ADAPTIVE CAPACITY AND HUMAN COGNITION

Prepared for presentation at the
Open Meeting of the Global Environmental Change Research Community,
Montreal, Canada, 16-18 October, 2003

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Abstract

The decisions of people, acting either to avoid impacts to things they value or to benefit from opportunities associated with climate change, partly drive the process of adaptation to climate change and its impacts. To answer the question of why some people show adaptive behavior while others do not, it makes sense to build a theory of adaptation and adaptive capacity based on our understanding of the decision-making process. Two disciplinary perspectives offer guidance for a cognitive perspective upon adaptation and adaptive capacity: psychology and behavioral economics. From these disciplinary perspectives, we first review research on adaptation and adaptive capacity in climate change research. Our main criticism relates to the neglect of 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. In the last section, we present data from two very different case studies that show the explanatory power of the model proposed. The first examines the precautionary behavior 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.

1 Social science research on human adaptation to climate change

1.1 Historical development of the research field

Since the 1980s extensive research has been conducted on potential and observed impacts of climate change on natural and social systems. It was tried to estimate the probability and intensity of higher temperatures – globally and locally – 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 (for a recent review see McCarthy et al., 2001).

In the beginning of this new research stream, the social sciences' contribution centered on the topic of mitigation. Within the climate change literature, "mitigation" refers to limiting global climate change through reducing the emissions of greenhouse gases (GHGs); since GHG emissions account for more than 80% of rising GHG concentrations in the atmosphere, scientists and policy-makers focused on emissions reductions as a way of "mitigating" the effects of climate change. Starting in the late 1990s, a new topic for the social sciences has gained importance in climate change research: adaptation. The latest report by the Intergovernmental Panel on Climate Change (IPCC) reflects the state of the science on this issue, and describes adaptation with the following definition:

> Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices and structures to moderate potential changes or to benefit from opportunities associated with climate change (Smit & Pilifosova, 2001, p. 879).

Two reasons account for the importance of adaptation as a topic within climate change research: To correctly assess climate change costs or risks, it is essential to include so-called "autonomous adaptation" by the affected human or natural systems (Fankhauser, 1996; Pittock & Jones, 2000; Smit et al., 1999; Tol et al., 1998; UNEP, 1998; Yohe et al., 1996; cited in Smit & Pilifosova, 2001, p. 881). On the other hand, adaptation has also come to be considered an important response option, along with mitigation (Fankhauser, 1996; Kane & Shogren, 2000; Pielke, 1998; Smith, 1996; cited in Smit & Pilifosova, 2001, p. 881). Because of the long reaction time in the climate system, even with reductions in GHG emissions, global temperatures are expected to increase. Other changes in climate – including extreme events – are likely, and sea level will continue to rise (Raper et al., 1996; White & Etkin, 1997; Wigley, 1999; cited in Smit & Pilifosova, 2001, p. 881). It appears that mitigation alone can not prevent climate from changing over the coming decades and centuries; hence, adaptation will be necessary to dampen (i.e., in common language, "mitigate") the impacts of climate change on human and natural systems.

Much of the early work on adaptation consisted of suggested response options in association with climate impact scenarios in various sectors, for example constructing seawalls in low-lying areas, or shifting cropping patterns in response to changes in rainfall. The latest report by the IPCC summarizes the use of a major explanatory variable "adaptive capacity" underlying adaptation to climate change and determining its efficacy. "Adaptive capacity is the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change." (Smit & Pilifosova, 2001, p. 879).

In the following sub-section, we describe in more detail the state of research on adaptation

and adaptive capacity. In all cases, we are referring to adaptation undertaken by people to climate change and its impacts. Clearly, other forces are at work, such as globalization, land-use change, and economic development; scholars recognize that adaptation takes place within this greater context.

1.2 Adaptation

In summarizing social science research, the IPCC authors state that "adaptation refers both to the *process* of adapting and to the *condition* of being adapted" (Smit & Pilifosova, 2001, p. 879). As with other inconsistencies in the IPCC's use of terminology (for example, using two contradictory definitions for "vulnerability"), this has the potential to confuse. Instead we use adaptation only in the meaning of a process, and – more specifically – we regard adaptation as a socio-cognitive-behavioral process. Hence, we see adaptation not only as adaptive behavior, but also as changes in cognitions (e.g., risk perceptions), which are socially constructed and negotiated. For example, the behavioral adaptation of communities in flood-prone areas to an increased risk of flooding due to climate change (e.g., by building higher levies or houses less prone to damage by water) is preceded by an increase in perceptions of the risk of flooding. These risks are discussed within and between public agencies, scientific bodies, the media, private households and companies at risk.

