Available online at www.sciencedirect.com
SCIENCE DIRECT®
Global Environmental Change 15 (2005) 199–213
Global Environmental Change
www.elsevier.com/locate/gloenvcha

Adaptive capacity and human cognition: The process of individual adaptation to climate change

Torsten Grothmann[a,*], Anthony Patt[b]

[a]Department of Global Change and Social Systems, Potsdam Institute for Climate Impact Research, P.O. Box 60 12 03, 14412 Potsdam, Germany
[b]Department of Geography, Boston University

Received 8 March 2004; received in revised form 30 November 2004; accepted 24 January 2005

Abstract

Adaptation has emerged as an important area of research and assessment among climate change scientists. Most scholarly work has identified resource constraints as being the most significant determinants of adaptation. However, empirical research on adaptation has so far mostly not addressed the importance of measurable and alterable psychological factors in determining adaptation. Drawing from the literature in psychology and behavioural economics, we develop a socio-cognitive Model of Private Proactive Adaptation to Climate Change (MPPACC). MPPACC separates out the psychological steps to taking action in response to perception, and allows one to see where the most important bottlenecks occur—including risk perception and perceived adaptive capacity, a factor largely neglected in previous climate change research. We then examine two case studies—one from urban Germany and one from rural Zimbabwe—to explore the validity of MPPACC to explaining adaptation. In the German study, we find that MPPACC provides better statistical power than traditional socio-economic models. In the Zimbabwean case study, we find a qualitative match between MPPACC and adaptive behaviour. Finally, we discuss the important implications of our findings both on vulnerability and adaptation assessments, and on efforts to promote adaptation through outside intervention.

Keywords: Climate change; Adaptation; Adaptive capacity; Protection motivation theory; Behavioural economics

1. Introduction

Since the widespread recognition of anthropogenic climate change as a serious concern, in the 1980s, scientists from many disciplines have undertaken research and assessment of the likely impacts. For example, they have estimated the probability and intensity of higher temperatures, sea level rise, weather extremes, the breakdown of the thermohaline circulation, the effect on biodiversity, and the loss of property and lives because of these changes (McCarthy et al., 2001). After contributing to climate change impact assessments, the social sciences' contribution centered on the topic of mitigation: how best and at what cost to limit global climate change through reducing the emissions of greenhouse gases. Soon also adaptation to climate change, the adjustments by the affected human and natural systems to moderate potential changes or to benefit from opportunities associated with climate change, gained social scientists' attention. It was seen as essential to include adaptation by the affected human or natural systems in the assessment of climate change impacts. By making certain assumptions about how people and societies will respond to climate change, and incorporating these responses in the assessment of damages, economists could more accurately compare the costs and benefits of particular mitigation policies (Fankhauser, 1996; Pittock and Jones, 2000; Smit et al., 1999; Tol et al., 1998; UNEP, 1991; Yohe et al., 1996).

More recently, *adaptation* has also come to be considered an important response option worthy of

*Corresponding author. Tel.: +49 331 288 2557; fax: +49 331 288 2642.
E-mail addresses: torsten.grothmann@web.de (T. Grothmann), apatt@bu.edu (A. Patt).

0959-3780/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.gloenvcha.2005.01.002

research and assessment, not simply in order to guide the selection of the best mitigation policies, but rather to reduce the vulnerability of groups of people to the impacts of climate change, and hence minimize the costs associated with the inevitable (Kane and Shogren, 2000; Pielke, 1998; Smit and Pilifosova, 2001). This has, in part, stemmed from a realization that a certain amount of climate change will occur, and that society can take concrete steps to minimize the net losses (including taking advantage of opportunities for gains) (Schröter et al., 2005).

Social scientists' contribution to the study and assessment of adaptation has crossed several disciplines, and drawn off of a long tradition of studying vulnerability to natural hazards and to food insecurity (Dilley and Boudreau, 2001). Geographers and anthropologists have identified many ways in which traditional practices allow for greater adaptive capacity, and how a disruption of social cohesion reduces people's adaptive capacity, making them less resilient to environmental stress (Adger, 2000; Adger et al., 2003; Scoones et al., 1996). At the same time as traditional practices and power structures may increase a society's adaptive capacity, they may stand in the way of people making more permanent adjustments in response to the occurrence, or threat, of longer-term environmental change (Adger, 1999, 2000; Patt and Gwata, 2002; Ribot, 2002; Ribot et al., 1996). Specialists in particular areas of adaptation (e.g., agriculture, or coastal zone management) have identified particular policies, such as enhanced communication of climate-related information or the development of insurance networks, that can assist adaptation (Freeman and Kunreuther, 2002; Klein et al., 1999, 2001; Patt, 2003; Phillips, 2003; Podestá et al., 2003; Wilbanks, 2003). Likewise, scholars of international relations and international institutions have identified appropriate funding and incentive building mechanisms (Klein, 2002). Economists have started to develop indicators for adaptive capacity (Yohe and Tol, 2002a, b).

However, with few exceptions (Hartmuth, 2002; Kroemker and Mosler, 2002; Linneweber et al., 2002; Patt, 2001; Viscusi and Chesson, 1999; Weber, 1997), there has been little study of the psychological dimensions of adaptation. This stands in contrast to the many studies examining the interplay between psychology and mitigative behaviour (e.g., Hammitt and Harvey, 2000; O'Connor et al., 1999, 2002; Poortinga et al., 2003) and the lay public's misconceptions about causes and effects of climate change (e.g., Bostrom et al., 1994; Boyes and Stanisstreet, 1997, 1998; Dunlap, 1996; Francis et al., 1993; Henderson-Sellers, 1990; Kempton, 1991; Koulaidis and Christidou, 1999; Löfstedt, 1992; McDaniels et al., 1996; Read et al., 1994). Although people's beliefs about risks, chances and adaptation options drive much of the process of adaptation to climate change, the role of cognition in adaptation to climate change has so far been largely neglected.

In this paper, we argue from both theory and case study evidence that policy makers in fact ought to consider the psychological aspects of adaptation. The theoretical argument derives from literature in the related fields of psychology and behavioural economics. From these disciplinary perspectives, we first review research on adaptation and adaptive capacity in climate change research, and in particular the failure to consider motivation and perceived adaptive capacity in this research. Second, we propose a socio-cognitive model of adaptation and adaptive capacity that compensates for the weaknesses of adaptation theorizing from a cognitive perspective. Third, we present data from two very different case studies that show the explanatory power of the model proposed. The first examines the precautionary behaviour of German residents of flood-prone regions to protect themselves from damage. The second examines the decisions of Zimbabwean farmers to take steps to mitigate the effects of forecasted drought. We conclude the paper with a discussion of implications for vulnerability assessment, adaptation policy, and questions for further research.

2. Constraints to adaptation: from physical, to institutional, to psychological

Research and assessment of climate change adaptation have developed out of three prior lines of inquiry (Schröter et al., 2005). First, there exists a long tradition among geographers of examining the vulnerability of people and places to natural hazards, such as floods, earthquakes, and fires. Researchers have shown how the existence of particular institutions (e.g., the media) can play a role in amplifying or attenuating the associated risks (Kasperson and Kasperson, 1996). Within the hazards literature, there has been some study of how people behave under conditions of uncertainty, and the possibility that they systematically underestimate the likelihood of the hazard affecting them, with dire consequences (Freeman and Kunreuther, 2002; Kunreuther, 1996). The recognition that climate change may lead to more extreme events provides the direct link from this line of research to climate change vulnerability and adaptation work (McBean, 2004). Second, researchers have been expanding the list of causes for episodes of food insecurity, from occurrence of drought to underlying social conditions and structures (Downing, 1991; Ribot et al., 1996). Such study of food security vulnerability, likewise, links to climate change vulnerability because of the likely increase of food insecurity triggering events (Kasperson and Kasperson, 2001; Kelly and Adger, 2000). Third, within the climate change community there has been a history of integrated

assessment modeling, in order to suggest optimal climate change mitigation pathways (Glantz, 2003). These studies, in turn, have required extensive assessment of the impacts of climate change, in order to arrive at estimates of climate-related losses that could be averted through policy change (McCarthy et al., 2001). The link from impacts assessment to vulnerability assessment is the recognition that adaptation is not just something to be undertaken at some future time, when and if climate change occurs, but that it is an inevitable activity that is already ongoing, and thus able to be studied (Kelly and Adger, 2000). Current assessment of adaptation often takes place within the assessment of vulnerability, since the two are now seen as inextricably linked (Luers et al., 2003; O'Brien et al., 2004).

