Reg Environ Change (2015) 15:1081–1093
DOI 10.1007/s10113-014-0692-y

ORIGINAL ARTICLE

Coping with drought risk: empirical analysis of farmers' drought adaptation in the south-west Netherlands

Rianne van Duinen · Tatiana Filatova · Peter Geurts · Anne van der Veen

Received: 5 March 2014 / Accepted: 2 September 2014 / Published online: 19 September 2014

Abstract Climate change projections show that periods of droughts are likely to increase, causing decreasing water availability, salinization, and consequently farm income loss in the south-west Netherlands. Adaptation is the key to decrease a farmer's drought vulnerability and to secure the agricultural sector's performance at the aggregate level. Possible adaptation strategies include responses at the field scale, farm-level measures and joint adaptation measures. Using the results of a recent survey, we explore farmers' adaptive behaviour to drought. We give detailed insight into the influence of risk appraisal and coping appraisal factors on the current level of farmers' adaptation motivation and the adoption of three types of adaptive responses. Our findings show that behavioural factors make a significant contribution to explain the actual level of farmers' adaptation motivation. Furthermore, we find that components of threat and coping appraisal influence adoption decisions differently across three types of drought adaptation measures.

Keywords Drought · Adaptation · Agriculture · Protection motivation theory · The Netherlands

Introduction

Agricultural damage resulting from drought-induced freshwater shortages and salinization is a problem world-wide. Even though the Netherlands has a maritime climate, it experiences occasional drought events, most recently in 1949, 1976 and 2003. Climate change projections show that both the frequency and severity of droughts are likely to increase. Freshwater is a vital production factor for the agricultural sector. Temporary precipitation shortages reduce soil moisture levels and increase salt concentrations. This reduces crop productivity and quality, increases

Editor: Elena M. Bennett.

Electronic supplementary material The online version of this article (doi:10.1007/s10113-014-0692-y) contains supplementary material, which is available to authorized users.

R. van Duinen · A. van der Veen
Department of Water Engineering and Management, University of Twente, Drienerlolaan 5, P.O. Box 217, 7500 AE Enschede, Netherlands
e-mail: A.vanderVeen@utwente.nl

R. van Duinen (✉) · T. Filatova
Department of Economics, Scenarios and Innovation, Deltares, Daltonlaan 400, P.O. Box 85467, 3508 AL Utrecht, Netherlands
e-mail: rianne.vanduinen@deltares.nl

T. Filatova
Centre for Studies in Technology and Sustainable Development, University of Twente, Drienerlolaan 5, P.O. Box 217, 7500 AE Enschede, Netherlands
e-mail: t.filatova@utwente.nl

P. Geurts
Department of Public Administration, University of Twente, Drienerlolaan 5, P.O. Box 217, 7500 AE Enschede, Netherlands
e-mail: p.a.t.m.geurts@utwente.nl

A. van der Veen
ITC, Department of Urban and Regional Planning and Geo-information Management, University of Twente, Hengelosestraat 99, P.O. Box 217, 7500 AE Enschede, Netherlands

production costs, and reduces farm income. In an extremely dry year, the economic cost to the Dutch agricultural sector would be 1.5 billion euros. In the most unfavourable climate scenario, the economic damage due to droughts is expected to increase by a factor of 1.7 by 2050 (Deltares 2012).

Adaptation to drought is vital, especially in the light of climate change, and may be pursued in the form of private or public adaptation (Frankhauser et al. 1999; Mendelsohn 2000; Stern 2006). Private adaptation, defined as the behavioural responses of individual farmers to drought for private benefit, plays an important role in reducing their vulnerability and enhances the performance of the agricultural sector as a whole. A broad range of established and innovative private adaptation measures exists including irrigation, storage of water in basins, switching to more drought-resistant crop varieties, freshwater injection into deep aquifers and desalinization of salt or brackish water using reverse osmosis techniques (Tolk 2012). Adaptation can be constrained by many factors, such as socioeconomic, institutional, biophysical, psychological and financial barriers, and therefore, private adaptation cannot be expected to be entirely autonomous (Adger et al. 2005; Reidsma et al. 2010).

Public adaptation, defined as the adaptive responses of governments, is often required to reinforce private initiatives and may include the provision of financial incentives, the removal of institutional barriers or the creation of awareness. The factors that influence private adaptive behaviour need to be well understood to design successful public drought-risk management strategies that will enhance farmers' adaptive capacity. Thus, climate change adaptation needs to be aligned on different levels to achieve synergies and maximize the positive effects. In agriculture, in addition to private and public adaptation, farmers also engage in joint drought adaptation measures with their neighbours and other nearby farmers. Here, the issues of social interaction and the emergence of trust and subjective norms are important in the farmers' appraisal of drought risks as well as in judging the feasibility of adaptation measures.

The literature suggests a need for further research regarding actual adaptation behaviour in order to identify vulnerable farm types and to develop well-targeted public policies (Nicholas and Durham 2012). This requires a quantitative empirical analysis of factors determining farmers' adaptation. Adaptive decision-making, when confronted by risk, is a much-investigated topic, with input from several research disciplines. The main differences in approach stem from the underlying assumptions regarding individual decision-making.

On the one hand, there are economic modelling studies that investigate the effects that costs, benefits, production constraints and water availability uncertainty have on the adaptation of a profit- or a utility-maximizing farm. Here, farmers are assumed to be rational, often risk averse, and homogenous. There are many examples of economic studies that employ constrained optimization models to study farmers' adaptive decision-making in the context of water scarcity. These studies investigate how farmers might adapt to droughts by changing cropping patterns, optimizing the timing of planting/sowing, investing in irrigation or modernizing irrigation systems (Toft and O'Hanlon 1979; Benli and Kodal 2003; Maneta et al. 2009; Cortignani and Severini 2009; García-Vila and Fereres 2012; Connor et al. 2012; Graveline et al. 2014). Due to the underlying assumptions that facilitate analysing farm adaptation at the sector or regional level, traditional economic studies often lack the behavioural grounding required to fully explain and understand private adaptation decision-making.

Alternatively, there are empirical socioeconomic studies, issuing from both economics and agricultural sciences, that go beyond economic assumptions of rationality and homogeneity by recognizing heterogeneity in farmers' decision-making. Recent empirical studies analysing farmers' drought adaptation include Deressa et al. (2009), Below et al. (2012), Jara-Rojas et al. (2012) and Gebrehiwot and van der Veen (2013). Rather than relying solely on the economic principle of farmers deciding to adapt when the expected profit or utility of an adaptive response is positive, these studies include a wide range of socioeconomic, institutional, biophysical and financial factors. The significant contributions made by several such variables show that adaptation decisions are not driven only by rational economic considerations of costs and benefits (Knowler and Bradshaw 2007).

