International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

Address: IIASA, Schlossplatz 1, A-2361 Laxenburg, Austria

Email: repository@iiasa.ac.at

Working paper

Drivers of farmers' adaptive behavior in managing drought risks: A literature review focusing on North-America, Europe, and Australia

Susanne Hanger-Kopp
hanger@iiasa.ac.at

WP-21-004

Approved by:

Name Raya Muttarak
Program: Population and Just Societies Program
Date: 27 April 2021

powered by klima+energie fonds + FARM Subsidized drought insurance and its alternatives

Table of contents

ZVR 524808900

Disclaimer:

The authors gratefully acknowledge funding from IIASA and the National Member Organizations that support the institute (The Austrian Academy of Sciences; The Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES); The National Natural Science Foundation of China (NSFC); The Academy of Scientific Research and Technology (ASRT), Egypt; The Finnish Committee for IIASA; The Association for the Advancement of IIASA, Germany; The Technology Information, Forecasting and Assessment Council (TIFAC), India; The Indonesian National Committee for IIASA; The Iran National Science Foundation (INSF); The Israel Committee for IIASA; The Japan Committee for IIASA; The National Research Foundation of Korea (NRF); The Mexican National Committee for IIASA; The Research Council of Norway (RCN); The Russian Academy of Sciences (RAS); Ministry of Education, Science, Research and Sport, Slovakia; The National Research Foundation (NRF), South Africa; The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS); The Ukrainian Academy of Sciences; The Research Councils of the UK; The National Academy of Sciences (NAS), USA; The Vietnam Academy of Science and Technology (VAST).

The authors gratefully acknowledge funding from Austrian Climate Research Program (ACRP) for the research project FARM – Farmers and Risk Management: Examining subsidized drought insurance and its alternatives (grant number B567169).

Abstract

Academic output on risk management in agriculture, particularly the behavior of farmers, has been growing exponentially over the past two decades. While farmers have always faced multiple types of risks, climate risks particularly drought are the most widespread and impactful. Social scientists have paid a lot of attention to identifying the underlying factors that promote risk reduction/adaptive behavior. Although multiple motivations have been identified, their effects on risk reduction remain ambiguous. Due to the context-specific nature of drought risk management, the role of individual perceptions, and the intensive data collection required, such studies can only be case studies at the national or sub-national levels. This review sets out to synthesize the findings of these studies focusing on drivers of farmer's drought risk management, which in often is used synonymously or in an overlapping way with adaptive behavior to climate change. The review focuses on post-industrialized countries complemented with studies from BRICS countries, and summarizes diverse risk management strategies employed in the face of weather- and climate related risks.

About the author

Susanne Hanger-Kopp is a research scholar at IIASA's Equity and Justice Research Group, Population and Just Societies Program, and lecturer at the Climate Policy Group at ETH Zurich, Switzerland.
(Contact: hanger@iiasa.ac.at)

1 Introduction

Climate change is a growing concern for both policymakers and farmers across Europe, adding uncertainty to an already uncertain occupation; one that is characterized by market price volatility, pest and animal health risks and high vulnerability to weather conditions. Climate change is expected to affect agricultural production in two fundamental ways: first, by shifting agricultural ecosystems, and second, by worsening the intensity and severity of weather extremes. Agro-climatological observations from the past decades indicate that the thermal growing season, in general, has become longer, while crop growth cycles have been shortening (EEA 2017).

Concurrently, projected increases in extreme weather events are expected to increase crop yield variability leading to yield reductions in the future throughout Europe. These extremes, including heatwaves, floods and droughts, have already caused enormous damages in the agricultural sector. For example, the severe drought that affected large parts of Europe in 2003, most importantly Portugal, Spain, Italy, France, Austria, and Germany, led to a 10% decline in agricultural production in the EUs arable sector, compared to the previous year (García-Herrera et al., 2010). Similar falls in production have been reported more recently, for from 2017 to 2018 (European Commission, 2019). Following the 2014 winter floods in the UK, yield losses reached 20% in certain regions, while total agricultural damages were estimated in the range of £11.8-24.9 million (ADAS 2014). By investigating mean temperature and precipitation changes, Moore and Lobell (2015) suggest that without adaptation, crop yields and agricultural profitability in European countries will significantly decrease by 2040 in comparison with the 1960-1989 baseline.

Although climate variability and weather extremes have always constituted integral risks to any farming endeavor, the extent of potential negative impacts is unprecedented and warrants special attention, particularly in the context of market and regulatory uncertainty, as well as resulting structural changes in the agricultural sector. National and international institutions have been recognizing this increasingly, which shows a shift from ex-post to ex-ante disaster risk management, in line with ideas of climate change adaptation, although the two policy areas only slowly converge (UNISDR 2015).

Climate and drought risk management in the agricultural sector may happen at various levels from the farm to provincial, national, and even supra-national levels like in the case of the European Union (EU). However, it is at the farm-level where production level based decisions are ultimately made and where higher-level policies take effect. Therefore, for decades, researchers have focused on studying farm-level decision-making in various contexts including the adoption of innovative technologies and specific farm management practices; as well as the participation in agri-environmental and conservation schemes (Knowler and Bradshaw 2007; Prokopy et al. 2008; Vanslembrouck et al. 2002; Lynne 1995). However, literature specifically on drought management, which are often similar if not identical with climate adaptation decisions in agriculture is comparably limited for high-income countries. Indeed, over the past decade many studies have emerged for lower income countries, where the sector is more vulnerable to natural hazards, and damages, especially with respect to droughts, are more devastating both from both economic and from humanitarian points of view (FAO 2015).

In this paper, we offer a systematic survey of studies of risk management and adaptation behavior of farmers in North America, Europe, and Australia. We focus exclusively on empirical standardized questionnaire-based studies, which aim to explain one or more drivers of risk management and adaptation behavior of farmers. The results highlight different trends in academic thinking as well as dominant variable choices and impacts. In the following sections, we describe the scope of this review (2), the various theories explaining risk management and adaptive behavior and the studies reviewed, which apply these theories (3), both the use of the dependent – risk management and adaptation measures (5) and independent – behavioral drivers variables (6), including the special case of insurance, which can be treated at both. This review is a background document for qualitative and quantitative work in an Austrian research project on agricultural drought risk management. Its main purpose is thus academic. However, the results are interesting for identifying and designing functional agricultural risk management and adaptation policies, particularly in high-income countries where there is a lack of evidence.

2 Method and scope

The literature started out in a random fashion, based on the review of available papers and with no geographic focus – which may explain outliers from the process described below. Keywords of a systematic literature search were extracted from this scoping process. The systematic literature search was carried out in Scopus using the following search algorithm for the years 2009-2017:

((TITLE ("risk management") OR TITLE (adapt*) AND TITLE (farmer*) OR TITLE (agricultur*)) AND DOCTYPE (ar OR re) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"ECON") OR LIMIT-TO (SUBJAREA,"BUSI") OR LIMIT-TO (SUBJAREA,"MULT") OR LIMIT-TO (SUBJAREA,"DECI") OR LIMIT-TO (SUBJAREA,"PSYC")) AND (LIMIT-TO (SRCTYPE,"j")))

This means that we looked for keyword combinations including risk management or various word endings related to "adaptation" as well as variations of "farmer" or "agriculture" in the article title. The standard search that goes beyond the scope of the article title to include also abstract and keywords would have yielded too many irrelevant articles. Therefore, there is a possibility that we might have missed article with a somewhat different description of the research topic. The literature search was limited to articles published in English language. We further focused the search results on journal articles from the subject areas Environmental Science, Social Sciences, Economics, Econometrics and Finance, Business, Management and Accounting, Multidisciplinary, Decision Science and Psychology. Articles from this area had to make an explicit reference in their title to risk management or any words or word combination that included the root adapt, in combination with farmer or agriculture in any variations. This strategy allows other risks than climate risks to be considered. Only one article (van Winsen et al. 2016), was captured by that expansion of search algorithm, and addresses agricultural risk more broadly. We included it as the overall final set of articles to be included was low.