One of the central differences between adaptation and mitigation as a response to climate change, in addition to the aspect of the problem they address, is the scale at which the response might take place (Füssel and Klein, 2005). As Adger (2001) argues, mitigation is an activity that must take place at the global scale, in order to be effective. Adaptation, by contrast, can take place at a number of scales, from local to global, addressing climate-related problems at that particular level, and making use of capacities available to that group of actors (Adger, 2001). Hence, it is not surprising that a great many studies within the adaptation literature focus on assessing capacity at the local or regional level, and the various constraints—institutional, informational, and financial—that often stand in the way (Berkes and Jolly, 2001; Broad et al., 2002; Dessai and Hulme, 2004; Glantz, 2003; Kelly and Adger, 2000; Lüdecke et al., 1999; O'Brien et al., 2004; Parson et al., 2003; Wilbanks, 2003). Adger (2000), e.g., highlights the presence of factors associated with the transition of Vietnam from a Marxist to a market economy, which on the one hand hinder the capacity of the country to engage in centralized adaptive planning, and yet on the other hand provide additional wealth, reducing vulnerability (Adger, 2000). From studies such as this come some general lessons about the effects of social, economic, and political institutions in the adaptation process, particularly in developing countries (Adger et al., 2003).

With explicit reference to scale—both spatial and temporal—researchers have developed numerous taxonomies of adaptation (Bijlsma et al., 1996; Bryant et al., 2000; Carter et al., 1994; Leary, 1999; Reilly and Schimmelpfennig, 1999; Smithers and Smit, 1997; Stakhiv, 1994; UNEP, 1991). Klein (1998, 2003) distinguishes between *proactive* and *reactive* adaptation, as well as between *private* versus *public* adaptation. The first dimension refers to the timing of the adaptation, and whether it is motivated by predictions of an event occurring at an undetermined time in the future, or by the onset of the event itself. The second dimension refers to the actors, and therefore to the question of who adapts. A great number of researchers have conducted their research within the laboratory of extreme events and climate variability, suggesting that the factors that determine the responses to such events are often the same that influence the capacity to adapt to longer-term climate change (Golnaraghi and Kaul, 1995; Podestá et al., 2002; Ziervogel and Downing, 2004), especially since adaptation to climate change may involve primarily a response to a greater threat of the extreme (McBean, 2004). Later in this paper we draw from two case studies that are examples of responses to the risks of climate change related extreme events (flood and drought), and we suggest that they do shed important light on longer-term adaptation, since adaptation to climate change by private actors (like homeowners or farmers) does not qualify as adaptation to climate change as such (i.e., a global, long-term phenomenon) but as adaptation to climate change related regional and short-term impacts.

To identify the important bottlenecks, it is important to have an accurate conceptual model of the process of adaptation. Risbey et al. (1999) suggests four stages in the public adaptation process: *signal detection*, where it is decided what is adapted to and what is ignored; *evaluation*, where the signal is interpreted and foreseeable consequences are evaluated; *decision and response*, which results in an observable change in the behaviour and performance of the system; and *feedback*, which involves monitoring of the outcomes of decisions to assess whether they are as expected. Similarly, based on empirical studies of coastal management, Klein et al. (1999) structure what they call *planned* adaptation (public adaptation in our terminology) in four recurring steps: information collecting and awareness building, planning and design, implementation, and monitoring and evaluation.

These types of steps, of course, mirror the common assumptions about the policy development process. At the same time, however, they begin to suggest a failure of communication between the different disciplines: those concerned with climate change adaptation, on the one hand, and those concerned with human agency and social decision-making processes on the others. Seminal research in the American public sector, e.g., quickly dispelled the myth that decision-making follows a uni-directional sequential process, replacing it with a model of a halting 'incremental' process with periods of recycling, iteration and reformulation (Lindblom, 1959; Braybrooke and Lindblom, 1963). Although Lindblom's work began in public administration, further work in private sector organizations has come to similar (e.g., Quinn, 1978, 1980) or even more radical conclusions, discovering problem-solving processes lacking sequential characteristics (e.g., Mintzberg et al., 1976), sometimes seemingly chaotic (e.g., Cohen et al., 1972), and intimately connected with issues of power and political behaviour (e.g., Bachrach and Baratz, 1962). Likewise at

the level of the individual, researchers have reevaluated many of the assumptions of microeconomics from a psychological viewpoint, using psychological research methods. Many of these relate specifically to adaptation, such as the tendency of people to underestimate large probabilities and overestimate small ones (Crocker, 1981; Kahneman and Tversky, 1979). Many argue that designing effective public policy necessitates an appreciation of the conditions under which the individual actors are most prone to make decisions at cross purposes, decisions that they themselves will later come to regret (Gowda and Fox, 2002). In all cases, fixing problems of poor decision-making requires understanding how the process of decision-making actually takes place.

The failure to bring empirical literature on the science of decision-making, at the public, private, and individual levels into research on climate change adaptation has led to a focus on financial, technical, and institutional constraints as the primary determinants of adaptive capacity. As Smit and Pilifosova (2001, p. 882) summarize: 'These determinants of adaptive capacity relate to the economic, social, institutional, and technological conditions that facilitate or constrain the development and deployment of adaptive measures.' They argue that countries with limited economic resources, low levels of technology, poor information and skills, poor infrastructure, unstable or weak institutions, and inequitable empowerment and access to resources have little capacity to adapt and are highly vulnerable. Adger (2003, p. 29) argues, for individuals, that their capacity to adapt to climate change 'is a function of their access to resources'. Some scholars have noted that the influence of resources is not in terms of expanding options but rather operates through access to information (Phillips, 2003), while others suggest that resources alone are of questionable importance (Patt and Gwata, 2002).

Against this backdrop of neglect of knowledge on decision-making, there has been a growing amount of empirical research examining the link between cognitive factors and adaptation. Weber (1997) identifies perception and expectation of climate change as important preconditions for economic and technological adaptation of US farmers. From the perspective of behavioural economics, Patt and his colleagues work on decisions of subsistence farmers in Zimbabwe to follow seasonal climate forecasts and identify credibility and farmers' trust in the forecasts as major factors (Patt and Gwata, 2002; Patt, 2001; Suarez and Patt, 2004). Viscusi and Chesson (1999) detect ambiguity aversion (fear) and ambiguity seeking (hope) as relevant factors for the response of coastal North Carolina managers and business owners to the risks of storm damage posed by risks of climate change. Empirical studies that focus on psychological factors in climate change adaptation in Germany stem from Linneweber and his colleagues (Hartmuth, 2002; Linneweber et al., 2002). They relate perceptions and evaluations with regard to coastal zone protection of involved actors and decision-makers on the German island Sylt, which is at risk of climate change impacts, to their 'social representations' and positions in the social system. Not an empirical study, Kroemker and Mosler (2002) develop a theoretical model of adaptation to climate change based on perceptions of climate change risks and adaptation options.

The two cognitive factors we want to focus on in this paper are risk perception and perceived adaptive capacity. Perceptions of climate change risks have already been addressed in the few studies examining the link between cognitive factors and climate change adaptation. With regard to adaptation to climate change, the main determinant of the motivation to adapt—what an actor *wants* to do, indicated by motives like goals, values or norms—is the relative risk perception. The relative risk perception expresses the perceived probability of being exposed to climate change impacts and to the appraisal of how harmful these impacts would be to things an actor values (perceived severity), relative to the appraisal of how harmful and urgent other problems or challenges in life are. To use a natural-hazard example, the perceived probability relates to a person's expectancy of being exposed to a flood. The judgment that a flood in the area would harm valued things, such as home or property, would relate to the perceived severity. This process can be seen as a case of nominal/actual value comparison: the bigger the difference between the nominal value (what a person wants to happen or not to happen) and the actual value (what a person expects to happen), the more motivation or 'energy' is released for adaptation.

But if this energy really goes into adaptation is decided upon a cognitive factor largely neglected not only in the larger adaptation literature but also in the few psychological studies on climate change adaptation: perceived adaptive capacity. The objective ability or capacity of a human actor (what an individual, a group, or a culture *could* do, indicated by the availability and the access to resources) only partly determines if an adaptive response is taken. Even as important as this objective ability is the subjective or perceived ability of human actors because the subjective ability can be very different from the objective ability. In Bangladesh, e.g., religious people regard floods, tornadoes, and cyclones as an Act of God against which they cannot and should not do anything, so that in some cases they have to be forced to take refuge in shelters (Schmuck, 2000). Hence, human actors are not always aware of their objective action scope. Or, they perceive actions, which they could perform physically (e.g., going to a flood shelter), normatively as impossible. But people can also

overestimate their action scope. In psychology, these perceptions are called 'illusions of control' (e.g., Wortman, 1976). 'What relevant data we have on people's perceptions of environmental risks... suggest that people perceive little personal control over global and regional environmental problems' (Gardner and Stern, 1996, p. 224). Hence, there could very well be a systematic bias towards underestimating the objective adaptive capacity with regard to climate change impacts, which often appear irrational to an outside observer. We are not proposing that objective resources like the socio-economic features stated by the IPCC authors or institutional structures and entitlements are unimportant determinants of adaptive capacity and adaptation. But if agents systematically underestimate their own ability to adapt, this qualifies as a more important 'bottleneck' for adaptation than the objective physical, institutional or economic constraints.

