Climate and Society

A complex and conditional relationship

Elisabeth Meze-Hausken

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To my Mother

Acknowledgement

There is nothing worse than working creatively without a serious discussion partner close to you, without someone being interested, understanding your way of thinking, challenging your theories, motivating your engagement, encouraging your curiosity and cheering you up when you feel empty and despairing.

That I finally am willing to submit my thesis, is all due to a recent three months summer research as YSSP at IIASA, International Institute for Applied Systems Analyses, to whom I owe my greatest thanks. There, I learned that lateral thinkers, unorthodox methods, people swimming against the stream and fighting for their dreams really get appreciated and taken seriously. And especially young researchers are nurtured carefully. The time there gave me back my self-confidence and strength, the believe in myself that I do the right things, and many new friends.

Before that summer, I fortunately managed at least occasionally to meet people at seminars and conferences with whom I could share my fascination and destiny or exchange e-mails on a scientific basis. A big thanks to Declan Conway who invited me to UEA twice, where I could enjoy an environment which is very closely related to my type of research, and to Reinhard Mook at UiT/Tromsø who used his valuable retirement time to re-think and critically analyse my threshold paper. My colleagues at the IFG, especially Winfried, Anne, Siren and Sebastian, are thanked for sharing my ups and downs and for their patience in hearing once in a while my complaints of feeling isolated. Even though I am a non-geographer and only have been very limited used by, rather than of little use to, the department, I am glad that I could utilize an office-space even when my official contract had run out. Thanks to IfG for the extraordinary travel support I received for going to conferences! Ann Nilsen did a great job in encouraging me to finalize my thesis.

Of my five papers I am presenting here, Paper 4 caused me most struggle to prepare and many times I was very close to giving up. But I am proud that I, against all odds, dared to go about it, even if I could not convince anyone to join me. It proved to be the right decision.

Dawit, you have been the most helpful research assistant during my fieldwork in Ethiopia. It was not easy for me experiencing a cultural shock, preparations of a border war with “test”-bombs exploding close to me (while knowing I have a baby left at home in Europe), seeing tremendous suffering during drought and famine, with people who had no food or sip of water for days, parents who just closed the eyes of their dead children and beastly smelling air due to hundreds of cadavers around. Unconsciously, I joined the famine with rejecting to eat myself. Every time since then, when I see people at home complaining about their financial problems before pay-day, I just become angry

and frustrated about the seemingly unsaturated society with demands which are so trivial compared to the daily fight for pure survival in other places of the world.
In a way, I should also remember my countless physiotherapists who did their best to reduce my muscle pains and make it possible to fulfil my research.
Maybe it is not the most rational and recommendable approach to get three children while doing a PhD, but when looking back, I do not regret it at all: Amanda, Jasmin and Lancelot, you could have given me more night-sleep, but nevertheless, you made me laugh every day and helped me to keep emotional in my otherwise very rational behaviour and thinking. And Jan, I know you never regarded a PhD-research as an adequate job, but I learned from other people's stories that you are proud of having a wife who investigates peculiar questions. Mum and Dad, it would have been wonderful to live closer to you, enjoying you as baby-sitters to lessen my bad conscience when sticking my nose into books and articles during weekends and holidays. Thanks for your encouragement from the distant Alps.
I really admire the people of Europe's rainiest city for their stoic acceptance of and humour about weeks and months of adverse weather conditions. One must be born here to manage; that's why I am trying to head further South.

Abstract

Too little rainfall causes human adaptation problems. Too much rainfall as well. The same is valid for temperature. What makes people vulnerable to climate and what impacts can climate cause on society? Where lies the border of what is still acceptable and what not? When do people change their habits and where is intervention needed? What role do people's perceptions about climate play? And can we draw conclusions from one region or time-period to another?

This thesis is a contribution to the literature on climate and society linkages. With case-studies from Ethiopia and Norway as well as a literature review from many other regions, it provides empirical evidence of the complexity of the climate-society relationship. It describes the difficulties associated with deterministic approaches to understanding and predicting the human impacts of climate extremes and climate change. Several aspects are covered: Paper 1 elaborates the issue of climate vulnerability and discusses the problem of how to distinguish between climate as a trigger or just one out of many influence factors for a specific human response such as migration. The case-study is directed towards dryland regions and Ethiopia. In Paper 2, again focusing on Ethiopia, the divergence between climate perceptions and climate measurements is taken up. By explaining the possible origin of the low correlation between them, the importance of other environmental and social variables becomes evident. Paper 3 attempts to attach meteorological data to weather narratives in the media and by this annotating what makes up a good and bad weather day in Europe's rainiest city, Bergen, Norway. The data suggest that it is supply and demand of specific weather events which influence people's perceptions of attaching positive or negative features to it. The importance of the seasonal occurrence of weather events is revealed. By exploring human climate thresholds, Paper 4 draws on empirical results of a literature review. By presenting a stimulus-response model, it describes climate's influence on the human body and on human perceptions, which determine jointly when and where climate can trigger and influence certain human activities. Paper 5 is turning back to experiences from Ethiopia, from a combined climate statistics and financial-economic perspective. It investigates the subject of climate micro-insurance as a possible adaptation to climate extremes and change from the perspective of an insurance provider. The issue of climate risk pooling as well as making use of non-covariate spatial climate behaviour for reducing necessary risk capital is addressed.

But as we are all different, people do not necessarily respond to the same climate stimulus in the same way. Culture, technology and physiological adaptation contribute their part in influencing human well-being and in setting limits to society, for example of where to live, what impacts to expect and what decisions to take.

List of Papers

Paper I
Elisabeth Meze-Hausken (2000) Migration caused by climate change: How vulnerable are people in dryland areas? A Case-study in Northern Ethiopia. *Mitigation and Adaptation Strategies for Global Change* 5: 379-406.

Paper II
Elisabeth Meze-Hausken (2004) Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia. *Climate Research* 27: 19-31.

Paper III
Elisabeth Meze-Hausken (2007) Seasons in the sun – Weather and climate front-page news stories in Europe's rainiest city, Bergen, Norway. *International Journal of Biometeorology* 52(1): 17-31

Paper IV
Elisabeth Meze-Hausken, On the (im-)possibilities of defining human climate thresholds. *Climatic Change:* Accepted for publication.

Paper V
Elisabeth Meze-Hausken, Anthony Patt, and Steffen Fritz, Hedging climate risk for micro-insurance providers in Africa. Submitted to *Global Environmental Change*

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1. INTRODUCTION

After having been living for several years in Europe's rainiest city, Bergen, our family decided during 2004/2005 to spend a period on Malta in the Mediterranean Sea. Unfortunately, we experienced what was to be the coldest winter there for 46 years. One storm after another whipped huge waves over the harbour walls not designed for these types of weather, crashing the few small rowing boats left into individual planks. On one such day, exposed to pouring rain, it happened that my husband went to the local butcher to get some meat. Rather surprised to receive a customer during such weather, the butcher recommended my husband would do better to buy a bottle of wine instead, lie in bed and to wait until the rainfall was over.
Back in Bergen, applying the same strategy as suggested by the Maltese butcher, would result in permanent drunkenness and stays in bed for weeks, especially during autumn or winter where 60 days of rain in a row are no rarity.

This little story shows in a simple way what this thesis is all about: 1) how climate affects people; 2) that perceptions and impacts in one place differ considerably from another place; 3) and that people may be differently vulnerable to certain weather conditions and have different thresholds for taking action.

Especially since the 1990s, there is a popular tendency to associate individual weather calamities or social disruptions such as famine with climate change. Blame is given to the anthropogenic influence on climate leading to extensive research on how a likely human induced climate change may affect society: climate models try to project future climate, and climate impact models estimate the measurable scale of consequences for specific categories such as transport, food availability, health or migration. As this thesis will show, the climate change phenomenon has to be placed into its wider context. Ecological and climatological dynamics, changes in socio-cultural processes and livelihood practise have to be taken into consideration when explaining human response to and perceptions on climate. While the relationship between people and climate goes two ways, specifically, people affecting the climate through emissions, and climate affecting society through its variability, change and extremes, only the latter context is taken up in this thesis. Here, the focus is primarily on how past and present climate variability and extremes affect(ed) human decisions, economic costs, perceptions and livelihood, and the findings are only *implicitly* applied to anthropogenic climate change. For this reason, the title of the thesis itself is chosen to be simple and relates to climate only. Rather than giving the perspective of an – until now – stable relationship between climate and society which suddenly becomes disrupted by anthropogenic interference, the thesis emphasizes that variability of climate and its impacts on and adaptability of society are a permanent feature and adjustment process. Nevertheless, this approach should not undermine the urgency of addressing the issue of anthropogenically induced climate change and the potential seriousness in terms of impacts it may cause.

This thesis is based on a *cross-disciplinary approach* and is thus not embedded in one particular discipline. The overarching theme does however address itself to perspectives and concepts that belong in the social sciences.

