Environmental Risk and Sustainability
The Case of Commercial Livestock Farming in Semi-Arid Rangelands

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Contents

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Chapter 1: Introduction

1. Motivation

Environmental risk is a fundamental factor for the well-being of humans. Consider, for example, the possibilities that wildfires burn forests, that floods destroy homes or that droughts devastate crops and livestock: environmental risk affects everybody to some degree but may go so far as to impact on people's entire livelihoods (Smith and Petley, 2009: 223–224, 248–251, 262–264). Most people dislike risk and it thus makes them less well-off (e.g. Dohmen et al., 2005; Harrison et al., 2007a; Harrison et al., 2010) and they make a greater or lesser effort to avoid it. Naturally, this also applies to environmental risk, but it is especially difficult to avoid this risk as it characterizes many ecosystem services that are essential for fulfilling basic human needs (MEA, 2005b).

In their use of these services, people manage the ecological-economic systems that provide them. This management induces environmental changes that may affect the well-being of future generations (Stern, 2000). Sustainability requires to "pass on a world of undiminished life opportunities to members of future generations" (Howarth, 2007: 656), but in many systems across the earth this is ostensibly not ensured: rainforests are irreversibly cleared, oceans are overfished and pristine savannas are turned into deserts. This is problematic since people can no longer fulfill their needs by using services that derive from these systems and since there often do not exist adequate substitutes (Baumgärtner and Quaas, 2009). Thus, unsustainable management ultimately affects human well-being adversely, not only of the present generation but critically also of future generations.

Both environmental risk and sustainability are especially critical in semi-arid rangelands, a globally important ecological-economic system that covers approximately 8% of the Earth's surface and provides livelihood for hundreds of millions of people (MEA, 2005a: 627). Precipitation in these rangelands is frequently low and additionally highly variable (MEA, 2005a; Chapman, 2010: Map 2). As rain-fed livestock farming is the main land use, highly variable precipitation is a predominant environmental risk. The majority of *intra*-annual precipitation falls in a single rainy season and *inter*-annual precipitation is characterized by frequent years of low rainfall or even droughts. At the same time, 10–20% of rangelands suffer from persistent degradation (MEA, 2005a: 637). This degradation may include bush encroachment, that is the disturbance of the characteristic grass-bush coexistence by "invasion and/or thickening of aggressive undesired woody vegetation" (de Klerk, 2004: 2), biodiversity loss and groundwater depletion (de Klerk, 2004; MET, 2006; CCA, 2010).

A key to understanding processes in semi-arid rangelands is the behavior of farmers. They are the economic actors that directly interact with the environment. Furthermore, they are exposed to many types of environmental risk, not only temporarily but throughout their entire life. At the same time, it is their application of unsustainable management strategies that is at least partly responsible for the degradation (de Klerk, 2004; MEA, 2005a). The latter is the case not only in communal livestock farming where rangeland is a common pool resource and where it may be rational for farmers to "produce outcomes that are not in anyone's long-term interest" (Ostrom, 1999: 279); it is also the case in commercial livestock farming (de Klerk, 2004) even though property-owning farmers exclusively manage rangeland and may do so over a period of decades.

Against this backdrop, I empirically study environmental risk and sustainability with a focus on *commercial* livestock farming in semi-arid rangelands. These are important farming systems throughout North and South America, Australia and Southern Africa (MEA, 2005a). One prime example is commercial cattle farming in Namibia, which is likewise subject to a number of environmental risks, including high precipitation risk. It also suffers from degradation in the form of extensive bush encroachment (de Klerk, 2004) and of biodiversity loss (MET, 2006), and considerable groundwater depletion may occur in the near future (CCA, 2010). In addition, it is economically important, contributing by far the largest share (37 %) to total agricultural output and directly 1–2% to GDP (MAWF, 2009: 7, 9). I chose this specific system as my case study and, on this basis, provide five research papers that concern environmental risk, sustainability and their impact on human behavior.

In the remainder of this chapter I will describe my research papers in Section 2 and discuss and conclude on their results in Section 3. The individual papers are presented in Chapters 2 to 6.

2. Research papers

This thesis contains five research papers on the basis of my case study of commercial cattle farming in Namibia (Figure 1). The *first* paper is a review of literature and data on risks, management and sustainability in said system, which is the foundation for the *second* paper that concerns the creation of a data base by means of a survey among farmers. This data base in turn constitutes the foundation for my remaining papers, of which the *third* paper is a characterization of commercial cattle farms. The fourth and fifth paper concern specific aspects of farmers' behavior and their interaction with environmental risk and sustainability, and allow insights also beyond my case study. Specifically, the *fourth* paper is a study of the impact of environmental risk on risk preferences, and the *fifth* paper a study of the impact of norms of sustainability on management.

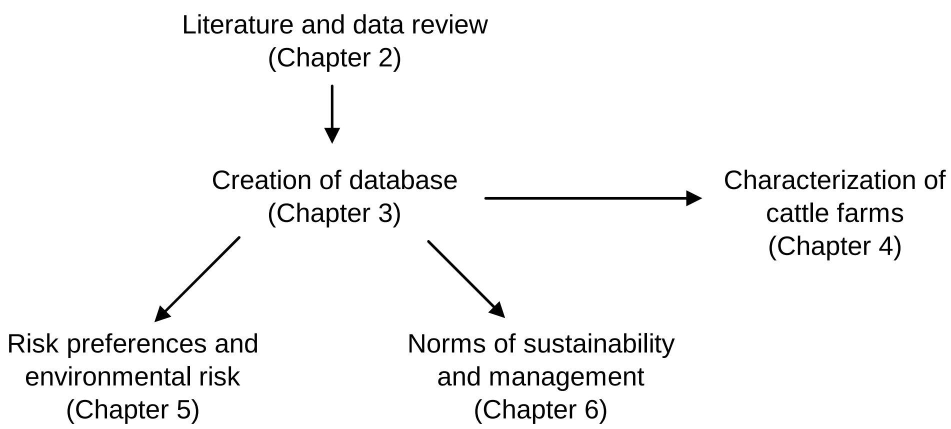

Figure 1: Structure and papers of the thesis. Main relations between papers are indicated by arrows.

My first paper, ***A review of risk, management and sustainability in commercial cattle farming in Namibia (Chapter 2)***, reviews which risks farmers face, which strategies they may and do employ to manage these risks and which of these strategies are linked to issues of sustainability, specifically to bush encroachment, biodiversity loss and groundwater depletion.[1] There is no previous comprehensive review on this matter. Mendelsohn (2006), pp. 41–49, provides a review of communal and commercial cattle farming, but the review is short and considers commercial cattle farming only in general terms. Atlas of Namibia Project (2002) characterizes the whole country and includes some environmental risks, management strategies and issues of sustainability but excludes many others, and its focus is not on commercial cattle farming. I thus set out to fill this gap, reviewing research publications,

[1] I compiled an early version of this review at the beginning of my thesis (the years 2007 and 2008) as a basis for my subsequent research. I have now updated it to reflect recent developments. None of these developments invalidate the conclusions that I have drawn from the earlier version.

reports by (non-)governmental organizations and newspaper articles. Some aspects that are important in the context of this review have been treated thoroughly such as bush encroachment (de Klerk, 2004), but published information on many other aspects is scarce. To compensate at least partly, I do not only review the aforementioned literature but also as yet unpublished data, and I also include information from qualitative interviews with 62 farmers and decision makers that I conducted during four research cruises to Namibia in the period 2007–2010.