3. A socio-cognitive model of private proactive adaptation to climate change (MPPACC): risk perception and perceived adaptive capacity

To explain why some people show adaptive behaviour while others do not, we develop a process Model of private proactive adaptation to climate change (MPPACC) based on Protection Motivation Theory (PMT) (Rogers, 1983; Rogers and Prentice-Dunn, 1997). Rogers originally proposed PMT in the context of health threats, where it has been applied quite successfully (cf., Floyd et al., 2000; Milne et al., 2000), and it is now accepted as one of the four major theories within the domain of psychological research on health behaviour. The theory appears to have broad applicability, including to natural and technological hazards, although studies applying PMT to environmental problems or natural hazards have been rare. One study by Mulilis and Lippa (1990) successfully applied PMT to earthquake preparedness. Although one theoretical article exists (Kroemker and Mosler, 2002), adaptation to climate change and its impacts has so far not been empirically studied using PMT.

One main feature of PMT in general, and the model presented here in particular, is its differentiation between two major perceptual processes. In the first process—'*risk appraisal*'—a person assesses a threat's probability and damage potential to things he or she values, under the condition of no change in his or her own behaviour. In the second—'*adaptation appraisal*'—a person evaluates his or her ability to avert being harmed by the threat, along with the costs of taking such action. Whereas the cognitive process of risk appraisal results in a particular risk perception, the result of the adaptation appraisal process is a specific perceived adaptive capacity. Fig. 1 depicts the model as we apply it to proactive private adaptation to climate change.[1]

In Fig. 1, risk appraisal has two subcomponents. First, *perceived probability* is the person's expectancy of being exposed to the threat (to use a natural-hazard example, that a flood reaches the house in which a person lives). Second, *perceived severity* is the person's appraisal of how harmful the consequences of the threat would be to things he or she values if the threat were to actually occur (e.g., a farmer's judgment that a drought in the area would harm valued things, such as food security or income).

Adaptation appraisal by contrast, comes after the risk perception process, and only starts if a specific threshold of threat appraisal is exceeded: 'A minimum level of threat or concern must exist before people start contemplating the benefits of possible actions and ruminate their competence to actually perform them' (Schwarzer, 1992, p. 235). Adaptation appraisal as well as its result, the perceived adaptive capacity, has three subcomponents. First, it includes a person's *perceived adaptation efficacy*, i.e., the belief in adaptive actions or responses to be effective in protecting oneself or others from being harmed by the threat (e.g., a judgment that changing cropping patterns would prevent damage from a drought). The second component, *perceived self-efficacy*, refers to the person's perceived ability actually to perform or carry out these adaptive responses (e.g., a person with few technical skills might perceive it as rather difficult to relocate electric devices in upper floors to prevent damage from flood). The third component, *perceived adaptation costs*, is the assumed costs of taking the adaptive response. This can include any costs (e.g., monetary, personal, time, effort) associated with taking the risk-reducing adaptive response. Although adaptation costs and self-efficacy are related—a person may find an adaptive response 'difficult' either because of small self-efficacy or high response costs—it is useful to differentiate them conceptually.

Based on the outcomes of the risk- and adaptation-appraisal processes, a person responds to the threat. Two general types of responses can be differentiated: *adaptation* and '*maladaptation*'. Adaptive responses are those that prevent damage,[2] and are taken if the risk perception and the perceived adaptive capacity are high. 'Maladaptive' responses include avoidant reactions (e.g., denial of the threat, wishful thinking, fatalism) and 'wrong' adaptations that actually increase climate change damage although not intended to do so (e.g.,

[1] To increase understandability in the environmental risk and climate change community, we do not follow the terminology used by Rogers.

[2] Adaptation to climate change refers to responses that avoid damage or increase benefits. The model presented here does not explain responses that increase benefits. The motivation for responses that increase benefits would not come from risk perceptions but from perceptions of chances.

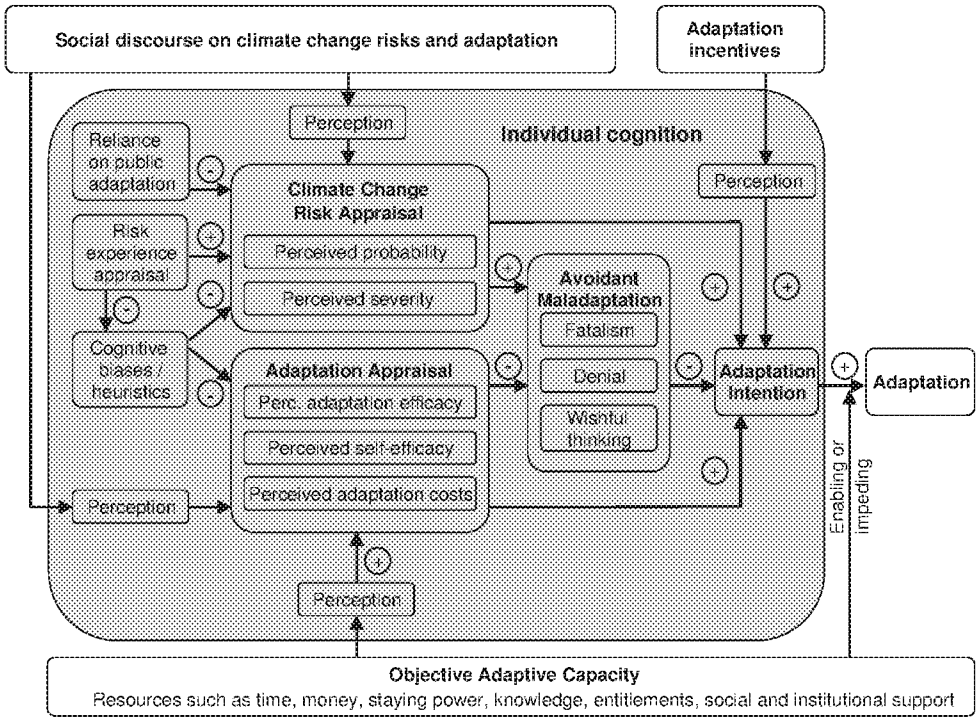

Fig. 1. Process model of private proactive adaptation to climate change (MPPACC).

rehabilitation programs that encourage development on flood plains and in exposed coastal zones) (Burton, 1996). In this paper, we only focus on the avoidant maladaptive responses. They do not prevent monetary or physical damage in the case of a climate change impact, but only the negative emotional consequences of the perceived risk of those impacts (e.g., fear). A person would take an avoidant maladaptation if his or her risk perception is high but the perceived adaptive capacity is low.[3]

If the person chooses the adaptive responses, he or she first forms a decision or intention to take these actions. While Rogers and his colleagues label this intention 'protection motivation', we name it *adaptation intention*. It is essential to distinguish between intention and actual behavioural adaptation, because people often have intentions but do not carry them out in actual behaviour. One of the reasons for this small intention realization is a lack of *objective adaptive capacity* (e.g., lack of resources like time, money, staying power, knowledge, entitlements, social or institutional support) that was not expected when the intentions were formed. In this case, the perceived behavioural options were overestimated (perceived adaptive capacity > objective adaptive capacity) or misestimated before. In line with this argument, we depict objective adaptive capacity in Fig. 1 as a direct determinant of adaptation. Objective adaptive capacity influences also the perceived adaptive capacity, since people's perceptions of their adaptive capacities are normally partly realistic. On the other hand, *cognitive biases and heuristics*, not included in the original PMT, can irrationally affect one's perceived adaptive capacity (e.g., Cervone and Peake, 1986; Kerr, 1989), leading to over-, under-, or misestimation of adaptive capacity. In most cases we expect a systematic bias towards an underestimation of adaptive capacity (Gardner and Stern, 1996, p. 224).

Data from other fields support this model of adaptation. In their meta-analysis of 27 studies testing PMT and a total of 7694 participants in the field of health behaviour, Milne et al. (2000) found risk perception to be positively correlated with avoidant maladaptation. This led them to conclude that high risk perception provides motivational energy to do something, either adaptive or maladaptive (e.g., Abraham et al., 1994; Rippetoe and Rogers, 1987). The specific response taken is then decided on the basis of the perceived adaptive capacity: In general, perceived self-efficacy and adaptation efficacy have been found to be negatively correlated with avoidant maladaptation, such as denial of the problem (e.g., Abraham et al., 1994; Eppright et al., 1994; Rippetoe and Rogers, 1987;

[3]Arguably, adaptiveness is a question of 'best fit' to an objective situation in which a person finds him- or herself. Therefore, an avoidant reaction, such as denial of the risk of flooding, could also be seen as an adaptive coping strategy for an ill and poor person living in a flood-prone area, who objectively has very little means of preventing flood damage proactively or reactively. In such a case, denial would be an adaptive response to protect this person's psychological well being before a flood, although this response would not be an adaptive one in the sense of preventing damage, if a flood actually occurs.

Tanner et al., 1989), but positively with adaptation (e.g., Abraham et al., 1994; Schwarzer and Fuchs, 1996). In addition, avoidant maladaptation has been found to inhibit adaptation intention (Abraham et al., 1994; Rippetoe and Rogers, 1987; van der Velde and van der Pligt, 1991).