Five papers comprise this thesis, with case-studies ranging from geographic regions in Eastern Africa to Norway. They illuminate the relationship between climate and society from different angles and reflect a wide spectrum of climate research. While these five papers may be quite diverse on a first glance, they have in common one main thing: climate extremes and their impacts on society, both on their physiology and psychology: Paper I deals mostly with famine and thirst as the impacts of climate anomalies and resulting migration. Paper II looks on the perceptional side of similar climate events, but investigates perceptions in terms of needs and experiences. Paper III takes again up the issue of climate and weather perceptions, although in a different geographic setting. While in Paper I and II climate is a necessity for human survival, Paper III describes climate more as an amenity, in a society with high adaptive capacity. Paper IV can be seen as the umbrella for the three papers, discussing by empirical examples and theoretical analysis how climate impacts human physiology and psychology, as well as raising a discourse on climate thresholds which initiate or end different human actions. Paper V focuses again on climate extremes, and its impact on the financial market, in the regions discussed in Paper I and II. Its strong economic focus is not unique for this paper, as indirectly, economy – but mostly household economy – is discussed as being impacted by climate extremes in Paper I and II. As such, while there is no single common denominator for all the five papers, from five approaches they all address a common topic; that of the interrelationship between human agency and climate variability and extremes.

Based on my interdisciplinary approach to the research topic Figure 1 illustrates the relationship between the concepts that are central to the overall argument in the thesis:
(1) Variability: the only stable about climate is its variability, which requires permanent human adaptation, and vice versa, the only stable about society is its constant change. (2) Vulnerability: peoples' vulnerability contributes to the impact the individual and hence, the society, experiences due to climatic variability, extremes and change. (3) Thresholds: a threshold represents a turning point where the climate stimulus has reached a level that initiates or ends a human response. (4) Perceptions: what people think about climate and how they sense its composite variables, is determined by their experiences and expectations, and influences the human response to changed climate conditions. These individual components or concepts are elaborated further in Chapter 3. The fuzzy background in Figure 1 represents the physical, economic, political, social and cultural environment which has its variable influence on the climate-societal relationship. While this context is drawn in grey font, the size of the box should indicate that this background may have considerable importance to the outcome. Sometimes there is more, sometimes less weight given to climate, and other reasons emphasised as influencing human reactions. How far it is the social being making his/her own life decisions, or nature affecting human actions and practically overruling their ability to decide, is highly case dependent.

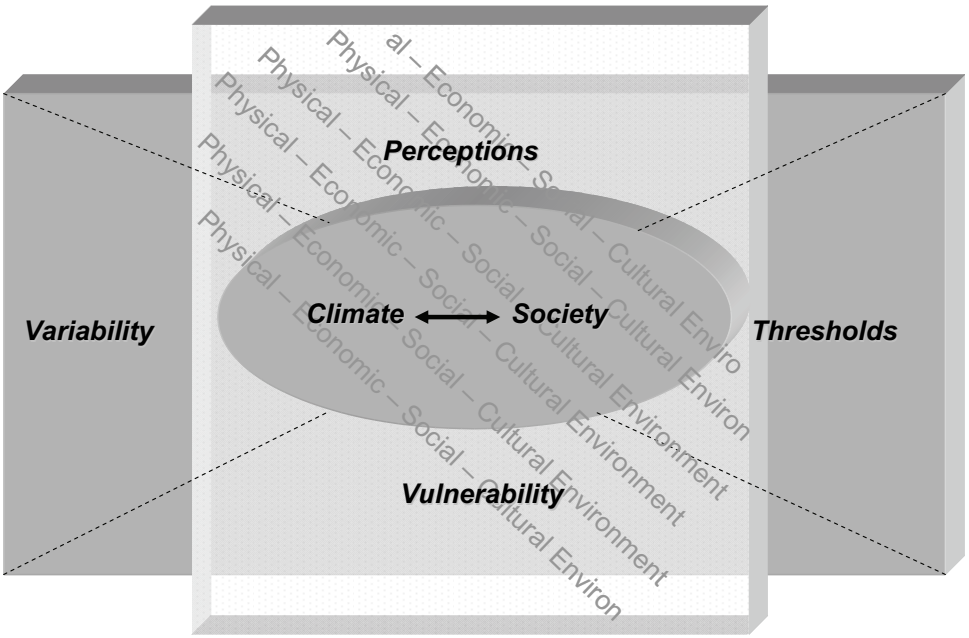

Figure 1: The general concept of the thesis. For detailed explanation, see text.

Although no comparison between these geographic areas has been performed, the two case-study regions, North Ethiopia and western Norway, are as different as they can be, in respect of their climate, vulnerability and thresholds for certain impacts. Both regions have rainfall as their critical variable, but in different ways. While western Norway has much, Ethiopia suffers generally from too little rainfall. The subsistence farming and pastoralist society in Ethiopia is highly dependent on the timing, intensity and frequency of rainfall as a means of providing food and drinking water for their families. For them, climate is a matter of survival, rainfall a necessity for inhabiting their area. In western Norway, little rainfall is a luxury good for those who like outdoor activities, while extensive rainfall creates electricity income. There, weather mostly represents an amenity value, as, regardless of the type of weather, the adaptive capacity to most extremes is high: the road infrastructure allows for excessive rainwater to discharge, and cinemas, libraries and simply home TV guarantee entertainment during continuous rain.

It is evident that a study on the relationship between people and climate must be interdisciplinary, addressing issues which touch fields of climate statistics, environmental sciences, sociology, geography and anthropology, with additional input from development studies and human physiology and several more. That I feel comfortable in such an

interdisciplinary environment derives certainly from my graduate studies in both climate change and business economics, giving me the necessary background to enlighten the interaction between natural and social science components. While such an interdisciplinary research study required me to rapidly acquire knowledge and research terminology of unfamiliar disciplines on the way, cascading complexities challenged me as a young researcher positively and negatively. Faced with arguments, and sometimes my own temptation to limit the scope to one primary discipline and leave the rest to "future research" by others, I felt such an approach would leave my research questions unsolved.

In the following, the assembly of this thesis is described: Chapter 2 raises the main research questions which are dealt with in four papers. These questions illuminate the theme of how climate influences society from different perspectives. Concepts and terminology are dealt with in Chapter 3. Methods are presented in Chapter 4. The individual papers and their main findings are summarized in Chapter 5. The final section summarizes the thesis' contribution to the field of climate impact research. The five papers are listed in the Annex.

2. RESEARCH QUESTIONS

While the research process behind this particular thesis did not invite one specific and narrowly defined research question that could be written up in a monograph, there is nevertheless an overarching theme that is addressed in the five individual papers: how climatic change and variability affect different aspects of human societies in varying contexts.

Five research questions (plus sub-questions) outline the individual papers. They cover the aspects described in Figure 1 (and discussed in more detail in Chapter 4). While all questions cover the aspect of climate variability, either explicitly or implicitly, each question addresses at least one or two other aspects of Figure 1.

> Question 1: *Can climate change really cause mass-migration? Or, what contextual conditions may trigger mass-migration?*

The original starting point of my thesis, which was revised and refined during the study process, was a critical reflection of a relatively deterministic hypothesis on climate change and human migration, which assumes a linear causal relationship between global warming and a potential exponential increase in climate refugees. Question 1 has been challenged by a publication (Myers & Kent, 1995) which claims that already now millions of migrants could be called climate migrants, and many hundred millions would follow in the decades to come, due to climate change. This fear was also made very visual in the film "The March" by Dawit Wheatley (1990), in which due to global warming thousands of Africans from sub-Saharan regions try to escape their destiny by walking through dried out land towards Europe, and politicians closing the borders towards the West, responding with military action. Even if this is science fiction, one may ask whether such a scenario could

become true. Do people really simply take their belongings and search for a better life somewhere else, or is the process much more complex, people more tight to their land and resistant to such traumatic changes? And what conditions must be involved causing migration at the end?

Question 1 implies a rather simplistic relationship between climate change as a cause and mass-migration as a direct impact of the climate stimulus. Paper 1 investigates this claim empirically, based on a study on climatic extremes and migration in Northern Ethiopia. The question does not go into migration theory, although a distinction is made between an opportunity driven migrant due to environmental degradation, and a necessity driven refugee due to a climate disaster.
A sub-question is related to the issue of whether historical analogy could serve as a possible method in exploring the issue of climate and migration: How can insight into past climatic extremes such as drought and resulting migration be used as a kind of measure for what may be expected in the future under anthropogenic global warming?

Implications of the answers to both these two questions can provide insight into the complex processes of climate as a push factor for migration, and into the causal links, thus interrogating the claim of mass migration. A more practical applicability is related to crisis management, as well as to general development aspects.

> Question(s) 2: *How do observations on climatic extremes and climatic change reflect in peoples' perceptions? And what contextual conditions could be possible causes for contradictions between data (hard facts) and perceptions?*

These questions arose from findings during field-work: The local people stated that they have lost a rainy season during the last recent decades, and that farmers have changed their farming strategies in accordance to it. In addition, two different livelihood groups in that region perceived rainfall changes and extreme droughts quite differently. Where one group experienced an emergency situation, another one managed well through a prolonged dry spell.

Two opposing realities, one found in climate measurements and the other in people's climate apprehension and awareness reveal important implications for intervention strategies:
A climate change may not have great implications for society, maybe because it is not seen as one, at least not as a negative one. Or society responds to perceived changes even if measurements do not indicate a change in climate. The people may also perceive individual climate anomalies as extraordinary extremes (such as the drought of the century, the worst event in human memories….), accredited to a first fingerprint and proof of anthropogenic climate change. This would create a crisis without underlying scientific basis (although I do not want to entertain any doubts on the science of anthropogenic warming!).
In situations where climate gives the *appearance* of having changed (not when the change has been measured), environmental, cultural-economic and political factors need to be included into any analysis to explain such a perception.