This search algorithm yielded 568 journal articles. An additional search including "risk reduc*" as a relevant subcategory of risk management yielded no further relevant results that also fulfilled the criteria below. Also, a search for reviews instead of journal articles did not yield any further relevant results.

Several criteria were used to select papers based on this list of 568 results. Looking within these results (title, abstract, keywords) for "survey" "questionnaire", or "standardized interviews", reduced the results to 262 articles. We reviewed only studies that focused on the analysis of standardized surveys of farmers, with the main dependent variable being any forms of agricultural adaptation to drought or risk management of drought. Indeed, the search algorithm allowed for any risks to be considered, but few studies consider climate risks other than droughts in any case. We also include the two studies we found on agricultural adaptation to floods. Finally, we selected only studies that were conducted either in North America, Europe, Australia/New Zealand. Ultimately, 15 studies met our criteria, were selected for a detailed review, and form the basis for the insights of this working paper.

3 Theoretical background

Interdisciplinary empirical frameworks using primarily a combination of economic, psychological, and sociological thinking, with econometric and psychometric methods dominating analysis, currently characterize peer-reviewed academic literature on risk management and climate change adaptation.

While straight forward psychological ideas such as Expectancy Value Theory (EVT), and its economic counterpart Expected Utility Theory (EUT) are still at the heart of many studies, it has become common to expand upon standard frameworks of social-psychology and behavioral economics to create more complex explanatory constructs for human behavior, going far beyond ideas of rational choices. However, a considerable number of studies does not explicitly build on any theoretical foundation, which limits theory development, and comparability of studies.

Here, we provide an overview of dominant theoretical frameworks in the analysis of farmer's risk management and climate adaptation behavior. It is particularly in these and similar areas of high uncertainty, where elsewhere useful rational choice approaches fail. We can observe a trend from linear to more complex models of explanation. We introduce the studies applying these methods or adapted versions thereof.

3.1 Expectancy Value Theory (EVT)

The simplest form of a social-psychological explaining motivation of risk-taking behavior is Expectancy Value Theory (EVT) developed in the 1960s (Atkinson 1957). EVT proposes two factors as key determinants for individual behavior: Expectancy about whether a task can be performed and the value attached to the task. EVT is essentially a rational choice theory approached from the discipline of psychology; attitudes are still the product of linear deliberation (such as in expected utility models), but the difference is that EVT explores the antecedent factors contributing to attitudes. In economics, applying so called subjective expected utility, for example Meraner and Finger (2017) include farm characteristics, farmer's characteristics, risk perception, risk attitude, as well as household characteristics to investigate different dimensions of farm-level decision making. In the context of agricultural drought risk management and adaptive behavior, we found no direct application of EVT, but its reasoning is at heart of many existing studies.

3.2 Theory of reasoned action (TRA)/Theory of planned behavior (TPB)

Building on EVT, Theory of Reasoned Action (TRA) assumes that most socially relevant behaviors are under volitional control, and that a person's intention to perform a particular behavior is both the immediate determinant and the single best predictor of that behavior (Ajzen and Fishbein, 1980). An intention to perform a behavior is influenced by attitudes towards the action, including the individual's positive or negative beliefs and evaluations of the outcome of the behavior. It is also influenced by subjective norms, including the perceived expectations of the social environment (e.g. family or colleagues) about a person's behavior; and the motivation for a person to comply with others' wishes. Behavioral intention then results in action. Theory of Planned Behavior (TBP) is the extended version of TRA, including additional factors related to behavioral control (Ajzen, 2012, 1991). 'Behavioral control' represents the perceived ease or difficulty of performing the behavior and is a function of control beliefs. Conceptually it is very similar to self-efficacy (see under the Protection-Motivation Theory (PMT)) and includes knowledge of relevant skills, experience, emotions, past track record and external circumstances. TBP, however, just like TRA does not consider risk perception.

There are several studies that build on TRA/TPB to study farmers' behavior in different contexts such as soil conservation, grass land management, and general best management practices (Beedell and Rehman 2000; Bergevoet et al. 2004; Martínez-García et al. 2013; Reimer et al. 2012; Wauters et al. 2010; Willock et al. 1999). Climate change adaptation is specifically addressed by Wheeler et al. (2013) and Roesch-McNally et al. (2017). Wheeler et al. (2013) combine TPB with a 5 Capitals approach to model irrigators' future strategies. Variables related to human, social, physical, financial and natural capital are used as independent variables in the restricted OLS regression intended to estimate actual farming behavior. Roesch-McNally et al. (2017) link TPB and the Reasoned Action Approach with an adaptation typology, which has been particularly developed to facilitate decision making in agriculture, such as climate related stimuli, aspects of scale and responsibility, the form of adaptation, non-climatic factors/conditions, and finally evaluation of adaptation effects. They find that TPB applies particularly in the attitude towards adaptation and that farmers are highly individualistic actors, with subjective norms playing an important role in farmer's decisions on adaptation.

3.3 Protection-Motivation Theory (PMT)

PMT incorporates both risk perception ('threat appraisal') and coping evaluation ('coping or control appraisal') as determinants of protective behavior (Rogers, 1975). Threat appraisal concerns the (perceived) probability and (perceived) severity of the occurrence of a specific event. If the perceived threat is high, enough, in comparison with the benefits of maladaptive response, the person will look for and evaluate adaptive responses (coping appraisal). In the coping appraisal process, the person evaluates his or her ability to cope with and avert the threat.

The main argument for applying PMT is the comprehensive inclusion of psychological drivers of adaptive behavior, particularly that of risk perception (e.g. van Duinen et al. 2015). However, also here most studies do not apply the framework as intended by its originators, but expand and complement it with the intention to improve the accuracy of predicting behavior. For instance, Grothmann and Patt (2005), developed the Model of Private Proactive Adaptation to Climate Change (MPPACC) a psychological model based on PMT, for identifying cognitive drivers of adaptive behavior in the context of flood and drought risk. Since then the framework has become widely popular in disaster risk management and climate adaptation (Frank et al. 2011, van Duinen et al. 2015a and 2015b, Zheng an Dallimer, Woods et al. 2017). Woods et al. (2017), in turn, applied elements of MPPACC in combination with prospect theory and other theories about risk aversion. They argue from a realist point of view for the importance to consider farmers behavior as boundedly rational apart from "objective conditions such as vulnerability or available resources". While studies do not find fully consistent results supporting PMT, the overall findings are supportive to this theory at least at a low level of explanatory power (see annex 1). In the studies presented here, we have not found major negative critique on PMT.