We add to the complexity of existing PMT models by including additional variables in our MPPACC. It has been described already that *cognitive biases* and 'judgment heuristics' can affect people's perceived adaptive capacity irrationally. But they also influence risk perception. Errors of judgment are often most serious when levels of uncertainty are high (Patt and Zeckhauser, 2002; Rabin, 1998), which matches precisely the context within which adaptation must take place (Barnett, 2001). One widespread bias is the so-called optimistic bias or unrealistic optimism (Weinstein 1980, 1983, 1987). People often perceive their personal risk of being harmed by a certain threat (e.g., a storm) as smaller than the average risk. Another common bias is the so-called availability heuristic. This heuristic describes a process by which people estimate risks by searching their memories for vivid examples of such an event occurring (Tversky and Kahneman, 1974). This can lead to several biases: events that have occurred more recently are judged more likely to happen again, and events which create a more vivid memory, such as a plane crash versus an automobile accident, are often judged as more likely (Crocker, 1981; Kahneman and Tversky, 1979). On average, we expect that the different biases have a minimizing effect on climate change risk perception, leading to an underestimation of risk.

Nearly all studies on effects of personal experience on self-protective behaviour regarding natural hazards show preparedness increasing with the severity of past damage (Weinstein, 1989). Therefore, it seems reasonable to assume that *risk experience appraisal* plays an essential role in motivating people to take adaptive action against climate change. While risk perception assesses the probability and severity of a hypothetical threat in the future, risk experience appraisal assesses the severity of a risk experience in the past. It is assumed that risk experience has some positive influence on risk perception. Unlike risk perception, there is no uncertainty involved in the risk experience. Therefore, we assume that the risk experience appraisal influences the cognitive biases, mainly the optimistic bias, negatively, resulting in a higher risk perception.

Unlike the many health protective behaviours for which PMT was developed (e.g., quitting smoking, brushing one's teeth, or using condoms), private adaptation to climate change can be achieved by others' adaptive actions. To prevent cavities, a person has to brush his or her own teeth, and cannot rely on anyone else to do it for him or her. But private adaptation (e.g., private flood preparedness) sometimes will be redundant if public agencies conduct adaptation (e.g., successfully build levies to prevent floodwaters reaching people's doorsteps). If people rely on the efficacy of the public or administrative adaptation they will probably take less precautionary action themselves. Therefore, *reliance on public adaptation* is included in the model of private adaptation.

Cognition of an individual always depends on his or her socio-physical context, and the *social discourse* is important. For example, people's perceptions of risk or adaptive capacity with regard to climate change are influenced and shaped by what they hear about climate change in the media, from friends, colleagues, neighbours, or public agencies. Kasperson et al. (1988) introduced the framework of 'social amplification of risk' that addresses the influence of the broader societal, institutional and cultural context upon hazard perception and behaviour. We include the social discourse (or more specifically: the perception of the social discourse) as a determinant of people's risk perception and perceived adaptive capacity in our model. In addition, we include *adaptation incentives* (like tax reductions, laws or social norms for adaptation) and the perception of these incentives as a determinant of the adaptation intention. Adaptation incentives can play the role of providing additional motivation for adaptation, but can also play the role of being an alternative source of motivation in case there is no risk perception.

4. Explanatory power of the MPPACC: two case studies

We have argued that the objective ability or capacity of a human actor only partly determines whether that actor will take an adaptive response. By actor, we refer mainly to an individual, but also to a group, or a society. Risk perception and perceived adaptive capacity are factors we believe to be important, but which most adaptation models in the climate change literature have so far omitted. To examine the explanatory power of our model, we now use it to analyse results from two case studies. Each study predated the development of the current model. The first of these is a study of decisions to adapt to the threat of flooding in Cologne, Germany, a city of about 1 million residents on the banks of the Rhine River. More information about the background of that study is described in Grothmann and Reusswig (2005). The second is a study of decisions to change farming practices to adapt to predictions of seasonal rainfall in Zimbabwe. The background of this study is presented in more detail in Patt and Gwata (2002). Both case studies deal with people's adaptive responses to the risk of extreme events and information about climate variability, which many researchers have highlighted as central features of climate change (McCarthy et al., 2001).

4.1. Residents' proactive adaptation in Germany to the risk of river flooding

The design of the Cologne study allows us to compare the validity of our socio-cognitive model of private proactive adaptation (including only perceptual variables like perceived adaptive capacity) to a classical 'objective adaptive capacity model' based solely on socio-economic variables. We interviewed 157 randomly chosen residents living within flood-prone areas of Cologne, a major city with a population of about 1 million located on the Rhine River in Germany. Respondents were asked for their past experiences with flooding, perceptions of risk regarding future floods, reliance on public flood protection, perceived adaptive capacity, avoidant maladaptation, and finally actual self-protective behaviour regarding the following four measures of flood adaptation:

- informing oneself about options for self-protection from flood damage,
- avoiding expensive furnishings in the basement and first floor,
- purchasing flood protection devices like protective barriers for windows and doors or pumps,
- taking structural measures (e.g., putting the heating in upper floors).

Two regression analyses were used to assess the explanatory power of the proposed socio-cognitive model of residents' proactive damage prevention compared to the socio-economic 'objective adaptive capacity model' (including age, gender, highest school degree, household's net income, tenant or owner of the dwelling). The socio-economic model yielded significant explanations of the variance in adaptive responses only in three of four cases—for avoidance of expensive furnishings it could not provide any significant explanation—accounting for between 3% and 35% of the variance. Among the three significant socio-economic regressions, only home ownership was always statistically significant. Controlling for ownership, household income predicted only the purchase of flood protection devices. By contrast, the socio-cognitive model of proactive flood damage prevention could explain between 26% and 45% of the variance in the four different adaptive responses, yielding statistically significant explanations in all four cases. A panel study by Grothmann (2005) after the August 2002 flood in eastern Germany with a much larger sample ($N = 1000$) appears to yield very similar results. Consequently the socio-cognitive model (including risk perception, perceived adaptive capacity, etc.) could explain private proactive adaptation better than the socio-economic model (including home ownership, etc.).

That ownership turned out to be an important factor in explaining residents' adaptive responses is unsurprising, since owners have both more to lose because of floods, and more opportunity to take independent action.[4] The relative insignificance of households' net income for adaptation is, by contrast, a surprising result. Assessments of vulnerability to climate change—in most cases conducted on the level of nations—very often take GDP as one or the only determinant of adaptive capacity and adaptation. Yohe and Tol (2002a, b), e.g., studied vulnerability to flooding events along the Rhine River in the Netherlands, using per capita GDP as an explanatory variable. They found that wealth did significantly correlate with reductions in vulnerability, measured in terms of numbers of people affected by flooding events. Their results can be reconciled with ours in three ways. First, they did not control for home ownership, a variable that was highly intercorrelated with income in our Cologne study but which explained adaptation to a higher degree, indicating that ownership is the more important determinant of adaptation. Second, Yohe and Tol did not specifically study private adaptation, but rather the combined effects of private and public adaptation on present day vulnerability. Third, it may also be that the adaptation decisions accumulating over time and multiple actors, and hence the present day vulnerability, do correlate with wealth to an extent that a single snapshot of adaptation does not; the psychological factors may cancel each other out, whereas wealth does not. In either case, the use of GDP as an indicator of adaptive capacity may prove useful for the first purpose of adaptation assessment, namely predicting damage from climate-related events. Our results suggest, however, that it may be less useful for the second purpose of adaptation research and assessment, understanding the process of adaptation in order to promote it more effectively.

4.2. Farmers' proactive adaptation in Zimbabwe to the risk of drought

The German case study illustrates the importance of socio-cognitive factors for adaptation in a highly developed country context. In this section, a case study from rural Zimbabwe examines the other end of the development spectrum, and shows the role that cognitive biases and lack of perceived adaptive capacity can play in adaptation. The basis of this case study is ongoing work examining decision-making by subsis-

[4]Accordingly, ownership was correlated with perceived adaptive capacity regarding structural measures ($r = .31, p < .01$) and purchase of flood protection devices ($r = .24, p < .01$), meaning that owners regarded their ability to undertake these protective responses as higher than did tenants.

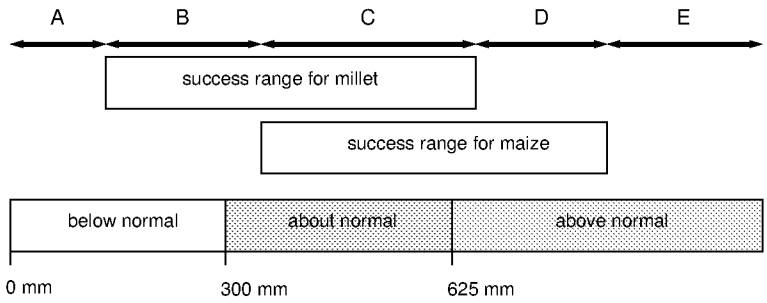

Fig. 2. Idealized forecast evaluation framework.

tence farmers, given information about seasonal climate variability. In a 5 year study, researchers are examining whether farmers in four villages in Zimbabwe are able to use the seasonal climate forecasts in order to change their decisions, and improve their yields (Patt and Gwata, 2002). Several past studies, undertaken in several developing countries, have shown that forecasts offer farmers enough information to make strategic choices that will improve their harvests (Glantz, 2001; Phillips et al., 1998), and have also shown cognitive constraints to be a fruitful area for investigation (Ziervogel, 2004).