Together with findings of Paper 1, Questions 2 refer to the importance of timely interventions of governmental and private actions in order to prevent impacts such as famine or migration.

> Question 3: *How is the cliché of good and bad weather described in the print-media manifested in meteorological data? What circumstances contribute to form specific weather perceptions?*

This question has as a point of origin the diversity of contexts in which weather and climate information is taken up in a newspaper's front-page stories. Similarly to research question 2, parallels are drawn between how weather and climate are described by perceptional notion and gauge measurements. Albeit here I do not seek to confirm perceptions of a specific weather condition or climatic trend through meteorological data. Rather, the spectrum of the notion of good and bad weather is grasped by attaching meteorological measurements to the weather descriptions given by journalists. It is hypothesized that defining a day as good is a matter of supply and demand. This would for example suggest that during seasons with generally much rainfall and darkness, even a day with relatively little sunshine gives the impression of a good or beautiful day.

Practical use of this question refers primarily of the method: Print media's presentation of weather and climate issue serves as a proxy to get indications on the importance of sunshine and rain within a society. This could serve as a useful tool for projecting potential impacts of climatic change on people's weather perceptions, and in a wider sense, on life quality.

> Question(s) 4: *To what extent can human thresholds to climate be identified and measured, given the contextual variations over space and time? What climate stimulus causes when and what reaction?*

The issue of climate thresholds has been stimulated by Article 2 of the Framework Convention on Climate Change (FCCC), which demands the prevention of a *dangerous* climate change. This would presume that 'dangerous' can be define, meaning that one can separate between dangerous and safe and that this separation is identified by a threshold.
Through questions 4 a discussion is raised where that turning point which triggers a certain situation or reaction (wanted or unwanted, dangerous or beneficial) may lie. Paper 4 which takes up the threshold issue, distinguishes, but does not separate, triggers on the human physiology and on the human mind, involving as well subjective elements such as perceptions, wants, needs and experiences. It shows how physiological and subjective thresholds interact with each other in a dynamic perspective.

These questions challenge once again the issue of analogy, discussing how far it is possible to transfer knowledge about threshold values at one point in time or location to another. Practical applicability of the questions can be dedicated towards e.g. laws and regulations as well as terms and timing for intervention during climate anomalies.

Question 5: *What are the benefits of pooling an increasing number of regions in terms of necessary risk capital for climate insurance in an African context, and in what way does the spatial covariance of rainfall between regions explain reductions in risk capital for pooling?*

Adaptation to climate extremes and change in Africa from a financial perspective is a rather new issue, recently addressed by the World Bank and the World Food Programme, as well as a small number of private actors. Climate micro-insurance, as a stand-alone product or in combination with micro-credit given to subsistence farmers can be considered as both, an adaptation mechanism to climate change, as well as a possibility for industrialized countries to compensate developing countries for the burden of climate change they have caused.
One reason why the issue of climate insurance in developing countries has so far received only little response from the financial world is the high risk of potential losses any insurance provider faces, as well as the high amounts of necessary risk capital in the start of any insurance scheme. The questions above are addressed in Paper 5 to explore possible options for reducing the needed amount of risk capital for an insurance provider, in order to make the path for provision in Africa more attractive. A geographical approach related to the number of regions in a pool, as well as the climatology – as a combination of frequency and intensity of extreme climate events – of a region offers insight into options for capital savings from the viewpoint of an insurer.

3. CONCEPTS AND TERMINOLOGY

The cross-disciplinary studies that form the backbone of this thesis do not rest on one single body of theory. The connection between the five papers is rather to be found in the concepts that were introduced in Figure 1.
These concepts are characterized by their often unclear and different meanings when used in different contexts and by different authors. Several papers (e.g. Brooks, 2003, Meze-Hausken, Paper 4, O'Brien *et al.*, 2004) have tried to harmonize one or several of these terms and reconcile apparently contradictory definitions. Here, some of the diversity, as well as their relevance in respect to my individual research papers are presented.

Concept	Discussed in:
Variability	Paper 1, Paper 2, Paper 3, Paper 4, Paper 5
Vulnerability	Paper 1, (Paper 2), (Paper 4)
Thresholds	Paper 1, Paper 2, (Paper 3), Paper 4, Paper 5
Perceptions	Paper 2, Paper 3, Paper 4

Figure 2: Representation of the concepts in the individual papers.

3.1 Climate variability - Climate change and climate extremes

Any review of the literature[1] reveals little agreement on the utilization of the terms climate change (regardless of its cause) and climate variability, as well as climate extremes. Deploying one of these specific terms depends primarily on the scientific discipline one comes from, on the time-perspective chosen or the message intended to be proclaimed. While climate variability refers to some oscillation around a reference level, change requires that the system undergoes alteration, meaning to become different. Since changes originate in variations and are reflected in variations, many regard them as one and the same thing. Others separate them but lack a principled account. Depending on the issue in focus, one draws a *line* technically between the change which is in progress and the variation which has not become a change. This line demands that to indicate a climate change, a significant difference in certain characteristics of climate has to be found when several periods of time are compared. Having said this, a closer look at the processes of climate in its peculiarity is needed.

The history of climate is a non-stationary time series without true climatic "normals" (Bryson, 1997). The change in global climate is a response to natural variations in other systems. Their origins are related to lithospheric plate movements, changes in the composition of greenhouse gases in the atmosphere, volcanism, variations in the Earth's orbit and variations in the solar constant, bringing about long-term oscillations over thousands and millions of years. Natural records (proxies) that tell of past changes are scattered over the globe. They can be recovered only piece by piece, and reassembled like a jigsaw puzzle, through the efforts of many people over many years. What emerges is not only a record of climate change and variability, but a clearer picture of the climate system itself. While we have formidable evidence about these processes, much uncertainty (not in terms of its existence but in terms of outcomes) concerns the very recent processes of anthropogenically induced climatic change. These include primarily burning of fossil fuels, aerosols and land use change. In the past decades, much emphasis has been given to the detection of the enhanced anthropogenic greenhouse effect, overlapping the natural forcing of climate (IPCC, 2007; Houghton *et al.*, 2001, Houghton *et al.*, 1995). At this point, the IPCC denotes that the term climate change refers to *any* change in climate over time with variability related to the natural variation in climate, and human activity as an additional contributor to this change.

Climatic extremes or extreme weather events represent an anomaly within its statistical reference distribution, by definition rarer than the 10^{th} or 90^{th} percentile (IPCC 2001 Glossary[2]). The occurrence of climatic extremes is thought to increase under anthropogenic

[1] Compare studies about geological subjects e.g. Haywood A.M., Valdes P.J. & Sellwood B.W. (2002) Magnitude of climate variability during middle Pliocene warmth: a palaeoclimate modelling study. *Palaeogeography Palaeoclimatology Palaeoecology*, **188**(1-2), 1-24., which use climate variability for time horizons over thousands of years, with climate change studies e.g.Warr K. & Smith S. (1993) *Science Matters - Changing Climate*. The Open University, Milton Keynes., which talk about change from everything lasting thousands of years to decades.

[2] See http://www.ipcc.ch/

warming, due to the assumption that a warmer atmosphere with higher (kinetic) energy will lead to more frequent pushes towards the one or the other direction (Meehl *et al.*, 2000). Climatic extremes make significant noise on social and biological systems, disrupting eventually the capability to restore its balance to the pre-event state or lead to complete collapse (dying of species, flooding of flat islands). They have their power in the rarity of occurrence, thus the unexpectedness of the event and the little preparedness, which is valid for most human and natural systems alike.

In reference to my Paper I and II, dealing mostly with rainfall during human memory time of about 10-40 years, it is certainly most adequate, even if it has not always been applied consistently, to refer to such periods as climate variations, without corroborating the purely natural component, if random fluctuations appear year by year or decade by decade (based on random fluctuations in the general pattern of atmospheric and oceanic circulations). I eventually refer to trends and thus, climatic change (meaning different distribution in the mean or other statistics), if a one-directional path can be traced. Outliers on both ends, meaning very little rainfall (drought) or excessive precipitation, are referred to as climatic extremes. Although evident, climate variability as an inherent feature of the climate system is not adverse in itself, but becomes a hazard to society when causing undesired impacts. With regard to the occurrence of extreme drought events, repeatedly used by famine- and disaster early warning reports as both an indicator of an on-going climate change in Ethiopia and as a scream for emergency, the history of drought (Paper I) has shown that practically every 3rd year would be defined as drought year somewhere in the country. Following the IPCC's classification of climate variability and extremes, this either makes drought a part of the normal cycle of the area, or demands a re-definition of drought[3], justifying the statistical frequency distribution of drought as an extreme event.
Paper II deals with climate change as it has been *perceived* by the local society in Ethiopia, regardless of its cause. Although the data analysis based on monthly rainfall data did not reveal any trend towards decay in rainfall, it is certainly probable that intra-monthly changes of frequency, intensity and starting and ending of rainfall may be veiled.
Paper III applies the extreme event definition insofar as it focuses on anomalous good and bad days from people's perceptions in Norway, without questioning the statistical validity of its extreme appearance and discusses the subjective cognition which leads to such a perception.
In Paper IV, both extreme events and climate change are dealt with by exploring empirical examples on human physiological and subjective response to sudden or gradual shifts in climate parameters.
Paper V uses interannual variability in rainfall for calculating risk for rainfall failure, expected payouts for insurers and premiums for farmers, if such failures and resulting harvest failures are insured. Future changes in frequency and intensity of adverse events are only acknowledged, but not yet incorporated in the financial calculations.