While compiling this review it became clear that literature and existing data bases did not contain information crucial for pursuing the latter three research papers that I outlined above and that I present in Chapters 4 to 6. Thus, as detailed in my second paper, ***Sustainable use of ecosystem services under multiple risks – A survey of commercial cattle farmers in semi-arid rangelands in Namibia (Chapter 3)***, I created a comprehensive data base myself by conceptualizing and conducting a large-scale, representative survey among commercial cattle farmers in Namibia. Part of the survey was a mail-in questionnaire in which I elicited information on 1) personal and farm features, 2) risk perception, 3) management strategies, 4) individual risk and time preferences, and 5) norms[2] of sustainability. The other part of the survey were in-field risk and time experiments with payout of real money that I used to validate corresponding experiments with hypothetical payouts in the questionnaire. I prepared this survey on two research trips to Namibia in 2007 which involved discussing the survey with farmers and decision makers, acquiring address databases of members of the Namibia Agricultural Union (NAU) (the largest interest group of farmers) and of customers of MeatCo (the largest slaughterhouse) and building trust as well as promoting the survey (as farmers made bad experiences with previous surveys). I conducted the survey in August/September 2008. The questionnaire was sent to 1,916 of an estimated 2,500 cattle farmers (76.6%). Experiments were conducted with 39 farmers who were randomly chosen from amongst those NAU-members who farmed cattle full-time.

Building on this data base I pursued the remaining papers. My third paper, ***Characterizing commercial cattle farms in Namibia: Risk, management and sustainability (Chapter 4)***, concerns the characterization of cattle farms and was motivated by the aforementioned scarcity of published information pertaining to risk, management and sustainability in Namibian commercial cattle farming. Such a characterization is important to further the

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[2] Some clarification on the terminology used throughout this thesis is needed. In the introduction, I will use the term "norms of sustainability" or, more specifically, "personal norms of sustainability" (see below in this section). In some of the research papers as well as in the questionnaire I use the term "normative view of sustainability" instead.

understanding of this system and to point out interesting issues that warrant closer attention. Additionally, it may ultimately contribute to the development of policies aimed at promoting sustainability in this system. To this end, I compiled descriptive statistics on all characteristics elicited in the survey. I also analyzed characteristics jointly in a hierarchical cluster analysis to examine whether farms can be classified into distinct subgroups.

Subsequently, I proceeded with the two research papers that concern specific aspects of human behavior and their interaction with environmental risk and sustainability. My fourth paper, ***Risk preferences under heterogeneous environmental risk (Chapter 5)***, concerns the study of risk preferences with a focus of the impact of environmental risk on these preferences. Behavior in economics is traditionally considered to be determined by preferences and the opportunity set. Preferences are typically considered to be stable, thus any change in behavior has to be driven by changes in the opportunity set. Recently, however, studies have demonstrated that risk preferences are not generally stable but that they are endogenous to external cues (Palacios-Huerta and Santos, 2004; Voors et al., 2011). Despite the importance of environmental risk, no study has yet examined whether this risk may be such an external cue. This potential endogeneity of risk preferences towards environmental risk is the motivation for and focus of this research paper, specifically endogeneity with respect to risk experienced in childhood and adolescence.

The environmental risk I consider is inter-annual precipitation risk. I calculated this risk from simulated precipitation data as available actual precipitation data are too patchy. Data on risk preferences and socio-demographic characteristics were elicited in the survey and I acquired the necessary other data from various organizations, namely i) Geographic Information System data for farm locations from the Namibian Ministry of Agriculture, Water and Forestry, ii) actual precipitation data from the Namibia Meteorological Service, iii) simulated precipitation data from the Max-Planck Institute for Meteorology, Hamburg, iv) records of previous farm ownership from the Deed's Office of Namibia and v) farm input and output price data from Agra Co-operative Ltd. and Meat Board of Namibia. With maximum likelihood, I then estimated the effect of on-farm precipitation risk, early life history and their interaction on risk aversion. I controlled for background input and output price risks, for liquidity constrains and socio-demographic characteristics.

Finally, my fifth paper, ***Personal norms of sustainability and their impact on management – The case of rangeland management in semi-arid regions (Chapter 6)***, focuses on the impact of norms of sustainability on management. This paper was motivated by the observation that sustainability can be considered as a norm that prescribes behavior affecting the well-being of future generations through changes in the environment (Solow, 1993; Stern, 2000; Howarth, 2007). As such, it is an independent behavioral determinant besides egoistic preference and the opportunity set (Brekke et al., 2003; Young and Burke, 2010), but one that people do not generally have to comply with. An extensive literature exists that studies norms that determine environmentally significant behavior, such as recycling (e.g. Hopper and Nielsen, 1991; Thogersen, 1999), waste reduction (e.g. Thogersen, 1999) or green energy consumption (e.g. Ek and Söderholm, 2008). Often these norms are implicitly or explicitly equated with norms of sustainability. However, it remains questionable whether this equation is valid as important aspects of sustainability are not explicitly clarified, such as what specific notion of sustainability is employed or whether the behavior at hand aims at sustainability. Furthermore, the objects of study are typically consumers, but consumer behavior is only indirectly linked to the environment. Instead, the direct impact on the environment is exerted by production, in particular by farmers in agriculture. Against this background, the primary focus of this paper is the analysis of the impact of norms of sustainability on farmers' management, with a secondary focus on their characterization and their determination by socio-demographic and environmental characteristics.

To this end, I properly conceptualized norms of sustainability according to the norm-activation theory (Schwartz, 1973, 1977) as personal norms of sustainability which give concrete guidance on how to act sustainably and which are heterogeneous across individuals. Personal norms must be activated to affect behavior, i.e. individuals must be aware that their actions entail negative consequences for others and feel capable for averting these consequences. I operationalized personal norms under the notion of strong ecological-economic sustainability (Pearce et al., 1989; Daly et al., 1994; Ekins et al., 2003; Baumgärtner and Quaas, 2009). Based on prior identification of components critical to the sustainability of the system (Quaas et al., 2007; Baumgärtner and Quaas, 2009), I examined two specific personal norms of sustainability. These are the level at or above which the ecosystem condition should be sustained ("personal ecosystem norm") and the level at or above which farmers' income should be sustained ("personal income norm"). Finally, I analyzed the impact of personal norms on farm management with the dual-preferences model (Brekke et al., 2003; Conlin et al., 2003; Young and Burke, 2010). I derived from this model the concrete functional form of the regression equation with which I then, in pursue of my primary focus, estimated the effect of the personal norms on management. For my secondary focus, I characterized the distribution of personal norms in the population by descriptive statistics and identified their determinants by regressing personal norms on various socio-demographic and environmental characteristics.

3. Discussion and conclusion

I began with a literature and data review, bolstered by qualitative interviews, as detailed in ***A review of risk, management and sustainability in commercial cattle farming in Namibia (Chapter 2)***. I find firstly that commercial cattle farming is subject to at least 13 environmental, economic, social and political risks, many of which are heterogeneous across farmers. Secondly, most risks may be managed by alternative strategies or a combination of strategies, and many strategies in turn affect multiple risks. There appears to be an emphasis on strategies that work by adjusting organization and production processes of the farm. In contrast, strategies that make use of financial products are rarely used, apparently due to an insufficient supply of suitable financial products but possibly also due to farmers' scepticism towards these strategies. Thirdly, farmers' risk management may contribute directly and indirectly to bush encroachment, biodiversity loss and the projected groundwater depletion, especially the choice of high stocking rates and the exclusion of large wildlife grazers (and thus inevitably also browsers) from farms.

This review is limited by paucity of information even after complementing literature with unpublished data. It would be desirable, for example, to assess the magnitude of the reviewed risks. However, with the exception of five risks – including precipitation and price risks which I assess to be high – the available information does not permit such an assessment. Similarly, information was also scarce on which risk management strategies farmers actually do employ as well as on the precise link between strategies and issues of sustainability. It was this limited availability of information that was the motivation for the later creation of the data base by means of my survey among commercial cattle farmers.

Subsequently, I proceeded with the creation of said database, as detailed in ***Sustainable use of ecosystem services under multiple risks – A survey of commercial cattle farmers in semi-arid rangelands in Namibia (Chapter 3)***. Out of the sent-out questionnaires, 399 were returned (20.8%), and response rate to individual questions exceeded 95% for most non-sensitive and 90% for most sensitive questions. An optional question for farm identification was answered by 75.1% of survey participants.