Researchers have proposed numerous dimensions to adaptation, as a way of systematizing thinking on the issue (Bijlsma et al., 1996; Bryant et al., 2000; Carter et al., 1994; Klein, 1998; Leary, 1999; Reilly & Schimmelpfennig, 2000; Smithers & Smit, 1997; Stakhiv, 1994; UNEP, 1998). Following Klein (1998) we highlight two of these dimensions that prove useful for thinking about individual behavior: *proactive* versus *reactive* adaptation, and *private* versus *public* adaptation. The first dimension refers to the form, or more specifically, to the timing of the adaptation. For example, adaptation to the risk of flooding can happen reactively (e.g., by carrying furniture upstairs) or proactively (e.g., by installing electric devices in upper floors, rather than in the basement). The second dimension refers to the actors, and therefore to the question of who adapts (e.g., in the case of flooding public agencies, or residents at risk). Consciously we do not use the terms "autonomous" for private adaptation and "planned" for public adaptation, which would follow the usage of these terms summarized by the IPCC. "Autonomous or spontaneous adaptations are considered to be those that take place – invariably in reactive response (after initial impacts are manifest) to climatic stimuli – as a matter of course, without the directed intervention of a public agency. (...) Thus defined, autonomous and planned adaptation largely correspond with private and public adaptation, respectively" (Smit & Pilifosova, 2001, p. 883/4). We regard this terminology as misleading. Talking of autonomous adaptation with regard to private actors like households, farmers or companies implies that for their behavior no planning is involved (basically equating them with irrational actors), whereas public agencies are idealized as rational actors. Research on human behavior shows that so-called experts in public agencies and so-called lay people in the general public are both rational to a certain extent, but in different ways (see for example Slovic et al., 1979).

Researchers have suggested that different steps or stages form the structure of the adaptation process. Risbey et al. (1999) differentiate four stages in the adaptation process:

1. Signal detection, where it is decided what is adapted to (the signal) and what is ignored (noise);
2. Evaluation, where the signal is interpreted and foreseeable consequences are evaluated;
3. Decision and response, which results in an observable change in the behavior and

performance of the system; and
4. Feedback, which involves monitoring of the outcomes of decisions to assess whether they are as expected.

Similarly, Klein et al. (1999) structure planned adaptation (public adaptation in our terminology) in four steps:

1. information collecting and awareness raising
2. planning and design
3. implementation
4. monitoring and evaluation

Two critical aspects of these process conceptualizations need to be addressed. First, the role of human cognitions are tackled only superficially. For example, these process models do not consider cognitive biases like the tendency for people to underestimate large probabilities and overestimate small ones (Crocker, 1981), or the role of trust in government agencies (Sandman, 1987). Second, these proposed steps closely resemble the classical normative management cycle: planning, implementation and evaluation. Management studies have shown, repeatedly and consistently, that these steps do not prove useful to describe the empirical reality how management actually occurs, and indeed may prove to be normatively incorrect. Research in the American public sector (Lindblom, 1959; Braybrooke & Lindblom, 1963) quickly dispelled the myth that decision-making, in public institutions at least, was a uni-directional ("linear"), sequential process. Decisions here were made in a halting 'incremental' way with periods of recycling, iteration and reformulation. 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 behavior (e.g., Bachrach & Baratz, 1962). Therefore, we ask the question: if the steps proposed above for the process of adaptation are not valid for management in very hierarchical and structured human systems like business organizations, why should they be true for adaptation in much less hierarchical and structured human systems adapting to climate change like households, communities, settlements, cities, or developing countries?

Adaptation is important in the climate change issue in two ways – one relating to the assessment of impacts and vulnerabilities, the other to the development and evaluation of response options (Smit & Pilifosova, 2001, p. 881). With regard to these two purposes of adaptation research, the stepwise adaptation procedures proposed by Risbey et al. (1999) and Klein et al. (1999) at least appear to be useful as a normative orientation for the process of the development and evaluation of response options – although even this may be doubted. If management empirically is not happening in the proposed sequence this may be for good reasons. For the other purpose – the assessment of impacts and vulnerabilities – the usefulness of the proposed stages has to be doubted even stronger. If real adaptation is not following these linear, sequential processes – which is very likely on the background of the management studies described above – these steps cannot be used to predict future adaptation and the degree by which this decreases potential climate change impacts or increases potential benefits.