3.2 Climate vulnerability

[3] Socio-economic drought rather than meteorological drought.

The ambiguous definition of vulnerability derives from differential understanding in physical science of hazard research and social science. Kelly and Adger (1999) start their discussion with identifying the linguistic roots of the term vulnerability. The origin of this word lies in the Latin *vulnus*, meaning 'a wound' and *vulnerabilis*, describing by the Romans the state of a soldier lying wounded on the battlefield. They go further by using the 'wounded soldier' approach to define the ability of individuals and social groupings to respond to, or cope with, recover from and adapt to external stress. Their focus is the existing socio-economic and institutional constraints (a state that exists within a system from before) which limit the ability to respond to stress, emphasizing the 'social vulnerability'. 'Physical' or 'bio-vulnerability' on the other side, addresses the issue of risk, referring to the probability of the occurrence of a hazard and the probability of a disaster or outcome (Brooks, 2003, O'Brien *et al.*, 2004), including its intensity, duration and speed of onset (Adger, 1996). Social vulnerability may be viewed as one of the determinants of biophysical vulnerability which combines the human exposure to hazards and the system's sensitivity to hazards (Brooks, 2003). Basically, three factors are included in an integrative approach to vulnerability: (1) exposure to a crisis, (2) severe consequences, and (3) inadequate capacity (Bohle *et al.*, 1994, Downing *et al.*, 1996, Yamin *et al.*, 2005). O'Brien at al. (2004) conceives vulnerability as a differential concept, due to the variations of risk and coping ability over space, time, and social groups. For them, the level of vulnerability varies depending on the unit of analysis, from the individual to the group or region. They point out the confusion of distinguishing between related concepts of exposure, sensitivity and adaptive capacity, as to what influences what, reminding of a chicken and egg situation. 'Does vulnerability influence adaptive capacity', or vice versa? Thus, O'Brien et al. (2004) synergize this problem by conceptualizing vulnerability and its loose antonym resilience as 'representing different states along a multidimensional continuum', including biophysical and social properties.

In Paper I, I take up a local level focus on vulnerability among drought affected farmers in Northern Ethiopia. In order to handle the numerous factors contributing to climatically induced[4] vulnerability, an index-based approach has been chosen. Indices or indicators are statistical concepts providing an indirect way of measuring a given quantity or state (Sullivan & Meigh, 2005) at a certain location or situation. They encapsulate various factors or variables into a single number. In my case, when addressing human vulnerability to migrate resulting from exposure to drought, the variables chosen were based on processes which have been specified during the interviews as critical for people's degrading livelihood, influencing their migration decision after a drought. Still, subjectivity and intuition about human-environmental interactions guided the final choice of variables. These variables include a representative range of social and physical factors on household-level. While some can be referred to a generic determinant of vulnerability (Brooks *et al.*, 2005) which could be described as the baseline, e.g. economic endowments, influence of political situation, family size, other variables tried to grasp the context-specific determinants of vulnerability (*ibid.*), e.g. water availability, off-farm working possibilities.

[4] When writing climatically *induced* rather than only climatic vulnerability, it is to point out that one cannot pick out climate as a separate unit for vulnerability but rather one that is embedded in the a environmental-social compound.

Although the weighting and summing up of vulnerability index has not been tested further, e.g. by weighting in different ways, and this is a shortcoming of my approach, the main message will be the same: that it is social and biophysical factors in combination contributing to vulnerability. Nevertheless, several limitations of an index-based vulnerability approach are apparent: Sometimes one individual factor can offset the weakness or strength of others, thus making the difference in triggering a response. This fact is difficult to be picked up by an index. In addition, while an index may classify people as vulnerable, they are certainly not helpless, as described in Paper I by an analysis of coping strategies. In addition, as vulnerability does not necessarily lead to a specific action, it cannot be used as a valid indicator in itself for calculating potential impacts. A stimulus first needs to surpass a certain threshold, in order to trigger factual actions or response, as discussed in Paper IV. Due to the highly context specific approach, comparative assessments of vulnerability with regions outside Sub-Saharan Africa would not be meaningful.
Looking back, I do not feel very comfortable with an index-approach any longer. To my mind, the value of an index gets lost in the momentum of the local system: If one adjusts an index to each region, situation and hazard, comparability is disabled. If kept comparable, indices feel too inelastic to capture the peculiarity and thus, local exceptionality of relevant factors.

3.3 Climate thresholds

Thresholds have been discussed in theoretical and empirical detail exhaustively in Paper 4, therefore, only the main facets of this concepts are recapitulated here. While climate extremes or variability as defined above signify the stimulus, and vulnerability refers to both the probability of occurrence of the stimulus and the baseline sensitivity of the system, thresholds mark a kind of turning point or point of entry for the actual response of the system.
In respect to climate or climate change, the two ways of approaching thresholds are reiterated: the one refers to the question of "Can climate thresholds for society be established or measured" and the other "Can human thresholds to climate be established or measured". Partially, this is a matter of semantics, a subtle distinction in which way to set up the question. But partially, it is referred to the goal in mind. While the first question specifies *a climate variable as a threshold*, which causes a specific human reaction, in the second question *the reaction signifies the threshold*, which can be traced back to a certain climate condition.
The interest for the threshold terminology arrived – as already briefly mentioned in Chapter 2 – from the demand of the FCCC to prevent a dangerous climate change. When expanding the view of climate change not only being dangerous but providing opportunities as well, I defined a threshold as a general turning point for something to happen, which is not restricted to negative consequences.
Paper I touches the threshold concept by investigating what triggers climate induced migration. Rather than suggesting a specific climate condition as the initiation for an action, the response process after the onset of a climate extreme is illuminated and crucial moments evaluated.

Paper II examines –among other issues - the different thresholds to climatic extremes of two livelihood groups: while one group experiences an emergency situation, another one still manages to overcome a tough period satisfactorily.
In Paper III, thresholds are treated implicitly when analysing what combination of climate variables distinguish a good from a bad weather day.
Thresholds in the sense of starting points for insurance payouts after rainfall failure are discussed in Paper V. They differ for each geographic region based on local yield levels and drought response, as well as occurrence rate of drought. Here, thresholds are here defined in terms of economic feasibility of an insurance scheme rather than on real-term climate disaster implications in a region.

3.4 Climate perceptions

Climate models and impact studies have given us reproducible and quantitative results on potential outcomes of climate change to different environmental and social systems. One component, climate perceptions, has nevertheless been mostly ignored by the climate community, or maybe just as taken for granted and thus not incorporated. Perceptions in humans describe one's ultimate experience of the world, a process whereby a sensory stimulation is translated into organized experience (Encyclopædia Britannica, 2006, Lindsay & Norman, 1977). Climate perceptions grasp the 'soft' side of influences triggering a response. As they are not directly observable, their validity or characteristics can be checked only indirectly. Although handled mostly by highly advanced methods within psychology and brain research, the concept of perceptions has been applied in a simpler and more integrated form into hazard research. There, e.g. risk assessments are carried out on potential victims about information and attitudes to the environment or climate (Mitchell, 1984). So far, the IPCC, especially Working Group II, has not included climate perceptions in their impact assessments, but key persons in the group have started to realize their importance and hope to include this issue in their next assessment report (P. Linden, pers. comm.).

Perceptions are dealt with in Paper II, III and IV, although from different angles. In Paper II perceptions on drought and climatic changes during human memory time are grasped through qualitative interviews and the degree of correspondence between this perception and statistical data over the same period evaluated. Reasons for deviations have been reflected.
Paper III comprehends people's perceptions through proxies by analysing media descriptions of weather anomalies. The physical world, meaning, measurements on individual weather parameters, is attached to good and bad weather day descriptions, as such measurements and perceptions complement each other.
In Paper IV, perceptions characterize moments for response or impact, not alone, but as one element in a complex decision and response system. The model represented there indicates that perceptions contribute in changing thresholds.

4. METHODS

Due to the fact that a interdisciplinary approach informed my studies of climate-society relationships, no straightforward methodological entry could be chosen. The subject is not clearly delimitable or considered as an own or established field of research with uniformly accepted procedures of performance. Thus, it was the individual research question under investigation, which guided the choice of method to be applied, and the process of selection can be considered as a careful testing of possible quantitative and qualitative approximations rather than a well tested and ready-to-serve standard approach. Triangulating, using more than one technique or source of information to cross-check answers and comparing and complementing information from different sources (Valentine, 1997, quoted in Longhurst, 2003) characterizes probably best the accomplishment of the overall study method. Triangulation is not considered as a tool or strategy of validation, but an alternative to validation (Flick, 1992, in Denzin & Lincoln, 2003,), and as such an attempt to secure an in-depth understanding of the phenomenon in question (Denzin & Lincoln, 1994, p.2)

4.1 Field-work critically reflected – rapid rural appraisal, interviews

Twice, field-work was undertaken in the North of Ethiopia, southern Tigray and the North Afar zone, during spring 1999 and summer 2002. The area was chosen as it is a region prone to recurrent droughts, famine and migration. It was assumed that the issue of human vulnerability to climate (change), people's traditional coping strategies and their perception on on-going climatic extremes/changes can be examined clearly. People depend very much on climate in their subsistence of livelihood. Practically all farming is rainfed agriculture, and pastoralism is characterized by transhumance. A more detailed description of the main geographic features of the region, its topography, livelihood strategies and some demographic features can be looked up in Paper I and II.