To date, the quantitative empirical literature has mainly identified resource constraints and socioeconomic characteristics as the major factors in determining adaptation to drought. While understanding the objective determinants of actual farm adaptation is important, if farmers' judgements of drought risks and their coping capacity are systematically biased, this could hamper successful adaptation even more (Grothmann and Patt 2005). Several studies have addressed the importance of farmers' climate risk perceptions in adaptive decision-making (Maddison 2007; Gbetibouo 2009; Deressa et al. 2011; Mandleni and Anim 2011; Wheeler et al. 2013). However, attention has not been given to the role of other subjective adaptation factors, such as perceived cost and effectiveness of adaptation measures, and neither has the importance of perceived self-efficacy been addressed in the agricultural adaptation literature. Insights into the influence of these coping variables could provide valuable information for drought-risk management policies. This could indicate whether policies should emphasize the effectiveness of potential adaptation measures, focus on the costs of adaptation measures or provide practical guidelines on how to deploy such measures (Bubeck et al. 2013).

This study aims to improve the understanding of psychological influences on farmers' actual adaptation in the context of drought-induced water shortages and salinization risk. Based on a case study of farmers in the south-west of the Netherlands, this paper captures the extent of farmers' drought-risk perceptions, the perceived effectiveness and perceived cost of adaptation measures, and the types of adaptive responses made in farming practices. The focus on the psychological dimension of farmers' climate change adaptation is new and may provide important information for the design of public drought-risk management policies aiming to enhance farmers' adaptive capacities. The analyses in this paper are based on a survey of 142 farmers conducted between January and March 2013.

Materials and methods

Case study area

The south-west of the Netherlands is a vulnerable agricultural area. Historically, it is a transition area between freshwater and saltwater, causing groundwater and surface water resources in many places to contain high chloride concentrations. A distinction can be made between areas with and without access to an external water supply (Fig. 1). Areas without an external water supply are dependent on natural systems, whereas areas with an external water supply have access to freshwater from lakes, rivers or pipelines (see Table 1).

Agriculture in Walcheren, Noord-Beveland and a large part of Zuid-Beveland exclusively depends on precipitation and fresh groundwater for its water supply. In these areas, any excessive precipitation infiltrates the ground, forming a thin freshwater lens in the crops' root zone. In dry

Fig. 1 Location of study area

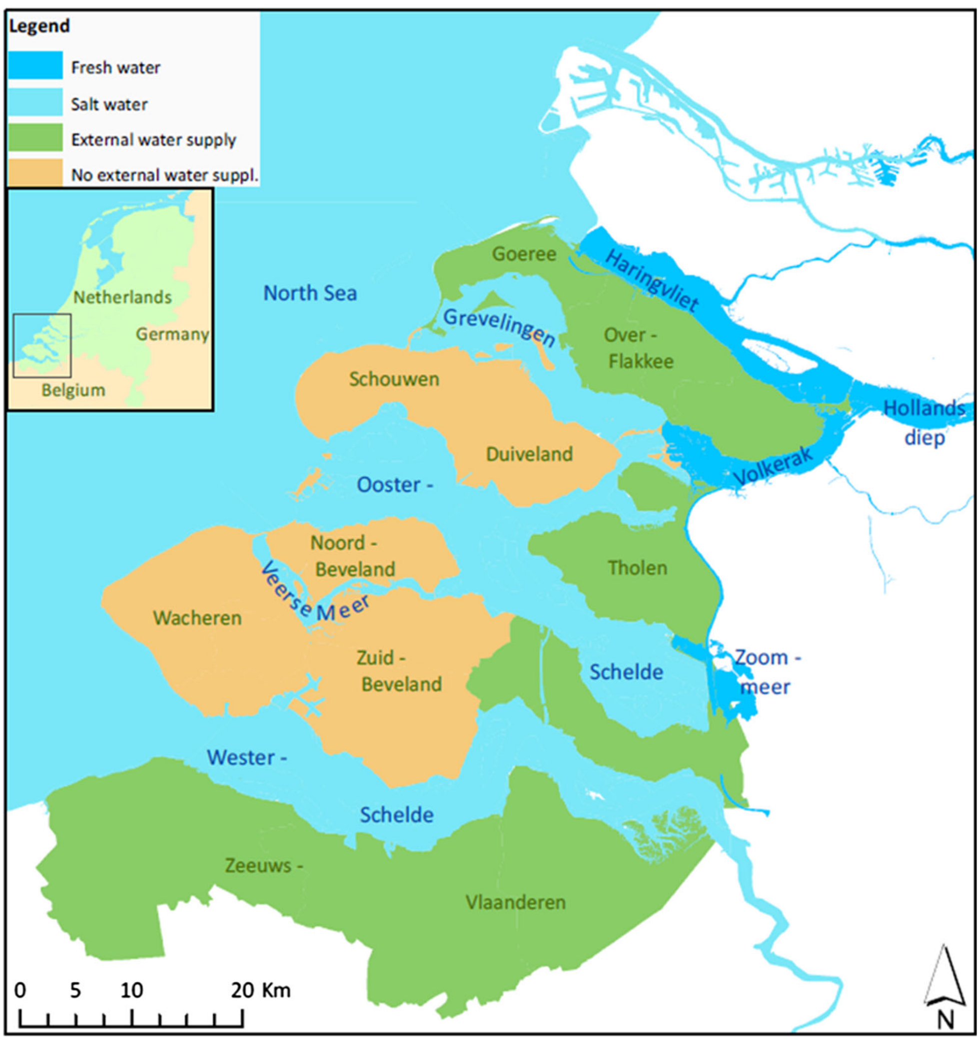

Table 1 Freshwater supply in the Netherlands' south-west

System	Source of water supply	Geographical location
No external water supply	Natural system (i.e. only precipitation)	Walcheren, Noord-Beveland, part of Zuid-Beveland.
External water supply	Natural system + water supply from lakes and rivers	Goeree-Overflakkee, Tholen, Zeeuws-Vlaanderen.
	Natural system + water supply through pipeline	Part of Zuid-Beveland

circumstances, the freshwater lenses disappear leading to crop damage due to excessive dry and salty conditions. The proper functioning of the natural system is dependent on precipitation and evaporation.

Goeree-Overflakkee and Tholen gained an external freshwater supply when large compartment dams were constructed in 1970 to protect the area from flooding, creating large freshwater lakes. Currently, water boards primarily use this freshwater to flush the water system in order to limit salt concentrations in both the ground and surface water resources. Freshwater availability in these basins depends on river discharge. During droughts, river discharges decline, reducing the availability of water for flushing the system, irrigation and supplying other sectors. In extreme dry situations, water boards may prohibit irrigation.

Zeeuws-Vlaanderen has historically had access to freshwater from the regional water system in Belgium. On-farm piped water supplies are only available in Zuid-Beveland. In normal years, with sufficient precipitation, this system provides an ample supply. In dry years, however, the pipeline capacity is insufficient.