Each year in September, climatologists from southern Africa, the World Meteorological Organization, the International Research Institute for Climate Prediction, and several other international organizations meet at the Southern African Regional Climate Outlook Forum (SARCOF), in which they develop a rainfall forecast for numerous homogenous rainfall zones in the region (NOAA, 1999). The climatologists make use of the definition of above normal, about normal, and below normal rainfall, which are those ranges that occur one-third of the time (SARCOF-6, 2002). Defining the ranges for a particular geographical place (e.g., a village) requires examining the 30-year rainfall record, and identifying the ranges of rainfall that fell in the 10 wettest years, the 10 medium years, and the 10 driest years. The seasonal forecast, based on leading rainfall indicators such as the state of El Niño, expresses the probabilities of receiving rainfall within each of those ranges for the coming season, something more or less than 33% for each range (Mason et al., 1999a, b).

Immediately after the SARCOF, the researchers conduct daylong climate workshops with subsistence farmers and other local stakeholders, in which the group discusses the forecast and what it means for the planting decisions for the coming season (Suarez and Patt, 2004). Among these stakeholders are representatives for the agricultural extension service, which operates offices in all major towns, employing an extension officer to advise subsistence farmers in each village about best farming practices, marketing of crops, and selection of inputs. Typically, farmers begin planting in late October, so the workshops come early enough for the farmers to use the information when they make their personal planting decisions (Patt, 2005; Phillips et al., 2001). The researchers collect data on those decisions in a controlled household survey (surveying roughly equal numbers of people who had attended the workshops, and those who had not), and at the following year's workshop.

Fig. 2 provides an idealized (and much simplified) example of how the information *could* influence farmers to change their planting decisions, based in part on Patt (2005) and Phillips et al. (2001). The lower boxes represent the rainfall ranges unique to a hypothetical location: in ten of the last 30 years, this location received less than 300 mm; in 10 of the last 30 years, this location received between 300 and 635 mm; and in 10 of the last 30 years, this location received more than 625 mm. Above this, two rectangles represent approximate 'success ranges' for millet and for maize: the range of rainfall within which the crop will reach maturity and produce a reasonable harvest, without wilting (too dry) or waterlogging (too wet). Above these rectangles, thus, are five separate ranges of outcomes: A is the range within which both millet and maize will fail due to wilting; B is the range within which millet succeeds but maize fails; C is the range within which both crops succeed; D is the range within which maize succeeds but millet fails; E is the range within which both crops fail due to waterlogging.

Farmers prefer planting maize, for several good reasons. First, maize kernels are protected by the maize husks, meaning that birds and insects are less likely to eat the grains before harvest, whereas millet kernels are exposed. Second, dried maize kernels are larger and softer than millet kernels, meaning that they are easier to grind into meal, and then cook faster. Third, a successful maize yield is larger than a successful millet yield, in terms of tons of grain per hectare. Fourth, for 20 years both the commercial seed companies and the government of Zimbabwe have been promoting maize as more 'modern' than millet. For all of these reasons, farmers are in the habit of planting maize, and not millet. Not surprisingly, farmers say they prefer the taste

of cooked maize meal to cooked millet meal, because it is what they are used to.

During the workshops, the researchers and farmers together discuss the concepts inherent in Fig. 2: the meaning of the seasonal climate forecast in terms of the probabilities of different rainfall totals for their village, the planting options they have, and the amounts of rainfall under which the different options will succeed or fail, and analyse the planting decision accordingly. Consider a year in which there is a forecast that is on the dry side, something that occurs every few years, mainly because of El Niño. In 1997, e.g., the forecast was a 50% chance of below normal rain, a 35% chance of about normal rain, and a 15% chance of above normal rain. In such a year, the probability of being within range B is quite high (perhaps 50%), whereas the probability of being within range D is quite low (perhaps 10%). To an 'objective' analyst, this would seem to provide a good reason for planting millet instead of maize, despite the preferences for maize revealed in the last paragraph.

Farmers' reactions to the forecasts, at least at first, are often quite different, however. Most importantly, and consistent with the theory of probability weighting, farmers tend to show the following cognitive bias: They are insensitive to differences between the probabilities of A, B, C, D, and E, treating all of them roughly equally, and describing them with words like 'might' (Kahneman and Tversky, 1979; Kammen and Hassenzahl, 1999). Probability weighting suggests that many people do not respond to possible events in direct proportion to their assessed probabilities; they underweight large probabilities, and overweight small probabilities.

Typically, farmers choose not to change their actions, and continue to plant maize. They justify this behaviour with two lines of argument. First, they act as if D were still about as likely as B. That is, they might get a harvest with millet but not maize, and they might get a harvest with maize but not millet. They draw little distinction between the quantitative differences, and the forecast has not changed the qualitative differences. Second, there still looms the possibility of range A: even if they plant millet, the crops might still wilt due to dryness. Again, they show little sensitivity to the changing magnitude of threat.

In the first 2 years of the project, this pattern was especially pronounced, and discussions with farmers indicate that very few, if any, of them would change a decision in response to a forecast of dry conditions. Indeed, most farmers said that they had never done so when their local rainfall indicators (observations of bird migration, wind direction, winter frost, etc.), which they trust about as much as the SARCOF climate forecast, predicted low rainfall with high probability. Farmers said that in order to change their decisions, they would have to be very sure (more than 75%) that B *would* be the case, and also confident that A *would not* be the case. This is true despite the admonitions of the agricultural extension service to plant millet in all but the wettest of years. By the third year of the project, recently completed, it appears that those farmers who had attended each of the forecast workshops were starting to experiment with changing their decisions in response to the information. Partly, this seems a result of the repetition of role playing games within the workshops, as well as enforced evaluation of the decisions that take place at the workshops.

These results are consistent with the theme of this paper, and with the model shown in Fig. 1. First and foremost, farmers are not making changes in response to the information, and this is limited not by a lack of means—indeed, millet seed is more readily available and less expensive than maize seed—but by a lack of adaptation intention. Second, there are two factors that lead to this lack of intention. On the one hand, farmers' perception of the risks associated with not taking adaptive measures deviate from the objectively assessed risks. This shows up in their insensitivity to the difference between the relative likelihoods of being within ranges B and D, despite the climate forecast indicating such a difference. On the other hand, farmers are unwilling to believe that their actions can actually protect themselves from harm, indicating low perceived adaptive capacity. This appears in their emphasizing the possibility of arriving in range A, where despite planting millet, the crops still failed due to wilting. Third, the intervention study offers the hope that the lack of adaptation intention can be overcome by repetitive analysis of decisions and role plays. The results also appear to confirm others' findings about the role of cognitive factors in limiting the use of seasonal climate forecasts (Ziervogel, 2004).

5. Conclusion

Within the climate change literature, past work on adaptation and adaptive capacity has focused on factors—such as resources—that could determine whether people have an objective ability to act, and have modeled the process of adaptation in relatively simple, linear terms. Adaptation to climate change is just one example, however, of human decision-making under conditions of uncertainty. Outside of climate change, a large literature dealing with human decision-making and action suggests that motivation and perceived abilities are important determinants of human action. Several socio-cognitive variables have been shown to influence people's intentions, and actions in predictable ways. In this paper, we have argued that this general literature is likely to offer insights for the more specific case of action that climate change adaptation

represents. Hence, we have developed a socio-cognitive MPPACC based on PMT including risk perception and perceived adaptive capacity as the main determinants of adaptation. Perceived adaptive capacity has largely been neglected in the previous literature on adaptation to climate change. We argue, models of adaptation and adaptive capacity ought to include socio-cognitive variables. Our two case studies support this conclusion. The Cologne study showed that socio-cognitive factors did a better job of explaining adaptive behaviour than did objective socio-economic factors, such as home ownership and household income. The Zimbabwe case study showed how evidence of people's failure to adapt can be explained by cognitive factors.

Our findings are important because they suggest that a well-defined model of human decision-making—such as the PMT and MPPACC models—can offer predictive power to the task of assessing individual adaptive capacity. To the extent that our model does describe and predict the process of adaptation, it has important implications both on vulnerability and adaptation assessment, and on efforts to promote adaptation through outside intervention. First, it may be possible to make better predictions about future adaptation and vulnerability by including socio-cognitive indicators, such as perceived adaptive capacity. In most cases these indicators have to be measured through surveys (e.g., by asking people for their perceived ability to avoid damage from climate change impacts) and cannot be gained from existing public statistics. Second, it may be possible to do a better job of increasing adaptive capacity in general, or promoting particular adaptations. If the most important determinant of adaptive capacity is wealth, then there is little to do to increase it other than make people richer, something which is almost always a pre-existing policy goal. By contrast, if perceived adaptive capacity and other socio-cognitive factors influence adaptation and people's perceived adaptive capacity is lower than their objective adaptive capacity, then there may exist important policy options that have as-yet gone unnoticed. Moreover, in taking actions to promote particular adaptations, it would be worthwhile for policy makers to focus on the cognitive barriers that may exist. This of course is a practice that has long existed within risk communication, but which could also inform climate change policy. The risk communication literature contains many lessons for the structuring of information campaigns to promote consistent and sensible actions on the part of stakeholders, while preserving long-term trust between these people and the experts. The important role of perceived adaptive capacity in our case studies recommends that in addition to the communication of risk people need to get information on possible, effective and not too costly adaptation options. If only the risks are communicated without communicating adaptation options, people will probably react by avoidant maladaptive responses like denial of the risk.