3.4 Studies without or with less known approaches

Several studies aiming to understand drivers of farmers' adaptive behavior do not utilize established psychological theories but instead are guided by empirical analysis. Li et al. (2017), for the case of Hungary, refrained from using a theory-based approach for their study on farmers' adaptation. They create a "*conceptual framework [that] was developed based on current climate change and adaptive management literature*" (Li et al. 2017, p. 22) and use the categories of human, social, and financial capital to classify drivers beyond what they call the basic perception model. They measure basic perception as a combination of awareness of extreme events and water shortage, and belief in individual vulnerability, exposure of local agriculture, and climate change hazard. The more complete five capital approach (Ellis, 2000; Nelson et al., 2005) includes natural, and physical capital, in addition to human, social, and financial capitals, and first has been expanded by Wheeler et al. (2013) in the assumption that these capitals influence farmers behavior. A study which implicitly follows an agricultural economics tradition, but does not explicitly use a theoretical framing, is van Winsen et al. (2016), who study Flemish farmers by means of a postal survey. They analyze their data by means of a structural equation model and are thus able to distinguish direct from indirect relationships.

van Haden et al. (2012), surveyed 162 farmers in California's central valley about their mitigation and adaptation behavior. They tested the hypothesis that global beliefs and concerns about climate change will have a strong influence on farmers' mitigation behavior, while psychologically proximate concerns for local climate impacts will motivate farmers' adaptation behavior. The author considered six relevant measures to construe dependent variables for adaptation behavior using factor analysis. The independent variables were perceived climate impacts and concern about the same, and a set of structural and socio-economic control variables. Building on the same survey used by van Haden, Niles et al. (2013) combine ideas from different psychological approaches including aspects of the above mentioned models (mostly risk perception), hierarchical models, explaining specific climate risk attitudes as depending on higher level more abstract attitudes on climate risks, and the psychological distance model, assuming that recent more tangible events (e.g. climate change impacts) influence current preferences more than less tangible long past events.

Niles et al. (2015) combine ecological and psychological approaches to develop the limiting factor hypothesis. Based on Liebig's Law of the Minimum, they "argue that an agricultural system's adaptation to climate change is fundamentally hindered by, and vulnerable to, the most limiting factor within the system." (p. 179). In their study they highlight a clear link between limiting factors and productivity as both water and temperature can fundamentally impact the growth potential of a crop.
For the Midwestern U.S. Mase et al. (2017) conducted a large-scale mail survey (n≈4,700) and used an OLS Regression to estimate the importance of farmers' climate change beliefs, perceptions of weather variability, perceived risks from weather, and innovation and adaptation attitudes in their adaptation behavior.

Lubell et al. (2013) propose the adaptive rangeland decision-making framework. Roche (2016) applies this framework to a study of Californian ranchers (n=507). The framework considers the influence of social and ecological systems, for example policy, economics, and types of ecosystems, on individual adaptation decisions, which consist of individual social values, management goals, capacities and strategies. Together they determine the management outcome.

4 Measuring risk management and adaptive behavior (the dependent variable)

Risk management and adaptive behavior are usually measured in the form of specific adaptation measures taken. Comparison is difficult as categorizations of risk management and adaptive behavior, albeit similar, vary widely. The following examples show that indices of adaptive behavior based on similar but different dimensions are made, and adaptive behavior is often evaluated based on the number of measures taken in one particular dimension. Authors rarely give a detailed explanation why they choose the respective categories, but they often fit the geographical, economic and institutional context of of the case study area (e.g. van Duinen et al. 2015).

Wheeler et al. (2013), stress the importance of distinguishing between planned and actual adaptation measures (as do for example Niles et al. 2016) and show that intentions reasonably well match actual behavior under business as usual conditions. They create an adaptation index and use it as the dependent variable, which is based on the number of expansive (land purchase, increasing irrigated area, purchase of permanent water), accommodating (improving irrigation efficiency, changing crop mix) and contractive (selling land, decreasing irrigated area, selling permanent water) strategies. However, they also model these strategies separately. Roesch McNally et al. (2016) investigate the intention to adopt three specific agricultural practices: no-till farming, cover crops and subsurface tile drainage, as examples for "selected production and conservation measures". Van Duinen et al. (2015b), adaptation motivation, and include all together twelve adaptation measures, categorized as field-scale, farm-level and joint measures that are directly related to drought risk and farmers can implement them independently from institutions such as agricultural cooperatives and local/regional governments. Survey participants reported on the number of implemented adaptation measures, indicating drought risk preparedness (van Duinen et al., 2015). Van Winsen et al. (2016) all distinguish between ex-ante and ex-post measures, where less risk-averse farmers rather take ex-ante measures than risk averse farmers, which is counter intuitive. Meraner and Finger (2017) elicit information on 16 risk management measures in three overall categories on-farm agricultural measures, on-farm non-agricultural measures, and off-farm measures. Their dependent variable is this portfolio of measures. Van Haden et al. (2012) use factor analysis to create dependent adaptation variables "new irrigation practices" and "new cropping practices". Roche (2016) creates indices for proactive and reactive measures. Li et al (2017) also elicit the number of adaptation measures (out of 8 measures) as indicative for adaptive behavior without further categorization.

There are studies that address rather the attitude towards adaptation or risk management at a generic level rather than farmer's actual behavior or intention. For example, Arbuckle et al. (2013), asked for farmer's attitude towards adaptation at a generic level "Iowa farmer's should take…". Niles et al. (2013), for example study only one very specific measure, in this case the response to climate risk policies translating to the participation in climate change incentive programs.

5 Factors associated with farmers' adaptive behavior (the independent variables)

This section provides an overview of the factors influencing farmers' adaptation decisions based on the reviewed literature.

5.1 Threat appraisal (risk perception)

Threat appraisal is a cognitive evaluation of risk perception that describes the individual's assessment of the level of threat. Frequently this is measured as an index of perceived likelihood and severity of impact (Meraner and Finger, 2017; van Duinen et al., 2015), or level of concern (Mase et al., 2017; Woods et al., 2017). Higher threat appraisal is often associated in the literature with more likely intention to adopt a protective behavior (Mase et al. 2017, Woods et al. 2017, Niles et al. 2013). There are, however, also contradictory evidence presented in the literature. For example, Van Duinen et al. (2015a) conclude that while perceived severity is an important influencing factor in farmers' drought adaptation decision-making, perceived probability has, in most cases, an insignificant effect. Niles et al. (2016) investigate concerns about climate change and environmental issues and find an association only with adaptation intentions, but not with actual adaptation. Broader studies on agricultural risk management are equally inconsistent in finding an association between risk perception and risk reduction behavior. Van Winsen et al. (2016) find no significant association between threat appraisal and risk reduction behavior among Flemish farmers, whereas Meraner and Finger (2017) do for German livestock farmers. In the latter case, influential perceptions are related to market risks rather than production risks, which include weather-related extreme events.

While many studies elicit risk perception in much detail, there are examples for broader definitions. Arbuckle et al. (2013), for instance, focus on the impacts of climate change generically on agriculture in the region, farmer's own operations, and the chance for a higher frequency of extreme events. Adaptation and climate change attitude however was not explicitly included in the search algorithm used for this review.

5.2 Risk attitude

Risk attitude also known as risk preference, risk aversion or risk propensity is a different concept from that of threat appraisal, as it concerns not the evaluation of a specific risk at hand, but the generic disposition of a farmer towards risk and risky endeavors. Risk attitudes vary from risk averse to risk seeking. As different persons hold different risk attitudes, they deal differently with risks regardless of their individual perception. Van Winsen et al. (2016) specifically looks at the relationship between risk perception and risk attitude as they affect risk management behavior of Dutch farmers. They find that while risk perception has no direct significant impact on behavior, risk attitude does. Risk attitude of farmers is also a concept found in economics. For example, Meraner and Finger (2017) find no association between risk attitude and adaptive behavior.

5.3 Previous (drought) experience

Generally, previous experience is rarely included in analyses of behavioral drivers in agriculture. A few existing evidence on the impact of previous exposure to extreme climate events on adaptive behavior is mixed. While Roche (2016) and Niles et al. (2013) find a significant association between past drought operation experience or climate change experience, respectively and adaptive behavior of Californian ranchers, Niles et al. (2015) find no association between previous experience and adaptation to drought for New Zealand.