One limitation was the exclusion of communal farmers due to difficulty of access and a constrained budget. As such, future analyses on the basis of this database may not apply to communal livestock farming, which is an important farming system in Namibian as well in other African rangelands. A second limitation is that I inevitably incurred a sample bias as NAU members are overrepresented due to promoting the survey mainly in this subpopulation. As the NAU represents white commercial farmers, this bias entails an underrepresentation of indigenous farmers and (likely) of emerging[3] commercial farmers. Both characterize a minority in the population and I thus do not consider these biases to be large. Nonetheless, I conclude that future analyses on the basis of this dataset that explicitly focus on these three characteristics (i.e. NAU members, ethnicity, emerging commercial farmers) should be approached with great caution.[4] Besides these three characteristic, other socio-demographic characteristics appear to be unbiased. Thus, by and large the dataset appears to be a representative sample of Namibian commercial cattle farmers.

Overall, I conclude that the return rate of 20.8% for the mail-in questionnaire is excellent for Namibia where return rates for postal questionnaires in recent years were apparently in the range of a few percent (Marggraff, 2008; Schumann, 2009; Joubert, 2010). It is also excellent when considering that the questionnaire was long and challenging and that farmers are very skeptic towards this form of data collection. In regards to the latter point, I believe that the trust building beforehand paid off, which is best illustrated in the high number of participants (75.1%) who identified their farm. Altogether, the database is unique and highly useful for research beyond what I have conducted in this thesis. It is already used in other studies as an empirical data source (Engler et al., 2011; Schröter et al., 2011) and to infer or validate model parameters (Lukomska et al., 2010; Müller et al., 2011).

Using the survey database I characterized commercial livestock farming, as described in the paper ***Characterizing commercial cattle farms in Namibia: Risk, management and sustainability (Chapter 4)***. I firstly find that cattle farms are heterogeneous in many individual characteristics. Secondly, I also find heterogeneity when characteristics are jointly analyzed in a cluster analysis as it classifies farms into three distinct clusters. Classification is predominantly driven by environmental conditions and financial management of risk and to a lesser extent by organizational structure of the farms and ethnicity: the most distinct of the three identified clusters is best characterized by high grazing capacity, low perceived rainfall risk and low financial risk management; of the remaining two, one is best characterized by a

[3] The term ‚emerging commercial farmers’ refers to those indigenous farmers that received governmental support for establishing a farm enterprise.

[4] Even though these three characteristics are not the focus of any of my subsequent papers, I tested where possible for robustness of inclusion/exclusion or alternative variable specification of these characteristics. I find that my findings are unchanged.

high proportion of multiple owners, the other by a high proportion of Afrikaans farmers. Risk and time preferences and personal norms of sustainability play only a marginal role for classification. Finally, classification is neither driven by income nor by weekend farming which is a characteristic commonly used for classification in Namibia.

One limitation concerns the limited number of robustness checks that I performed in the cluster analysis. I conducted one such check since I used not one but two measures to infer the optimal number of clusters, but there are other possible checks. Doing these checks properly is, however, very time consuming. The aim of this cluster analysis was not to test specific hypotheses, for which more in-depth analyses are necessary. Rather, the aim was to identify general patterns and to point out interesting issues that warrant closer attention. In the light of this, I consider a cluster analysis with only limited robustness checks still adequate.

The aforementioned results suggest that farmers cannot simply be treated as a homogenous group due to heterogeneity found both when characteristics are considered individually and when they are considered jointly. Furthermore, descriptive statistics and cluster analysis point to interesting issues that warrant closer attention. For example, income does not differ across clusters. This is surprising in the light of the observed differences in environmental conditions, specifically grazing capacity, and in financial risk management, as one might expect that differences in these characteristics are associated with differences in income. One possible explanation is that increased financial risk management, while stabilizing income, may negatively impact on grazing condition and thus ultimately lead to a degradation of the system (Quaas and Baumgärtner, 2008). Altogether, this study furthers the understanding of the system, indeed points out interesting issues for further attention and may ultimately contribute to the development of policies aimed at promoting sustainability in Namibian commercial cattle farming.

In the paper ***Risk preferences under heterogeneous environmental risk (Chapter 5)***, I find evidence that suggests that farmers self-select themselves onto farms according to their risk preferences, with *more* risk averse farmers choosing *less* risky farms. More importantly, I also find evidence that risk preferences are endogenous to precipitation risk experienced in childhood and adolescence (but not in adulthood). Specifically, those farmers who grow up under higher risk are more risk averse in later life. Past risk experience can even become the dominant feature of the relationship between risk preferences and environmental risk: farmers who grow up on their farm for at least 9 years during childhood or adolescence are the *more* risk averse the higher the precipitation risk is on their farm, that is the *more* risky their farm is. Results are neither confounded by precipitation risk simultaneously acting as a background risk to choices in the risk experiments, nor by price background risks or liquidity constraints.

I note two limitations in this paper. The first limitation arises from an artifact in the experiments where a quarter of the farmers indicated themselves as either very risk averse or very risk loving. I consider this to be due to a design mistake of the experiment, which was not picked up in the pre-testing rounds. As a consequence, I excluded those farmers from the analysis that gave extreme responses ("artifact farmers"). Ideally, I would have checked whether their exclusion affects results by rerunning the model with the artifact farmers included. This was, however, not possible due to a confounding problem: Data on previous farm ownership from the Deed's Office was unavailable for the artifact farmers. As the next best thing I instead checked for robustness of results using a simplified regression equation that did not contain the risk variable, the life history variable and their interaction effect.[5] Using this equation, model runs with and without the artifact farmers yielded qualitatively the same results. Thus, by testing what I could I find no evidence that excluding artifact farmers changes results.

The second limitation arises from the necessity to use simulated data instead of actual rainfall data. This is indeed a problem when spatially and temporally precise data is required. However, I aggregated data per rainy season and subsequently to inter-annual averages and coefficients of variation. At that level of aggregation, simulated and actual rainfall data should not diverge greatly. Indeed, correlation is high between averages (coefficients of variation) calculated from actual rainfall data and averages (coefficients of variation) calculated from simulated rainfall data.

My results have general implications since risk preferences play a fundamental role in economic theory. For example, (Harsanyi, 1953, 1955, 1977) justifies the Utilitarian social welfare function based on an argument where an impartial observer chooses social states behind a veil of ignorance according to von-Neumann-Morgenstern risk preferences. Endogeneity of risk preferences imposes an obvious challenge to this type of argument. But my results also have specific implications for the management of ecosystems in the context of climate change. Climate change is considered to entail an increase in environmental risks, such as of fires, floods or droughts, which already affect many regions worldwide (Schneider et al., 2007). This alters peoples' opportunity sets and, *ceteris paribus* (given risk preferences, in particular), increases the demand for insurance against environmental risks. According to

[5] The artifact and the exclusion of artifact farmers, but not this check, are described in the paper.

my results, however, an increase in experienced environmental risk might make future generations ever more risk averse. This additionally increases future insurance demand. It also poses a challenge to the actuarial calculation of insurance premiums, and the functioning of competitive insurance markets over the long-run. Thus, development of well-functioning insurance markets in developing regions may become even more important, but also more challenging, with ongoing climate change in the coming decades.

Finally, in the paper, ***Personal norms of sustainability and their impact on management – The case of rangeland management in semi-arid regions (Chapter 6)***, I find that farmers have personal norms of sustainability that are heterogeneous across individuals, that are independent from each other and that vary only little with socio-demographic characteristics. More importantly, I find no evidence that personal norms influence management which implies, according to the norm-activation theory, that these norms are not activated.

Some limitations concern this paper. Firstly, it is theoretically impossible to demonstrate that an impact of personal norms on management does *not* exist as I cannot accept the null hypothesis of no impact but only fail to reject it. It may be that such an impact exists but that sample biases or the application of inappropriate econometric methods preclude its detection. I already discussed sample biases above and conclude that my sample is very likely representative in characteristics crucial to this study.[6] Furthermore, rerunning analyses with alternative regression models and alternative variable and equation specification showed that results are robust. Thus, while I cannot make a definite statement, I consider it highly likely that personal norms do not impact on management.