While the model we present is well supported in the literature, the evidence we present draws from two very limited examples, which in turn represent very different social systems. To some extent, the fact that similar patterns were observed in urban Europe and rural Africa makes it easier to generalize these findings. Nevertheless, further research could answer several important questions. First, to what extent is the MPPACC model applicable beyond the two case studies we have presented, to describe, explain and predict adaptation across a wide range of cultures and conditions? Second, to what extent does a model relying on socio-cognitive factors apply to public adaptation, i.e., that undertaken by administrative bodies? Third, to what extent do socio-cognitive factors cancel themselves out over multiple actors and time: do they predict broader changes in societal vulnerability, or are other factors more important when looking at aggregate adaptation decisions? Fourth, what is a more complete and general list of socio-cognitive factors that do appear to play a role, and how can policies influence those factors most effectively to improve both adaptive capacity and overall societal welfare? This is a long list of questions, and answering them will take years of work by a wide group of social scientists. Ultimately, however, answering them may improve our understanding of the link between human decision-making and the task future generations will face better to manage changes in the world around them.

Acknowledgments

Funding for this research came from the Potsdam Institute for Climate Impact Research, the German Ministry of Education and Research, and from the United States National Oceanic and Atmospheric Administration Human Dimensions of Global Change and Environment Science and Development research programs. The authors would like to acknowledge the comments and suggestions of Fritz Reusswig, Richard Klein, and two anonymous reviewers. All remaining errors are the fault of the two authors.

References

Abraham, S.C.S., Sheeran, P., Abrams, D., Spears, R., 1994. Exploring teenagers' adaptive and maladaptive thinking in relation to the threat of HIV infection. Psychology and Health 9, 253–272.

Adger, W.N., 1999. Social vulnerability to climate change and extremes in coastal Vietnam. World Development 27 (2), 249–269.

Adger, W.N., 2000. Institutional adaptation to environmental risk under transition in Vietnam. Annals of the Association of American Geographers 90 (4), 738–758.

Adger, W.N., 2001. Scales of governance and environmental justice for adaptation and mitigation of climate change. Journal of International Development 13, 921–931.

Adger, W.N., 2003. Social Aspects of adaptive capacity. In: Smith, J.B., Klein, R.J.T., Huq, S. (Eds.), Climate Change, Adaptive Capacity and Development. Imperial College Press, London, pp. 29–49.

Adger, W.N., Huq, S., Brown, K., Hulme, M., 2003. Adaptation to climate change in the developing world. Progress in Development Studies 3 (3), 179–195.

Bachrach, P., Baratz, M.S., 1962. The two faces of power. American Political Science Review 56, 947–952.

Barnett, J., 2001. Adapting to climate change in the Pacific island countries: the problem of uncertainty. World Development 29 (6), 977–993.

Berkes, F., Jolly, D., 2001. Adapting to climate change: social-ecological resilience in a Canadian western Arctic community. Conservation Ecology 5 (2), 18 (online).

Bijlsma, L., Ehler, C.N., Klein, R.J.T., Kulshrestha, S.M., McLean, R.F., Mimura, N., Nicholls, R.J., Nurse, L.A., Pérez Nieto, H., Stakhiv, E.Z., Turner, R.K., Warrick, R.A., 1996. Coastal zones and small islands. In: Watson, R.T., Zinyowera, M.C., Moss, R.H. (Eds.), Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change: Scientific–Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, pp. 289–324.

Bostrom, A., Morgan, M.G., Fischhoff, B., Read, D., 1994. What do people know about global climate change? I. Mental models. Risk Analysis 14 (6), 959–970.

Boyes, E., Stanisstreet, M., 1997. Children's models of understanding of two major global environmental issues (ozone layer and greenhouse effect). Research in Science and Technological Education 15 (1), 19–28.

Boyes, E., Stanisstreet, M., 1998. High school students' perceptions of how major global environmental effects might cause skin cancer. Journal of Environmental Education 29 (2), 31–36.

Braybrooke, D., Lindblom, C.E., 1963. A Strategy of Decision. Free Press, New York.

Broad, K., Pfaff, A.S., Glantz, M., 2002. Effective and equitable dissemination of seasonal-to-interannual climate forecasts: policy implications from the peruvian fishery during El Nino 1997–98. Climatic Change 54, 415–438.

Bryant, C.R., Smit, B., Brklacich, M., Johnston, T.R., Smithers, J., Chiotti, Q., Singh, B., 2000. Adaptation in Canadian agriculture to climatic variability and change. Climatic Change 45 (1), 181–201.

Burton, I., 1996. The growth of adaptation capacity: practice and policy. In: Smith, J.B., Bhatti, N., Menzhulin, G.V., Benioff, R., Campos, M., Jallow, B., Rijsberman, F., Budyko, M.I., Dixon, R.K. (Eds.), Adapting to Climate Change: An International Perspective. Springer, New York, NY, pp. 55–67.

Carter, T.R., Parry, M.L., Harasawa, H., Nishioka, S., 1994. IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations. University College, London, United Kingdom, and Centre for Global Environmental Research, Tsukuba, Japan (59pp).

Cervone, D., Peake, P.K., 1986. Anchoring, efficacy, and action: the influence of judgmental heuristics on self-efficacy judgments and behaviour. Journal of Personality and Social Psychology 50, 492–501.

Cohen, M.D., March, J.G., Olsen, J.P., 1972. The garbage can model of organizational choice. Administrative Science Quarterly 17 (March), 1–25.

Crocker, J., 1981. Judgment of covariation by social perceivers. Psychological Bulletin 90, 272–292.

Dessai, S., Hulme, M., 2004. Does climate adaptation policy need probabilities? Climate Policy 4, 107–128.

Dilley, M., Boudreau, T.E., 2001. Coming to terms with vulnerability: a critique of the food security definition. Food Policy 26, 229–247.

Downing, T.E., 1991. Vulnerability to Hunger in Africa: a climate change perspective. Global Environmental Change 1, 365–380.

Dunlap, R.E., 1996. Public Perceptions of Global Warming: A Cross-National Comparison. HDP Third Scientific Symposium, Geneva: HDP.

Eppright, D.R., Tanner Jr., J.F., Hunt, 1994. Knowledge and the ordered protection motivation model: tools for preventing AIDS. Journal of Business Research 30, 13–24.

Fankhauser, S., 1996. The potential costs of climate change adaptation. In: Smith, J., Bhatti, N., Menzhulin, G., Benioff, R., Budyko, M.I., Campos, M., Jallow, B., Rijsberman, F. (Eds.), Adapting to Climate Change: An International Perspective. Springer, New York, pp. 80–96.

Floyd, D.L., Prentice-Dunn, S., Rogers, R.W., 2000. A meta-analysis of research on protection motivation theory. Journal of Applied and Social Psychology 30, 407–429.

Francis, C., Boyes, E., Qualter, A., Stanisstreet, M., 1993. Ideas of elementary students about reducing the greenhouse effect. Science Education 77 (4), 375–392.

Freeman, P.K., Kunreuther, H., 2002. Environmental risk management for developing countries. The Geneva Papers on Risk and Insurance 27 (2), 196–214.

Füssel, H.-M., Klein, R.J.T., 2005. Climate change vulnerability assessments: an evolution of conceptual thinking. Climatic Change, in press.

Gardner, G.T., Stern, P.C., 1996. Environmental problems and human behavior. Needham Heights, Allyn & Bacon.

Glantz, M., 2001. Currents of Change: Impacts of El Niño and La Niña on Climate and Society, second ed. Cambridge University Press, Cambridge.

Glantz, M., 2003. Climate Affairs: A Primer. Island Press, Washington, DC.

Golnaraghi, M., Kaul, R., 1995. The science and policymaking: responding to ENSO. Environment 37 (pp. 16–20, 38–44).

Gowda, R., Fox, J. (Eds.), 2002. Judgments, Decisions, and Public Policy. Cambridge University Press, Cambridge UK.

Grothmann, T., Reusswig, F., 2005. People at risk of flooding: why some residents take precautionary action while others do not. Natural Hazards, in press.

Grothmann (2005). Climate change, weather extremes and private damage prevention. Development, testing and practical applicability of the theory of private proactive precaution against weather extremes. (In German: Klimawandel, Wetterextreme und private Schadensvorsorge. Entwicklung, Überprüfung und praktische Anwendbarkeit der Theorie privater proaktiver Wetterextrem-Vorsorge.) Dissertation, in preparation.