The intensive droughts of the mid 1980s in Ethiopia, resulting in approximately 1 million dead and many more millions of migrants (both internal and international), driven by hunger, thirst and civil war, gave rise to the question whether this happening could serve as an analogue for what may/could be expected under anthropogenic climate change in the near future.

a) Rapid Rural Appraisal (RRA)

The first field-work in 1999 in the highlands of southern Tigray was conducted to investigate whether people could be found who could be classified as real climate migrants. A climatic extreme, in this case any drought during their life-time should have been the only or main reason for their migration. One may certainly wonder why I had not done a comparative study on local people who did and those who did not migrate during drought, in order to examine the differences in vulnerability leading to or preventing migration. This may have been a useful approach indeed. Nevertheless, my main intention was to explore as to how far projections on mass migration under climate change (Myers, 1994, Trolldalen

et al., 1992) may be valid by examining whether I could already find people fitting in this category of climate migrants, based on past climate events. Therefore, the problem in focus was a different one.

A Rapid Rural Appraisal (RRA) was performed based on interviews with key informants, review of secondary sources, and a questionnaire survey. The RRA was carried out with the help of four students from the local agricultural college who I trained and accompanied most of the time. A RRA is performed to elicit and extract information by outsiders (and for the research benefit for outsiders in the first place), as opposed to a Participatory Rural Appraisal which is designed for local people's knowledge (Chambers, 1994). The origins of RRA can be found in farm systems research, designed to obtain new information and to formulate new hypotheses about rural life (Crawford, 1997). As a bridge between comprehensive formal surveys and unstructured research methods, Chambers (1994) suggests nevertheless to exchange the first R (rapid) with "relaxed" as such studies usually require care, patience and planning to have plenty of time.

For the questionnaire survey (Lafferty, 2003), farming villages were selected in those areas which had been especially badly hit by rainfall failure during 1984/85, although there, many respondents referred to droughts before and after those years as well when asked about migration. The selection of candidates for the questionnaire had to be done with care: Ethiopia, and especially the northern highlands were exposed to decades of civil war, leading to cease fire not before 1991. Those candidates, who claimed in a pre-investigation that political unrests or fighting contributed to a considerable extent to their decision to migrate during the droughts of 1984/85, were excluded. 104 participants who at least once had to migrate with drought as a main reason for it, were finally chosen for the questionnaire, which lasted around two hours to respond. Each of them got some background information on why the study would be conducted. The talks were arranged either in a village bar or in private huts. A mixture of open-ended and fixed-response questions elaborated, besides basic demographic questions, issues on baseline vulnerability of the farmers before the dramatic drought years resulting in migration, as well as the process from the start of the drought and the timely sequence of survival strategies applied to avert further starvation and eventual migration. Although the participants got questions on whether they left their homes for good or returned after the crisis had been overcome, this differentiation had not been followed up.

Key persons interviewed were agricultural extension workers, local village leaders, co-ordination officers of the Regional Government of Tigray, migration researchers at the National Disaster Planning and Preparedness Commission, agricultural researchers at the regional agricultural university as well as climatologists and famine early warning experts at the National Meteorological Services Agency, Addis Abeba. Their information served as a setting for interpreting the results of the questionnaire. Secondary sources refer to governmental and NGO reports on drought, famine early warnings and migration issues.

As a practical problem during field-work, I denoted little motivation from the interviewees to spend their time answering questions, as well as seemingly standardized and prefabricated answers that would "please" the interviewer. Several prospective participants also demanded money or food before deciding to accomplish the questionnaire, a matter

which was turned down, and instead everyone was invited to a drink. Investigating this strange occurrence revealed that these villages which were being badly hit by drought were closely located to the town of Korem, the main beneficiary region of Bob Geldorf's campaign Aid for Africa in 1996, 'teaching' local people that they can expect remunerations and donations from foreigners. In addition, the region was the main focus region of the local university, which gives research permission for, and sends researchers only to that single area, regardless of their specific field of research. Completely over-researched, being involved in too many interviews of mostly foreign researchers who do not directly contribute to an improvement of the local people's living situation caused frustration and boredom of the people who were forced by their local political leaders to provide insight into their poor life and privacy. The on-going border war with neighbouring Eritrea during my stay resulted in additional pressure for both the locals and me, surrounded by troop activities and low-flying battle jets dropping "test-bombs" on farming fields while performing questionnaires.

b) In-depth Interviews

The second field-work in 2002 was carried out in the adjacent Afar depression in North Ethiopia. The timing of my field-work could not have been planned better, as for the main rainy season, drought alert was projected. This proved to be right during my stay and gave me thus insight and first-hand experience on human response to drought.
Having become wiser due to the practical problems during my first field-work, I decided to continue without the regional university's backing, and chose a more remote region. According to rumours I got to hear during my first field-work, during the 1984/85 drought the farmers in that area were forced to leave their homes, giving space to in-migrating pastoralists who did consider the local living conditions as still satisfactory[5]. The rationale was to investigate by in-depth interviews whether these two livelihood groups have different climate induced thresholds in respect to suitable living conditions and migration. An in-depth interview[6] is a qualitative research technique that allows person to person discussion. It can lead to increased insight into people's behavior on important issues, their thoughts, feelings, and climate perceptions. The interviews were semi-structured (Longhurst, 2003) and encouraged an informant to talk at length about the topic of interest. In addition, discussions were held in focus groups, either on the local market or in villages. While the interviewed farmers came from nearby, pastoralists had up to two days march behind them when they arrived at the market. Recruiting of participants was done randomly by approaching them either on the market, in their village, on the road or on their field, as the purpose was not to get a representative sample of the population but rather a general insight about understandings of climate and human response.

The interviews with around 45 pastoralists and farmers, as well as several key-informants revealed facts and narratives about perceptions on drought, both previous ones and the on-

[5] Inquiries revealed that the drought-migrating Tigrinian farmers did not give space to Afar pastoralists, but instead, these two groups had lived side by side since the 1950s. During the 1980s droughts, the Afar managed to stay in the area while the Tigrinians gave up and migrated to aid-camps and towns for a period.
[6] In Paper II, I referred to 'open interview', meaning that they were semi-structured, as described in this section, and raising questions without providing possible answers.

going one, as well as on climate change. Key informants were local politicians, extension workers, teachers, drought researchers, the guard of the local weather station, as well as village leaders.

The North Afar, inhabited by native ethnic Afar pastoralists practising trans-humance, and recently in-migrated Tigrinian farmers, is one of the very remote and completely un-researched areas in Ethiopia, yet not served by roads suitable for cars or electricity. Hot and dry dusty climate makes the stay in this hostile environment very challenging. Until recently, not even the National food-aid or disaster preparedness commission accessed this region. Apparently, the local people had never had contact with foreigners, or researchers, and thus, were highly motivated in giving interviews, albeit the complete failure of the recent main rains (*meher*) and acute famine, water shortages as well as mass-dying of animals shaded and influenced their response. Surrounded by dramatic hunger and the dying of small children as a daily feature gave rise to reflecting on the field-work from an ethical perspective: how far is it justified to dig in human sorrow – just to satisfy scientific curiosity?

4.2 Content analysis

"Content analysis is a replicable and valid method for making specific inferences from text to other states or properties of it source" (Krippendorff 1969, p.103, in: Mayring, 2000). It enables one to sift through large volumes of data and by coding the content of documents, allows inference by identifying special characteristics of messages (Holsti, 1969 in: Stemler, 2001). While in most instances, the analysis is quantitative, meaning, a word-frequency count or a search for synonyms (Stemler, 2001), I used in Paper III a qualitative content analysis where themes and main ideas of the text produce the primary content. The intention was both to identify and select front-page articles specifically devoted to climate and weather topics, for instance discussing storm damage, accidents due to icy roads, climate conferences or a beautiful summer day, or those articles that treated weather and climate at least tangentially, such as describing a sport or out-door event and referring to the weather conditions surrounding that event. Both climate and weather by word or by meaning were criteria for the selection of an article.

In the first place, I attempted to categorize the articles according to the primary topic dealt with, and sampling unit was the individual front-page article, regardless of its size. If the headline already contained a weather or climate theme, this one was selected for the coding. While there were around 80 categories in the start, they had been compiled to nine main groups later in the process. As obvious, the demarcation of the categories was artificial and not absolutely distinct. For reliability, coding of the texts was performed twice. Still, the weakness of that approach was that the categories which emerged in the course of preliminary examination of the data were set in terms of intuitive borders, rather than pre-established coding rules. In addition, to group a text covering two topics equally, resulted in much subjective judgment. Further, a front-page text is ambiguous in itself, as the rules of what comes on the front-page are diffuse: it depends on the editorial policy, the competition with other news, as well as on the emotional impact of a story (Davis & McLeod, 2003).

As a result, I decided not to come up with quantifications of texts in the individual groups, but rather rough indications of which type of topics got what level of attention in the front-page news, as the specific numbers were not of primary importance for the further investigation. This enabled me to get an overview over the importance of individual weather/climate aspects in the newspaper, and in a second step, to select certain types of articles for further investigation, as described below.

