaptation appraisal combines an assessment of how effectively a proposed response would curtail the threat of the negative impact (response efficacy), with an assessment of the capacity of the individual to employ that particular response (self-efficacy), along with an assessment of the potential costs of doing so (Milne et al. 2000).

PMT was first employed in the 1970s within social psychology studies of health behaviours (Rogers 1975) and has since been highly influential across a range of disciplinary areas including business studies, computing and environmental science. It has been applied in relation to a wide array of different threats, including information security (Haag et al. 2021; Herath and Rao 2009), pollution risks (Wang et al. 2019) and the threat of extreme weather and climate change (Bubeck et al. 2012; Kuruppu and Liverman 2011; Grothmann and Patt 2005; Grothmann and Reusswig 2006). Most studies related to extreme weather have concentrated on flood protection, often in a European context (e.g. Babcicky and Seebauer 2017; Bamberg et al. 2017; Bradford et al. 2012; Poussin et al. 2014). Few studies have used PMT to explore drought adaptation in the Global South, although a body of research is building in Asian (e.g. Keshavarz and Karami 2016; Truelove et al. 2015) and African (e.g. Gebrehiwot and van der Veen 2015; Tabe-Ojong et al. 2020; Wens et al. 2021) contexts.

Knowledge and understanding of climate change are positively associated with farmers' adaptation intentions (Ngo et al. 2020). Studies have noted the influence of different sources of information for risk and adaptation appraisal (Milne et al. 2000), including social networks (Babcicky and Seebauer 2017; Haer et al. 2016) and public institutions (Grothmann and Reusswig 2006), and the role of institutions in communicating climate information to influence local level responses (Dorward et al. 2020; Haer et al. 2016; Steynor et al. 2021). The provision of drought warnings, forecasts and advice can effectively build resilience to drought by mitigating impacts and leading to faster recoveries within farming communities in developing countries (Ewbank et al. 2019). Optimising the provision of this information is an increasingly key necessity for policy makers, climate services and agricultural development practitioners.

This paper aims to build understanding of the processes that determine adaptation to drought amongst farmers in Northern Thailand. In it, we explore and compare the roles that risk appraisal and adaptation appraisal play as determinants of past adaptations and their perceived success and as determinants of responsiveness to official adaptation recommendations and the desire to implement further adaptations in future. We also investigate the extent to which exposure to and perceptions of both formal and informal drought communications are associated with these adaptation outcomes.

Key questions:

1. To what extent do PMT and drought communication variables influence adaptation outcome variables?
2. Which determinants affect adaption and risk appraisal?
3. What role do socioeconomic factors (age, education and wealth) play in determining access to drought communications?

Based on these questions, we discuss the extent to which PMT variables predict adaptation outcome variables and how institutional drought communications influence farmers' motivations and actions to protect their production activities from the risk of drought. By using the PMT framework to understand the relative importance of farmers' appraisals of risk and of adaptive responses within their agricultural decision-making and illustrating the influence of drought communications, the paper provides communication design recommendations that should increase farmers' implementation of adaptations to reduce the negative impacts of drought on agricultural livelihoods.

## 2 Methodology

### 2.1 Case study

As Southeast Asia's second largest economy, Thailand's development significantly affects its neighbours, and the country plays an important role in policy-making within the wider region (Kiguchi et al. 2021). Agricultural production in Thailand, like other countries in Southeast Asia, is important for global food supply, with the region as a whole contributing 40% of global rice exports (Yuan et al 2022). However, rice yields have stagnated in Thailand in recent decades, as they have in several neighbouring countries, with drought having played a major role in crop losses in Thailand, Cambodia and Myanmar since 2015 (Venkatappa et al. 2021). Across Southeast Asia, there is an increasing risk of agricultural drought in the near term (Amnuaylojaroen and Chanvichit 2019), with projections suggesting countries across the region will experience longer, more intense and more severe droughts prior to 2050 due to the impacts of climate change under a range of probable emission scenarios (Supharatid and Nafung 2021). Identifying strategies to support farmers to stabilise and increase yields whilst reducing their vulnerability to drought is therefore a key concern for policy makers across the region that may look to Thailand as an example.

Drought has already had major impacts on the availability of water for irrigation in Thailand in recent years (Kiguchi et al. 2021), with this problem set to grow in the near future (Chang et al. 2021; Singhrattna and Babel 2011). Due to the recent incidence and severity of agricultural drought impacts, the Ping River catchment (a major tributary of Thailand's main interior river, the Chao Phraya) was chosen for data collection. Significant regional droughts took place in 2015–2016 and 2019–2020 (Khan and Gilani 2021; Pak-uthai 2019), with reports that the timing of government drought warnings and advice hampered effective farm responses (Khan and Gilani 2021). Despite the major agricultural impacts and increasing risk of drought in Thailand, few studies have focused on climate risk communications (Arunrat et al. 2017; Lebel et al. 2018). As such, Northern Thailand provides a suitable context for investigating how institutional drought communications currently support farmers to build resilience to drought and for identifying strategies to optimise such support in future.