Relevant adaptation measures

The relevance of adaptation measures may differ significantly depending on the biophysical, socioeconomic, cultural and institutional conditions. We have considered adaptation measures fitting the geographical, economic and institutional context of the south-west of the Netherlands. The drought adaptation strategies to be included in the survey were selected in three stages: (1) selection based on the biophysical conditions and secondary literature review; (2) external validation through interviews with experts; and (3) fine-tuning based on the feedback from farmers.

Firstly, we recognize that interrelated drought and salinity problems are typical for this area as well as a large area supporting dry-land agriculture. Farm adaptation strategies that cannot be directly related to drought risk, such as diversification of farm activities, the selling/buying of land and the relocation of farms, have not been included in this study. Such actions are probably carried out for other reasons, such as in response to EU policy reforms. Tolk (2012) overviewed all relevant adaptation measures to drought and salinity in the south-west of the Netherlands. From this overview, we shortlisted several measures on the basis of a single criterion: the ability of farmers to implement the adaptation measure independently from institutions such as agricultural cooperatives and regional/local governments. Adaptation measures concerning spatial planning, water pricing and large-scale infrastructure have therefore not been included in the analysis.

Secondly, the set of adaptation strategies was very carefully arranged and externally validated. Here, we reviewed the set of measures and consulted experts with local knowledge. The set of experts included water management specialists from the local water board and agricultural specialists from organizations in the Netherlands. Thirdly, we tested the survey and the set of adaptation strategies in several in-depth interviews with farmers, resulting in 12 adaptation measures for the final survey. To check whether the selected adaptation measures were comprehensive, the survey contained an extra question asking farmers whether they had implemented any other measures. Of the 142 respondents, 70.4 % did not report any drought measures beyond the twelve listed in the survey and a further 26.8 % mentioned adaptation measures that were not applicable to our study as they required input from public authorities. Just four respondents mentioned a measure that fitted within our remit but was not on our list: All had applied organic matter to optimize the moisture retaining capacity of the soil.

Tolk (2012) clustered the 12 adaptation options in three groups (see Table 2) depending on the scale of the implementation: (1) field-scale measures; (2) farm-level measures; and (3) joint measures. We would expect the implementation scale to matter in farmers' adaptive behaviour since implementing field-scale measures will be less costly and require less behavioural change than farm-level or joint measures. We have investigated the contribution of several psychological variables with regard to adopting adaptation measures within each of these three adaptation categories.

Field-level measures concern changes in the natural water system of individual fields in order to increase freshwater availability and prevent local water shortages and salinization damage. Optimizing the height and spread of drains, water-level-sensitive drainage, and water regulation in ditches all help prevent the loss of groundwater lenses and salt-water percolation in dry periods. These

Table 2 Description of drought adaptation measures

Name	Description	Effect in dry periods	Scale
Optimizing depth and separation of drains	Increasing the depth and spread of drains expands the freshwater lens	Prevents groundwater lenses disappearing and the percolation of salt water	Field
Water-level-regulated drainage	The water level in drains is actively increased in summer enlarging the freshwater lens		
Decrease water level in ditches	Water levels in ditches are actively decreased in winter preventing freshwater drainage and enlarging the freshwater lens		
Drain off percolating salt water with a deep drain	Extra deep drain to collect and transport saline groundwater to the ditches, decreasing the percolation pressure		
Freshwater storage in basin	Freshwater storage in a basin	Extra water available for irrigation	
Irrigation	Sprinkler irrigation and drip irrigation	Decreases the crop's exposure to droughts	Farm
Switch to salt/drought-resistant crops	Switch to salt/drought-resistant crop varieties or crop types	Decreases the crop's sensitivity to droughts	
Weather insurance	Insurance against financial losses due to catastrophic drought-induced yield failure	Decreases a farmer's financial risk	
Desalinate brackish water	Reverse osmosis technique to desalinate water	Extra water available for irrigation	
Freshwater extraction from creek or sand ridges	Drain to extract freshwater from a water lens in a creek- or sand ridge	Extra water available for irrigation	Joint
Freshwater extraction from phreatic aquifers	Well to access freshwater from a phreatic aquifer		
Freshwater injection into deep aquifers	Freshwater storage in a deep aquifer through water injection during wet periods and extraction during dry periods		

measures are also effective in preventing damage from flooding. Storing freshwater in a basin increases its availability for irrigation.

Farm-level measures concern changes in water use. At the farm-level, there are several options to increase freshwater availability, reduce freshwater demand and secure the farm's income. Adopting sprinkler or drip irrigation reduces a crop's exposure in dry circumstances. Switching to crop varieties that are drought- or salt- resistant decreases the crop's sensitivity to drought. Taking out insurance against financial loss due to catastrophic drought-induced yield failure decreases a farmers' financial risk. Desalinization of brackish water through reverse osmosis is a commonly used strategy to increase water availability for irrigation in glasshouse horticulture. Such farmers often own on-farm desalination technology. This requires a large investment but glasshouse horticulture is typically very productive with high gross margins making capital-intensive investments attractive. In some areas of the Netherlands, farmers desalinate brackish groundwater on such a scale that it causes water quality issues due to infiltration of the 'brine' effluent.

In line with Mendelsohn (2000), we define joint measures as adaptive responses that require cooperation among neighbouring farmers with benefits shared across the involved farms. Here, measures concern rather large investments in infrastructure that increases the water available for irrigation. As an example, freshwater can be injected into deep aquifers, creating a freshwater reserve in a saline environment during periods with excessive precipitation, and then withdrawn during dry periods through the use of vertical wells. This technique has been applied in the Dutch glasshouse sector since 1983. To successfully implement this technique, several environmental requirements have to be met: A freshwater aquifer should be available, the geological formation should be fairly impermeable and horizontal water flow should be low. The investment and exploitation costs depend on the performance (the percentage of injected freshwater that can be extracted) and the scale of implementation. Usually, farmers cooperate to profit from economies of scale and to satisfy all the technical requirements. To successfully implement this type of measure, farmers need to be motivated to adapt and to cooperate with their neighbours.

Research hypotheses

Several social-psychological theories explaining farmers' adaptive decision-making exist. Theory of Reasoned Action and Theory of Planned Behaviour are two closely related social-psychological theories that have been applied in studies on farmers' adaptive decision-making (Lynne et al. 1995; Beedell and Rehman 1999; Rehman et al. 2007; Wauters et al. 2010). These theories state that one's attitude towards a measure, social norm, and perceived behavioural control are significant factors of adaptive decision-making (Fishbein and Ajzen 1975; Ajzen 1985). However, they do not incorporate risk perception as a determinant of farmers' adaptation, whereas several studies have successfully demonstrated that perceiving risk stimulates adaptation (Grothmann and Patt 2005; Adger et al. 2009; Kuruppu and Liverman 2011).