Comparing text contents with climate measurements

In an attempt to put numbers to qualitative weather descriptions, and in such, quantifying the cliché of what makes a good or bad weather day, I selected front-page articles with weather descriptions and compared them with meteorological data of the described day. All those articles were selected where (a) a specific day was the main news due to its especially sunny, rainy, hot or cold weather, or those (b) where an event was the main topic but with a specific reference to the weather during that event (such as an out-door concert, an anniversary with open-air festivals or visits of famous persons). The articles had to be linked geographically to Bergen directly, and thus tied to meteorological data from one specific station.
The rationale was to contrast perceived weather, as described in the news through a journalist, with actual weather data, without judging of how representative these descriptions are. The texts were placed in the two categories "bad" or "good" weather, according to which of the two focuses was chosen in the description. Connotations of the text like 'sunshine', 'finally summer', or 'beautiful spring day' were classified as good, while 'freezing', 'gray' and wet', or 'rainy' were coded as bad. But also simply cold or windy air during a summer event may be a reason that an event was characterized as bad, if people, or the journalist, expected warmer weather. Nuances of very good or very bad weather were left out for reasons of simplicity. The articles were divided into seasons, as it is hypothesized that people may have a different view of a good/bad day in winter compared to during summer, in relation to amount of sunshine, temperature or precipitation. Outcome was a spectrum in climate variables of what was considered a positive or negative day in respect to weather.
While I have not found other studies doing similar investigations in this field, I considered this method as a tentative approach for grasping societal perceptions on weather and climate in a quantitative way. Nevertheless, when working with news articles, and thus, views of journalists on weather, all the underlying restrictions and uncertainties as to how far these views actually represent people's perceptions or the selection process behind an article to be chosen for the first page (which was the subordinate selection criteria for further investigation) certainly allow only careful interpretation of the results.

4.3 Climate statistics

The amount of climate data analysis has been kept to simple statistics, restricted to mean, standard variation and coefficient of variation, as well as deviations from mean of time-series qualifying for a 30-years period determined by the World Meteorological Office (either 1961-90 or 1971-2000). Dorling (2003) argues that simple statistics are more easily understood and more convincing. In the case here, they are primarily used to be compared

with qualitative data (people's perception), and with regard to the availability of data, any more sophisticated analysis would have not been suitable. The data for Ethiopia, obtained from D. Conway, CRU/UEA Norwich, were restricted to monthly precipitation values, as daily data were not obtainable. The primary goal was to set these monthly and yearly series in contrast with people's perceptions on rainfall over the same period. Mass curves for months and seasons have been constructed to roughly investigate possible trends in rainfall. While I got hold of daily rainfall data in Ethiopia just recently by Segele and Lamb (2005), these have not been analysed within the scope of this thesis. In that case, more advanced time-series analysis would have been suitable. Paper I and Paper II operate with different rainfall means and time-series when making comments on potential rainfall trends. While rainfall development with 1961-90 data may indicate a decrease in rainfall for certain stations in the North of Ethiopia (Paper I), the 1971-00 trend shows for certain stations an increase in rainfall, a recovery from the below normal period of the mid 1980s. Such divergence may bias the interpretation of results and demands careful analysis of such data over the whole period where data are available.
The precipitation and temperature data for Bergen used in Paper III, I got from the Norwegian Meteorological Institute (DNMI), and the sunshine date I obtained from H.A. Olset, Geophysical Institute of the University of Bergen, Norway. Here, again, no time series analysis has been performed, but the data have been used as attachment to weather perceptions as described in the newspaper.

4.4. Monte Carlo Method

Monte Carlo Methods are stochastic techniques-meaning they are based on the use of random numbers and probability statistics to investigate problems. They can be seen as a computational algorithm which simulates, as in this case (Paper V), the behaviour of annual rainfall for individual sites in Ethiopia. In each simulation, the model draws a particular random year from a given distribution. That year gives rainfall values for each geographic site. With the output, it further calculates potential yield losses of farmers and insurance payout in each location, and across the locations in the aggregate (pairs of location, pooling with three locations) in case of rainfall failure. The spatial rainfall correlation between the locations within one year is kept. While the method allows to simulate a broad spectrum of potential climatic conditions and resulting risk for bankruptcy of an insurance scheme by providing a distribution curve of necessary risk capital based on 10.000 trials, several draw-backs exist which are discussed in more detail in Paper V.

5. SUMMARIZED RESULTS OF THE INDIVIDUAL PAPERS

5.1 Migration caused by climate change: How vulnerable are people in dryland areas? A case study in Northern Ethiopia

Paper I deals with drought affected people in Northern Ethiopia and their vulnerability to climatic extremes, investigating how likely people are to migrate. Persons have been questioned who at least once in their life migrated after a disastrous drought. Their

vulnerability before the onset of a climate anomaly has been mapped as well the processes and timely sequence of strategies applied to avert famine and break-down of livelihood. The field-work showed (1) that it was possible to find real climate migrants in North Ethiopia, fitting the description of Myers (1994, Myers & Kent, 1995), but not straightforward. In respect to drought which affects crop growth and drinking water supply, it is relatively difficult to categorise someone as a climate migrant. Food supply especially is not directly related to climate, as issues such as entitlements (Sen, 1991), logistics, transport, trade, political stability as well as others contribute to determine or averting starvation. (2) One hypothesis was that better endowed families or those with a greater social network before the onset of a drought are less vulnerable and manage greater resistance to migration. However, the study reveals that during drought, basic survival needs surpass any other factors: a deficiency in drinking water forced people to migrate instantly regardless of their original economic or social status, and thus, baseline vulnerability. This confirms that vulnerability is a highly complex phenomenon. It is a relative concept as well, not only over space, time or social groups but also in respect to the importance of certain factors in contributing to an overall vulnerability. (3) Similarly as vulnerability does not necessarily make someone a migrant, to fall into a wider definition of a climate migrant does not mean someone was highly vulnerable from before. As such, a causal relationship between climate as a trigger and migration as an effect is not very clear: there are many other issues involved and many steps in between where other actions than migration are stimulated. Migration is probably one of the very dramatic outcomes. (4) Location specific settings of vulnerability and changes in the characteristics of the society and environment allow only careful analogical reasoning: the predictive value of past knowledge and understanding of relationships between variables is relatively limited. (5) The choice and differentiation of coping strategies contributes decisively to the prevention of harmful consequences.

The paper concludes that as long as a socio-economic and political system enables successful performance of coping strategies, the people for whom drought is a recurrent phenomenon, show high adaptation and resistance to climatic forces. Therefore, although it cannot be excluded that climate change may contribute to migration decisions in dryland areas, any mass migration scenario is highly unlikely.

5.2 Contrasting climate variability and meteorological drought with perceived drought and climate change in Northern Ethiopia

Paper II has its roots in a narrative telling that in a certain village in North Ethiopia, during an extensive drought in the 1980s farmers had to migrate due to starvation and lack of water, while pastoralists from adjacent areas moved into the location and managed to overcome the tough period satisfactorily. While it turned out that pastoralists did not move into the area of the drought-migrating farmers, as these two groups had lived side-by-side from before, it nevertheless gave rise to the question why one group managed better through a dry spell than another: rainfall needs of pastoralists and farmers differ, in terms of timing, intensity and frequency. In addition, these two groups have different strategies in case of rainfall failure, some more suitable than others.

The second issue in Paper II was related to farmers' and pastoralists' perceptions that climate has changed during memory time and that they have lost one rainy season. They even changed their agricultural cycle accordingly. The low correlation between the objective reality (rainfall data) and the constructed reality (rainfall perceptions) about a lost season demanded a deeper investigation of how perceptions actually arrive: (1) When comparing individual rainfall seasons, people use optimal rainfall as a benchmark. Optimal rainfall is defined in terms of desired economic performance, and differs for different livelihood groups. But optimal rainfall does not match normal rainfall, a statistical mean. (2) The need for sufficient and reliable rainfall has changed during the recent decades: population increased and immigration of farmers into the pastoralist areas increased the competition for natural resources. (3) Most farmers migrated into that region during the 1950s and 1960s from the highlands, where they had higher rainfall in general. The period they migrated into the mid-lands was known to be relatively wet. Thus, people compare the current situation with what they were used to before in the highlands *and* with a period in time which may not be representative for the mean rainfall conditions in their new neighbourhood over long time. Maybe the area would have not been suitable in the long run for rainfed agriculture at all? (4) As the analysis of rainfall was based on monthly data, daily data – if they had been available – may have revealed changes in rainfall intensity or frequency, as well as starting or ending of the rainy season.

Resulting, both the combination of data paucity and the social and environmental context in which perceptions have been formed, may serve as an explanation for the divergence between climate statistics and people's conception of reality.