### 2.2 Sampling and data collection

The research team purposively selected a sample of villages exposed to different levels of drought over the last decade. Villages both within and outside of formal irrigation zones were selected to represent a range of typical agricultural production profiles (such as rice, longan and livestock production). According to the customary context, the village headperson (a village elder who acts as the community leader) in each village was contacted initially, and the research team requested their permission to conduct the research. The village headperson then invited farm household heads to participate. As opposed to random sampling of households, this method may have resulted in a degree of sampling bias, meaning that the sample should not be interpreted as fully representative. In particular, readers should bear in mind the possibility that due to the selection of participants by the village headperson, older, wealthier farmers may be over-represented, whilst poorer, younger farmers and female-headed farms may be under-represented. However, this sampling approach was considered the most appropriate given the local socio-cultural context, and the validity of the analysis reported herein is not contingent on a perfectly representative sample. Trained enumerators undertook data collection after obtaining informed consent. In total, 176 questionnaires were completed in January 2020 with a close to even distribution of respondents coming from the provinces of Chiang Mai ($n$ = 41), Lamphun ($n$ = 45), Kamphaeng Phet ($n$ = 45) and Tak ($n$ = 45). The structured questionnaire collected socioeconomic, agricultural, risk appraisal, adaptation appraisal, adaptation behaviour and drought communications data from farmers. The questionnaire was originally written in English, translated into Thai and administered before translation back to English for analysis. Questionnaires were anonymised, and the questionnaire and dataset can be found at https://doi.org/10.17862/cranfield.rd.16553136.

### 2.3 Data processing and analysis

#### 2.3.1 Adaptation outcome variables

The first set of questions within the questionnaire collected data from respondents on their adaptation actions and perceptions. In particular, respondents provided information about the number of adaptations they had undertaken in the past (Ai), whether or not they considered these adaptations to have successfully reduced their longer term vulnerability to drought (Aii), whether they had changed anything about their agricultural production activities in response to having a received a drought warning (Aiii) and whether or not they had a desire to implement any further adaptations that they had not yet been able to (Aiv) (see Table 1 for further details).

#### 2.3.2 PMT variables

Respondents were then asked to indicate agreement (measured on a five-point scale from strongly agree to strongly disagree) with statements constructed to investigate

**Table 1** Description and questionnaire numbers for key adaptation, PMT and drought communication variables

| Variable name | Variable type | Variable composition and explanation |
|---|---|---|
| Total adaptation count (Ai) | Continuous | Total count of number of past adaptations indicated by the respondent |
| Proportion adaptations successful (Aii) | Continuous | Total count of adaptations perceived to reduce vulnerability to drought impacts in future divided by grand total of adaptations |
| Adapted in response to drought warning (Aiii) | Dichotomous (0, 1) | Yes/no response to questions, "During previous droughts was your household informed that a drought was coming? Did your household farm change anything as a result of receiving this information?" |
| Desires to adapt further (Aiv) | Dichotomous (0, 1) | Yes/no response to question, "To reduce the impacts of droughts in the long-term, are there any adaptations you would like to undertake but did not yet?" |
| Adaptation appraisal | Continuous | Sum of adaptation cost scores subtracted from sum of adaptation and self-efficacy statement scores. ("Appropriate adaptation strategies exist for protecting farms like mine from drought" + "I feel confident implementing adaptation strategies for protecting my household farm from drought" + "I consider myself well informed about drought") minus ("I work hard every day, so I feel too tired to implement the necessary adaptation strategies" + "Farm work is too busy, so there is no extra time to implement the necessary adaptation strategies" + "I have not got enough money to implement the necessary adaptation strategies") |
| Risk appraisal | Continuous | Combined scale (sum) consisting of three statements<br>"My household farm is likely to be affected by drought in the next five years" + "The impacts of drought on my farm are likely to be severe" + "The impacts of drought on my household farm are worse than before" |
| Drought information types count | Continuous | Sum of drought information types received by respondent |
| Drought information channels count | Continuous | Sum of information channels through which drought information was received |
| Drought information efficacy scores | Continuous | Agreement (using a five-point scale) that drought information had: helped them prepare for drought ("helped prepare"); arrived early enough in the season to be of use ("early enough"); was relevant to the household's farming activities ("relevant"); was accurate ("accurate"); was in the correct format ("best format"); and whether the organisation providing the information was receptive to receiving farmer drought and adaptation information back ("receptive"). These measures were combined to form a single variable |
| Number of other farmers drought communications were received from | Ordinal | Number of farmers (ranked groups) that had informed household a drought was coming and what to do |

their levels of adaptation appraisal and risk appraisal (Milne et al. 2000) (see Table 1). An overall adaptation appraisal score was calculated, based on the sum of perceived self-efficacy and perceived response efficacy scores, less the sum of perceived response costs scores. Similarly, an overall risk appraisal score was based on the sum of perceived vulnerability and perceived severity scores.

#### 2.3.3 Drought communications

The questionnaire then collected information on whether respondents had received drought warnings, which types of drought monitoring information they had received (for example, weather forecasts, river discharge information and irrigation availability forecasts) and which channels drought information was received through, in addition to the perceived efficacy of that information. These were converted into counts of drought information types and channels and a perceived drought information efficacy score (Table 1).