On the other hand, these stage concepts provide a good starting point for systematic empirical analyses of adaptation processes, and as yet it is still an open empirical question whether they are really not at all useful to describe real world adaptation. There has been little empirical research on the processes of adaptation decision-making in the climate change literature – a weakness recognized by the IPCC (Smit & Pilifosova, 2001) – especially with regard to

private adaptation. It therefore seems useful to explore empirically how well the sequential model of adaptation – rooted in the rational actor paradigm – describes and explains adaptation. In the words of statisticians, how much variance in the behavior do evaluations of the risks and the options for avoiding them explain? In section 2 of this paper we propose a socio-cognitive model of private proactive adaptation that assumes relatively logical and sequential processes of human decision-making and behavior. In section 3 we empirically test this model and discuss its weaknesses.

1.3 Adaptive Capacity

The second main concept within research on adaptation to climate change is the concept of adaptive capacity: the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change (Smit & Pilifosova, 2001, p. 879). Considerable attention has been devoted to the so-called determinants of adaptive capacity, which are characteristics of communities, countries, and regions that influence their propensity or ability to adapt and hence their vulnerability to risks associated with climate change. As Smit and Pilifosova (2001, p. 882) state: "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."

Therefore, the so-called "determinants" of adaptive capacity are also seen as determinants of adaptation. Although scholarship on adaptive capacity and the determinants of adaptation is extremely limited in the climate change field, there is considerable understanding of the conditions that influence the adaptability of societies to climate stimuli in the fields of hazard, resource management, and sustainable development. From this literature, the IPCC-authors identify a list of socioeconomic features of communities or regions that seem to determine their adaptive capacity and adaptation (Smit & Pilifosova, 2001, pp. 895-897):

1. economic wealth / resources
2. technology (e.g., warning systems, irrigation, flood control measures)
3. information and skills
4. (Social) infrastructure (e.g., availability of and access to resources)
5. institutions
6. equity

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. Similarly, Adger (2003, p. 29) argues, for individuals, that their capacity to adapt to climate change "is a function of their access to resources".

Two weaknesses of the theoretical development on adaptation and adaptive capacity need to be addressed from the viewpoint of psychological research – the neglect of subjective adaptive capacity and the disregard of motivation and motives. First, 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 ability of human actors because the subjective ability can be very different from the objective ability. For example, in Bangladesh Muslim women alone at home during a cyclone warning are not making use of the cyclone shelters because – due to religious normative beliefs – they do not think that they can leave the house without their men (Schmuck-Widmann, 1996). Similarly, some homeowners in flood-

prone areas in Germany do not take any precaution to prevent flood losses because they do not perceive any options to do so (Grothmann & Reusswig, in revision). 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). Often, objective resources to perform certain actions and subjective perceptions of these resources correspond with each other. But there seem to be some (systematic) deviations in the perceptions from the actual resources, which often appear irrational to an outside observer.

With regard to the two aims of adaptation research – vulnerability assessments and policy advice – subjective adaptive capacity becomes important for both. Especially if the perceived behavioral options are underestimated (perceived adaptive capacity is less than objective adaptive capacity) the major determinant of adaptation is the perceived adaptive capacity, since the objective adaptation options are not even tried by the human actors. Therefore, in order to adequately predict future adaptation within vulnerability assessments and for the sake of policy advice, these perceptions have to be taken into account.

The second critique of the theoretical development on adaptation and adaptive capacity relates to the neglect of motivation. In addition to subjective adaptive capacity, motivation is the other major psychological determinant of adaptation. Whereas subjective adaptive capacity relates to the issue, what an actor thinks he or she *can* do, motivation relates to the question, what an actor *wants* to do, indicated by motives like goals, values or norms. With regard to adaptation to climate change the main determinant of the motivation to adapt is the relative risk perception. Risk perception relates to 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.

We assume, that these two basic components – perceived adaptive capacity and threat appraisal – are determining adaptation to climate change. This idea is in line with so-called expectancy value theories (see for example Atkinson, 1964) and with the protection motivation theory by Rogers and his colleagues (Rogers, 1983; Rogers & Prentice-Dunn, 1997). We present this theory in the next section.