5.3 Weather and Climate news in the newspaper of Europe's wettest city, Bergen/Norway.

Paper III deals with the portrayal of the various aspects of weather and climate treated in front-page news stories. Their content is used as a surrogate for grasping local peoples' climate perceptions. A content analysis reveals the broad range of weather and climate related topics in the news, from facts about weather anomalies to seasonal descriptions with poetic elements, which serves as a background and basis for interpreting the results of the quantitative study described in the following.
Like Paper II, Paper III compares perceptions on climate with climate measurements of the same variable (sunshine, temperature, rainfall) and time-context. The perspective is nevertheless different, as here it is not the verification of a perceived change through gauge measurements, but instead the quantification of a perceived weather condition which is described based on subjective cognition of a journalist. An attempt is presented to attach values of climate variables to weather as described by a narrative in news stories. Uncovering the cliché of good and bad weather reveals that seasonal aspects have to be taken into consideration for ascribing a day a good or bad weather image: (1) During winter, sunshine is most important for defining a day as beautiful, for the summer period, temperature is most decisive. (2) During spring, the expectations to finally escape the dark and wet winter are strong. There the threshold for what is regarded as beautiful weather is

lowest, meaning that at least some sunshine during the day or higher than average temperatures gives the appearance of a good weather day. (3) Characterizing a bad weather day is less related to the absolute amount of rainfall during a day, but rather has to be interpreted in respect to the amount of rainfall of the previous days or the number of days in a row of rainfall, as well as in respect to the context in which the bad day was mentioned in a text (e.g. accident).

It is evident that human perceptions of weather cannot be read off meteorological stations. Still, they have a value in itself: Choosing front-page news from the regional newspaper of Bergen, which is Europe's rainiest city, gives the study a special context, as one could hypothesize that there sunshine must be valued more highly (due to its rarity) and rainfall descriptions interpreted in a different light than in other European regions[7]. Considering projections of increase in rainfall of up to 20% in Western Norway due to anthropogenic climate change, perceptions of daily or seasonal weather anomalies may well play a role in how society will think about and experience such a projected aggravation in weather.

5.4 On the (im-)possibilities of defining human climate thresholds

In Paper IV, the discussion is taken up about how individual and compounded climate variables trigger reactions or behaviour changes *of* or impacts *to* individuals and societies. The paper differs from the other papers, as it does not have a single specific empirical study as the core of its discussion, but rather conveys a mixture of various examples based on a literature review, re-interpretation of research results and conceptualisation of a model. By means of four case-studies, on temperature extremes, drinking water, tourism and migration, it is illustrated that (1) effects of climate to the body physiology and to the human mind (subjective perceptions, expectations and experiences) can only for reasons of convenience be treated separately as the effects interact with each other and may enhance or reduce threshold levels to climate. (2) It is highly case-dependent whether climate is a real trigger for a reaction (such as sweating) or just one out of many influence factors (holiday destination choice, migration). (3) A quantification of thresholds is only highly restricted possible, sometimes in form of a range of values, sometimes only as a narrative. In many cases thresholds can only be determined by acceptance, demanding a value judgement of what climate stimulus is considered as dangerous/unwanted or still acceptable. (4) Thresholds which trigger a reaction are influenced by the experience of an individual with the climate stimulus. Repeated or continuous exposure creates both physiological adjustment and customisation. Through time, any socio-economic, cultural and technological change contributes their part in changing the reception of the stimulus and thus, alters the threshold levels. But sometimes, what is considered as development, such as technological progress, can have opposite effect on human beings, reducing their threshold level beyond which a response is produced, such as increased urbanisation creating heat islands.

[7] Any interpretation of the data as a hermeneutic self-reflection due to my geographic origin from a southern European region much drier and sunnier, has been avoided as much as possible.

It can be concluded that there is no universal dose-response relationship between one climate variable and a specific outcome, also because of the combined effect of interacting climate variables. Physiological factors as well as culture and technology contribute to a permanent re-adjustment process to climate stimuli and modify threshold levels. In respect to policy response, there is a need for dynamic decision making to adjust to changed thresholds over time and between places.

5.5. Hedging climate risk for micro-insurance providers in Africa

Paper V is following up earlier research on drought adaptation in Ethiopia, while taking a different approach and method. Having been involved for a period in the Risk and Vulnerability Group at IIASA, International Institute for Applied Systems Analysis in Vienna, where economists and statisticians research economic risk of micro-insurance provision in developing countries, this study continues in this area by investigating how to insure climate risk of subsistence farmers from an insurance provider's perspective. Offering climate insurance, especially in developing countries, can be seen as a possible strategy of industrial countries to bear their responsibility for impacts caused by anthropogenic climate change. Still, the financial sector's involvement would be only one of many measures to help people adapting to potential increases in the intensity and frequency of extreme climate events.
So far, the insurance sectors involvement in Africa has been very limited. One reason is the need for sufficient risk capital in order to prevent insolvency in case of recurrent adverse climate events. Paper V takes up the issue of how insurance contracts spread over different geographic regions with different climate risk can reduce the required risk capital. By means of a model, various climate scenarios for the next 30 years are simulated, based on past rainfall data in 15 regions in Ethiopia, and potential yield losses, payouts and consequently, required risk capital accumulated over time has been calculated. It has been shown that (1) already hedging climate risk between two regions reduces the necessary risk capital considerably, and further pooling of sites contributes to even higher savings in necessary risk capital. In addition (2), to some extent the height of the savings can be explained by the rainfall correlation between two sites. The lower or the more negative two sites correlate, the less risk capital is needed. This simply means that the more different two regions are in their occurrence of drought, the better the risk of drought failure and resulting insurance payout can be hedged. The study recommends that potential insurance providers, rather than starting small scale in a single developing country region with offering climate insurances which then will be scaled up over time will pool the risk by selecting several sites right from the beginning, even if the number of insurance contracts is kept low in the start. This principle geographic risk pooling has shown to work within the re-insurance sector in all the industrialized countries, and is worth applying in the developing world as well.

6. CONCLUSION – MAKING SENSE OF IT ALL

> *The outcome of any serious research can only be to make two questions grow where only one grew before.*
> Thorstein Veblen (1857 - 1929) US economist & social philosopher

A main goal when studying climate-societal interaction is to make some statements about the extent and way society will handle the impacts of increased global mean temperature as a result of anthropogenic interference[8]. One way for projecting these impacts is to investigate how humans have handled climate variability and extremes so far with focus on its specific contextual setting. Based on a number of case-studies it can be said that four issues characterize the climate-society interaction as a phenomenon. All the case-studies have shown that the climate-societal relationship is highly ***complex***. Actually, one needs to talk about 'relationship' in plural, because an individual or society faces various interactions with climate, acting parallel to each other. Grasping the numerous variables, their interactions, feedback processes and hierarchical structures seems a sheer impossible task. But exactly this complexity is a main feature of environmental problems which prevent reductionist approaches from having any, but the most limited useful effect (Funtowicz & Ravetz, 1990, 1999). It is highly case-dependent how weather, seasons and climate extremes impact our everyday life, sometimes directly, sometimes indirectly, and varies between individuals as well. Being able to say something such as how and to what extent climate determines, means one can only infer from a single event at the time.
Changes in involved environmental and social variables, together with the ambiguities surrounding the development of the climate stimuli give rise to ***uncertainties*** involved in projections for future outcomes. These uncertainties are an accumulation and adding up of individual uncertainties derived from the projections of human socio-economic development which decide about the path of greenhouse gas development, the radiative forcing and climate response, feedback-processes, and finally the climate impact and adaptation/mitigation effect (Figure 3). Valuing these uncertainties is a matter of one's risk attitude and environmental/technological ideology.

[8] Although as stated earlier, *this* study concentrates primarily on impacts of climate variability and extremes, and only secondly refers to anthropogenic climate change.

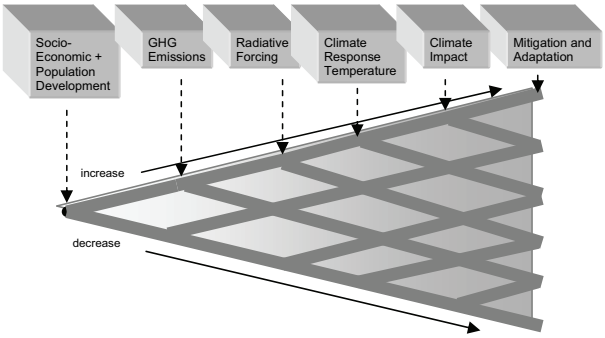

Figure 3: The accumulation of uncertainty in scenario assumptions, based on one's risk attitude and environmental/technological ideology (Beniston, 2002, adapted from Viner, 2002).

By grasping peoples' perceptions on climate and weather and contrasting them with factual measurements, other ***stakeholders*** than the established science community become important formal interpreters of climate anomalies. Until the 1980s, "climate science" remained within the confines of academic pursuits, based on disciplines such as meteorology, oceanography, glaciology and some aspects of geography (Bray & von Storch, 1999). Later, an extended peer community of the Intergovernmental Panel on Climate Change (IPCC) assessment reports (IPCC, 2007; Houghton *et al.*, 2001, Houghton *et al.*, 1995) became established, involving experts, different governments and non-governmental organisations. Today this extended peer community from the academia starts to lose their monopoly as official experts and sources of truth, closely being caught up by lay persons revolution of the internet and potential victims of climate change. Their expertise and first-hand experience, as seen with farmers and pastoralists in Ethiopia, or inhabitants of weather exposed western Norway, become an important part in the formation of scientific findings and interpretation. In addition, they start to take charge of their own destinies and prepare for the impacts ahead. Nevertheless, as the Intergovernmental Panel of Climate Change (IPCC) suggests, future evaluations in their scientific assessments may include "soft science", such as the incorporation of local knowledge on climate (e.g. Ibrahim, 2006) and climatic perceptions collected by sociologists, geographers and anthropologists as well.