Secondly, I cannot estimate management strategies jointly in a simultaneous equation model, even though management strategies are very likely interrelated, as I could not construct suitable instrumental variables. Instead, I estimated the effect of personal norms on a given management strategy *without* including the respective other strategies. As a robustness check, I reran the same regression model *with* the other strategies included. This check show that I do not incur an unobserved variable bias in respect to the coefficients of primary interest, that is the personal norm coefficients, if I exclude the respective other strategies, and I thus consider this approach to be justified.

Thirdly, the behavioral model I formulated describes behavior under certainty. I may thus consider only deterministic sustainability. Given that commercial cattle farming is subject to a

[6] In addition to the above discussed potential biases, I also tested here for a bias in the personal norm variables and on-farm management strategy variables. I find no evidence for such a bias.

variety of risks, a more realistic approach would be the formulation of a model that describes behavior (i.e. management) under uncertainty and thereby also considers sustainability under uncertainty. I tried the latter approach but found the data lacking: albeit I elicited the necessary information on personal norms of sustainability under uncertainty, I could not elicit the necessary information on ecosystem condition and income – specifically, their individual on-farm distributions – in my cross-sectional survey. In the future, this issue could be solved by creating a panel which is, however, a costly undertaking.

Nonetheless, I consider my results relevant as they provide novel insights into why the behavior of farmers may contribute to degradation of Namibian rangelands: they may have personal norm of sustainability but these norms may not be activated. This suggests that activation of norms may promote the sustainability of the specific system at hand. Based on anecdotic evidence, I hypothesize that norms do not impact on management because farmers feel not capable of averting adverse consequences of their management behavior. I have no information on why they might not feel capable, which is needed to decide whether taking measures for activation is justified (farmers might have ethically sound reasons for not feeling capable) and exactly what measures to take. Thus, more research is needed which I consider worthwhile as the further study of personal norms and their activation is a promising approach to promote sustainability in commercial livestock farming in semi-arid rangelands.

Chapter 2: A review of risk, management and sustainability in commercial cattle farming in Namibia

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Abstract

Commercial cattle farming is an important land use in Namibia. It is confronted by a variety of environmental, economic, social and political risks. Farmers apply a variety of management strategies to deal with these risks, but the application of these management strategies may contribute to issues of sustainability, specifically to bush encroachment, biodiversity loss and groundwater depletion. In this paper I review which risks farmers face, which strategies they may and do employ to manage these risks and which of these strategies are linked to issues of sustainability.

Keywords: commercial cattle farming, Namibia, semi-arid rangelands, risk, management, sustainability

JEL-classification: P48, Q15, Q56

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1. Introduction

Commercial cattle farming in Namibia is located in its semi-arid rangelands. It is an important land use, covering with 14.5 million hectares (Mendelsohn, 2006: 42) almost one-fifth (18%) of the country's surface and contributing the largest share (37%) to agricultural output as well as directly 1–2% to GDP (MAWF, 2009: 7, 9). It is confronted by various environmental, economic, social and political risks (e.g. Sweet, 1998; Atlas of Namibia Project, 2002; Mendelsohn, 2006; Meyn, 2007). Farmers manage these risks by strategies that adjust the organization and production processes of the farm, that make use of financial products and off-farm assets and that entail membership to various groups. Commercial cattle farming is also confronted by issues of sustainability in the form of bush encroachment (de Klerk, 2004), biodiversity loss (Loots, 2005; MET, 2006) and looming groundwater depletion (CCA, 2010). Environmental factors appear to be one cause (e.g. de Klerk, 2004), but a growing literature suggests that it is also anthropogenic factors, including farmers' risk management, that contributes to these issues (e.g. Maggs et al., 1998; de Klerk, 2004; Zimmermann et al., 2008; CCA, 2010).

Notwithstanding, there is no review that comprehensively describes risk, management and sustainability for Namibian commercial cattle farming. Mendelsohn (2006), pp. 41–49, discusses communal and commercial cattle farming, but his treatment is brief and only in general terms. Atlas of Namibia Project (2002) portraits the whole country and includes some environmental risks, management strategies and issues of sustainability but excludes many others, and its focus is not on commercial cattle farming. Thus, I fill the gap in this review by pursuing three questions: Exactly which risks do farmers face? What strategies may they – and actually do they – apply to manage these risks? Which of these strategies may contribute to the aforementioned issues of sustainability, that is to bush encroachment, biodiversity loss and groundwater depletion?

To this end, I draw on research papers, reports by (non-)governmental agencies and newspaper articles. Some aspects were previously thoroughly treated, such as bush encroachment (de Klerk, 2004), but information on many other aspects is scarce. To compensate for this scarcity, I do not only review literature but also as yet unpublished data, and I also include information from qualitative interviews with 62 farmers and decision makers of the agricultural, financial and political sector that I conducted during four research cruises to Namibia in the period 2007–2010.

Before summarizing my conclusions I note that an early version of this review served as a background paper for the development and conduction of a survey among commercial cattle farmers in 2008 (Olbrich et al., 2009). This survey elicited – among other things – farmers' perception of risks, the importance they ascribe to different risk management strategies and the extent of on-farm bush encroachment. A descriptive analysis of this survey is given by Olbrich et al. (2011a), and that paper may be viewed as a companion paper to this review. I will not explicitly refer to Olbrich et al. (2011a) in the later course of this paper, instead leaving it to the interested reader to draw upon it.

I conclude in this review firstly that farmers face at least 13 different environmental, economic, social and political risks, with many of these risks being heterogeneous across farmers. Secondly, most risks may be managed by alternative strategies or a combination of strategies, and a given strategy may in turn affect multiple risks. Specifically those strategies that make use of financial products appear to be applied only rarely, apparently due to an insufficient supply of adequate financial products but possibly also due to farmers' skepticism towards these strategies. Thirdly, farmers' risk management appears to contribute directly and indirectly to bush encroachment, biodiversity loss and the projected groundwater depletion. Specifically, it is choice of a high stocking rate and the exclusion of large herbivorous wildlife grazers – which inevitable also excludes large browsers – that appear to contribute. Overall, I find that information on many aspects is scarce and conclude that individual farm-level data is needed to adequately study risk, management and sustainability in Namibian commercial cattle farming.

This paper is organized as follows: I describe the commercial cattle farming system in Section 2 before approaching risks in Section 3, risk management strategies in Section 4 and issues of sustainability in Section 5. Finally, I conclude in Section 6. A list of all interview partners is given in the Appendix. Throughout the paper I will quote literature sources, data sources and interviewed decision makers but – for sake of confidentiality – not interviewed farmers.

2. System description

2.1 Biogeography

Cattle farming in Namibia is extensive grazing farming where cattle feed on rain-fed pasture. The commercial cattle farming region (CCFR), that is the cattle farming region where land is private property, covers 14.5 million hectares (Mendelsohn, 2006: 42) and is located in the semi-arid rangelands in central Namibia (Figure 1). These rangelands are subject to a strong seasonality of precipitation with most precipitation falling in a single rainy season (November to April). Precipitation conditions in the southern and western parts of the country are too low and variable and permit at most small stock farming (Atlas of Namibia Project, 2002: Figures 3.18 and 3.21; Mendelsohn, 2006). The northern and eastern parts have favorable conditions but are communal farming regions from which the CCFR is physically separated by the Veterinary Cordon Fence (Scoones et al., 2010).[7]

The main biome in the CCFR is Acacia-Tree-and-Scrub savanna (Atlas of Namibia Project, 2002: Figure 4.2). It is characterized by a coexistence of grass vegetation, mainly *Stipagrostis* ssp., and bush vegetation, mainly *Acacia* spp., *Baikaiea* spp., *Colophospermum mopane, Dichrostachys cineria* and *Terminalia sericea* (de Klerk, 2004; WWF, 2010). Primary production of grass is limited by recent precipitation and thus also seasonal (Ward and Ngairorue, 2000; du Plessis, 2001; Atlas of Namibia Project, 2002: 101) whereas primary production of bush is "fairly independent of recent precipitation" (Atlas of Namibia Project, 2002: 101). The savanna is inhabited by a variety of wildlife, among them large herbivorous mammals (e.g. gemsbok, springbok, kudu) and predating mammals (e.g. cheetahs, leopards) (Atlas of Namibia Project, 2002: Figures 4.38–4.52; Barnes et al., 2009).