2 A socio-cognitive model of private proactive adaptation: "risk perception" and "perceived adaptive capacity"

In order to explain why some people show protective behavior while others do not, we developed a process model of adaptation and adaptive capacity mainly based on "protection motivation theory" (PMT). This theory by Donald Rogers and his colleagues (Rogers, 1983; Rogers & Prentice-Dunn, 1997) is one of the four major theories within the domain of psychological research on health behavior. Though Rogers originally proposed the theory in the context of health threats – where it has been applied quite successfully (see Floyd, Prentice-Dunn & Rogers, 2000; Milne, Sheeran, & Orbell, 2000) – the theory appears to have broad applicability, including to natural and technological hazards. But 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. Adaptation to climate change has so far, it appears, not been 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 – *'threat appraisal'* (also known as risk perception) – 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 behavior. In the second – *'coping appraisal'* (perceived adaptive capacity) – a person evaluates his or her ability to cope with and avert being harmed by the threat, along with the costs of taking such action.

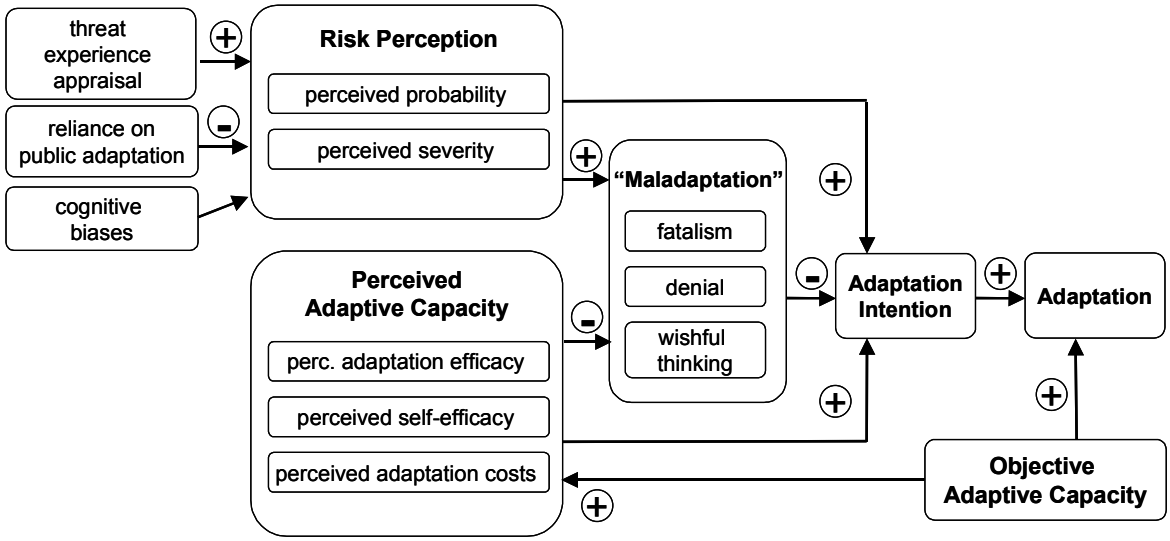

Figure 1. Socio-cognitive model of proactive private adaptation to climate change impacts

Figure 1 shows a diagram of the model as developed by the authors for the context of proactive private adaptation to climate change. The risk perception 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). Rogers and Prentice-Dunn (1997) use the term 'vulnerability' instead of 'probability'. Here the latter term is preferred to stress its strong connection to the natural science understanding of risk (probability x damage) and to avoid misunderstandings in the climate-change community, where vulnerability has a very different meaning. 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., the judgment that a flood in the area would harm valued things, such as home or property). Rogers and his colleagues define the threat appraisal (or risk perception) in a slightly different way: Additionally to perceived probability and perceived severity, they also include perceived rewards of the maladaptive response (e.g., continuation of smoking) in their model (Rogers and Prentice-Dunn, 1997). These maladaptive response rewards can be intrinsic (e.g., physical and psychological pleasure) or extrinsic (e.g., approval by friends). The authors of this article refrained from including maladaptive response rewards in their model of adaptation to climate change because the rewards of the maladaptive response (e.g., doing nothing to protect one's own household from flood damage) do not seem to be different from the non-occurrence of the adaptive responses' costs (e.g., expenditure on

relocating electric devices in upper floors), a variable included in the coping appraisal. Such a doubling of basically the same factor should be avoided.