Compared to studies focusing on droughts, there are more studies that focus on previous flood experience and risk management or adaptation. Hamilton-Webb et al. (2017), explored farmers at risk from floods, to understand the relationship between risk experience and risk response. While the authors establish such an association, they find that most adaptation behavior stems from normal practice. Studies on flood risk among households in general found previous experience to be a good indicator for fear of floods as well as perceived likelihood and could be said to be a mediating factor for flood mitigation behavior (Siegrist and Gutscher, 2008; Terpstra, 2011).

5.4 Coping appraisal (response efficacy, self-efficacy and cost)

In the coping appraisal process, people evaluate their ability to cope with a specific threat based on three main parameters. Response efficacy concerns the perceived effectiveness of a particular behavioral response in reducing risk. Self-efficacy refers to the respondent's belief that (s)he can successfully implement the coping action, while cost covers both monetary and non-monetary expenses (Rogers, 1983). The hypothesis is often that self-efficacy and response efficacy positively correlate with adaptation ('the higher the farmer perceives effectiveness of the measure and his own ability, the greater the likelihood of adaptation), while costs have an opposite effect (van Duinen et al. 2015a). Some studies combine these variables into one factor, e.g. by principal component analysis (PCA) or other methods (Duinen et al. 2015b; Feng et al. 2017). Most reviewed studies measure 'perceived cost' on a Likert scale e.g. by asking farmers 'how costly do you consider each of the following adaptation measures in terms of time/effort/money?' (Duinen at el. 2015a, supplementary material), and they all confirm a negative relationship, regardless of the respondents' decision stages (Duinen et al. 2015a; Feng et al. 2017). On the contrary, the direction of the effect of perceived response efficacy and self-efficacy is never found to be negative, although its significance varies.

Woods et al. (2017), use *perceived adaptive capacity* as a comparable, but somewhat different composite indicator. Different to other studies they measure adaptive capacity by asking for the perceived absence or presence of three types of barriers, meta-barriers, capacity barriers, and water barriers, which were in turn broken down into more detail. Interestingly all three categories of perceived barriers to adaptation are significantly and positively correlated with a likelihood to adapt in the future, i.e. the greater the perceived barriers to adaptation, the more farmers indicate they are likely to adapt. Meta-barriers and capacity barriers have a slightly stronger correlation with likelihood to adapt to potential negative impacts of climate change than other barriers

5.5 Belief in climate change

Several studies focus on farmers' belief in climate change and its role in adaptation decisions (Arbuckle et al. 2013; Wheeler et al. 2013; Mase et al. 2017, Woods et al. 2017). Belief in climate change is often found to significantly and positively affect adaptive behavior. For example, Arbuckle et al. (2013) show that farmers who believe that climate change is happening and can largely be attributed to human activity are significantly more likely to support both adaptation and mitigation actions. Belief that climate change is occurring and mostly or equally anthropogenic in nature is associated with higher levels of agreement with the adaptation statements, "Farmers should take additional steps to protect farmland from increased weather variability" and, "I should take additional steps to protect the land I farm from increased weather variability" (Arbuckle et al. 2013). Woods et al. (2017) find similar results for Danish farmers. Wheeler et al. (2013) draw a more complex picture and suggest that the effect of climate change beliefs depends on the adaptation strategy itself. For example, they find that believing in climate change is significantly and negatively associated with the purchase of additional farmland but at the same time, there is a positive relationship with other measures such as changing crop mix and adoption of more efficient irrigation techniques. They also report endogeneity between climate change beliefs and adaptation strategies suggesting that adaptive behavior might be also influencing climate change beliefs (and risk perceptions). Mase et al. (2017), however, find contradicting evidence in the Midwestern U.S., where belief in climate change is not associated with adaptation behavior. Li et al. (2017) similarly do not find evidence for such an association in the case of Hungarian farmers, although their study highlights indirect links via awareness of extreme events and water scarcity.

5.6 Social influence

Social influence is often considered as an important variable in farmers' risk perception and adaptive behavior; however it is defined and measured differently in the studies reviewed. For example, Feng et al. (2017) put the focus on communication, trust and learning and define social appraisal based on these factors. Van Duinen et al. (2015b) follow a more narrow approach, and use the following four statements (measured on seven-points scale) to define/calculate social influence: i) 'I only take important decisions when I am sure peer members would recommend them'; ii) 'It is very important that colleagues are positive about important farm decisions'; iii) 'I look at others to be sure I am making the right decisions'; iv) 'When I am insecure about decisions, I seek the opinions of colleagues' (van Duinen et al. 2015b). The outcome of these studies with respect to the relationship between social influence and adaptive behavior is not consistent. Van Duinen et al. (2015b) report an insignificant (albeit positive) relationship between social influence susceptibility and risk perception. Note, Niles et al. (2016), for example interpret social norms as environmental policy, we thus report results in section 5.8.

5.7 Socio-economic and demographic (objective) factors

Socio-economic and demographic factors are frequently included in studies on drivers of farmers adaptive behavior. The most commonly investigated variables include age, education, farm income/revenue, however studies present inconsistent evidence. For example, Wheeler et al. (2013), Mase et al. (2017), and Niles et al. (2013, 2016) identify a significant and negative association between age and adaptive behavior (i.e. adaptive behavior decreases as age increases), while Roesch-McNally et al. (2016) find both insignificant and significantly negative relationship depending on farmers' decision stages and the adaptation measure in question. In their review of agricultural best management practice studies (ABMPs), Prokopy et al. (2008) report that out of 109 models (in 26 different studies) 91 models suggest an insignificant relationship between age and the implementation of ABMPs. In a similar review, Knowler and

Bradshaw (2007) also report mixed evidence, 10 studies showing insignificant, 5 significantly negative and 3 significantly positive association between farmers' age and the adoption of conservation agricultural practices.

While gender is often included in studies of adaptation behavior in order to profile the sample, it is rarely considered as a driver of adaptation. Mase et al. (2017), who did include it found that women are twice as likely as men to purchase additional crop insurance, whereas gender is not significant in the overall model of adaptive behavior. Education and farm size are often found to play an insignificant role in farmers' adaptation decisions (e.g. Niles et al. 2016, Prokopy et al. 2008, Knowler and Bradshaw 2007, exceptions are reported for example by Mase et al. (2017) and Niles et al. (2013). Li et al. (2017), find a significantly positive link between farmers' income and their adaptive behavior. Roesch McNall et al. (2018) find that with increasing revenue farms are less likely to use diversified crop rotation.

5.8 Knowledge, information, and institutional incentives

Information about drought risk is increasingly available both from public and private sources, and in diverse formats, such as risk maps, forecasting services, brochures on risk management measures, and information events. However, there is little evidence how this influences farmer's risk reduction behavior. Grothmann and Patt (2005), show how risk-related information from forecasts may not directly translate into adaptive behavior of Zimbabwean subsistence farmers. Another study (for the case of floods) identifies a lack of information as a barrier to action (Hamilton-Webb et al. 2017).

Similarly, few studies explore the influence of institutional structures, and policies and regulations on farmer's adaptation behavior. Niles et al. (2016), for example, find a positive impact of environmental policies on actual adoption of climate adaptation measures.