Hammitt, J.K., Harvey, C.M., 2000. Equity, efficiency, uncertainty, and the mitigation of global climate change. Risk Analysis 20 (6), 851–860.

Hartmuth, G., 2002. Wenn Sylt versinkt...Insulare Repräsentationen des globalen Klimawandels. Umweltpsychologie 6 (2), 8–25.

Henderson-Sellers, A., 1990. Australian public perception of the greenhouse issue. Climatic Change 17, 69–96.

Kahneman, D., Tversky, A., 1979. Prospect theory: an analysis of decision under risk. Econometrica 47, 263–291.

Kammen, D., Hassenzahl, D., 1999. Should we Risk it? Exploring Environmental, Health, and Technological Problem Solving. Princeton University Press, Princeton NJ.

Kane, S.M., Shogren, J.F., 2000. Linking adaptation and mitigation in climate change policy. Climatic Change 45 (1), 75–102.

Kasperson, R.E., Kasperson, J.X., 1996. The social amplification and attenuation of risk. Annals of the American Academy of Political and Social Science 545, 95–105.

Kasperson, J.X., Kasperson, R.E., 2001. International Workshop on Vulnerability and Global Environmental Change. SEI Risk and Vulnerability Programme Report 2001-01. Stockholm Environment Institute, Stockholm, Sweden.

Kasperson, R.E., Renn, O., Slovic, P., Brown, H.S., Emel, J., Goble, R., Kasperson, J.X., Ratick, S., 1988. The social amplification of risk: a conceptual framework. Risk Analysis 8, 177–187.

Kelly, P.M., Adger, W.N., 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Climatic Change 47, 325–352.

Kempton, W., 1991. Lay perspectives on global climate change. Global Environmental Change 1 (3), 183–208.

Kerr, N.L., 1989. Illusions of efficacy: the effects of group size on perceived efficacy in social dilemmas. Journal of Experimental Social Psychology 25, 287–313.

Klein, R.J.T., 1998. Towards better understanding, assessment and funding of climate adaptation. Change 44, 15–19.

Klein, R.J.T., 2002. Adaptation to climate variability and change: what is optimal and appropriate. In: Giupponi, C., Schechter, M. (Eds.), Climate change and the Mediterranean: Socio-Economics of Impacts, Vulnerability and Adaptation. Edward Elgar, Cheltenham, UK.

Klein, R.J.T., 2003. Adaptation to climate variability and change: what is optimal and appropriate? In: Giupponi, C., Schechter, M. (Eds.), Climate Change in the Mediterranean: Socio-Economic Perspectives of Impacts, Vulnerability and Adaptation. Edward Elgar, Cheltenham, UK, pp. 32–50.

Klein, R.J.T., Nicholls, R., Mimura, N., 1999. Coastal adaptation to climate change: can the IPCC Technical Guidelines be applied? Mitigation and Adaptation Strategies for Global Change 4, 239–252.

Klein, R.J.T., Nicholls, R., Ragoonaden, S., Capobianco, M., Aston, J., Buckley, E., 2001. Technological options for adaptation to climate change in coastal zones. Journal of Coastal Research 17 (3), 531–543.

Koulaidis, V., Christidou, V., 1999. Models of students' thinking concerning the greenhouse effect and teaching implications. Science Education 83 (5), 559–576.

Kroemker, D., Mosler, H.-J., 2002. Human vulnerability—factors influencing the implementation of prevention and protection measures: an agent based approach. In: Steininger, K., Weck-Hannemann, H. (Eds.), Global Environmental Change in Alpine Regions. Impact, Recognition, Adaptation, and Mitigation. Edward Elgar, Cheltenham, pp. 95–114.

Kunreuther, H., 1996. Mitigating disaster losses through insurance. Journal of Risk and Uncertainty 12 (3), 171–187.

Leary, N.A., 1999. A framework for benefit–cost analysis of adaptation to climate change and climate variability. Mitigation and Adaptation Strategies for Global Change 4 (3–4), 307–318.

Lindblom, C.E., 1959. The science of "muddling through". Public Administrative Review 19 (2), 79–88.

Linneweber, V., Deising, S., Fritsche, I., Hartmuth, G., 2002. Globaler Wandel im lokalen Kontext: Sylter Perspektiven auf Klimaänderungen. In: Daschkeit, A., Schottes, P. (Eds.), Sylt. Klimafolgen für Mensch und Küste. Springer, Berlin, pp. 219–249.

Löfstedt, R.E., 1992. Lay perspectives concerning global climate change in Sweden. Energy and Environment 3 (2), 161–175.

Lüdecke, M., Moldenhauer, O., Petschel-Held, G., 1999. Rural poverty driven soil degradation under climate change: the sensitivity of the disposition towards the Sahel Syndrome with respect to climate. Environmental Modeling and Assessment 4, 315–326.

Luers, A.L., Lobell, D.B., Sklar, L.S., Addams, C.L., Matson, P., 2003. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. Global Environmental Change 13, 255–267.

Mason, S., et al., 1999a. The IRI seasonal climate prediction system and the 1997–98 El Niño event. Bulletin of the American Meteorological Society 80 (9), 1853–1873.

Mason, S., Goddard, L., Graham, N., Yulaeva, E., Sun, L., Arkin, P., 1999b. The IRI seasonal climate prediction system and the 1997–98 El Niño event. Bulletin of the American Meteorological Society 80 (9), 1853–1873.

McBean, G., 2004. Climate change and extreme weather: a basis for action. Natural Hazards 31, 177–190.

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S. (Eds.), 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Cambridge University Press, Cambridge.

McDaniels, T., Axelrod, L.J., Slovic, P., 1996. Perceived ecological risks of global change. A psychometric comparison of causes and consequences. Global Environmental Change 6 (2), 159–171.

Milne, S., Sheeran, P., Orbell, S., 2000. Prediction and intervention in health-related behaviour: a meta-analytic review of protection motivation theory. Journal of Applied Social Psychology 30, 106–143.

Mintzberg, H., Raisinghani, D., Theoret, A., 1976. The structure of "unstructured" decision processes. Administrative Science Quarterly 21, 246–275.

Mulilis, J.-P., Lippa, R., 1990. Behavioural change in earthquake preparedness due to negative threat appeals: a test of protection motivation theory. Journal of Applied Social Psychology 20, 619–638.

NOAA, 1999. An Experiment in the Application of Climate Forecasts: NOAA-OGP Activities Related to the 1997–98 El Niño event. NOAA Office of Global Programs, US Department of Commerce, Washington, DC.

O'Brien, K., Sygna, L., Haugen, J.E., 2004. Vulnerable or resilient? A multi-scale assessment of climate impacts and vulnerability in Norway. Climatic Change 64, 193–225.

O'Connor, R.E., Bord, R.J., Fisher, A., 1999. Risk perceptions, general environmental beliefs, and willingness to address climate change. Risk Analysis 19 (3), 461–471.

O'Connor, R.E., Bord, R.J., Yarnal, B., Wiefek, N., 2002. Who wants to reduce greenhouse gas emissions? Social Science Quarterly 83 (1), 1–17.

Parson, E., Corell, R., Barron, E., Burkett, V., Janetos, A., Joyce, L., Karl, T., Maccracken, M., Melillo, J., Morgan, M.G., Schimel, D., Wilbanks, T.J., 2003. Understanding climatis impacts, vulnerabilities, and adaptation in the United States: building a capacity of assessment. Climatic Change 57, 9–42.

Patt, A.G., 2001. Understanding uncertainty: forecasting seasonal climate for farmers in Zimbabwe. Risk Decision and Policy 6, 105–119.

Patt, A.G., 18–20 November 2003. Communication for adaptation: participation and institutions. Paper Presented at the Insights and Tools for Adaptation: Learning from Climate Variability, Washington, DC.

Patt, A.G., 2005. Trust, respect, patience, and sea surface temperatures: useful climate forecasting in Zimbabwe. In: Alcock, F., Cash, D., Mitchell, R., Clark, W. (Eds.), Information as Influence: How Institutions Mediate the Impact of Scientific Assessments on International Environmental Affairs. MIT Press, Cambridge MA, in press.

Patt, A.G., Gwata, C., 2002. Effective seasonal climate forecast applications: examining constraints for subsistence farmers in Zimbabwe. Global Environmental Change 12, 185–195.

Patt, A.G., Zeckhauser, R., 2002. Behavioral perceptions and policies toward the environment. In: Gowda, R., Fox, J. (Eds.), Judgments,

Decisions, and Public Policy. Cambridge University Press, Cambridge UK, pp. 265–302.

Phillips, J., 2003. Determinants of forecast use among communal farmers in Zimbabwe. In: O'Brien, K., Vogel, C. (Eds.), Coping with Climate Variability: The Use of Seasonal Climate Forecasts in Southern Africa. Ashgate, Aldershot, UK, pp. 110–128.