#### 2.3.4 Land and asset scores

In contexts where agricultural households use some of their produce for subsistence, monetary income may not accurately reflect household wealth. This necessitates assessing farm household wealth in terms of asset and land ownership. Scores for land and asset ownership were calculated following Cordova (2009) and Filmer and Pritchett (2001), whereby standardised scores for a range of culturally prevalent assets are derived from the frequency of their ownership (represented using a dummy variable as either 0 or 1) amongst respondent households in the dataset. In the case of land ownership, since this was a continuous variable, farm sizes were split into five bands (at cut points of 95%, 75%, 50%, 25% and 5% of the sample) represented by dummy variables. Standardised scores were then calculated based on frequencies for each band, and scores for household land ownership were made up by adding these scores cumulatively, so that those with land in the highest band accumulated the scores for the band they were in as well as all the lower bands.

#### 2.3.5 Statistical analysis

Relationships between the four adaptation outcome variables (Ai–Aiv), PMT variables and drought communications variables, in addition to socioeconomic (age, education and wealth), and agricultural and policy factors (formal irrigation support and drought compensation provision) were investigated using multiple regression analyses and, where relevant, *t*-tests, ANOVA, chi-square, Fisher's exact test and Pearson's and Spearman's correlation coefficients. Linear regression was used to identify significant determinants of the two continuous adaptation outcome variables Ai and Aii ("total adaptation count" and "proportion adaptations successful", respectively). Binary logistic regression was used to construct models for the two dichotomous adaptation outcome variables Aiii and Aiv ("adapted in response to drought warning" and "desires further adaptation", respectively), with interaction terms investigated for potential effects (Field 2018).

The regression analysis sought to investigate relationships between the PMT variables (adaptation appraisal and risk appraisal), the drought information variables and the four adaptation outcome variables (Ai–Aiv). Alternative regression analyses were run in turn incorporating either the compound adaptation and risk appraisal scores or their disaggregated component variables (such as, for example, agreement scores with the statements representing response efficacy and self-efficacy). This was done in order to compare results and determine whether the compound scores or the disaggregated scores were more powerful predictors of the independent adaptation variable (Babazadeh et al. 2017). Where the separate component factors proved to have stronger predictive power than the compound variables, these were included preferentially within the regression models presented in the results.

Following a principle of parsimony (Field 2018), variables found not to significantly predict the outcome variable were excluded (Braun and Oswald 2011). Variables were entered into the models hierarchically, with those expected to have the largest influence entered first.

## 3 Results

In the “3” section, RQ1 presents the factors influencing the four adaptation outcome variables using individual regression models. In each case, the influence of the PMT and drought communication variables on the adaptation outcome variables is described, and other influential variables are identified. RQ2 explores factors affecting adaptation and risk appraisal, and RQ3 identifies relationships between adaptation, drought communications and socioeconomic characteristics (age, education and wealth).

### 3.1 RQ1: To what extent do the PMT and drought communication variables influence adaptation outcome variables?

#### 3.1.1 Total adaptation count (regression model Ai)

Model Ai was significant ($F(8) = 12.232$, $p = .000$) and accounted for 37% of the variance in the total adaptation count scores (with an adjusted $R^2$ of .37). Of the PMT variables, only adaptation appraisal significantly predicted total adaptation count, risk appraisal did not. Of the adaptation appraisal components, the statement “Appropriate adaptation strategies exist for protecting my household farm from drought” was a stronger determinant than the aggregate “adaptation appraisal” variable; hence, only the “Appropriate…” statement variable was selected for inclusion in the model. Of the socioeconomic factors, only age was found to contribute significantly, with a negative relationship evident between age and the number of adaptations employed. In terms of drought communication variables, the count of types of drought information received significantly predicted total adaptation counts, as did agreement with the information efficacy statements, “early enough”, “accurate”, “relevant” and “best format”, and the number of farmers that information had been received from. Whilst the relationship between total adaptation count and the statements “relevant” and “accurate” were positive, the relationships with the statements “early enough” and “best format” were negative, suggesting that as the number of adaptations undertaken increased, agreement with these particular statements declined (see Table 2).

#### 3.1.2 Proportion of adaptations perceived as successful for longer term drought vulnerability reduction (regression model Aii)

Analysis showed that the drought communications variables did not improve model Aii, and this group of variables was excluded. The final model, which incorporated age, wealth,

**Table 2** Linear model of predictors of total adaptation count (model Ai, adjusted $R^2 = .37$, $F(8) = 12.232$, $p = .000$)

| | Unstandardised coefficients | | Standardised coefficients | t | Sig. | 95.0% confidence interval for B | |
|---|---|---|---|---|---|---|---|
| | *B* | Std. error | Beta | | | Lower bound | Upper bound |
| (Constant) | 1.140 | 1.394 | | 0.818 | 0.415 | −1.615 | 3.896 |
| "Appropriate adaptation strategies exist for protecting my household farm from drought" | 0.839 | 0.145 | 0.386 | 5.774 | 0.000 | 0.552 | 1.126 |
| Age group | −0.712 | 0.230 | −0.206 | −3.089 | 0.002 | −1.167 | −0.256 |
| Count of different drought monitoring information types received | 0.478 | 0.138 | 0.254 | 3.453 | 0.001 | 0.204 | 0.751 |
| "The information provided arrives early enough in the season to be useful to my household farm" | −0.527 | 0.168 | −0.233 | −3.140 | 0.002 | −0.859 | −0.195 |
| "The information provided is usually relevant to the farming in the household farm activities" | 0.605 | 0.253 | 0.207 | 2.393 | 0.018 | 0.105 | 1.105 |
| "I am confident that the information provided is accurate" | 0.722 | 0.224 | 0.243 | 3.217 | 0.002 | 0.278 | 1.165 |
| "The information is provided in the best format for farmers to access and understand it easily" | −0.845 | 0.261 | −0.273 | −3.240 | 0.001 | −1.360 | −0.329 |
| Information was received from how many farmers | 0.171 | 0.066 | 0.173 | 2.572 | 0.011 | 0.040 | 0.302 |