Protection Motivation Theory (PMT) incorporates both risk perception and coping evaluation as determinants of protective behaviour. It was first applied in studying how individuals protect themselves against health risks (Rogers 1975; Maddux and Rogers 1983). In the past decade, it has been widely and successfully applied to study private adaptive decision-making in the context of natural hazards and climate change (e.g. Grothmann and Patt 2005; Grothmann and Reusswig 2006; Martin et al. 2007a, b; Martin et al. 2009; Kuruppu and Liverman 2011; Bubeck et al. 2013; Mankad et al. 2013; Poussin et al. 2014).

The strength of PMT is that it offers a framework to systematically explore the importance of psychological factors in determining farmers' adaptation to drought risk. It offers a comprehensive theoretical framework that fits this study's research objective by incorporating both risk appraisal and coping appraisal factors linked to adaptive decision-making in a risky context. Grothmann and Patt 2005, explored the applicability of PMT in understanding farmers' adaptive behaviour concerning drought risk in Zimbabwe. However, to date, there are no PMT applications that statistically test its ability to explain farmers' adaptation to drought risk.

PMT describes two processes that can explain an individual's protective motivation: threat appraisal and coping appraisal. In the threat appraisal process, an individual evaluates the probability of a threat occurring (perceived probability) and the severity of its consequences (perceived severity) in the case of an inappropriate adaptive response. In other words, people have to believe they will be exposed to a harm-causing threat if they do not take protective measures. Several studies have applied PMT to analyse protective behaviour in the context of natural hazards and found a significant positive relationship between risk perception and protective behaviour. Martin et al. (2009) for example show that as the perceived risk increases, homeowners are more likely to undertake adaptive measures to protect themselves from wildfires. Bubeck et al. (2012) state that risk perception is often a statistically significant predictor of individual adaptation in the literature on the adoption of flood mitigation measures. Mankad et al. (2013) found that those urban dwellers who perceive a risk of water shortage are more likely, as a protective measure, to consider a rainwater tank.

Other recent studies that do not apply PMT but do examine farmers' adaptive behaviour also stress the significance of a positive causal relationship between farmers' climate risk perception and adaptive decision-making. Some studies argue that drought adaptation is a two-step process in which a perceived risk is a prerequisite for farmers to evaluate adaptive measures (Maddison 2007; Gbetibouo 2009; Deressa et al. 2011; Mandleni and Anim 2011). However, some empirical climate adaptation studies include risk perception as a factor that directly shapes adaptive action (Martin et al. 2009; Bubeck et al. 2012). That risk perception directly influences adaptive behaviour does seem plausible since farmers, even if they perceive the risk of drought as small, might still adapt if the adaptation cost is low, the effectiveness is high, or the measures are easy to implement.

Even though most authors argue that there is a positive causal relationship between risk perception and adaptive behaviour, there are indications that the true relationship may include endogenous two-way feedback, with adaptive behaviour also influencing risk perception. Wheeler et al. (2013) found that the relationship between climate change belief and the actual adoption of adaptive strategies is often endogenous, suggesting that the actual adoption of protective behaviour influences risk perceptions. Martin et al. (2007a, b) suggest that risk perception decreases when individuals move from the action or adoption phase to the maintenance phase in which they have executed the protective behaviour for a considerable time. This pattern is also highlighted by Siegrist (2013), who argues that risk perceptions are dynamic and may decline depending on past risk-mitigating behaviour.

In the coping appraisal process, people evaluate their ability to cope with, or avert, a threat. The coping appraisal process consists of three components. First, a person must believe that an adaptation measure will be effective in reducing harm (the perceived control efficacy). Second, the person needs to be convinced of their ability and will to carry out the response (perceived self-efficacy). Third, the cost of the adaptive response needs to be seen as reasonable (perceived cost). Several studies have found that coping appraisal factors have more influence than threat appraisal factors on protective behaviour (Bubeck et al. 2013; Poussin et al. 2014). These findings and arguments lead to the hypotheses (Table 3) to be empirically tested in this study.

Survey and sampling

During January and February 2013, a survey based on a potential sample of 1,474 members of a Dutch agricultural

Table 3 Research hypotheses regarding farmers' adaptation to climate-induced drought risks

No.	Hypothesis
1.	The greater a farmer's perceived drought probability, the higher the level of their drought-risk preparedness
2.	The more severe a farmer perceives the consequences of droughts, the higher the level of their drought-risk preparedness
3.	The greater a farmer's confidence in their own ability and will to successfully take adaptive measures, the greater their level of drought-risk preparedness
4.	The lower a farmer perceives the cost of adaptation measures, the higher their of drought-risk preparedness
5.	The higher a farmer perceives the effectiveness of adaptation measures, the higher their level of current drought-risk preparedness

organization (the LTO) was conducted to elicit farmers' risk perceptions and adaptive behaviour. TNS-NIPO, a Dutch organization specializing in data collection on the basis of questionnaires, supported the survey design, web-application, communication with respondents and database management. The survey was pretested in 12 interviews with farmers, in consultation with Scheldestromen (the local water board) and LTO. Based on these interviews, redundant questions were removed and ambiguous questions reworded.

Farmers on Goeree-Overflakkee were sent a letter asking if they would participate, either by returning the included paper questionnaire or by participating in the online survey. In other areas, farmers received an email asking if they would participate in an online survey. To stimulate responses, at least one reminder was sent out and people were offered a chance to win a lottery prize. In total, 142 responses (9.3 %) were received. The response rate in Goeree-Overflakkee (38 %) was higher than in the other areas. This is probably because respondents had the option to respond either online or by post. Furthermore, farmers in this area received an additional reminder.

Response bias is a danger with small samples. To check the representativeness of the sample, their age, education, farm size, farm type and access to an external water supply were compared to those of the population using data from CBS Statistics Netherlands. On average, farmers in the sample were slightly younger and better educated than the overall population they represented. Further, farmers above 65 years of age and/or with a low level of professional education are more under-represented in the online survey than in the paper questionnaire. Nevertheless, the differences between the population and the overall sample are small. Further, we would not expect any bias due to differences in the data collection methods as the content of the paper questionnaire was identical to the online survey. Supporting this belief, an independent sample *t* test revealed no significant differences in the number of measures adopted and the independent variables between those farmers on Goeree-Overflakkee who responded through the online survey and the paper questionnaire.

In our sample, farmers who cultivate grass and corn (probably livestock farmers) were under-represented. Only 12 % of the farmers in the sample cultivated grass or corn compared to 26 % of the actual population. This is balanced by an over-representation of arable farmers (81 % compared to 70 %) and those cultivating fruit and flowers (7 % compared to 4 %). The cultivation by livestock farmers (for animal foodstuffs) tends to use cropping patterns that are less sensitive to droughts. As such, one would expect their adaptation motivation to be lower than that of the other types of farmer. However, this does not lead us to presume that the regression estimates will be considerably biased since we would expect the included variables to behave in a similar way for all farmers.