5.9 Insurance and adaptive behaviour

Insurance has been a central element of the climate change adaptation and disaster risk management discourses at various levels. Researchers commonly claim that, in concept, insurance can go beyond enabling post-disaster relief, reconstruction and recovery, to be an effective pre-disaster tool for promoting risk reduction (Kunreuther 1996; Kunreuther and Michel-Kerjan 2011; Crichton 2008; Botzen 2013). There are several ways in which insurance can, in theory, contribute to climate risk management, disaster risk reduction (DRR in particular: (i) Incentivizing disaster risk reduction through premiums that reward preventative investment and behavior (risk-based pricing), (ii) providing incentives for DRR through deductibles, (iii) prescribing DRR activities as a condition for the insurance contract (warranties), (iv) providing large commercial clients with tailored DRR advice linked to insurance (risk engineering), (v) providing risk and DRR information to clients, and (vi) investing directly and indirectly in DRR. Others, however, argue that under certain conditions (e.g. full compensation and/or highly subsidized policies), insurance mechanisms can encourage the insured party not to undertake risk reduction – referred to as 'moral hazard' (IPCC 2012). Numerous studies have been published on these issues, mainly in the context of residential flood insurance, including Hanger et al. (2018), Hudson et al. (2016), and Poussin et al. (2014).

The link between insurance and farmers' adaptive behavior, however is less researched. Except for Roesch-McNally et al. (2016), the studies discussed in the previous sections do not include insurance as a decision factor in their models. The few studies available tend to focus on the US, where the highly subsidized federal crop insurance program works more like an income support program than a risk management program (Babcock 2013). Farmers in the US receive, on average USD 1.67 compensation for every dollar premium paid (Sumner and Zulauf 2012). More specifically, subsidized insurance could affect agricultural production in three ways: i) by increasing the expected income per unit, it could encourage farmers to plant insured crops and plant more of the crops with higher subsidy rates; ii) it could lead to expanding production on risky areas as insurance reduces the chances of losses from low yields and prices; and iii) disincentive the undertake of risk mitigation measures (Sumner and Zulauf 2012).

Studies that investigate the role of (subsidized) insurance in farmers' decision-making address various issues such as agricultural input use and the adoption of conservation tillage, crop rotation. Skees (2000) assesses the potential impacts of subsidized insurance on planting decisions/land use patterns, more specifically if it could encourage the expansion of agricultural production to risky regions in the US. He develops a simple OLS model to compare aggregated data from two five-year periods. No farm-level data is included in the model, explanatory variables cover market and government incentives, e.g. insurance subsidy per USD of revenue and disaster payments per USD of revenue. Results suggest that every 10-percentage point increase in participation in crop insurance leads to an increase of 5.9 acres in planted areas across the US (Skees 2000). Considering also additional variables, Wu and Babcock (1998) report that insured farmers adopt crop rotation less frequently, however they did not find significant association between insurance and the adoption of conservation tillage, which is not consistent with the conclusions of Roesch-McNally et al. (2016), although both studies were conducted in the US. Mase et al. (2017) conducted a mail survey among crop farmers (income >100,000 USD) in the Midwestern U.S. They found that almost 60% of respondents purchased additional insurance to manage climate risks. This measure is only second in popularity to in-field conservation practices. They thus confirm their hypothesis that insurance is a preferred adaptation measure compared to crop diversification (10%) and other measures. They highlight a significant positive association with farmer's risk perception, and innovation attitude, and the purchase of additional insurance.

6 Conclusions/key lessons

There is a growing body of academic literature addressing drivers of risk management and adaptation behavior. In the context of agriculture, this literature focuses largely on developing countries, where climate impacts are more severe and acute, and the pressure to act is higher. However, developed countries increasingly feel the impacts of climate change, and understanding adaptation behavior in agriculture is important, to create coherent, sustainable, and acceptable adaptation policies across sectors. This review addresses this gap and provides an overview of those studies available for countries in North America, Europe, and Australia. Interes

tingly studies available focus mostly on the US, with individual studies available for other countries
Many studies on drivers of adaptation still operate without conceptual frameworks, however, psychological models of adaptive behavior are increasingly common. TPA/TRA and PMT seem to be the preferred conceptual models underlying studies of farmer's risk reduction behavior. Most researchers use adapted and extended versions of these approaches designed around the ideas of threat and coping appraisals to take into account the different potential determinants of human behavior, particularly those that go beyond rational explanations. The complexity is reflected in the low explanatory factor of most models, which seems common in such studies. The explanatory variables and their framings vary widely across studies, which is testimony to the early, exploratory stages of this research, and the diversity of contexts in which adaptation takes place.

There are however some variables that occur frequently, besides certain socio-economic, structural and demographic variables such as age, education, farm size, and farm revenue. These include: belief in climate change, some form of threat and coping appraisal, as well as perception of previous or existing impacts, and social influence.

Only a small number of studies include agricultural insurance as a factor that might motivate or demotivate risk reduction among farmers. The investigation of the link between (subsidized) insurance and farm-level decision-making requires further research. Considering the recent European policy developments, it would be especially important to conduct more studies in the EU context.

The reviewed studies rarely, if at all, include the influence of existing agricultural information and regulation policies, which directly or indirectly may affect adaptation behavior. Across the board there is little evidence how different types of information influence farmer's risk reduction efforts, although the relevance of information both pertaining to climate change and its impact is increasingly highlighted.
Standardized surveys in general and those explaining adaptive behavior in particular are subject to certain types of bias and other limitations. For example, such studies can only include a limited number of variables due to both data collection and statistical analysis methods; with a few exceptions, e.g. Feng et al. (2017), standardized studies only explain small parts of the variation in behavior (see comparison of R^2 in the Annex). This is an indicator of the complexity of behavioral models, and indicates that still other factors may play a role in explaining drought risk management and adaptive behavior. Few, albeit increasing numbers, show how in-depth interviews, and discourse analysis can complement standardized surveys and help to better understand agricultural drought risk management and climate change (e.g. Eakin et al., 2016; Feola et al., 2015; Findlater et al., 2018; Mitter et al., 2019).

Update January 2021:
A Scopus search using an algorithm combining keywords on adaptive behavior, drought risk management, and agriculture[1] revealed that since 2018, mostly new studies continued to focus on developing countries, studies relevant to this review showed a most notable increase for China, while the other BRICS states as well as post-industrialized countries continue to receive little attention with respect to researching drivers of adaptive behavior and drought risk management in agriculture.

[1] Exact algorithm used on 21 January 2021: ((TITLE ("risk management") OR TITLE (adapt*) AND TITLE (farmer*) OR TITLE (agricultur*)) AND DOCTYPE (ar OR re) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"ECON") OR LIMIT-TO (SUBJAREA,"BUSI") OR LIMIT-TO (SUBJAREA,"MULT") OR LIMIT-TO (SUBJAREA,"DECI") OR LIMIT-TO (SUBJAREA,"PSYC")) AND (LIMIT-TO (SRCTYPE,"j"))) , an edited search including “risk reduc*” did not yield additional relevant insights.

7 References

ADAS (2014): Impacts of 2014 winter floods on agriculture in England. Available online at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/401235/RFI7086_Flood_Impacts_Report__2_.pdf, checked on 12/14/2020.

Arbuckle, J. Gordon; Morton, Lois Wright; Hobbs, Jon (2013): Farmer beliefs and concerns about climate change and attitudes toward adaptation and mitigation: Evidence from Iowa. In *Climatic Change* 118 (3-4), pp. 551–563. DOI: 10.1007/s10584-013-0700-0.

Atkinson, J. W. (1957): Motivational determinants of risk-taking behavior. In *Psychological review* 64, Part 1 (6), pp. 359–372. DOI: 10.1037/h0043445.

Babcock, B. (2013): Cutting wate in the crop insurance program. Environmental Working Group. Washington, DC. Available online at https://www.ewg.org/sites/default/files/u118/2013%20Cutting%20Crop%20Insurance%20Waste_.pdf?_ga=2.37165218.347641247.1608050113-513167086.1608050113, checked on 12/15/2020.