Coping appraisal, or perceived adaptive capacity, by contrast, comes after the risk perception process and only starts if a specific threshold of threat appraisal is passed. "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). The coping appraisal has also three subcomponents. First, it includes a person's *perceived adaptation efficacy*, that is, the belief in protective actions or responses to be effective in protecting oneself or others from being harmed by the threat (e.g., a judgment that relocating electric devices in upper floors would prevent damage from a flood). 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). The third component is *perceived adaptation costs*, the assumed costs of taking the preventive response. These can be any costs (e.g., monetary, personal, time, effort) associated with taking the risk-reducing adaptive response. Although adaptation costs and self-efficacy are related – if a person finds an adaptive response 'difficult', is this because of small self-efficacy or high response costs? – it is useful to differentiate them conceptually. In our studies, perceived self-efficacy refers to beliefs about one's ability and opportunities (e.g., "As a tenant I am not allowed to put electric devices in upper floors of the house …"), which can be independent of the perceived adaptation costs (e.g., "… although as an electrician it wouldn't be costly for me to do so."). But, as Rogers and Prentice-Dunn (1997, p. 116) state: "… the factors involved in threat appraisal and coping appraisal have rich meanings that may be conceptualized in a variety of ways."

Based on the outcomes of the threat- and coping-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 or increase benefits (e.g., precautionary action like avoidance of expensive interiors on flood-prone floors), and are taken if the risk perception and the perceived adaptive capacity are high. "Maladaptive" responses – including denial of the threat, wishful thinking and fatalism – 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 "maladaptive" responses if his or her risk perception is high but the perceived adaptive capacity is low. We are aware of the very judgmental connotation of the word "maladaptation". Actually, one can argue, that adaptiveness is a question of "best fit" to an objective situation a person is in. For example, denial of the risk of flooding can 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. We use the word adaptation for responses that actually prevent or mitigate damage in case of a climate change impact, and we use maladaptation to describe those responses that do not prevent such impacts.

If the person chooses the adaptive responses, he or she first forms a decision or intention to take these actions. This intention is called *adaptation intention*. It is essential to distinguish between intention and actual behavioral adaptation because people often have intentions but do not carry them out in actual behavior due to a lack of *objective adaptive capacity* (e.g., lack of resources like time, money, staying power, knowledge or social support) that they did not expect when forming their intentions. In this case the perceived behavioral options were overestimated

before (perceived adaptive capacity > objective adaptive capacity).

In their meta-analysis of 27 studies testing protection motivation theory and a total of 7,694 participants in the field of health behavior, Milne et al. (2000) state that risk perception has been found to be positively correlated with maladaptive responses, indicating that high threat perception makes one likely to adopt some coping response, either adaptive or maladaptive (e.g., Abraham et al., 1994; Rippetoe & Rogers, 1987). Therefore risk perception appears to provide the psychic energy for a response, but without determining which direction – adaptive or maladaptive – the response will take. The latter is then decided on the basis of the coping appraisal: In general, perceived self-efficacy and adaptation efficacy have been found to be negatively correlated with maladaptive responses (e.g., Abraham et al., 1994; Eppright, Tanner, & Hunt, 1994; Rippetoe & Rogers, 1987; Tanner, Day, & Crask, 1989), but positively with adaptive responses (e.g., Abraham et al., 1994; Schwarzer & Fuchs, 1996). In addition, maladaptive responses (avoidance, in particular) have been found to inhibit adaptation intention (Abraham et al., 1994; Rippetoe & Rogers, 1987; van der Velde & van der Pligt, 1991).

Besides the factors described so far we include further variables in our model of private proactive adaptation. First, the *threat experience appraisal* plays an essential role in motivating people to take precautionary action against the threat (e.g., Norris et al., 1999). While risk perception assesses the probability and severity of a hypothetical threat in the future, threat experience appraisal assesses the severity of a threat experience in the past. It is assumed that threat experience has some positive influence on risk perception. Unlike risk perception, there is no uncertainty involved in the threat experience. Therefore threat experience appraisal can also be seen as an indicator of perceived certainty that a threat might affect the person in the future.

Other than for the many health protective behaviors for which PMT was developed (e.g., quitting smoking, brushing one's teeth, or using condoms) private adaptation to climate change can be substituted by others' protective actions. To prevent cavities, a person has to brush his or her own teeth, and can not 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.