**Table 3** Linear model of predictors of proportion of adaptations perceived to successfully reduce vulnerability to future droughts (model Aii, adjusted $R^2 = .16$, $F(5) = 5.132$, $p = .000$)

| | Unstandardised coefficients | | Standardised coefficients | Sig. | 95.0% confidence interval for B | |
|---|---|---|---|---|---|---|
| | *B* | Std. error | Beta | | Lower bound | Upper bound |
| (Constant) | 0.231 | 0.174 | | 0.186 | −0.112 | 0.575 |
| Age | 0.136 | 0.047 | 0.221 | 0.004 | 0.044 | 0.228 |
| Wealth | −0.013 | 0.005 | −0.182 | 0.017 | −0.023 | −0.002 |
| Adaptation appraisal | 0.075 | 0.026 | 0.222 | 0.004 | 0.025 | 0.126 |
| Household raises animals | −0.135 | 0.054 | −0.184 | 0.014 | −0.242 | −0.028 |
| Household has land in official irrigation zone | 0.14 | 0.057 | 0.179 | 0.016 | 0.027 | 0.252 |

**Table 4** Binary logistic regression results showing predictors of whether the household changed anything in response to receiving a drought warning (model Aiii). $R^2$ .21 (Cox & Snell) and .285 (Nagelkerke). Model $\chi^2$ (5) = 36.573, $p = .000$)

| | | | | | | 95% confidence interval | |
|---|---|---|---|---|---|---|---|
| | *B* | Standard error | Wald statistic | Sig. | Odds ratio | Lower | Upper |
| (Constant) | −0.562 | 0.366 | 2.36 | 0.124 | 0.57 | | |
| Received financial drought compensation × fruit production | −1.182 | 0.433 | 7.454 | 0.006 | 0.307 | 0.131 | 0.716 |
| Instances of drought in last 10 years | 0.346 | 0.149 | 5.411 | 0.02 | 1.413 | 1.056 | 1.891 |
| Adaptation appraisal | 0.44 | 0.196 | 5.055 | 0.025 | 1.552 | 1.058 | 2.277 |
| Received weather forecast information | 1.148 | 0.52 | 4.874 | 0.027 | 3.153 | 1.138 | 8.74 |

adaptation appraisal, animal husbandry and land within a supported irrigation zone, was significant ($F(5) = 5.132$, $p = .000$) and accounted for 16% of the variance in the proportion of adaptations perceived as successful. All included variables significantly determined the proportion of adaptations perceived as successful, with negative relationships pertaining with wealth and animal husbandry, indicating that wealthier farmers and those that raised livestock tended to perceive a lower proportion of their past adaptations as successful than other farmers (see Table 3).

### 3.1.3 Respondent adapted their agricultural practice in response to receiving a drought warning (regression model Aiii)

Model Aiii, which used binary logistic regression to investigate decisions to adapt in response to official advice, was significant ($\chi^2$ (5) = 36.573, $p = .000$) and accounted for 29% of the variance. Both fruit production and rice production were found to interact significantly with having received financial drought compensation, although when both fruit and rice were included in the same model, the significance of the rice × compensation interaction was lost (Table 4). Nevertheless, this result points to a potentially important relationship between past receipt of drought compensation and behavioural responses to drought information amongst producers of these crops, which reduced the likelihood that households would have changed something about their agricultural or livelihood activities in response to receiving drought information. However, given the cross-sectional nature of our data, we cannot discern whether failing to adapt in response to advice came before or after receiving compensation. The other significant determinants (all of which increased the likelihood that households would indicate having changed something in response to the information they received) were the number of droughts that the household had experienced over the last 10 years, the respondent's adaptation appraisal score and if the respondent had received weather forecast information (Table 4). Amongst these variables, having received a weather forecast had an odds ratio of 3.15, meaning that the odds of households adapting in response to official advice were 3.15 times greater amongst households that had received weather forecast information than amongst those that had not. For every additional instance of drought the household reported experiencing in the last decade, the odds that they had adapted in response to a drought warning were increased by 1.41, and for every unit increase in adaptation appraisal, the odds increased by 1.56.

Although not found to contribute significantly to the logistic regression, growers that indicated having received information via a social network messaging group were statistically more likely to have changed something in response to official advice ($\chi^2 = 3.991$, $p = .046$), as were growers that had been educated to high school level or above ($\chi^2 = 7.780$, $p = .005$).

#### 3.1.4 Respondent indicated a desire to implement further adaptations (regression model Aiv)

Model Aiv was significant ($\chi^2$ (4) = 26.164, $p = .000$) and accounted for 23% of the variance. Within the model, the odds that a farmer would indicate wanting to make further drought adaptations were significantly increased (by 1.44) for each additional drought adaptation that they had previously implemented (Table 5). The odds also increased if they indicated lacking money for implementing adaptations, feeling well informed about drought risks or perceiving drought information to be in the right format for farmers. The odds were lowered amongst farmers that indicated stronger agreement that the drought information received had been relevant (Table 5). Whilst this last finding was unexpected, a potential explanation could be that a perceived lack of relevant drought information caused farmers to delay implementing their desired adaptations.