Beedell, Jason; Rehman, Tahir (2000): Using social-psychology models to understand farmers' conservation behaviour. In *Journal of Rural Studies* 16 (1), pp. 117–127. DOI: 10.1016/S0743-0167(99)00043-1.

Bergevoet, R. H. M.; Ondersteijn, C. J. M.; Saatkamp, H. W.; van Woerkum, C. M. J.; Huirne, R. B. M. (2004): Entrepreneurial behaviour of dutch dairy farmers under a milk quota system: goals, objectives and attitudes. In *Agricultural Systems* 80 (1), pp. 1–21. DOI: 10.1016/j.agsy.2003.05.001.

Botzen, W. J. Wouter (2013): Managing extreme climate risks through insurance. Cambridge: Cambridge University Press.

Crichton, David (2008): Role of Insurance in Reducing Flood Risk. In *Geneva Pap Risk Insur Issues Pract* 33 (1), pp. 117–132. DOI: 10.1057/palgrave.gpp.2510151.

Eakin, Hallie; York, Abigail; Aggarwal, Rimjhim; Waters, Summer; Welch, Jessica; Rubiños, Cathy et al. (2016): Cognitive and institutional influences on farmers' adaptive capacity: insights into barriers and opportunities for transformative change in central Arizona. In *Reg Environ Change* 16 (3), pp. 801–814. DOI: 10.1007/s10113-015-0789-y.

EEA (2017): Climate change, impacts and vulnerability in Europe 2016. An indicator-based report. Luxembourg: Publications Office of the European Union (EEA report, 2017,1). Available online at 978-92-9213-835-6, checked on 14 December 20020.

FAO (2015): The impacts of natural hazards and disasters on agriculture and food security and nutrition: a call for action to build resilient livelihoods. Food and Agriculture Organization of the United Nations. Available online at http://www.fao.org/news/story/en/item/280526/icode/, checked on 12/14/2020.

Feng, Xiaolong; Liu, Mingyue; Huo, Xuexi; Ma, Wanglin (2017): What Motivates Farmers' Adaptation to Climate Change? The Case of Apple Farmers of Shaanxi in China. In *Sustainability* 9 (4), p. 519. DOI: 10.3390/su9040519.

Findlater, Kieran M.; Satterfield, Terre; Kandlikar, Milind; Donner, Simon D. (2018): Six languages for a risky climate: how farmers react to weather and climate change. In *Climatic Change* 148 (4), pp. 451–465. DOI: 10.1007/s10584-018-2217-z.

Frank, Elisa; Eakin, Hallie; López-Carr, David (2011): Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. In *Global Environmental Change* 21 (1), pp. 66–76. DOI: 10.1016/j.gloenvcha.2010.11.001.

Grothmann, Torsten; Patt, Anthony (2005): Adaptive capacity and human cognition: The process of individual adaptation to climate change. In *Global Environmental Change* 15 (3), pp. 199–213. DOI: 10.1016/j.gloenvcha.2005.01.002.

Hamilton-Webb, A.; Manning, L.; Naylor, R.; Conway, J. (2017): The relationship between risk experience and risk response: a study of farmers and climate change. In *Journal of Risk Research* 20 (11), pp. 1379–1393. DOI: 10.1080/13669877.2016.1153506.

Hanger, Susanne; Linnerooth-Bayer, Joanne; Surminski, Swenja; Nenciu-Posner, Cristina; Lorant, Anna; Ionescu, Radu; Patt, Anthony (2018): Insurance, Public Assistance, and Household Flood Risk Reduction: A Comparative Study of Austria, England, and Romania. In *Risk analysis : an official publication of the Society for Risk Analysis* 38 (4), pp. 680–693. DOI: 10.1111/risa.12881.

Hudson, Paul; Botzen, W. WouterJ.; Feyen, Luc; Aerts, Jeroen C.J.H. (2016): Incentivising flood risk adaptation through risk based insurance premiums: Trade-offs between affordability and risk reduction. In *Ecological Economics* 125, pp. 1–13. DOI: 10.1016/j.ecolecon.2016.01.015.

Knowler, Duncan; Bradshaw, Ben (2007): Farmers' adoption of conservation agriculture: A review and synthesis of recent research. In *Food Policy* 32 (1), pp. 25–48. DOI: 10.1016/j.foodpol.2006.01.003.

Kovats, R. S.; Valentini, R.; Bouwer, L. M.; Georgopoulou, E.; Jacob, D.; Martin, E. et al. (2014): Europe. In IPCC (Ed.): Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Ingergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, USA: Cambridge University Press.

Kunreuther, Howard (1996): Mitigating disaster losses through insurance. In *J Risk Uncertainty* 12 (2-3), pp. 171–187. DOI: 10.1007/BF00055792.

Kunreuther, Howard; Michel-Kerjan, Erwann (2011): At war with the weather. Managing large-scale risks in a new era of catastrophes / Howard C. Kunreuther and Erwann O. Michel-Kerjan with Neil A. Doherty … [et al.]. Cambridge, Mass., London: MIT Press. Available online at http://www.jstor.org/stable/j.ctt5hhn3h.

Li, Sen; Juhász-Horváth, Linda; Harrison, Paula A.; Pintér, László; Rounsevell, Mark D. A. (2017): Relating farmer's perceptions of climate change risk to adaptation behaviour in Hungary. In *Journal of Environmental Management* 185, pp. 21–30. DOI: 10.1016/j.jenvman.2016.10.051.

Lubell, M. N.; Cutts, B. B.; Roche, L. M.; Hamilton, M.; Derner, J. D.; Kachergis, E.; Tate, K. W. (2013): Conservation Program Participation and Adaptive Rangeland Decision-Making. In *Rangeland Ecology & Management* 66 (6), pp. 609–620. DOI: 10.2111/REM-D-13-00025.1.

Lynne, Gary D. (1995): Modifying the Neo-Classical Approach to Technology Adoption With Behavioral Science Models. In *J. Agric. Appl. Econ.* 27 (1), pp. 67–80. DOI: 10.1017/S107407080001960X.

Marshall, N. A.; Park, S. E.; Adger, W. N.; Brown, K.; Howden, S. M. (2012): Transformational capacity and the influence of place and identity. In *Environ. Res. Lett.* 7 (3), p. 34022. DOI: 10.1088/1748-9326/7/3/034022.

Martínez-García, Carlos Galdino; Dorward, Peter; Rehman, Tahir (2013): Factors influencing adoption of improved grassland management by small-scale dairy farmers in central Mexico and the implications for future research on smallholder adoption in developing countries. In *Livestock Science* 152 (2), pp. 228–238. DOI: 10.1016/j.livsci.2012.10.007.

Mase, A. S.; Gramig, B. M.; Prokopy, L. S. (2017): Climate change beliefs, risk perceptions, and adaptation behavior among Midwestern U.S. crop farmers. In *Climate Risk Management* 15, pp. 8–17. DOI: 10.1016/j.crm.2016.11.004.

Meraner, M.; Finger, R. (2017): Risk perceptions, preferences and management strategies: evidence from a case study using German livestock farmers. In *Journal of Risk Research*. DOI: 10.1080/13669877.2017.1351476.

Moore, Frances C.; Lobell, David B. (2015): The fingerprint of climate trends on European crop yields. In *Proceedings of the National Academy of Sciences of the United States of America* 112 (9), pp. 2670–2675. DOI: 10.1073/pnas.1409606112.