Open water bodies in the commercial cattle farming region are ephemeral at best and thus play only a minor role for providing drinking water to cattle (Atlas of Namibia Project, 2002: 60–61). In contrast, groundwater is reasonably well available. It may either be found in aquifers recharged by precipitation that are close to the surface or in fossil aquifers that are sealed off and typically deep underground (Atlas of Namibia Project, 2002: 67).

2.2 Farms

There are an estimated 2,500 commercial cattle farmers in Namibia (Hager and Marggraff, 2007), each owning at least one farm. Due to extensive farming, individual farms cover large areas from several hundred to tens of thousands hectares (ha) but support only a small number of cattle. Stocking rates are largely between 0.05 and 0.2 Large Stock Units[8] per hectare (LSU/ha) (Mendelsohn, 2006: Figure 20), resulting, for example, in only a few hundred cattle being kept on a farm that is several thousand hectares large. All commercial cattle farms

[7] The Fence restricts movement of cattle and wild buffalos (Martin, 2005; Mbaiwa and Mbaiwa, 2006; Scoones et al., 2010) to keep the CCFR free of food-and-mouth and contagious-bovine-pleuropneumonia diseases, both prevalent beyond the Fence and highly detrimental to the export-dependent commercial cattle farming (Scoones et al., 2010).

[8] One cattle equals one Large Stock Unit.

combined cover the aforementioned 14.5 million hectares where an average of 840,000 cattle were kept during the period 2000–2007 (MAWF, 2009).[9]

Roughly 1/3 of a cattle herd are cows while the remaining 2/3 are offspring at various ages (Mendelsohn, 2006: 45). In addition, a herd typically has one bull for every 20–30 cows (Mendelsohn, 2006: 45). Regarding the cows, "75–90% [of them typically] produce a calf in a year" (Mendelsohn, 2006: 45) and they give birth after a pregnancy of nine months. Calves are weaned at age eight months ("weaners") and may then further be reared as oxen or replacement cows.

Main farm inputs are fence material, petrol (for transport within the large farms and to and from the typically distant markets), mineral licks and work by farm workers. Many inputs are purchased at Agra Co-operative Ltd., Namibia's largest retail company for farm equipment, as well as from a number of specialized companies. Information on the extent with which inputs are used is not available, except for farm workers: As a rough estimate, a farm has on average 7.5 workers[10] (MLSW, 2008: Table 5.3) and wages paid to workers constitute 16–18% of production costs (Werner, 2004: 23). In addition to the above inputs, farmland may be purchased on a well-functioning farmland market and is available principally anywhere in the CCFR (Fuller and Eiseb, 2002; Motinga, 2003). Farmland may also be acquired through lease for varying durations which are typically informally resolved between the involved farmers.

Main farm outputs are weaners and oxen which constitute 49% and 51%, respectively, of the 298,961 commercial cattle are on average annually marketed (MAWF, 2009: 14).[11] Weaners are sold as live animals at auctions, hundreds of which take place annually at various locations across Namibia and which are mainly organized by Agra Co-operative Ltd (Agra, unpublished). They are predominantly exported to feedlots in South Africa (after purchase on Namibian auctions) (Schutz, 2010). Oxen are sold to the slaughterhouse for conversion into beef, almost all of which takes place at MeatCo of Namibia, the largest slaughterhouse. Like weaners, most beef is exported. Main destinations are South Africa (45%) and the European Union (37%) – export to of which is especially profitable (Hoffmann, 2007) but also subject

[9] All numbers in this paper that are calculated from data of MAWF (2009) are calculated as averages for the period 2000–2007 (the latest available data) unless otherwise noted. I thus will not explicitly indicate this period anymore when I cite from MAWF (2009).

[10] This number was calculated as followed: the Namibia Labour Force Survey of the year 2008 states that 37,374 farm workers are employed in Namibia (MLSW, 2008: Table 5.3). Estimating that half of them (18,687) are employed on commercial cattle farms and taking the aforementioned 2,500 as the number of cattle farms, I arrive at the 7.5 farm workers per farm.

[11] Marketed cattle includes only weaners sold to South Africa and oxen sold to the slaughterhouse. Weaners sold within Namibia from farmer to farmer are not included, and no separate information exists on the extent of these sales relative to marketed cattle.

to strict animal health regulations –, while other overseas markets (3%) and domestic consumption (15%) play only a minor role (MAWF, 2009: calculated from Tables 3.2.3 and 3.2.4). Overall, outputs from commercial cattle farming contribute with N$ 819 million the largest share (37%) to the total agricultural output of N$ 2,242 million and approximately 1–2% to its GPD (MAWF, 2009: 7, 9).

2.3 Financial sector

The Namibian financial sector is comparatively well-developed (WB, 2009). Four commercial banks (Bank Windhoek, Ned Bank, First National Bank and Standard Bank) exist and provide a variety of financial services to farmers. In addition, a state-owned bank, Agribank of Namibia, specializes in financing agricultural activities by providing medium and long-term loans for farm investments. Approximately 30 insurance companies operate in Namibia (WB, 2009), with the market being dominated by four companies (Mutual & Federal, Old Mutual, Santam and Sanlam), and provide a range of conventional as well as agricultural insurances. Finally, the Namibian Stock Exchange allows for trade of stock and bonds, while agricultural derivatives may be traded at the South African Futures Exchange.

2.4 Interest groups and governmental support

Commercial cattle farmers are for historical reasons, that is German colonial rule and later South African administration, mainly of German and Afrikaans decent, but an increasing number of indigenous farmers now also farm cattle commercially. Commercial cattle farmers are represented by two major interest groups, the Namibia Agricultural Union (NAU) and the Emerging Commercial Farmers' Support Programme. The NAU is the older group, being founded in the 1940s (Keulder and Hishoono, 2009: 9), and represents mainly farmers of German and Afrikaans decent. It is also the larger group, accounting with approximately 2,500 members (including cattle, small stock and crop farmers) for roughly half of the estimated 4,500 commercial farmers (Hager and Marggraff, 2007). The NAU is hierarchically organized, with 75 local farm conventions across Namibia that are grouped into 10 regional divisions, which in turn are represented by a national board (Keulder and Hishoono, 2009: 9). The Emerging Commercial Farmers' Support Programme was established in 2007 (Tjaronda, 2008) as an interest group for indigenous commercial farmers. The Programme has 600–700 members as of June 2010 (Smith, 2010).

Governmental support was common before and during the first years of independence, mainly in the form of drought subsidies (NDTF, 1997). In 1997, the Namibian government curtailed these subsidies which nowadays will be granted only during the most severe droughts which occur on average only once every 14 years (NDTF, 1997: Annexure 1.3). No other subsidies are granted to non-indigenous commercial cattle farmers, while indigenous commercial cattle farmers have access to subsidized loans through Agribank of Namibia to help them establish farm enterprises.

3. Risks

In this section, I compile environmental risks (Section 3.1), economic risks (Section 3.2) as well as social and political risks (Section 3.3) that commercial cattle farming is subject to, and describe each risk as extensively as available literature, data or qualitative interviews permit.[12] All risks are listed in Table 1.

3.1 Environmental risks

Precipitation[13]/grass production risk

Precipitation and grass production in the CCFR co-vary strongly since grass production is limited by precipitation (c.f. Section 2.1) (Ward and Ngairorue, 2000; du Plessis, 2001; Atlas of Namibia Project, 2002: 101, Figure 4.7). As such, the precipitation risk transforms into a grass production risk, and I will consider for the remainder of the paper both risks jointly as a precipitation/grass production risk. In discussing this risk I now use precipitation data whose availability is, in contrast to grass production data, much better.