Whilst risk appraisal was not a significant predictor of a desire to implement further adaptations in this model, a *t*-test revealed that farmers that indicated a desire to adapt further had significantly higher risk appraisal scores than farmers that indicated that they did not wish to implement any further changes ($\bar{x} = 11.9$ vs $\bar{x} = 11.2, t = 1.985, p = 0.049$).

### 3.2 RQ2: Which determinants affect adaption and risk appraisal?

#### 3.2.1 Adaptation appraisal

Multiple significant associations were found using Pearson's correlation coefficient between adaptation appraisal and the drought information communications variables. In

**Table 5** Binary logistic regression results showing predictors of "Are there any further changes you would like to implement on the farm, but that you did not yet?" (model Aiv). $R^2$ .17 (Cox & Snell) and .229 (Nagelkerke). Model $\chi^2$ (4) = 26.164, $p$ = .000)

| | B | Standard error | Wald statistic | Sig. | Odds ratio | 95% C.I. for EXP (B) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower | Upper |
| Constant | −5.852 | 2.027 | 8.334 | 0.004 | 0.003 | | |
| "I have not got enough money to implement the necessary adaptation strategies" | 0.626 | 0.212 | 8.689 | 0.003 | 1.869 | 1.233 | 2.833 |
| Total number of adaptations | 0.365 | 0.111 | 10.869 | 0.001 | 1.44 | 1.159 | 1.789 |
| "I consider myself to be well informed about drought risks" | 0.633 | 0.264 | 5.746 | 0.017 | 1.883 | 1.122 | 3.158 |
| "The information provided is usually relevant to the farming in the household farm activities" | −0.959 | 0.409 | 5.512 | 0.019 | 0.383 | 0.172 | 0.853 |
| "The information is provided in the best format for farmers to access and understand it easily" | 1.037 | 0.394 | 6.935 | 0.008 | 2.82 | 1.304 | 6.102 |

particular, confidence in implementing adaptation strategies correlated with the number of types of climate information that had been received ($r$ = .23, $p$ = .04), the perception that climate information had helped the farmer prepare in the past ($r$ = .40, $p$ = .001) and that the information was provided in the best format for farmers ($r$ = .36, $p$ =.001).

Using multiple regression, adaptation appraisal scores were significantly determined by education (Beta .271, $p$ = .001), the total number of adaptations that had been undertaken in the past (Beta .220, $p$ = .005), the proportion of past adaptations perceived as successful (Beta .213, $p$ = .007) and the drought information efficacy score (Beta .199, $p$ = .013). The model was significant ($F$, 10.478; $p$ = .000), and these four variables accounted for a fifth of the variance in adaptation appraisal (adjusted $R^2$ = .21).

Wealth correlated significantly with adaptation appraisal ($r$ = .207, $p$ = .006), but did not contribute significantly to the regression model due to high semi-partial correlation with education. Older farmers (aged over 60) were also found to have significantly lower adaptation appraisal scores (mean = 0.27 vs 0.63 for younger farmers, $t$ = −2.161, $p$ = .032).

Adaptation appraisal was lower if a respondent perceived there to be higher costs associated with undertaking adaptations. Respondents' perceptions of adaptation costs were measured via their scores for the availability of time, energy and finance for implementing adaptations. Whilst correlation between the availability of time and energy for implementing adaptations was high (.61, $p$ = .000), there were no significant associations between financial capacity to adapt and these other factors, suggesting that financial constraints operate independently for a large proportion of the respondents.

Spearman's rank tests identified significant weak positive correlations between age and agreement that the respondent could not implement adaptations due to insufficient energy and time ($\rho$ (rho) =.20, $p$ = .009 and $\rho$ (rho) = .16, $p$ = .032, respectively). Conversely, education correlated negatively with all three types of perceived adaptation cost: energy ($\rho$ (rho) = −.25, $p$ =.001), time ($\rho$ (rho) = −.32, $p$ = .000) and money ($\rho$ (rho) = −.24, $p$ = .002).

### 3.2.2 Risk appraisal

Farmers' risk appraisal was not statistically associated with any of the climate information variables, apart from a weak positive association with how many other farmers the information was received from ($r$ = .183, $p$ = .016). Additionally, those that received information at a village meeting had significantly stronger mean agreement that their household was likely to be negatively affected by drought in the next 5 years, than those who received the information by other means (mean = 3.98 vs 3.59, $t$ = 2.655, $p$ = .021).

Growers that experienced drought in the most recent 3 years before the survey (in January 2020) displayed significantly higher agreement with the risk statements "The impacts of drought on my household farm are likely to be severe" (mean = 4.02, $t$ = 2.951, $p$ = .004) and "The impacts of drought on my farm are worse than before" (mean = 4.25, $t$ = 5.316, $p$ = .000) than those that did not have such recent experience of drought (means = 3.44 and 3.29, respectively). A positive correlation was observed with the total number of economic and crop drought impacts indicated by the farmer ($r$ = .262, $p$ = .000), and a weak negative correlation was observed between risk appraisal and adaptation appraisal ($r$ = −.169, $p$ = .026). These findings suggest that direct experience of drought influences risk appraisal, with more recent experiences having a more pronounced effect.