Farmers who do not have access to an external water supply are more susceptible to drought and therefore might be more motivated to participate in the survey. However, the data show that 29 % of the farmers in the sample are located in areas without access to an external water supply compared to 32 % of the farmers in the actual population.

Statistical methods

Two types of analysis are performed, the first analysing the level of farmers' drought-risk preparedness. Farmers' current adaptation motivation is measured as the sum of measures adopted—a common approach used elsewhere (Martin et al. 2007a, b; Bubeck et al. 2013; Poussin et al. 2014). In the survey, famers indicated which of the twelve listed adaptation measures they had adopted (see online resource 1). The count variable used indicates the number of implemented adaptation measures and follows a Poisson distribution (Poisson = 1.42). As drought-risk preparedness is measured using a count variable, a regression model is used based on a Poisson log-linear regression.

In the count model, we use the Wu-Hausman procedure for testing endogeneity to see whether the error term is correlated with the risk perception variables. The residuals of the Poisson regression are saved and then included in a new regression equation. A significant residual coefficient is indicative of endogeneity. If endogeneity is indicated, the model can be expressed in a reduced form where each of the suspected endogenous variables is regressed on to all the exogenous variables to investigate the behaviour of the overall model.

The second analysis investigates differences in the explanatory power of PMT variables regarding the adoption of adaptive responses in the three different scale categories. The adoption of a measure within a specific adaptation type is measured as a binary variable with the variable taking the value of unity if a farmer has implemented at least one adaptation measure within the specific category. Consequently, three separate binary logistic regression models are used. The descriptive statistics of both the dependent and independent variables are presented in online resource 2.

The independent variables are measured as follows. Firstly, the threat appraisal variables are measured following the method of Botzen et al. (2009). Respondents were asked to give a quantitative estimate of the return period and the financial damage for two scenarios: (1) a dry year and (2) an extremely dry year (see online resource 3). The definitions of such years are based on the descriptions of characteristic drought years by Klijn et al. (2011). They base the definition on the cumulative precipitation deficit during the growing season (from April through to the end of September) and the rate of return of such a deficit. A 'dry year' is defined as a cumulative precipitation deficit of 220 mm, which occurs approximately once every 10 years; an 'extremely dry year' is defined as a cumulative precipitation deficit of 360 mm, which occurs approximately once in 100 years. Perceived risk probability is measured as the average of the inverse return period in a dry and an extremely dry year, which can be interpreted as the perceived chance of a drought year. Perceived risk severity is measured as the average of the estimated financial damages in a dry and an extremely dry year.

To measure perceived control efficacy, respondents were asked to indicate how effective the twelve adaptation measures are in preventing financial losses due to water shortage and salinization. To measure perceived costs, respondents were asked the cost of adaptation measures in terms of time, effort and money. Both constructs are measured on seven-point item scales (see online resource 4). Four items on self-efficacy have been adapted from Martin et al. (2007a, b) and measured on a seven-point item scale. The Cronbach's alpha of the self-efficacy items is 0.807. A Principal Component Analysis showed one component with an eigenvalue of 2.90, explaining 72.41 % of the total variance, see online resource 5. Therefore, one self-efficacy scale has been constructed as the average of the underlying items.

Results

This section presents the results of a regression model of farmers' level of drought adaptation motivation and the results of three models considering the adoption of various types of adaptation measures. A correlation analysis was conducted for all four regression models to check for multicollinearity among the independent variables. The correlation analysis shows low correlations between the dependent variables, a strong indication that multicollinearity is absent. Inspection of the variance in the residuals in both the Poisson regression model and the binary logistic models revealed potential heteroskedasticity in the Poisson regression model. Therefore, this model was estimated using heteroskedasticity-robust standard errors.

Level of adaptation motivation

The results of a Poisson log-linear regression model of adaptation motivation are shown in Table 4. The Pearson goodness-of-fit test shows it is appropriate to assume a Poisson distribution of the dependent variable, ($\chi^2(118) = 89.71, p = 0.76$). The likelihood ratio indicates that the model is highly significant with $p = 0.00$. The incidence rate ratios (IRRs) can be interpreted as the rate at which the expected number of implemented adaptation measures changes when an independent variable increases by one unit.

Perceived probability is significantly and positively related with the number of implemented adaptation measures. This confirms Hypothesis 1 stating that farmers who perceive droughts to occur more frequently are more likely to implement adaptation measures. Perceived severity is also positively and significantly related to the number of implemented adaptation measures. A perception of

Table 4 Poisson regression of current level of adaptation motivation

Variable	Coefficient (*B*)	Standard error (SE)	IRR	95 % confidence intervals for IRR	
				Lower	Upper
Perceived probability	0.01**	0.01	1.01	1.00	1.03
Perceived severity	0.14***	0.03	1.15	1.06	1.21
Perceived control efficacy	0.15***	0.05	1.16	1.01	1.24
Perceived cost	−0.16***	0.06	0.85	0.78	0.95
Perceived self-efficacy	0.12**	0.06	1.13	1.01	1.06
Constant	−0.33	0.33	0.72	0.37	1.49
N	124				
χ^2	89.71	$df = 118$	$p = 0.760$		
Likelihood ratio (LR)	22.70	5	$p = 0.000$		

** Significant at the 5 % level, ** significant at the 1 % level suffering considerable harm from drought motivates farmers to implement more adaptation measures, confirming Hypothesis 2.

In line with Hypothesis 3, perceived control efficacy has a significant positive relationship with the number of implemented adaptation measures. This shows that trust in the effectiveness of adaptation measures motivates adaptation. Conversely, a higher perceived cost of adaptation measures reduces a farmer's motivation to implement adaptation measures, confirming Hypothesis 4. This suggests that farmers are more likely to engage in more adaptive behaviours if they perceive the cost, time and effort of implementing adaptation measures is low. Finally, the positive and significant estimate for perceived self-efficacy shows that an increasing trust in their own competence in implementing adaptation measures contributes to farmers' adaptation motivation (supporting Hypothesis 5).

In the Poisson regression model, we tested for reversed causality between risk perception and adaptation motivation. Endogeneity was tested by including the residuals of the model in a new regression equation. Here, the residuals were found to be significant predictors, confirming the presence of endogeneity in the model. However, the regression estimates for the PMT variables were not affected by the inclusion of the residuals indicating that they are unbiased but inefficient. A reduced form estimation reveals that the endogeneity is linked to the risk perception variables.

Adoption of three types of adaptation measures

Of the three scales of adaptation, field-scale measures had been used by 61.0 % of adopters followed by farm-level measures (46.1 %) and joint measures (12.1 %) (see online resource 6). The results of three binary logistic regression models predicting the adoption of these three types of adaptation measures are presented in Table 5.

The binary logistic regression model (see Table 5) explains 10 % of the total variance in implemented field-level measures. The odds ratio can be interpreted as the change in the probability of a farmer implementing a specific adaptation type. The only variables making a significant contribution to the model are perceived control efficacy and perceived cost.