Precipitation in the CCFR is low, with annual precipitation averaging 374 mm,[14] and highly variable.[15] *Intra*-annual precipitation displays a pronounced seasonality with 94% (352 mm) of precipitation falling in the rainy season (Figure 2). This pattern is fairly stable and thus predictable for the individual farmer. In contrast, *inter*-annual precipitation (Figure 3) is not predictable and thus the relevant precipitation risk for farmers. It is characterized by frequent years of droughts (Sweet, 1998), and thus of low grass production, which is reflected in the

[12] As neither literature nor data is available in equal extent for the risks I discuss, this invariably entails that some (sub-)sections are more extensive than others. The same applies to the risk management strategies discussed in the subsequent section.

[13] Precipitation data is daily precipitation provided by the Namibian Meteorological Service for 160 stations in the CCFR in the period 1913–2008 (NMS, unpublished). However, many stations have extensive gaps in the time series.

[14] The average, as well as the coefficient of variation later in this paragraph, are calculated for meteorological year which is defined as July to June in Southern Africa (Unganai, 1996; Burke, 1997). Average annual precipitation for the *calendar* year is with 370 mm almost identical to the value calculated for the *meteorological* year. The same is true for the coefficient of variation (0.34 versus 0.35).

[15] Annual precipitation across the whole country averages approximately 270 mm (Sweet, 1998).

coefficient of variation of annual precipitation being with 0.35 considerable higher than, for example, the 0.1–0.2 found in central Europe (Chapman, 2010: Map 2). Finally, it is spatially heterogeneous: Across the CCFR the coefficient of variation generally increases in north-easterly direction with values of above 0.40 in the south-west and of below 0.30 in the north-east (Atlas of Namibia Project, 2002: Figure 3.21), but also displays variability over small scales within this general trend (Figure 1).

Groundwater risk

Productivity of aquifers, that provide the groundwater, is spatially variable across the CCFR. There are several areas where productivity is generally high such as west of Windhoek or in 'Tsumeb-Otavi-Grootfontein' triangle, but productivity is low in many other areas such as in central Otjozondjupa (Atlas of Namibia Project, 2002: 2.25). Within these areas, however, local productivity may vary considerable over small scales (Atlas of Namibia Project, 2002: 2.25). Productivity may also be temporally variable if the aquifer in question is recharged by precipitation. As such, wells may become unproductive or even dry out in years of droughts. Given that inter-annual precipitation is not predictable, so is inter-annual aquifer productivity and the latter thus constitutes a risk to farmers. Having mentioned the inter-annual precipitation risk I want to point out that – unlike grass production risk – on-farm groundwater risk may not be correlated to on-farm precipitation risk. The reason is that groundwater may flow horizontally through aquifers (Atlas of Namibia Project, 2002: 2.25), and a given aquifer may not be recharged by local on-farm precipitation.

Bush fire risk

Bush fires destroy large areas of pasture, predominantly occurring at the end of the dry season from June to October (Atlas of Namibia Project, 2002: 106) when grass and bush vegetation is still ample but also dried out (de Klerk, 2004: 15). The major cause for bush fires is lighting. Accidental man-made bush fire by farmers occur only rarely (Siegfried, 1981; de Klerk, 2004: 18) partly due to strong regulations on the use of fire for clearing land (de Klerk, 2004: 18). Bush fires do not occur on the same scale every year but available information on their extent in the CCFR is limited to observations from two years: The region was almost unaffected by bushfire in the year 1997, while an estimated[16] 10% of the area was affected by fire in 2000 (Atlas of Namibia Project, 2002: Figure 4.10).

[16] Estimate was derived by visually inspecting Figure 4.10 in MET (2002).

Wildlife grazing risk

Wildlife grazing risk originates from large grazing mammals (e.g. gemsbok, hartebeest, zebra) or grazing/browsing mammals (e.g. springbok) (Atlas of Namibia Project, 2002: 99, Figures 4.37–4.45; Clauss et al., 2008), which I summarize here under the label "wildlife grazers". These grazers roam through the CCFR and may unexpectedly reduce pasture dedicated to cattle. Across the region, their density varies, being the highest east of Windhoek with 0.7 wildlife grazers/ha (Atlas of Namibia Project, 2002: Figure 4.37).[17]

In order to assess the magnitude of wildlife grazer density I compare it to cattle density. As one wildlife grazer typically consumes less pasture than one cattle, the unit wildlife grazer/ha may not simply be converted on a one-to-one basis to LSU/ha (the unit in which cattle density is measured). Furstenburg (2010), in Table 3, provides conversion factors for different grazer species which may be as low as 0.1 for springbok (i.e. 10 springbok/ha equal one LSU/ha) or as high as 0.7 for zebra (i.e. 1.4 zebra/ha equal one LSU/ha). Assuming a conservative factor of 0.1, the aforementioned density of 0.7 wildlife grazers/ha may be converted into a value of 0.07 LSU/ha. This is in the range of the cattle stocking rates of 0.05–0.2 LSU/ha commonly found in the CCFR (Mendelsohn, 2006: Figure 20). As such, wildlife grazers may seriously compete with cattle for pasture, thereby considerably lowering cattle production, and the wildlife grazer risk appears thus to be high. Finally, this risk is spatially heterogeneous, owing to spatial heterogeneity in wildlife grazer densities (Atlas of Namibia Project, 2002: Figure 4.37).

Wildlife predation risk

Wildlife predation risk originates from leopards (Atlas of Namibia Project, 2002: Figure 4.48; Marker and Dickman, 2005) that may kill cattle (Atlas of Namibia Project, 2002: 122).[18] Barnes et al. (2009), in their Table 4, estimates that there are 4,000 leopards in the commercial livestock[19] region. They have their highest density in the CCFR, where leopards may reach densities of 3.6 animals per 10,000 ha (Stein et al., 2011). No information is

[17] Figure 4.37 in Atlas of Namibia Project (2002) actually provides values only for eight large herbivorous mammal species combined. This value includes kudu, which is a pure browser, whereas all other species are grazers or grazers/browsers. However, kudu density is comparatively low compared to all other species combined (Atlas of Namibia Project, 2002: Figures 4.38–4.45). Therefore, for simplicity sake, I consider here the densities provided in Figure 4.37 to denote grazers and grazers/browsers only, that is to denote wildlife grazers per hectare.

[18] Another important predator, lions, have nowadays been largely exterminated from the CCFR. They play a role only for farms close to national parks (Atlas of Namibia Project, 2002: Figure 4.47), where they may spill-out of park boundary. In addition, cheetah may kill cattle, but this appears to happen only very rarely.

[19] Here, and henceforth, 'commercial *livestock* region' refers to both the commercial cattle and commercial small stock region combined.

available on kills by leopard, but given their density and the fact that leopard are opportunistic feeders that typically prey on a variety of small and large mammals, birds and reptiles (Bothma, 1998), I consider the predation risk to be low.

Cattle disease risk

A number of diseases, such as food-and-mouth disease, contagious bovine pleuropneumonia, anthrax or brucellosis (Mendelsohn, 2006: 20; Scoones et al., 2010) may afflict cattle. These diseases may kill cattle or make them unsuitable for sales, especially export sales. For the individual farmer, the risk arising specifically from two highly contagious diseases, the food-and-mouth disease and the contagious bovine pleuropneumonia, is exacerbated by the fact that it may not have to be his own cattle that are infected: In response to an outbreak of these diseases in the CCFR the government may shut cattle sales, as is being done from time to time in the communal cattle farming region where these diseases are common (Weidlich, 2007; Scoones et al., 2010), and this measure thus precludes also the marketing of healthy cattle from that region.[20]

Cattle reproduction risk

Reproduction risk arises from two sources. Firstly, already owned (newly acquired) bulls may become (turn out to be) infertile and fail to impregnate cows. Successful impregnation is typically only detected weeks after the mating procedure which, for logistic reasons, cannot be repeated until the next pre-set mating period. Since one bull typically mates with 20–30 cows, an infertile bull entails a considerable drop in temporal productivity. Giving high breeding standards in Namibia, however, infertile bulls are likely rare. Secondly, even a mating of an otherwise fertile bull does not ensure that a given cow becomes impregnated which results in individual cows being unproductive until the subsequent mating period. I have no information on how frequently such impregnations fail.