Poussin, Jennifer K.; Botzen, W. WouterJ.; Aerts, Jeroen C.J.H. (2014): Factors of influence on flood damage mitigation behaviour by households. In *Environmental Science & Policy* 40, pp. 69–77. DOI: 10.1016/j.envsci.2014.01.013.

Prokopy, L. S.; Floress, K.; Klotthor-Weinkauf, D.; Baumgart-Getz, A. (2008): Determinants of agricultural best management practice adoption: Evidence from the literature. In *Journal of Soil and Water Conservation* 63 (5), pp. 300–311. DOI: 10.2489/jswc.63.5.300.

Reimer, Adam P.; Weinkauf, Denise Klotthor; Prokopy, Linda Stalker (2012): The influence of perceptions of practice characteristics: An examination of agricultural best management practice adoption in two Indiana watersheds. In *Journal of Rural Studies* 28 (1), pp. 118–128. DOI: 10.1016/j.jrurstud.2011.09.005.

Roche, Leslie (2016): Adaptive Rangeland Decision-Making and Coping with Drought. In *Sustainability* 8 (12), p. 1334. DOI: 10.3390/su8121334.

Roesch-McNally, Gabrielle E.; Arbuckle, J. G.; Tyndall, John C. (2018): Barriers to implementing climate resilient agricultural strategies: The case of crop diversification in the U.S. Corn Belt. In *Global Environmental Change* 48, pp. 206–215. DOI: 10.1016/j.gloenvcha.2017.12.002.

Roesch-McNally, Gabrielle E.; Gordon Arbuckle, J.; Tyndall, John Charles (2017): What would farmers do? Adaptation intentions under a Corn Belt climate change scenario. In *Agric Hum Values* 34 (2), pp. 333–346. DOI: 10.1007/s10460-016-9719-y.

Skees, J. (2000): The potential influence of risk management programs on cropping decisions. Presentation at the ERS Conference (20 September 2000). Available online at http://globalagrisk.com/Pubs/2000%20Risk%20Mgmt%20Influence%20on%20Planting%20Decisons_jrs.pdf, checked on 12/15/2020.

Sumner, D. A.; Zulauf, C. (2012): Economic & Environmental Effects of Agricultural Insurance Programs. C-FARE.

UNISDR (2015): Sendai framework for disaster risk reduction 2015-2030. UNDRR. Geneva.

van Duinen, R.; Filatova, Tatiana; Geurts, Peter; van der Veen, Anne (2015a): Coping with drought risk: empirical analysis of farmers’ drought adaptation in the south-west Netherlands. In *Regional Environmental Change* 15 (6), pp. 1081–1093. DOI: 10.1007/s10113-014-0692-y.

van Duinen, Rianne; Filatova, Tatiana; Geurts, Peter; van der Veen, Anne (2015b): Empirical analysis of farmers' drought risk perception: objective factors, personal circumstances, and social influence. In *Risk analysis : an official publication of the Society for Risk Analysis* 35 (4), pp. 741–755. DOI: 10.1111/risa.12299.

van Haden, R.; Niles, Meredith T.; Lubell, Mark; Perlman, Joshua; Jackson, Louise E.; Clifton, Julian (2012): Global and Local Concerns: What Attitudes and Beliefs Motivate Farmers to Mitigate and Adapt to Climate Change? In *PLoS ONE* 7 (12), e52882. DOI: 10.1371/journal.pone.0052882.

van Winsen, F.; De, Mey; Lauwers, L.; Van, Passel; Vancauteren, M.; Wauters, E. (2016): Determinants of risk behaviour: Effects of perceived risks and risk attitude on farmers adoption of risk management strategies. In *Journal of Risk Research* 19 (1), pp. 56–78. DOI: 10.1080/13669877.2014.940597.

Vanslembrouck, Isabel; Huylenbroeck, Guido; Verbeke, Wim (2002): Determinants of the Willingness of Belgian Farmers to Participate in Agri-environmental Measures. In *J Agricultural Economics* 53 (3), pp. 489–511. DOI: 10.1111/j.1477-9552.2002.tb00034.x.

Wauters, Erwin; Bielders, Charles; Poesen, Jean; Govers, Gerard; Mathijs, Erik (2010): Adoption of soil conservation practices in Belgium: An examination of the theory of planned behaviour in the agri-environmental domain. In *Land Use Policy* 27 (1), pp. 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. In *Global Environmental Change* 23 (2), pp. 537–547. DOI: 10.1016/j.gloenvcha.2012.11.008.

Willock, Joyce; Deary, Ian J.; Edwards-Jones, Gareth; Gibson, Gavin J.; McGregor, Murray J.; Sutherland, Alistair et al. (1999): The Role of Attitudes and Objectives in Farmer Decision Making: Business and Environmentally-Oriented Behaviour in Scotland. In *Journal of Agricultural Economics* 50 (2), pp. 286–303. DOI: 10.1111/j.1477-9552.1999.tb00814.x.

Woods, Bryndís Arndal; Nielsen, Helle Ørsted; Pedersen, Anders Branth; Kristofersson, Dadi (2017): Farmers’ perceptions of climate change and their likely responses in Danish agriculture. In *Land Use Policy* 65, pp. 109–120. DOI: 10.1016/j.landusepol.2017.04.007.

Wu, JunJie; Babcock, Bruce A. (1998): The Choice of Tillage, Rotation, and Soil Testing Practices: Economic and Environmental Implications. In *American Journal of Agricultural Economics* 80 (3), pp. 494–511. DOI: 10.2307/1244552.

Zheng, Y.; Dallimer, M. (2016): What motivates rural households to adapt to climate change? In *Climate and Development* 8 (2), pp. 110–121. DOI: 10.1080/17565529.2015.1005037.

8 Annex: Overview of survey studies on drivers of drought risk management and adaptive behavior (as of March 2018).

ID	Author	Title	Theory and Method	n	R^2	Variables
1	Arbuckle et al. (2013)	Farmer beliefs and concerns about climate change and attitudes toward adaptation and mitigation: Evidence from Iowa	Minor reference to TPB Cumulative logit model.	1,276	(Nagelkerke) R^2=0.26-0.53	Dependent Variable (DV): support for adaptation (and) mitigation action in general not necessarily with respect to their specific farm. Adaptation measures are with respsect to increased precipitation as predicted by the IPCC for Iowa. Independent Variable (IV): overall index of concern about the impacts of climate change; variable on human ingenuity as a reason not to be concerned. Control Variables (CV): row crops farmed, age, educatoin Relationship (R): concerned farmers rather support adaptation and mitigation options, unconcerned one did not support mitigation options.
2	Arbuckle et al. (2015)	Relationship between farmers' belief about climate change, including its main causes and potential impacts, and their attitude towards adaptation and mitigation actions in the US	Values believes norms framework Standardized survey Structural equation model	1,276	n.a.	DV: Attitude towards adaptation measures (and mitigation measures) (5-point Likert agree-disagree) IV: Believes about climate change, trust in sources of information, risk perception. R: Positive effect of risk perception on attitude towards adaptation measures.
3	Van Duinen et al. (2015a)	Farmers' drought adaptation in the south-west Netherlands	PMT, Poisson regression and binary logistic regression	142	Nagelkerke R^2=0.1-0.43	DV: drought risk preparedness (= number of implemented risk mitigation measures) IV: perceived probability and severity (=threat appraisal), perceived control efficacy, cost and self-efficacy (=coping appraisal)
4	Haden et al. (2012)	What Attitudes and Beliefs Motivate Farmers to Mitigate and Adapt to Climate Change?	Standardized mail survey Multiple mediation models	162	R^2=0.19	DV: willingness to adopt adaptation measures (new irrigation and new cropping practices. (Likelihood to use new measures, 5-point Likert) IV: Perceived change in local water availability, perceived change in summer temperature, mediated by future local water/temp concerns; structural and socio-economic control variables (results of the latter not discussed in paper) R: Positive influence of perceived change in local water availability on willingness to adopt new adaptation measures. Otherwise no significant relationships
5	Hamilton-Webb et al. (2017)	The relationship between risk experience and risk response: a study of farmers and climate change	No theory. Argues based on Haden 2012 and Kahnemann. T-tests	200	n.a.	DV: climate risk response IV: experience with flood risk