The farm-level model explains 43 % of the total variance in the implementation of farm-level measures. Perceived severity is a significant and strong predictor in the threat appraisal process. The belief in being confronted with substantial drought damage has a strong effect on the implementation of farm-level measures. The strongest predictor among the coping appraisal variables is perceived self-efficacy. As with field-level measures, perceived cost

Table 5 Binary logistic regression of the adoption of three different types of measures

	B	SE	Odds ratio	95 % confidence intervals odds ratios	
				Lower	Upper
Field-scale measures					
Perceived probability	0.02	0.02	1.02	0.99	1.06
Perceived severity	0.07	0.19	1.08	0.74	1.57
Perceived control efficacy	0.25**	0.12	1.28	1.01	1.62
Perceived cost	−0.32**	0.14	0.73	0.55	0.97
Perceived self-efficacy	0.02	0.14	1.02	0.78	1.33
Intercept	0.30	1.00	1.34		
χ^2	10.63	$df = 5$	$p = 0.06$		
Δ % correctly predicted	2.1				
R^2 (Nagelkerke)	0.10				
Farm-level measures					
Perceived probability	0.03	0.02	1.03	0.99	1.07
Perceived severity	1.72***	0.60	5.58	1.72	18.14
Perceived control efficacy	0.33**	0.17	1.39	1.00	1.92
Perceived cost	−0.35**	0.16	0.70	0.51	0.96
Perceived self-efficacy	0.74***	0.17	2.09	1.48	2.93
Intercept	−4.16***	1.17	0.02		
$\chi 2$	54.75	$df = 5$	$p = 0.00$		
Δ % correctly predicted	25.5				
R^2 (Nagelkerke)	0.43				
Joint measures					
Perceived probability	−0.05	0.03	1.00	0.94	1.05
Perceived severity	0.65***	0.25	1.91	1.18	3.09
Perceived control efficacy	0.69**	0.31	2.00	1.08	3.66
Perceived cost	−0.61**	0.30	0.54	0.30	0.97
Perceived self-efficacy	0.32	0.25	1.38	0.85	2.24
Intercept	−3.91	2.13	0.02		
$\chi 2$	24.32	$df = 5$	$p = 0.01$		
Δ % correctly predicted	2.9				
R^2 (Nagelkerke)	0.30				

** significant at the 5 % level, *** significant at the 1 % level and control efficacy have a significant influence on adaptation of this type of drought measure as well.

The joint model explains 30 % of the total variance in adopted measures. As on the farm level, perceived severity is positively related with implementing joint drought adaptation measures. Of the coping appraisal variables, perceived control efficacy and perceived cost are significant variables. Comparing the odds ratios for perceived cost across the three models shows that it is a strong explanatory variable for the adoption of joint adaptation measures: For every point increase in perceived cost, the likelihood of implementing a joint measure decreases by a factor 0.54.

Discussion

We believe this to be the first study that has empirically investigated and quantitatively tested the behavioural factors in farmers' adaptation to droughts. In order to understand farmers' adaptation behaviour and compare their implementation of different types of adaptation measures, we explored adaptive behaviour based on PMT. Our results support PMT and previous empirical research in that we found that behavioural factors play an important role in farmers' adoption of drought mitigation strategies.

The significant and positive relationships between risk appraisal variables and the number of adaptation strategies implemented is consistent with the basic PMT idea that a positive outcome of the threat appraisal process increases motivation to protect. Farmers who perceive drought as a potential risk are more likely adopters of drought-mitigating strategies. Similar results were found by Miceli et al. (2008) regarding flooding, by Mankad et al. (2013) for urban water shortages and by Martin et al. (2009) concerning wildfires. A valuable direction for future research would be to investigate the extent to which farmers' judgements of drought probabilities and damage correspond to expert estimates. Farmers' perceptions may differ from actual drought risks due to drought experiences, perceived control and social influence. Such research could support the design of public drought-risk communication strategies since information shapes farmers' drought-risk perceptions and therefore indirectly their adaptive decision-making.

A closer look at the risk appraisal factors reveals that perceived probability has a minor, albeit significant, effect in the actual adaptation model and is insignificant in all three adoption models. One explanation could be that people generally find it difficult to assess risk probabilities (Botzen et al. 2009). Our results illustrate this in that 10.6 % of our respondents counter-intuitively assigned a higher likelihood to an extremely dry year than a dry year.

Another risk appraisal variable, perceived risk severity, was a significant and strong predictor in the actual adaptation model and also in two out of the three drought adoption models. In general, the interviewed farmers are more likely to adopt drought adaptation measures when they perceive higher financial damage from a drought event. Comparing the three adoption models for the different types of adaptation measures shows that the implementation scale matters with respect to the explanatory power of perceived severity. Perceived severity is a strong factor in explaining adoption of both farm-level and joint-level measures, but not field-level ones. A possible explanation could be that farm- and joint-level measures require large financial investments and considerable behavioural change and that, therefore, only farmers who fear substantial financial damage as a result of drought will consider such measures. Another possible explanation for the insignificance of perceived severity in the field-scale model could be that the majority of measures in this category are drainage measures. Of the 61 % of farmers who had implemented one or more field-level measures, 57.4 % had adopted drainage measures. Drainage measures are well-known solutions for flooding issues, and, maybe, farmers do not see these measures as drought-related. One of the policy recommendations arising from this study is to emphasize the multifunctional potential of field-level measures and to stress their double benefit, averting drought as well as flood damage.

The significant relationship between the coping appraisal variables and the number of adaptation strategies implemented confirms the view that coping appraisal is an important process. Several empirical studies on flood adaptation have found similar results (e.g. Grothmann and Reusswig 2006; Bubeck et al. 2013; Koerth et al. 2013; and Poussin et al. 2014). Perceived effectiveness and perceived cost were found to be significantly related to the adoption of adaptation measures on all three levels. Perceived cost is a strong variable in explaining the adoption of joint-level measures. A possible explanation could be that the implementation of joint measures requires cooperation among neighbouring farmers in order to profit from economies of scale and to find a location that fulfils all the environmental conditions. Establishing cooperation potentially involves high transaction costs, and these are an important topic in the context of natural resource management and complex socio-ecological systems (Marshall 2013). For example, water extraction from creek- or sand ridges, and through water injection into aquifers, involves property rights and the reinforcement of extraction rules. Further research could usefully explore the influence of perceived transaction costs on jointly adopting drought measures.

Although the contribution of self-efficacy was significant in the farm-level model, it was insignificant in the field-level and joint-level models. A possible explanation could be that the field-level measures have been widely applied and are well known and therefore do not require much effort, knowledge and skills (i.e. self-efficacy). Implementing joint-level measures requires cooperation, and perhaps collective efficacy is perceived as more relevant than self-efficacy. Collective efficacy is the farmers' shared belief in their joint power to produce desired outcomes (Bandura 2001). Here, social influence and trust play important roles since strategic behaviour might hinder successful cooperation. Besides individual adaptive capacity, it requires a clear perception of the group's competence to work together. Future research could investigate farmers' collective efficacy in more detail.