The three variables, years since last drought experience (Beta −.216, $p$ = .011), number of farmers climate information was received from (Beta .185, $p$ = .027) and household engages in animal husbandry (Beta .139, $p$ = .096), resulted in a significant model ($F$ = 5.721, $p$ = .001) with an $R^2$ of .096.

### 3.3 RQ3: What role do socioeconomic factors (age, education and wealth) play in determining access to drought communications?

Statistical tests demonstrated the role of socioeconomic factors in determining access to drought warnings. Older farmers reported receiving drought communications through significantly fewer channels (mean = 1.0 vs 1.3 for farmers aged under 60, $t$ = −2.883, $p$ = .004) and tended to report receiving drought communications from a smaller number of other farmers (although $p$ = .059). Respondents in older age groups were less likely to have received drought warnings that were accompanied by advice on what to do (Fisher's exact test = 14.998, $p$ = .003), as were respondents with lower education levels (Fisher's exact test = 33.219, $p$ = .000).

Wealth was also a factor, with the highest mean household asset and land wealth scores found within households that received both a drought warning and advice on what to do (10.0), compared to lower scores amongst those that only received warnings (8.9), and those that received neither (5.4), $F$(2172) = 5.416, $p$ = .005.

Adaptation appraisal scores followed the same pattern, with the lowest mean scores in households that received no warning or advice (−0.85), mean scores of 0.36 in households that only received the drought warning and mean scores of 0.73 in households that received both the warning and advice, $F$(2169) = 15.419, $p$ = .000. Respondents that received drought warnings accompanied by adaptation advice were significantly more likely to have changed something as a result, than those that received the drought warning alone (67.5% compared to only 25.0%, $\chi 2$ = 24.696, $p$ = .000).

## 4 Discussion

### 4.1 Conceptual diagram

Figure 1 provides a conceptual overview of the main relationships reported in the results above, with the routes connecting the four adaptation outcome variables with risk appraisal and adaptation appraisal illustrated. Also shown are other sociodemographic and policy factors found to have significant effects on either adaptation outcomes or the cognitive pathways associated with adaptation appraisal and/or risk appraisal. Being in a formal irrigation zone is indicated as a policy intervention since farmers based in these areas benefit from irrigation zone policies which provide additional government-funded support. The results synthesised in Fig. 1 show that adaptation appraisal interacted directly with all four of the adaptation outcome variables whilst only a weak association was found between risk appraisal and one of the adaptation outcome variables. This lends weight to the idea (reported in the context of flooding by Babcicky and Seebauer 2019) that, although there may be two separate PMT pathways, only the one operating through adaptation or coping appraisal leads to the implementation of protective measures. As such, the results support Babcicky and Seebauer (2019), suggesting that the traditional interpretation of PMT, where high risk appraisal and high adaptation appraisal combined lead to the implementation of protective measures, may not be empirically accurate in this kind of context.

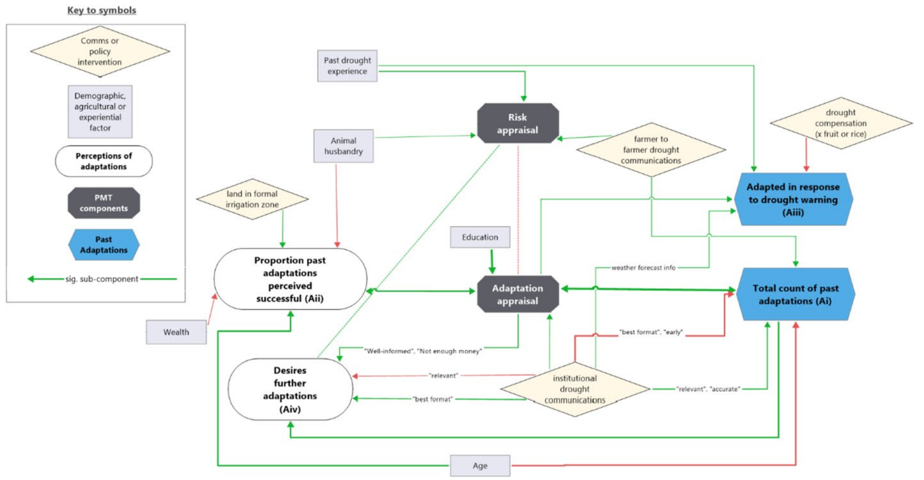


**Fig. 1** The relationships represented are those uncovered using regression analysis, but the diagram additionally includes two relationships identified using other statistical tests: a negative correlation between adaptation and risk appraisal and a difference in mean risk appraisal relating to desire to implement further adaptations (both represented by dashed lines). These additions are considered relevant to the discussion. Arrows represent the direction of influence that was modelled, with line thickness representing the strength of the relationship and colour representing whether the relationship was positive (green) or negative (red). For simplicity, symbols are used to represent groups of variables as described in the key. Where the modelling identified relationships with sub-components of these variable groups, the individual variable is identified using a label at the middle of the relationship line