In section 1.2 we highlighted the failure of current adaptation theory to take into account *cognitive biases* and "judgment heuristics". For example, most people estimate the likelihood of an event with the availability heuristic: searching their memories for vivid examples of such an event occurring. This, then, 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. Another cognitive bias is the tendency for people to underestimate large probabilities and overestimate small ones (Crocker, 1981).

In the next section, we present data from two very different case studies that show the explanatory power of the model proposed. The first examines the precautionary behavior 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.

3 Explanatory power of the model: Two case studies

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

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 to an individual, but also to a group, or a society. Motivation and perceived adaptive capacity are the factors we believe to be important, but so far omitted from adaptation models in climate change literature. We now compare the validity of the socio-cognitive model of private proactive adaptation (including only perceptual variables like perceived adaptive capacity) to a classical "objective adaptive capacity model" just based on factual socio-economic variables, examining results from an interview study (presented in detail in Grothmann & Reusswig, in review) with 157 randomly chosen residents living within flood-prone areas of Cologne, a major city with a population of about 1 million located on the river Rhine in western Germany. Respondents were asked for their past experiences with flooding, perceptions of risk regarding future floods, reliance on public flood protection, beliefs about the efficacy of different risk minimizing responses and their ability to perform these, perceived adaptation costs, non-protective responses, and finally actual self-protective behavior 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-cognitive model of proactive flood damage prevention could explain 27-44% of the variance in the four different protective responses, yielding statistically significant explanations in all four cases. The socio-economic model yielded significant explanations of the variance in protective responses only in three of four cases – for avoidance of expensive furnishings the socioeconomic model could not provide any significant explanation – accounting for 4-29% of the variance. The only statistically significant predictor in these three cases was ownership. Level of income and education had no significant explanatory power for proactive adaptation. An ongoing panel study by Grothmann, Reusswig and Linneweber (in preparation) after the August 2002 flood in eastern Germany with a much larger sample (N = 1,000) appears to yield very similar results.

The insignificance of households' net income for adaptation is an especially 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. Whereas GDP is an indicator of economic resources on the level of nations, household's net income is an indicator of economic resources on the level of households. We do not know of any vulnerability studies that tested empirically how strongly GDP really influences adaptive capacity and adaptation. But based on our results for households' adaptation, we doubt the superior importance of economic resources for adaptation. Also on the national level, past experiences with climate change or variability, perceptions of risk regarding future impacts and perceived adaptive capacity are probably important or even more important

determinants of adaptation. One could argue that in Germany most people's income is above the threshold that would hinder people to adapt, whereas some nations' "income" would lie below such a threshold – making GDP an important predictor of adaptation in international comparisons. One could also argue that at the larger geographical scale, cognitive factors would tend to cancel each other out, whereas socio-economic factors would accumulate; certainly, it is an area ripe for research as to whether this is the case.

That ownership turned out to be an important factor in explaining residents' protective responses is unsurprising. First, owners have – compared to tenants – much more to lose because of floods, since lots of damage occurs to the building when a flood occurs. Second, owners have more opportunity to take independent action: whereas a tenant is normally not allowed to make structural changes to the building he is living in, an owner has this opportunity[1].

Nevertheless, the socio-economic model (including the ownership variable) could explain only half of the protective responses' variance that was explained by the socio-cognitive model. This demonstrates that the inclusion of human cognitions in models of adaptive capacity and adaptation strongly improves the degree of explanation.

On the other hand, reaching levels of 27-44% explained variance for behavioral measures by the socio-cognitive model is – based on standards in psychological research – only a good level of explanation; 45% is regarded as very good[2]. In section 1.2 we have noted that we wanted to explore how well a sequential model – rooted in the rational actor paradigm – describes and explains adaptation. The classical rational actor paradigm assumes a major overlap between objective and subjective reality (e.g., by the assumption of total information) and consequently denies the necessity to include perceptual or cognitive variables into models of human behavior. Our socio-cognitive model of proactive private adaptation comprises *subjective* risk and *subjective* adaptive capacity as the main determinants of adaptation and therefore already is very much different from the classical rational actor model. Nevertheless, the proposed model is assuming a more or less structured, sequential decision process underlying adaptation. The merely good degree of explanation by this model indicates that it might be useful to include knowledge from those management studies mentioned in section 1.2, which show that problem-solving processes can lack sequential characteristics or can be seemingly chaotic. By inclusion of those factors and processes – leaving assumptions about structure and logic in human behavior even further behind – future studies might yield better levels of explanations.