Although the study has successfully demonstrated that farmers' motivation to adapt to drought risks is heterogeneous and affected by both risk appraisal and coping appraisal factors, it has certain sampling limitations. Although livestock farmers were slightly underrepresented in the sample, we see no reason why the regression estimates should be significantly biased since we would expect the PMT variables to be similar for all types of farmers. Further, farmers above 65 years of age and farmers with a low education level are slightly under-represented in our sample, probably due to the use of online questionnaires. We do not believe this has distorted our findings since the adoption of adaptation measures, the risk appraisal variables and the coping appraisal variables are not significantly different between those who responded through the online survey and those completing the paper questionnaire.

Finally, although we saw a reversed causal relationship between risk perception and adaptation motivation, this endogeneity did not yield biased regression estimates. The literature suggests that risk perception is augmented in the adoption phase but that it declines in the longer run as a consequence of the risk not materializing. Longitudinal research is required to investigate the potentially changing relationship between adaptation motivation, risk appraisal and coping appraisal across different stages of a farmer's adaptation process.

Conclusions

This paper has presented survey data from 142 drought-prone farmers in the south-west of the Netherlands with the objective of examining the influence of behavioural factors on their adaptive behaviour. The results show that farmers employ a wide range of adaptation measures to reduce the adverse impacts of drought on their crops and income. The results indicate that behavioural factors are important in farmers' adaptive decision-making as several cognitive variables make significant contributions in our drought adaptation models. This indicates that PMT is a useful theory for investigating farmers' adaptation to drought risk. These results add to earlier empirical studies that have mainly focused on socioeconomic, physical and institutional factors.

Of the risk appraisal variables studied, perceived severity is important in determining drought-risk adaptation, whereas perceived probability of damage was found to be mostly insignificant. Communication campaigns by agricultural organizations and policymakers to boost drought-risk awareness among farmers should focus on crop failures and financial damage and avoid concepts such as likelihood and return period as these are poorly understood. The results also indicate that perceived control efficacy, perceived cost and perceived self-efficacy considerably influence drought mitigation behaviour. This implies that policies that emphasize the effectiveness of potential adaptation measures, address the costs of adaptation measures or provide practical guidelines could potentially enhance farmers' capacity to cope with droughts. Finally, the empirical evidence suggests that various components of the threat and coping appraisal processes influence adoption decisions differently across three scales of drought adaptation measures. As such, the implementation scale clearly matters and should therefore be considered in future studies and policies.

Acknowledgments This research is part of the Dutch 'Knowledge for Climate' national research programme and has been co-funded by a strategic research project of Deltares. The financial support of the Netherlands Organization for Scientific Research (NWO) VENI Grant 451-11-033 is highly appreciated.

References

Adger WN, Nigel A, Tompkins E (2005) Successful adaptation to climate change across scales. Glob Environ Change 15:77–86. doi:10.1016/j.gloenvcha.2004.12.005

Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR, Naess LO, Wolf J, Wreford A (2009) Are there social limits to adaptation to climate change? Clim Change 93:335–354. doi:10.1007/s10574-008-9520-z

Ajzen I (1985) From intentions to actions: a theory of planned behaviour. In: Kuhle J, Beckmann J (eds) Action-control: from cognition to behaviour. Springer, Heidelberg, pp 11–39

Bandura A (2001) Social cognitive theory: an agentic perspective. Annu Rev Psychol 52:1–26

Beedell J, Rehman T (1999) Using social psychology models to understand farmers' conservation behaviour. J Rural Stud 16:117–127. doi:10.1016/S0743-0167(99)00043-1

Benli B, Kodal S (2003) A non-linear model for farm optimization with adequate and limited water supplies: application to the

South-east Anatolian Project (GAP) region. Agric Water Manag 62:187–203. doi:10.1016/S0378-3774(03)00095-7

Below TB, Mutabazib KD, Kirschkea D, Frankea C, Sieberc S, Siebertc R, Tscherningc K (2012) Can farmers' adaptation to climate change be explained by socio-economic household-level variables? Global Environ Change 22:223–235

Block LG, Keller PA (1998) Beyond protection motivation: an integrative theory of health appeals. J Appl Soc Psychol 28:1584–1608. doi:10.1111/j.1559-1816.1998.tb01691.x

Botzen WJW, Aerts JCJH, van den Bergh JCJM (2009) Dependence of flood risk perceptions on socioeconomic and objective risk factors. Water Resour Res 45, doi:10.1029/2009WR007743

Bubeck P, Botzen WJW, Aerts JCJH (2012) A review of risk perceptions and other factors that influence flood mitigation behavior. Risk Anal 32:1481–1495. doi:10.1111/j.1539-6924.2011.01783.x

Bubeck P, Botzen WJW, Kreibich H, Aerts JCJH (2013) Detailed insights into the influence of flood-coping appraisals on mitigation behaviour. Glob Environ Change 23:1327–1338. doi:10.1016/j.gloenvcha.2013.05.009

Connor JD, Schwabe K, King D, Knapp K (2012) Irrigated agriculture and climate change: the influence of water supply variability and salinity on adaptation. Ecol Econ 77:149–157. doi:10.1016/j.ecolecon.2012.02.021

Cortignani R, Severini S (2009) Modeling farm-level adoption of deficit irrigation using positive mathematical programming. Agric Water Manag 96:1785–1791. doi:10.1016/j.agwat.2009.07.016

Deressa TT, Hasson RM, Ringler C, Alemu T, Yesuf M (2009) Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Glob Environ Change 19:248–255. doi:10.1016/j.gloenvcha.2009.01.002

Deressa TT, Hassan RM, Ringler C (2011) Perception and adaptation to climate change by farmers in the Nile basin of Ethiopia. J Agric Sci 149:23–31. doi:10.1017/S0021859610000687

Deltares (2012) Zoetwatervoorziening in Nederland: aangescherpte landelijke knelpuntenanalyse 21e eeuw. Deltares report no 1205970–000-VEB-0013

Fishbein M, Ajzen I (1975) Belief, attitude, intention and behaviour: an introduction to theory and research. Addison-Wesley, Reading

Frankhauser S, Smith JB, Tol RSJ (1999) Weathering climate change: some simple rules to guide adaptation decisions. Ecol Econ 30:67–78. doi:10.1016/S0921-8009(98)00117-7

García-Vila M, Fereres E (2012) Combining the simulation crop model AquaCrop with an economic model for the optimization of irrigation management at farm level. Eur J Agron 36:21–31. doi:10.1016/j.eja.2011.08.003

Gbetibouo GA (2009) Understanding farmers' perception and adaptations to climate change and variability. IFPRI discussion paper 00849, International Food Policy Research Institute