## 4.2 To what extent do PMT variables predict adaptation outcomes?

Looking at the relationship between PMT variables and the adaptation outcome variables analysed, this study reveals a much more pronounced connection between adaptation and adaptation appraisal than between adaptation and risk appraisal, which reflects findings from many previous PMT studies exploring a range of different risks and contexts (Bubeck et al. 2012; Milne et al. 2000; Poussin et al. 2014; Sheeran et al. 2014; Truelove et al. 2015). It has been argued that risk appraisal could be higher prior to an adaptation being undertaken, but then decline in light of adaptation success (Bamberg et al. 2017). Our finding of significantly higher mean risk appraisal scores amongst respondents that indicated wanting to implement further adaptations supports this possibility. However, since no significant associations were found between adaptation counts and other more stable factors that correlate with risk appraisal (for example, the number of droughts and drought impacts respondents reported having experienced), the authors argue that the findings suggest adaptation appraisal is the more robust behavioural predictor of the two PMT constructs (Milne et al. 2000).

The finding of a weak negative correlation between adaptation appraisal and risk appraisal illustrates that, rather than being purely additive, it is possible that high levels of risk perception may lower perceived capacity to adapt, or vice versa. The conceptual diagram in Fig. 1 depicts positive feedbacks between adaptation and adaptation appraisal, showing that direct experience of implementing adaptation and perceived adaptation success may increase cognitive readiness to adapt in future. These findings suggest that direct experience, observation and learning about adaptation and drought risk continually reshape perceptions, illustrating processes of adaptation as continuous rather than finite and suggesting that adaptation experience and a pro-adaptive mindset are mutually reinforcing. This identification of positive adaptation feedbacks mirrors those identified by Noll et al. (2022) in the context of flood adaptation. On the basis that adaptation actions may trigger further adaptation intentions, drought communications and adaptation campaigns should not be regarded as standalone responses, but rather as elements within long-term support programmes geared towards developing cultures of resilience and capacity-building (Ewbank et al. 2019). This finding is of particular relevance for countries where agricultural impacts from drought are projected to increase in coming decades.

### 4.3 To what extent do institutional drought communications influence farmers' motivations and actions to protect their production activities from the risk of drought?

Whilst direct personal experience of climate impacts strongly shapes adaptation motivations (Niles et al. 2015), climate and adaptation information received through personal and institutional networks also affects adaptation decision-making (Babcicky and Seebauer 2017). Further, contrary to the suggestion that top-down campaigns may have limited capacity to affect the uptake of protective measures against extreme climate events (Haer et al. 2016), our results indicate that institutional drought communications (via community, private or government institutions) interact significantly with adaptation attitudes and actions amongst agricultural producers. The diamonds in Fig. 1 illustrate where drought communications or direct policy interventions (the provision of drought compensation or official irrigation support) significantly predicted adaptation outcome variables. It is evident that both the size of a farmer's local drought information network and the nature of the drought information they receive via institutional channels interact significantly with adaptation intention and behaviour. The study has shown that receiving more different types of drought information as well as the perceived efficacy of the information received are both positively associated with higher confidence in implementing adaptations and with the number of adaptations farmers have employed in the past. Additionally, our findings support the importance that drought information is accompanied by practical advice on what to do to limit negative impacts (Ewbank et al. 2019; Haer et al. 2016; Koerth et al. 2013).

Although the institutional drought communication measures significantly contributed to adaptation outcome variables (namely, adaptation appraisal scores, past adaptation counts and whether respondents reported having adapted in response to official advice), they appeared not to contribute to respondents' drought risk appraisal. Instead, risk appraisal was influenced by local communication factors, such as the number of farmers drought information was received from, and whether information was received at a village meeting. This supports findings that local and informal risk communications are more likely to alter risk perceptions (Binh et al. 2020). Additionally, risk appraisal was influenced by direct personal experience of drought, supporting the suggestion that factors which are more psychologically close (either in time, space or socially) determine risk perceptions more strongly than official communications (Binh et al. 2020; Niles et al. 2015; Steynor et al. 2021).

The finding of a significant influence of local farmer communications on risk appraisal and past adaptation points to the role of social connectedness in facilitating access to information and as an important determinant of adaptation responses. Moreover, the apparent role of smartphone messaging group membership in enhancing responsiveness to official advice should not be overlooked. Overall, these findings highlight the benefits of strengthening opportunities for all farmers to participate in local and institutional drought communications networks via locally appropriate and accessible means, particularly in agricultural development contexts similar to the case study presented here.

### 4.4 Which types of farmers are less likely to implement successful drought adaptations and why?

Demographic variables such as age and education are important determinants of disaster warning response, with evidence that different segments of at risk populations may comprehend information differently (Mayhorn and McLaughlin 2014). Our findings reflect socio-economic patterns well-established by diffusion of innovations scholars (E. M. Rogers 2003), namely that education, age and wealth determine capacity to implement new behaviours. The study found that older farmers were more likely to indicate adaptation constraints, such as a lack of time or energy. Older farmers were also likely to receive drought information from fewer local farmers and via fewer communication channels. As such, this study highlights that older farmers may be less able to adapt to drought and supports findings that older individuals may have different communication needs and support should be tailored accordingly (Walkling and Haworth 2020). As drought information communications move online in future, the need may grow to implement additional communication strategies which ensure that older and poorer population segments do not end up missing out.