3.2 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

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[1] 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.

[2] These rather small standards are due to measurement difficulties in psychological research: Not only are people very different in character and the contexts they live in, they are normally also unwilling to participate in interviews longer than 30 minutes – so that not all personal and contextual factors that might be influential for one person's or another's behavior can be measured.

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 subsistence farmers, given information about seasonal climate variability. In a five 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 & Gwata, 2002).

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, 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 ten wettest years, the ten medium years, and the ten 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., 1999). 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 & Patt, in press). 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, in press; 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.

Figure 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 (in press) 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 300mm; in ten of the last 30 years, this location received between 300 and 635 mm; and in ten 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 twenty 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

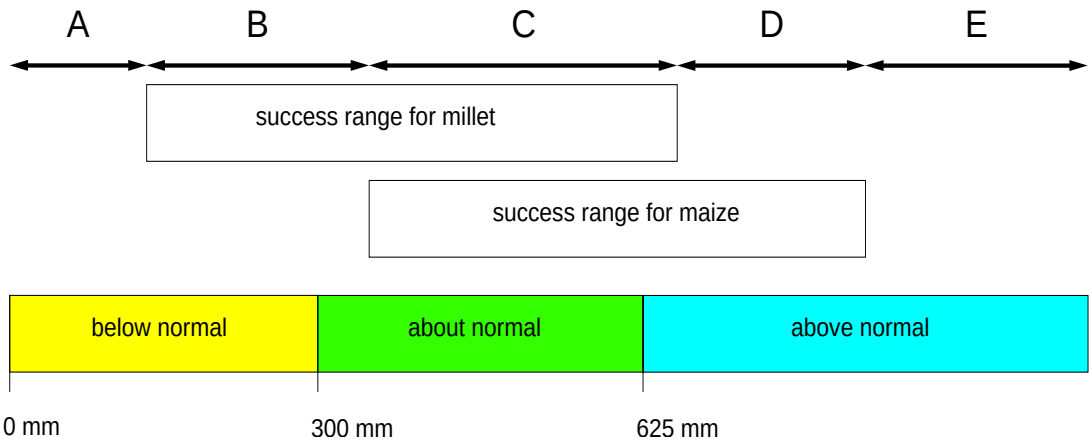

Figure 2. Idealized Forecast Evaluation Framework

habit of planting maize, and not planting 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 Figure 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 analyze 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, for example, 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' reaction 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 & Tversky, 1979; Kammen & 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, based on two lines of argument. First, they act as if D were still about as likely as B; they might get a harvest with millet but not maize, and they might get a harvest with maize but not millet. The forecast has not changed this. Second, there still looms the possibility of range A; even if they plant millet, the crops might still wilt due to dryness.

In the first two 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 takes place at the workshops.

These results are consistent with the theme of this paper. 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 protective 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.

4 Conclusion

When people act either to avoid impacts to things they value or to benefit from opportunities associated with climate change, we call this adaptation. Past work on adaptive capacity has focused on people's resources, and other factors that could determine whether they have an objective ability to act. Outside of climate change, however, a large literature dealing with human decision-making and action suggests that motivation and perceived abilities are also important determinants of human action. Several socio-cognitive variables have been shown to influence people's motivation, and hence the decisions they make, 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 argue, models of adaptive capacity ought to include these variables.

We have drawn from two case studies, each presented in more detail in other papers, but each suggesting the importance of socio-cognitive factors in adaptation and adaptive capacity. In Germany, the quantitative data demonstrates that the explanatory power of a socio-cognitive model is higher than a socio-economic model. Particularly noteworthy was the relative unimportance of personal income, something at odds with most models' assumptions of adaptive capacity at the level of nations. Future research is certainly necessary to examine whether this represents a flaw in the national models, or if differences in the scale of decision-making are responsible. In Zimbabwe, we have presented qualitative data based on interviews with farmers. Here, we show that several cognitive factors appear to have limited farmers' motivation to make changes.

By including socio-cognitive factors, future researchers can improve their assessment of adaptive capacity, and therefore of vulnerability. Additionally, policy makers hoping to promote people's adaptation will be able to influence people's actions more effectively.

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