Gebrehiwot T, van der Veen A (2013) Farm level adaptation to climate change: the case of farmer's in the Ethiopian Highlands. Environ Manage 52:29–44. doi:10.1007/s00267-013-0039-3

Graveline N, Majone B, van Duinen R, Ansink E (2014) Hydro-economic modeling of water scarcity under global change: an application to the Gállego river basin (Spain). Reg Environ Change 14:119–132. doi:10.1007/s10113-013-0472-0

Grothmann T, Patt A (2005) Adaptive capacity and human cognition: the process of individual adaptation to climate change. Glob Environ Change 15:199–213. doi:10.1016/j.gloenvcha.2005.01.002

Grothmann T, Reusswig F (2006) People at risk of flooding: why some residents take precautionary action while others do not. Nat Hazards 38:101–120. doi:10.1007/s11069-005-8604-6

Jara-Rojas R, Bravo-Ureta BE, Díaz J (2012) Adoption of water conservation practices: a socioeconomic analysis of small-scale farmers in Central Chile. Agric Syst 10:54–62. doi:10.1016/j.agsy.2012.03.008

Klijn F, ter Maat J, van Velzen E (2011) Zoetwatervoorziening in Nederland: Landelijke analyse knelpunten in de 21e eeuw. Deltares rapport, Delft

Klijn F, ter Maat J, van Velzen E, Hunink J (2012) Zoetwatervoorziening in Nederland: aangescherpte landelijke knelpuntenanalyse 21e eeuw. Delatres rapport, Delft

Knowler D, Bradshaw B (2007) Farmers' adoption of conservation agriculture: a review and synthesis of recent research. Food Policy 32:25–48. doi:10.1016/j.foodpol.2006.01.003

Koerth J, Jones N, Vafeidis AT, Dimitrakoloulos PG, Melliou A, Chatzidimitriou E, Koukoulas S (2013) Household adaptation and intention to adapt to coastal flooding in the Axios–Loudias–Aliakmonas National Park, Greece. Ocean Coast Manag 82:43–50. doi:10.1016/j.ocecoaman.2013.05.008

Kuruppu N, Liverman D (2011) Mental preparation for climate adaptation: the role of cognition and culture in enhancing adaptive capacity of water management in Kiribati. Glob Environ Change 21:657–669. doi:10.1016/j.gloenvcha.2010.12.002

Lynne GD, Casey FC, Hodges A, Rahmani M (1995) Conservation technology adoption decisions and the theory of planned behaviour. J Econ Psychol 16:581–598. doi:10.1016/0167-4870(95)00031-6

Maddison D (2007) The perception of and adaptation to climate change in Africa. Policy research working paper 4308, The World Bank

Maddux JE, Rogers RW (1983) Protection motivation and self-efficacy: a revised theory of fear appeals and attitude change. J Exp Soci Psychol 19: 469–479

Mandleni B, Anim FDK (2011) Climate change awareness and decision on adaptation measures by livestock farmers in South Africa. J Agric Sci 3:258–268. doi:10.5539/jas.v3n3p258

Maneta MP, Torres MO, Wallender WW, Vosti S, Howit R, Rodrigues L, Bassoi LH, Panday S (2009) A spatially distributed hydroeconomic model to assess the effects of drought on land use, farm profits, and agricultural employment. Water Resour Res 45, doi:10.1029/2008WR007534

Mankad A, Greenhill M, Tucker D, Tapsuwan S (2013) Motivational indicators of protective behaviour in response to urban water shortage threat. J Hydrol 491:100–107. doi:10.1016/j.jhydrol.2013.04.002

Marshall GR (2013) Transaction costs, collective action and adaptation in managing complex social-ecological systems. Ecol Econ 88:185–194. doi:10.1016/j.ecolecon.2012.12.030

Martin IM, Bender H, Raish C (2007a) Making the decision to mitigate risk. In: WE Martin, C Raish, Kent B, (eds) Wildfire risk: human perceptions and management implications: resources for the future. Washington, DC, p 117–141

Martin IM, Bender H, Raish C (2007b) What motivates individuals to protect themselves from risks: the case of wildland fires. Risk Anal 27:887–900. doi:10.1111/j.1539-6924.2007.00930.x

Martin WE, Martin IM, Kent BL (2009) The role of risk perceptions in the risk mitigation process: the case of wildfire in high risk communities. J Environ Manage 91:489–498. doi:10.1016/j.jenvman.2009.09.007

Mendelsohn R (2000) Efficient adaptation to climate change. Clim Change 45:583–600

Miceli R, Sotgiu I, Settanni M (2008) Disaster preparedness and perception of flood risk: a study in an Alpine valley in Italy. J Environ Psychol 28:164–173

Nicholas KA, Durham WH (2012) Farm-scale adaptation and vulnerability to environmental stresses: insights from winegrowing in Northern California. Global Environ Change 22:483–494

Poussin JK, Botzen WJ, Aerts CJH (2014) Factors of influence on flood damage mitigation behaviour by households. Environ Sci Policy 40:69–77. doi:10.1016/j.envsci.2014.01.013

Rehman T, McKemey K, Yates CM, Cooke RJ, Garforth CJ, Tranter RB, Park JR, Dorward PT (2007) Identifying and understanding factors influencing the uptake of new technologies on dairy farms in SW England using the theory of reasoned action. Agric Syst 94:281–293. doi:10.1016/j.agsy.2006.09.006

Reidsma P, Ewert F, Oude-Lansink A, Leemans R (2010) Adaptation to climate change and climate variability in European agriculture: the importance of farm level responses. Eur J Agron 32:91–102. doi:10.1016/j.eja.2009.06.003

Rogers RW (1975) A protection motivation theory of fear appeals and attitude change. J Psychol 91

Siegrist M (2013) The necessity for longitudinal studies in risk perception research. Risk Anal 22:50–51. doi:10.1111/j.1539-6924.2012.01941.x

Stern N (2006) Review on the economics of climate change. Cambridge University Press, New York

Toft HI, O'Hanlon PW (1979) A dynamic programming model for on-farm decision making in a drought. Rev of Mark Agric Econ 47:5–16

Tolk L (2012) Zoetwater verheldert: Maatregelen voor zoetwater zelfvoorzienendheid in beeld. Kennis voor Klimaat, rapportnummer KvK 90/2013

Wauters E, Bielders C, Poesen J, Govers G, Mathijs E (2010) Adoption of soil conservation practices in Belgium: an examination of the theory of planned behaviour in the agri-environmental domain. Land Use Policy 27:86–94. doi:10.1016/j.landusepol.2009.02.009

Wheeler S, Zuo A, Bjornlund H (2013) Farmers' climate change beliefs and adaptation strategies for a water scarce future in Australia. Glob Environ Change 23:537–547. doi:10.1016/j.gloenvcha.2012.11.008