Phillips, J., Cane, M.A., Rosenzweig, C., 1998. ENSO, seasonal rainfall patterns and simulated maize yield variability in Zimbabwe. Agricultural and Forest Meteorology 90, 39–50.

Phillips, J., Makaudze, E., Unganai, L., 2001. Current and potential use of climate forecasts for resource-poor farmers in Zimbabwe. Impacts of El Niño and climate variability on agriculture. American Society of Agronomy Special Publication Series 63, 87–100.

Pielke, R.A., 1998. Rethinking the role of adaptation in climate policy. Global Environmental Change 8 (2), 159–170.

Pittock, B., Jones, R.N., 2000. Adaptation to what and why? Environmental Monitoring and Assessment 61 (1), 9–35.

Podestá, G., Letson, D., Messina, C., Royce, F., Ferreyra, A., Jones, J., Hansen, J., Llovet, I., Grondona, M., O'Brien, J., 2002. Use of ENSO-related climate forecast information in agricultural decision-making in Argentina: a pilot experience. Agricultural Systems 74, 371–392.

Podestá, G., Broad, K., Letson, D., Weber, E., Hansen, J.W., Satorre, E., Herzer, H., Rajagopalan, B., Menéndez, A., 2003. Interannual climate variability and agriculture in Argentina: what did we learn. Paper Presented at the Insights and Tools for Adaptation: Learning from Climate Variability, Washington, DC.

Poortinga, W., Steg, L., Vlek, C., 2003. Myths of nature and environmental management strategies. A field study on energy reductions in traffic and transport. In: Moser, G.U.R.D.-P.V. (Ed.), People, Places, and Sustainability. Hogrefe and Huber Publishers, Ashland, OH, pp. 280–290.

Quinn, J.B., 1978. Strategic change: logical incrementalism. Sloan Management Review Fall, 7–21.

Quinn, J.B., 1980. Strategies for Change: Logical Incrementalism. Irwin, Homewood, IL.

Rabin, M., 1998. Psychology and economics. Journal of Economic Literature 36 (1), 11–46.

Read, D., Bostrom, A., Morgan, M.G., Fischhoff, B., Smuts, T., 1994. What do people know about global climate change? Survey studies of educated laypeople. Risk Analysis 14 (6), 971–982.

Reilly, J., Schimmelpfennig, D., 1999. Agricultural impact assessment, vulnerability, and the scope for adaptation. Climatic Change 43, 745–788.

Ribot, J., 2002. Democratic Decentralization of Natural Resources: Institutionalizing Popular Participation. World Resources Institute, Washington, DC.

Ribot, J.C., Magalhaes, A., Panagides, S. (Eds.), 1996. Climate Variability, Climate Change, and Social Vulnerability in the Semi-Arid Tropics. Cambridge University Press, Cambridge.

Rippetoe, P.A., Rogers, R.W., 1987. Effects of components of protection motivation theory on adaptive and maladaptive coping with a health threat. Journal of Personality and Social Psychology 52, 596–604.

Risbey, J., Kandlikar, M., Dowlatabadi, H., Graetz, D., 1999. Scale, context and decision-making in agricultural adaptation to climate variability and change. Mitigation and Adaptation Strategies for Global Change 4 (2), 137–165.

Rogers, R.W., 1983. Cognitive and physiological processes in fear appeals and attitude change: a revised theory of protection motivation. In: Cacioppo, B.L., Petty, L.L. (Eds.), Social Psychophysiology: A Sourcebook. Guilford, London, UK, pp. 153–176.

Rogers, R.W., Prentice-Dunn, S., 1997. Protection motivation theory. In: Gochman, D.S. (Ed.), Handbook of Health Behaviour Research. I: Personal and Social Determinants. Plenum Press, New York, NY, pp. 113–132.

SARCOF-6, 2002. Statement from the sixth Southern African Regional Climate Outlook Forum (SARCOF-6), held in Harare, Zimbabwe, 4–6 September 2002. Paper Presented at the SARCOF-6, Harare, Zimbabwe.

Schmuck, H., 2000. An act of Allah: religious explanations for floods in Bangladesh as survival strategy. International Journal of Mass Emergencies and Disasters 18 (1), 85–95.

Schröter, D., Polsky, C., Patt, A., 2005. Assessing vulnerabilities to the effects of global change: an eight step approach. Mitigation and Adaptation Strategies for Global Change, in press.

Schwarzer, R., 1992. Self-efficacy in the adoption and maintenance of health behaviours: theoretical approaches and a new model. In: Schwarzer, R. (Ed.), Self-Efficacy: Thought Control of Action. Hemisphere, Washington, DC, pp. 217–243.

Schwarzer, R., Fuchs, R., 1996. Self-efficacy and health behaviours. In: Conner, M., Norman, P. (Eds.), Predicting Health Behaviour: Research and Practice with Social Cognition Models. Open University Press, Buckingham, UK, pp. 163–196.

Scoones, I., Chibudu, C., Chikura, S., Jeranyama, P., Machaka, D., Machanja, W., Mavedzenge, B., Mombeshora, B., Mudhara, M., Mudziwo, C., Murimbarimba, F., Za, B., 1996. Hazards and Opportunities: Farming Livelihoods in Dryland Africa, Lessons from Zimbabwe. Zed Books Ltd, London.

Smit, B., Pilifosova, O., 2001. Adaptation to climate change in the context of sustainable development and equity. In: McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S. (Eds.), Climate Change 2001: Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge, pp. 877–912.

Smit, B., Burton, I., Klein, R.J.T., Street, R., 1999. The science of adaptation: a framework for assessment. Mitigation and Adaptation Strategies for Global Change 4, 199–213.

Smithers, J., Smit, B., 1997. Human adaptation to climatic variability and change. Global Environmental Change 7 (2), 129–146.

Stakhiv, E.Z., 1994. Managing water resources for adaptation to climate change. Engineering Risk in Natural Resources Management 275, 379–393.

Suarez, P., Patt, A., 2004. Caution, cognition, and credibility: the risks of climate forecast application. Risk Decision and Policy 9, 75–89.

Tanner Jr., J.F., Day, E., Crask, M.R., 1989. Protection motivation theory: an extension of fear appeals theory in communication. Journal of Business Research 19, 267–276.

Tol, R.S.J., Fankhauser, S., Smith, J.B., 1998. The scope for adaptation to climate change: what can we learn from the impact literature? Global Environmental change 8 (2), 109–123.

Tversky, A., Kahneman, D., 1974. Judgment under uncertainty: heuristics and biases. Science 211, 1124–1131.

UNEP, 1991. Handbook on methods for climate impact assessment and adaptation strategies. In: Feenstra, J., Burton, I., Smith, J., Tol, R. (Eds.), United Nations Environment Program. Institute for Environmental Studies, Amsterdam, The Netherlands (359pp).

van der Velde, F.W., van der Pligt, J., 1991. AIDS-related health behaviour: coping, protection motivation, and previous behaviour. Journal of Behavioral Medicine 14, 429–451.

Viscusi, W.K., Chesson, H., 1999. Hopes and fears: the conflicting effects of risk ambiguity. Theory and Decision 47 (2), 153–178.

Weber, E.U., 1997. Perception and expectation of climate change: precondition for economic and technological adaptation. In: Bazerman, M.H., Messick, D.M., Tenbrunsel, A., Wade-Benzoni, K. (Eds.), Psychological Perspectives to Environmental and Ethical Issues in Management. Jossey-Bass, San Francisco, CA, pp. 314–341.

Weinstein, N., 1980. Unrealistic optimism about future life events. Journal of Personality and Social Psychology 39, 806–820.

Weinstein, N., 1983. Reducing unrealistic optimism about illness susceptibility. Health Psychology 2, 11–20.

Weinstein, N., 1987. Unrealistic optimism about susceptibility to health problems: conclusions from a community-wide sample. Journal of Behavioral Medicine 10, 481–500.

Weinstein, N.D., 1989. Effects of personal experience on self-protective behaviour. Psychological Bulletin 105, 31–50.

Wilbanks, T.J., 2003. Integrating climate change and sustainable development in a place-based context. Climate Policy 3S1, S147–S154.

Wortman, C., 1976. Causal attributions and personal control. In: Harvey, J.H., Ickes, W.J., Kidd, R.F. (Eds.), New Directions in Attribution Research, vol. 1. Hillsdale, Lawrence Erlbaum, New Jersey, pp. 19–52.

Yohe, G., Tol, R.S.J., 2002a. Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. Global Environmental Change 12, 25–40.

Yohe, G., Tol, R., 2002b. Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. Global Environmental Change 12, 25–40.

Yohe, G., Neumann, J., Marshall, P., Ameden, A., 1996. The economic costs of sea-level rise on developed property in the United States. Climate Change 32, 387–410.

Ziervogel, G., 2004. Targeting seasonal climate forecasts for integration into household level decisions: the case of smallholder farmers in Lesotho. The Geographical Journal 170, 6–21.

Ziervogel, G., Downing, T., 2004. Stakeholder networks: improving seasonal climate forecasts. Climatic Change 65, 73–101.