						R: experience and believe in climate change associated, also with adaptive behavior although study suggests that adaptation efforts found are rather part of regular farming practice.
6	Li et al. (2017)	Relating farmer's perceptions of climate change risk to adaptation behaviour in Hungary	No theoretical model Standardized survey Multivariate analysis (path analysis)	110	R^2=0.04	DV: adaptation behavior assessed based on a list of seven measures IV: farmers' awareness of climate change related phenomena, beliefs in climate change risks R: awareness of extreme events positive effect on adaptation behavior
7	Mase et al. 2017	Climate change beliefs, risk perceptions, and adaptation behavior among Midwestern U.S. crop farmers	No main theory, reference to MPPACC, and Theory of Planned Behavior Regression analyses (OLS, logistic regression) and ordinal statistical model	4778	R^2=0.138	DV: (Stated) implemented/planned production based and financial adaptation measures. Index of 7 measures. IV: attitudes towards changing weather and adaptation, climate change belief/risk perception, perception of climate variability Control variables: Demographic variables, including farmer age, gender, state, and education were included in regression analyses where appropriate.
8	Niles et al. (2013)	Perceptions and responses to climate policy risks among California farmers	Mix of MPPACC (climate risk perception), hierarchical models (constraints of abstract postures on specific attitudes), and psychological distance models Structural equation modeling	162	n.a.	DV: climate risk response, translated to participation in government programs in climate change incentive programs. IV: Climate Change Experience, Past Policy Experience, Climate Change Beliefand Climate Change Risk. Past Policy Experience was measured by assessing a farmer's overall perspective on four past environmental policies CV: Significant demographic and farm characteristics including organic status, education level, whether a farmer was full time, and local origin were also included in this model. R: risk appraisal as well as climate change experiences, and experiences with policies affect climate policy risk response
9	Niles et al. (2015)	How limiting factors drive agricultural adaptation to climate change	Liebig's Law of the Minimum with the Psychological Distance Theory Multiple mediation models	490		DV: adoption of adaptation meaures IV: limiting factors within a farm system (water or temperature impacts) aka regional context
10	Niles et al. (2016)	Farmer's intended and actual adoption of climate change mitigation and adaptation strategies	TPB Regression models	490	R^2=0.12-0.32	DV: intended and actual adoption of adaptation measures IV: attitudes, subjective norms, and perceived capacity R: different drivers for intended and actual adoption. Attitudes and believes influenced intentions, subjective norms neither, and perceived capacity both.
11	Roche (2016)	Adaptation strategies and decision-making factors of rangelanders against drought in California	Adaptive rangeland decision-making framework Standardized survey Conditional inference regression tree and structural equation modelling	479	n.a.	DV: Drought adaptation LCA created four classes of drought strategies. IV: drought experience, management capacity, goal setting and information sources, operation structure Rs: drought experience has a significant influence on adaptive behavior, so do, but to a lesser degree the information resource network mediated via management capacity and goal setting.
12	Roesch-McNally et al. (2017)	Adaptation intentions of Corn Belt farmers in the light of climate change	TPB and Reasoned Action Approach, binary logistic regression	4778	Pseudo R^2=0.19	DV: increased future use of no-till farming, cover crops and subsurface tile drainage practices (= intention to increase the use of selected mitigation practices)

						IV: attitude towards adaptation, risk perception and strategies (flooding, drought, extreme rains, erosion, diversification, crop insurance); normative influences (productivist, stewardship, visiting farmers); perceived behavioral control (knowledge and skills, confidence in practices); background factors (age, education, income, erodible land, current practices in use)
13	Roesch McNally et al. (2018)	Barriers to implementing climate resilient agricultural strategies: The case of crop diversification in the U.S. Corn Belt	No theoretical backdrop Standardized survey, and qualitative interviews Multi-level modeling, The dependent variable is a binary response variable; therefore, we use a hierarchical generalized linear model (HGLM)	4778 159	R^2=0.11	DV: decision to use extended crop rotations IV: Productivist identity (factor score), Stewardship identiy (factor score), **All Cattle (count)**, Crop Insurance (ha covered), Corn Markets supplied (six options), Water Concern (sum scale of concern with respect to four risks), **HEL (ha of highly erodible land planted in 2011)**, **DiversifyAdapt** (intention to increase div. rotation in response to climate change), AltMarkets (position towards new markets for alternative crops), Education, **Farm Revenue**$^-$
14	Wheeler et al. (2013)	Irrigating farmers' adaptation to water scarcity in Australia	Theory of planned behavior in combination with modified 5C approach, OLS, bivariate and binary probit regression	1510	R^2 =0.37 Pseudo R^2 = 0.07-0.26	DV: adaptive index based on planned strategies (continuous variable ranging from -3 to +5) IV: Human capital (believes in CC, tradition factor, commerce factor, environment factor, technology factor, age, gender, education, health, risk attitude, experience, successor in place, whole farm plan); Farm capital (irrigated hectares, dryland hectares, fulltime employees, annual crops horticulture, grazing, purchased and sold water, increased/decreased irrigated area, purchased farmland, change in crop mix, improved irrigation efficiency, water received, reuse area, drip infrastructure, organic certified farm); Social capital (membership in environmental group, information from GO/NGO); Financial capital (positive productivity change, farm operating surplus, farm debt/equity ratio, larger off farm work); Regional capital (net evaporation, mean end season allocation)
15	Van Winsen et al. (2016)	Determinants of risk behaviour: effects of perceived risks and risk attitude on farmer's adoption of risk management strategies	Structural-equation modeling	500	n.a.	DV: intention to adopt agricultural risk management in the near future (5-point Likert). Diversifying income (tourism, farmers market), diversifying production, obtaining price contracts, hedging on future markets, buying non-obligatory insurances, investing in technical optimization of farm, investing in scale enlargement, working harder in times of financial uncertainty, postponing private purchases, obtaining an off-farm income, keeping a financial buffer IV: risk attitude and risk perception as sole explanatory factors CV: farm size, level of education, age,
16	Woods et al. (2017)	Farmers' perceptions of climate change and their likely responses in Danish agriculture	Elements of MPPACC, loss aversion vs. prefperence for gains, prospect theory Standardized survey (online panel) Descriptive statistics and an ordered probit model	1053	n.a.	DV: climate change risk perception, belief in global climate change, perceived barriers to undertaking adaptive action (perceived adaptive capacity), and loss aversion versus preference for actions that lead to gains IV: climate change risk perception, belief in global climate change, perceived barriers to undertaking adaptive action (perceived adaptive capacity), and loss aversion versus preference for actions that lead to gains

						CV: (1) the number of years spent on the farm, which can affect a farmers' path dependency and routines; (2) farm income, which affects objective adaptation capacity; (3) farm area; and (4) the number of crops grown at the farm, both of which affect the "maneuverability" of farm practice

DV=Dependent variables, IV=Independent variables, CV= Control variables, R=relationships discovered.

International Institute for
Applied Systems Analysis
IIASA www.iiasa.ac.at

Address: IIASA, Schlossplatz 1, A-2361 Laxenburg, Austria

Email: repository@iiasa.ac.at