3.2 Economic risks

Input price risks

Information for input prices is available only for petrol, and only for South African petrol prices which I here take as a proxy for Namibian ones.[21] From the beginning of this century

[20] Due to the exceedingly high risk arising from these two diseases, the Veterinary Cordon Fence has been constructed. So far, it successfully keeps the CCFR free of both diseases.

[21] Price data used is monthly averaged prices for Petrol Unleaded 95 in South Africa. These data is provided by the South African Department of Energy for the period 1986–2011 (DE, 2011).

until 2005 this price was fairly stable (Figure 4). Since then, it became much more volatile, rising from 4.32 South African Rand[22]/litre in January 2005 to an all time peak of 10.70 Rand/litre in July 2008 and, after a strong dip in January 2009, to a new peak of 10.25 Rand/litre in April 2011. At both peaks the petrol price has risen by 43% and 23%, respectively, over the preceding six months.

Output price risks

Prices for the main outputs, oxen sold to the slaughterhouse and live weaners sold at auctions, are likewise temporally variable (Figure 5).[23] Albeit there was a period in recent years of relative stable, if slightly increasing, prices (2003–2005), there were also periods of high volatility (2001–2003 and 2005–2009). Similar to the petrol price risk, the output prices may change considerably in only a short period. For example, in the six months previous to June 2003 and April 2007 the ox carcass price fell by 33% and 14%, respectively, and the weaner price by 20% and 26%, respectively.

At this point I note that both output risks are essentially homogenous across farmers. For ox carcass prices this is due to almost all oxen (90% in the period 2000–2007) being sold the same company, that is MeatCo of Namibia (MAWF, 2009: 14). For weaner prices this due to a small number of South African buyers purchasing the majority of weaners sold at auctions (Schutz, 2010) which results in weaner prices at principally independent auctions to be highly correlated: The Pearson's correlation coefficient is above 0.97 for any pair of major auction locations.

Trade risk

Export of beef and weaner to one of Namibia's main export location, South Africa, is unproblematic. Namibia and South Africa, together with Botswana, Lesotho, and Swaziland, form the Southern African Customs Union. Within the Union there is free interchange of a wide range in domestic products, including live cattle and cattle meat (BIDPA, 2010), and no changes to the trade treaties within the Union are envisioned in the near future.

However, trade risk arises from the present development of trade negotiations with the European Union, a premium market for exported beef (Hoffmann, 2007). Until 2002 Namibia

[22] The Namibian Dollar is fixed to the South African Rand on a one-to-one basis.

[23] Price data for oxen sold to the slaughterhouse are monthly averaged carcass prices provided by the Meat Board of Namibia for the period January 2001–June 2008 (Meat Board, unpublished). Data for weaner sales at auctions are kilogram prices provided for 4,329 auction that were conducted across Namibia in the period November 2000–August 2008 by Agra Co-operative Ltd. (Agra, unpublished). Major auction locations in the CCFR are Gobabis, Grootfontein, Okahandja, Otjiwarongo and Windhoek.

enjoyed preferential access with non-reciprocal tax exemptions for exports to the European Union as agreed under the Lomé Convention in 1975. This violated trade rules of the World Trade Organization, and in response Namibia and the European Union are presently negotiating an European Partnership Agreements (Meyn, 2007) that replaces Namibia' preferential access by a reciprocal free trade agreement. Namibia has stated its intention to sign an European Partnership Agreement in December 2007 (Frøystad et al., 2009), but has not yet done so out of concerns that the necessary opening of its markets to European products would severely hamper its economy (Jones et al., 2009). Should Namibia not sign an European Partnership Agreement, it will have to trade with the European Union under the Most-Favored-Nations terms, the consequence of which appear to be dire for commercial cattle farming: Meyn (2007) estimates that revenues of exported beefs would then decrease by 65% due to increased tariffs and duties. As it is only the export of beef and not that of weaners that is subject to trade negotiations, only those farmers who produce oxen are affected by the trade risk.

3.3 Social and political risks

Expropriation risk

As a consequence of German colonial rule and South African administration, commercial cattle farming was almost exclusively conducted by farmers of German or Afrikaans descent until independence in 1990. Following independence, the new Namibian government set out to redistribute land from the non-indigenous to the indigenous population. Initial approaches, including subsidized loans and government purchase of farms in a "willing buyer, willing seller scheme", were unsuccessful as only a small number of farms were redistributed (Harring and Odendaal, 2008). Subsequently, the government resorted to expropriation which has so far, however, not been extensive: Following three expropriations in 2005, no more farms were yet expropriated, and expropriated farmers were compensated with several million Namibian dollars (Harring and Odendaal, 2007). Furthermore, expropriation can be challenged in court (Harring and Odendaal, 2008) which was successful with respect to four other farms designated for expropriation (Weidlich, 2008). There are regular, more or less explicit, calls to increase the speed of expropriation (e.g. Maletsky, 2008; Shigwedha, 2011), but these calls do not come from important decision makers within the government. As such, there is no indication that the speed of expropriation will increase in the near future.

Labour legislation risk

Prior to independence, farm workers had few rights and were essentially dependent on the farm owner, for the better and worse (Werner, 2004). Since independence, labour legislation has been introduced that regulate, for example, the maximum work hours per week as per Labour Act 1992 (Republic of Namibia, 1992) and the extent of annual leave or the hiring of temporary workers as per Labour Act 2007 (Republic of Namibia, 2008). Furthermore, future strengthening of labour laws are called for such as a minimum wage of N$ 850 (Khobetsi, 2010) which is a considerable increase over the present N$ 501–600 that are typically paid on commercial farms owned by non-indigenous farmers (Karamata, 2006: 5). Notwithstanding the justification of tougher labour legislation, a possible strengthening of this legislation is a risk to farmers due to the rise in production cost.

Cattle theft risk

Theft of cattle was uncommon prior to independence, but theft risk has been increasing in recent years as regular media reports show (e.g. Isaacs, 2007; Duddy, 2009; Maketo, 2011; Smith, 2011). No comprehensive data are available on extent of theft, but anecdotic figures indicate that as much as 30 cattle may be stolen at one theft from a given farmer (Maketo, 2011). This is a significant loss from cattle herds that typically number only a few hundred animals. The theft risk appears to be spatially heterogeneous, with the risk being elevated in areas that boarder onto larger roads which make whisking away of cattle easy.

4. Risk management strategies

In this section I describe management strategies, grouped as those that adjust organization and production processes of the farm ("on-farm risk management strategies", Section 4.1), that make use of financial products or off-farm assets and income ("financial risk management strategies", Section 4.2) or that entail membership to certain groups ("collective risk management strategies", Section 4.3). I relate each strategy to those risks it may be used to manage (see also Table 1). I also review what evidence exists that farmers actually apply a given strategy. Finally, I note that some strategies I describe may also be used for purposes other than risk management, but a discriminate between purposes is beyond this review.

4.1 On-farm management

Spatial diversification of farmland

Spatial diversification by purchase or lease of farmland may be employed to manage spatially heterogeneous risks, specifically the precipitation/grass production risk, groundwater risk, wildlife grazing risk, wildlife predation risk and potentially also the theft risk. A necessary condition for this strategy is that purchase or lease of farmland is possible which is the case in Namibia. What data is available on purchase of farmland suggest that transactions between farmers in the CCFR are frequent (Fuller and Eiseb, 2002; Motinga, 2003): Approximately 1,272 such transactions took place in the period 1990–2002 when on average every second of the 2,500 commercial cattle farmers[24] purchased farmland.[25] This information is dated, but there is no indication that the dynamics of the farm market have changed recently. Lease of farmland is likely also common, but no official information exits on the extent of leases since they are typically resolved informally. Altogether, the prevalence of purchases and leases suggest that spatial diversification is principally a viable option.