The study findings also suggest that livestock producers experience drought risks and impacts differently, resulting in measurably higher risk appraisal scores and lower perceived success rates for past adaptations. This indicates that households which focus on livestock production may likewise benefit from specific targeted drought support, reflecting findings from different regional contexts that drought responses within the livestock sector are different to other agricultural sectors (Salmoral et al. 2020).

### 4.5 How might drought communications and policy be improved to support adaptation?

The absence of a strong link between risk appraisal and adaptation behaviour (aligning with many other PMT studies) suggests that seeking to heighten risk appraisal by incorporating fear appeals within official drought communications is unlikely to enhance adaptation behaviour amongst farmers and signals the possibility that fear appeals could be counterproductive. Whilst this study supports the communication of targeted drought information to farmers, emphasis should be placed upon accompanying drought information with positive messages about household coping capacity and practical tailored advice about adaptation strategies which enhance farmers' perceptions of both self- and adaptation efficacy (Binh et al. 2020; Ong and Araral 2021).

Although the findings do not support risk appraisal directly determining adaptation actions, higher risk appraisal levels may promote adaptation desire and/or intention (Milne et al. 2000). The findings indicated that risk appraisal levels may be higher following a direct experience of drought, but then decline thereafter. Drought communications should be targeted to take advantage of potential synergies between aspects of risk and adaptation appraisal (Sheeran et al. 2014), by ensuring that drought adaptation information and physical/financial assistance are made available soon after farming households have directly experienced drought, since this may lead to greater uptake than if only provided at a later stage.

The findings indicate that the constraint of not having enough money to implement the necessary adaptations may be delaying farmers from implementing desired further adaptations.

Given the lack of a correlation between financial and the other adaptation constraints measured (time and energy), providing financial support to farmers who indicate an inclination to adapt may boost the uptake of drought adaptation measures. In some instances, pursuing this proactive approach to building drought resilience may be preferable to providing drought compensation after losses have already been incurred, particularly given the negative relationship between compensation for major crops such as fruit and rice and responsiveness to official drought warnings and adaptation advice. This finding reflects Tabe-Ojong et al. (2020), who show that relief assistance may negatively influence household resilience strategies for coping with extreme weather events. However, given that our study is cross-sectional, it is not possible to establish whether compensation arrived before or after farmers failed to take action in response to official drought advice; hence, longitudinal research on this issue is warranted.

## 5 Conclusion

The study supports protective behavioural changes (in this case, implementation of drought adaptations) being more closely linked to adaptation appraisal than risk appraisal. Further, it has indicated that an inverse relationship can pertain between these PMT constructs. Both institutional and local drought communications contribute in important ways to adaptation actions and perceptions, but institutional communications appear to operate more through pathways leading to adaptation via adaptation appraisal. Conversely, local communications are of greater significance for risk appraisal, although the study has not found evidence to support a direct pathway from risk appraisal to adaptation. Institutional drought communications should include adaptation advice to promote adaptation behaviour amongst agricultural producers, with drought communications framed in positive terms, emphasising the efficacy of adaptation recommendations and the feasibility of implementing them for the producers themselves. Policy makers should employ measures that support farmer participation in both local and institutional drought communication networks.

The study shows that farmers who are older, less educated or poorer are less likely to adapt to drought due to perceived costs and reduced exposure to and assimilation of drought information. More research is needed on how to shape and supply institutional drought and adaptation communications to meet the needs of these segments of agricultural populations more effectively. Whilst financial support may sufficiently address adaptation constraints for some, evidence of time and energy constraints for, particularly, older farmers indicate a need for different targeting of adaptation support for these farmers, including the provision of social safety nets in cases where adaptation is improbable. Evidence that those practicing animal husbandry perceive greater levels of drought risk and lower levels of adaptation success than other agricultural producers also suggests a need for specific targeted support.

Understanding adaptation as a continuous (rather than finite) process, characterised by feedbacks between experience and appraisal, means that efforts to build drought resilience must go beyond providing assistance only when drought is forecast or causing measurable impacts. Efforts to reduce drought vulnerability should provide long-duration, continuous institutional support for resilience building. Such support needs to engender pro-adaptive mindsets across all sections of agricultural communities by improving social and institutional drought communication networks, ensuring that organisations are receptive to climate and adaptation information fed back by farmers and developing habits across the board of engaging in ongoing climate, drought and adaptation dialogue.

**Acknowledgements** We wish to thank the wider members of the STAR project team, the CMU students who performed the interviews and the participant farmers for their time.

**Author contribution** DR, CS and IH acquired the funding. CS, DR, IH and GS developed the survey instrument and conceived the original scope of the article. LP, SV and CE coordinated the fieldwork and translations. CS developed the statistical analysis. CS drafted the manuscript. All authors reviewed, edited and approved the manuscript.

**Funding** This project is funded through a NERC (Natural Environment Research Council, UK) grant for the STAR project (Strengthening Thailand's Agricultural drought Resilience) grant number NE/S003223/1 and Thailand Science Research and Innovation (TSRI) grant number is RDG6130017.

**Data availability** The dataset and questionnaire for this study can be found in the Cranfield Online Research Data (CORD) 10.17862/cranfield.rd.16553136.

## Declarations

**Ethics approval** The study gained ethical approval through the Cranfield University Research Ethics System (CURES) CURES/9419/2019.

**Competing interests** The authors declare no competing interests.



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