Changing temperature, wind and precipitation conditions due to anthropogenic climate change which may even manifest in rapid shifts and surprise effects requires ***urgency*** to act and to improve preparedness to adverse climate conditions. There is potential of non-reversal processes, both within the climate system and with respect to impacts on nature and humans, as well the possibility of high costs. This requires, instead of focusing on the universal truth and waiting for refined climate model results and detailed socio-economic forecasts of development paths (the latter one which may be impossible to reach anyway), to address the issue without delay. In addition, the time-horizon of the atmosphere, meaning the delay of radiation balance due to changed atmospheric composition, is long, taking up to around 200 years, depending on the individual greenhouse gas (Houghton *et al.*, 2001). Actions to mitigate greenhouse emissions today will not be measurable immediately in climatic terms. This means that the intergenerational equity principle (Turner & Pearce,

1992) will have to be addressed by policy actions, enabling future generations to have the same options and opportunities as present generations. Both aspects of uncertainty and urgency are present in the precautionary principle (O'Riordan & Cameron, 1994), which is concerned with reacting to the unintended harmful effects of progress (Ravetz, 2004).

To summarize, faced by the challenge of dealing with societal impacts of climate change, either as a researcher, a policy advisor or an individual person (potentially) affected by climate, one has to acknowledge the complexity of the issue, high levels of uncertainty involved, the necessity to act urgently, and the various and often conflicting stakes engaged. These features and in general, findings surrounding the climate system and climate impact modelling do not conform with the claims of the traditional assumptions of science, namely that science is both certain and value-free (Kuhn, 1962, in: Ravetz, 1999). Instead, they are manifested in the *post-normal science philosophy*, which addresses policy-relevant issues involving high risk and uncertainty (Funtowicz & Ravetz, 1990, 1999, Ravetz, 1999, Ravetz & Funtowicz, 1999). The post-normal science philosophy acknowledges that science (in many cases) needs to be open for a variety of interpretations through a plurality of legitimate perspectives and different types of knowledge, and different validation processes to ensure quality control. This resultantly leads to a more value laden character of science than in the Kuhn's tradition.

Funtowicz and Ravetz present post-normal science in relation to the more traditional problem-solving strategies by means of a diagram (Figure 5). It exhibits three kinds of inquiries or scientific advice in terms of the two attributes of "system uncertainty" and "decision stakes". Normal, or applied sciences refer to the use of standard scientific techniques and procedures for review and quality assurance, where both system uncertainty and decision stakes are low. With both attributes being medium, professional consultancy is based on expert judgment as the application of routine techniques is not enough. Errors are matters of personal opinions and based on competence. The last kind of inquiry refers to problems with extreme uncertainties in the understanding of complex systems where problem-solving strategies need to reckon the decision-stakes of the various stakeholders, so that the plurality of legitimate perspectives comes into force.

Ravetz and Funtowicz (Ravetz, 1999, Ravetz & Funtowicz, 1999) recognize that post-normal science has so far developed to an insight rather than a theory, as '*it is only one partial glimpse into a complex reality*'.

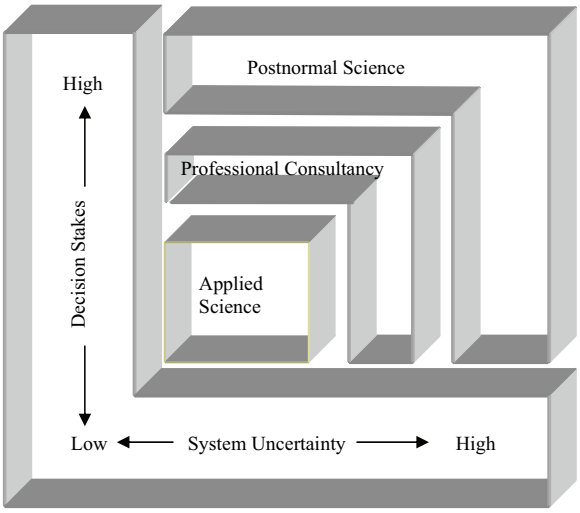

Figure 4: Three kinds of scientific advice – applied science, professional consultancy, post-normal science – measured by the uncertainties about the system on which advice must be given, and the magnitude of the public issues at stake in the decision (Funtowicz & Ravetz, 1990).

This *complex reality* is what all the papers in this thesis face, as well as its *partial glimpse* one gets when analysing the relationshipS between climate and society. The thematic and regional point of departure of this thesis was the impact of climate change on migration of people in dryland East Africa. Both personal reasons and the need to deepen knowledge on people's understanding of climate and its variability resulted in a shift towards more basic research on the complex relationship between the individual climate variables and the human physiological and mental/perceptional response. That relationship – although universal in its general existence, varies over time and space, in intensity and in level of economic expenses.

This thesis through its five papers has tried to contribute to the field of climate impact research with several aspects: (1) It illustrates the complexity of defining climate vulnerability, the baseline condition under which anomalous climate conditions strike a household or a society, and demonstrates that while vulnerability may say something about the potential to cope with such events, individual components of vulnerability separate success from failure of coping strategies. In some instances, a single variable can make the difference in triggering a response: For example, the two droughts in Ethiopia, described in Papers I and II, during the mid 1980s and 2002 were comparable from a meteorological point of view, as well as the baseline vulnerability of the population. Still, the political stability and early public intervention contributed to the fact that the impact in form of mass migration was absent during the latter climate anomaly. In the future, when projecting possible climate related migration, the absolute limits of natural resources, specifically rainfall, may be less important. Instead, it will be past negative experiences with climate disasters and better knowledge about opportunities elsewhere which will cause people to give up their livelihood in fear of drought and move away. This shows that the influence of

climate on a specific response varies depending on the situation. While some livelihood forms or types of impacts may be more directly related to climate influences on one place/situation, elsewhere other factors may outweigh climate, making it a minor contributor or trigger.

(2) It refers to the importance of perceptions people have about climate, its variability and potential change, a perspective which has so far been given little attention within climate impact research. As presented in Paper II and III, there are always two sides of one story: climate as it is measured and climate as it is perceived. The occasionally low correlation between these two needs to be explained in the wider environmental-social-economic context of the human receptor. This will ultimately decide about the magnitude and type of impact on society: Society may perceive a change where measurements do not indicate one, and respond to it. Or a quantified climate change may not be recognised as one and thus, does not result in great or negative implications for society, at least not in the first place.

(3) By focusing on climate thresholds, the thesis, and in specific Paper IV, unveils when and in what way a climatic stimulus, alone or in combination with others, triggers a certain (positive or negative) human response. While the measurement of the climate stimulus, meaning its strength or the physical change itself, is important to the reaction of the body physiology, it is perceptions, experiences, needs and expectations which play a significant role in determining the trigger point. Thresholds to climate have been found highly case-specific and variable. Due to the complexity of quantitative and qualitative mechanisms leading to a threshold point it is in many cases more a philosophical question rather than a universally valid finding of what to define the threshold of a climate change dangerous to society. Although knowledge can be gained on variability of thresholds due to adaptation (technological-cultural-social), policy makers would have to use means other than scientific measurements alone in agreeing upon an acceptable level of climate change.

(4) Repeatedly, the thesis discusses the suitability of using analogies in forecasting societal responses to climate change. It pinpoints the feature of variability of both climate *and* society. In respect to climate, following Bryson (1997) who states that '*the history of climate is a non-stationary time series'*, this would mean that there are no perfect climatic or environmental analogies in the last million years. Conversely, this would indicate that reconstruction of past climates must be based on methods that do not require perfect analogy. In respect to societal or human response, people are modulating and differ in their behavior, technology, economy and culture. Experience with climate disasters leads to adaptation, changes in laws and planning guidelines, as well as to change in perceptions on the severity of events. This leads to the conclusion that analogies drawn from climate-societal response during other historic times or from different geographic regions only have restrictive value for future projections, or at least must be interpreted in their specific setting.

(5) Adaptation to climate is a characteristic of human history. Short term adjustments to adverse anomalies, such as survival strategies applied under drought conditions, are tailored to the specific local environmental and social circumstances by the affected people. External interference, especial political disruption, may harm the fragile adjustment process. Adaptation help from outside, such as offering climate insurance to drought vulnerable farming areas as treated in Paper V, seems to be most effective when both, several regions are included in a portfolio for hedging risk *and* consideration is given to the strength of climate correlation between individual regions when selecting the portfolio. Increasing the number of regions and zero or negative correlation between sites reduces the

need for necessary risk capital for an insurance provider, and thus, increases the attractiveness for offering this type of adaptation help to affected people in developing countries in the first place.

As a result, I, and any scientist working with societal effects of anthropogenic climate change is faced with a manifold of challenges when required to come up with some general statements on *who* will be effected by *what* and *how,* and *what type of adaptation measures should be taken.* The case-studies have shown that there is no universal answer and that the specific context under which people live and get impacted by climate plays the most important role when coming up with scientific statements. The most recent IPCC-report (2007) drew a rather gloomy picture for the world population in the next decades, particularly for the most vulnerable population in developing countries, especially when drastic measures in reducing greenhouse-gases do not get introduced immediately. Many *individuals* will suffer or even die, as a result of famine, water scarcity, sea-level rise and climatic extremes. However, I believe that any Malthusian scenario of a climate disaster for *society* can be rejected. Climate may in fact present opportunities as well as disadvantages. While this may sound arrogant from the perspective of an upper-class society, history has shown that human ingenuity is tremendous and human adaptation very flexible.

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