Choice of stocking rate

Farmland is typically divided into camps that are alternately grazed. Subsequent to good rainy seasons with ample grass production this gives farmers the option of not grazing some of the camps during the dry season but instead retaining their pasture as a reserve for potentially unfavorable subsequent rainy seasons. The extent of resting is mainly determined by the stocking rate (Quaas et al., 2007).[26]

Choice of stocking rate may thus be used to manage the precipitation/grass production risk (Quaas et al., 2007; Quaas and Baumgärtner, 2008). Stocking rates across the CCFR appear to range between 0.05 and 0.2 LSU/ha (Mendelsohn, 2006: Figure 20), but this information alone does not allow an assessment of whether stocking rate is used for the purpose of risk

[24] This assumes that the number of cattle farmers in this period was the same as nowadays.

[25] This is the most recent data on purchase of farmland which is provided by Fuller and Eiseb (2002) and Motinga (2003) and encompasses 3,595 transactions. It covers the whole commercial livestock region and also includes transactions that were not conducted between different farmers, that is where the purpose of the transaction is a change in legal ownership structure with the previous owner still in charge. The number of transaction between farmers in the CCFR only was estimated as follows: Firstly, only those transactions of farmland were selected where farmland was located in the political region where commercial cattle farming is predominantly conducted, that is in the regions Erongo, Khomas, Omaheke and Otjiozondjupa. This amounted to 1,952 transactions. Secondly, all transactions from male white farmers to corporate entities (560) or to female white farmers (120) were excluded. This left the (conservative) estimate of 1,272 farm transactions.

[26] One might argue that choice of stocking rate and choice of the resting scheme (i.e. layout of camps, grazing duration in a given camp) are two separate management strategies. However, the precise setup is arguably much less important than the stocking rate in determining the extent of resting, and I thus consider only the choice of stocking rate as a risk management strategy.

management as variation in stocking rate may simply reflect heterogeneous (non-risky) conditions of the farmland that permit a lower or higher stocking rate. Interviews suggest that this strategy is indeed used by farmers to manage the precipitation/grass production risk (Kamupingene, 2008).

Forage reserves

Farmers may purchase hay in expectation of an unfavorable rainy season, and this strategy may thus be used to manage the precipitation/grass production risk. No information from the literature, data or qualitative interviews is available on the actual use of this management strategy.

Choice of production system

Three main production systems are applied in commercial cattle farming (Hugo, 2007; Klein, 2007; de Bryn et al. 2010). Firstly, calves may be reared until age 8 months and sold as weaners at auctions ("weaner production"). Secondly, weaner may be further reared as oxen to age 18–24 months and sold to the slaughterhouse for conversion to beef ("ox production"). Thirdly, farmers may not raise calves themselves but instead buy weaners at age 8 months, raise them for a further 10–16 months as oxen and sell them to the slaughterhouse ("speculation production").[27] Out of these systems, the potential profits are highest for ox production, but this system also has the most demanding requirements for environmental conditions: Pasture must be adequate from the cows' impregnation until the time the oxen is sold, i.e. for 27–33 months (including the mother cow's pregnancy of 9 months). Conversely, speculation production has the lowest potential profits as weaners are purchased, but grazing must be adequate for only 10–16 months. Weaner production is in between these two extremes in potential profit as well as in environmental requirements.

Thus, farmers may use the choice of production system to vary the duration for which grazing has to be adequate and thus manage the precipitation/production risk. Furthermore, as only ox producing farmers are subject to the trade risk (c.f. Section 3.2) farmers may eliminate their exposure to this risk by producing only weaners. Data on marketed cattle show that many (49%) of these are weaners (MAWF, 2009: 14) which implies that weaner production is extensively pursued. Oxen are the other main output (51% of marketed cattle) (MAWF, 2009: 14), but may be produced by both ox production and speculation production. Given that

[27] Besides these production systems, some farmers breed bulls. This production system is fundamentally different from the above, not least because bulls are heavily fed with supplementary feed and thus do not rely primarily on rain-fed pasture.

weaners are mainly exported to South Africa and thus not purchased by Namibian farmers (Schutz, 2010), the latter production system arguably plays only a minor role. All in all, these data on farm outputs suggest that choice of production system is a viable option for farmers.

Choice of production cycle

By choice of production cycle farmers may adjust the number of mating periods. One period is typically timed at the end of the rainy season (January–March), as suggested in Mendelsohn (2006), so that calves are born at the onset of the next rainy season.

By having an additional mating period later in the year, farmers may reduce the unproductive time of cows that were not successfully impregnated during the last mating period, and they may thus manage the reproduction risk. Furthermore, by temporally diversifying mating the offsprings' marketing is likewise temporally diversified which thus allows the management of the output price risk. Information from qualitative interviews suggests that farmers often have an additional mating period.

Choice of cattle breed

There is a large number of cattle breeds in Namibia with major cattle breeds being the introduced Brahman, Afrikaner, Simmentaler, Bonsmara as well as several indigenous breeds which are collectively known as Sanga (Mendelsohn, 2006: 48; Sweet and Burke, 2006: 5). Indigenous breeds are generally smaller, have a higher resistance to diseases and have a higher reproductive efficiency (Lepen, 1996; Mendelsohn, 2006). In contrast, introduced breeds are generally larger and have a higher growth rate.

Thus, by choice of cattle breed farmers may trade-off higher production against a reduction in exposure towards as the disease and reproduction risks. Interviews suggest that farmers do indeed use this strategy for these purposes, but it is unknown how frequent the use of this strategy is.

Herd organization

Splitting up the cattle stock into more than one herd may be used to manage the disease risk, as only part of the total cattle stock will be affected by a given outbreak. Mendelsohn (2006), p. 45, states that the organization into more than one herd is common where a herd contains 50–100 animals, and farmers may thus use this strategy as a management against the aforementioned risk.

Fire breaks

Farmers may manage the bush fire risk by preventing vegetation growth at the outer boundaries of their farm. This creates a bare stretch that serves as a fire break by reducing the likelihood of bush fires to spread from neighbors' farms to their own ones. It is unclear to what extent this strategy is employed.

Income diversification into wildlife-related

Income diversification may be achieved by engaging into other on-farm activities. Utilization of wildlife are important such activities (Sherbourne, 2004; van Schalkwyk et al., 2010) which comprises mainly wildlife-viewing and to a lesser extent trophy hunting and game farming (Barnes et al., 2009: 18).

By focusing on those game species that are grazers/browsers or browsers, diversification into wildlife-related activities may specifically be used for management of the precipitation/grass production risk since these species' forage is bushes whose production is – unlike grass production – not dependent on recent rainfall. Diversification into wild-life related activities may also be used to manage the cattle disease and reproduction risks, the output price risk, the trade risk and the cattle theft risk.

For the commercial livestock region, output from wildlife-related activities amounted to N$ 1,020 million in 2004 (Barnes et al., 2009: Table 5), the majority of which likely occurred in the CCFR since the majority of tourism facilities and hunting farms are located there (Erb, 2004: Figure 2.3; Mendelsohn, 2006: Figure 30). By contrast, output from commercial cattle farming averaged N$ 819 million in the period 2000–2007, and amounted to only N$ 648 million in 2004 (MAWF, 2009: Table 2.1). Thus, output from wildlife-related activities appears to at least equal output from cattle farming. These aggregated numbers alone do not tell whether wildlife-related activities are pursued by a few specialized farmers or as diversification strategies by cattle farmers. Erb (2004), p. 5, finds that 20% of farms in the CCFR are registered as hunting farms and may thus accommodate trophy hunting tourists. This proportion seems too large to assume that all registered hunting farms are specialized farms that do not conduct cattle farming. I thus conclude that, at least for trophy hunting, it is also cattle farmers who pursue wild-life related activities with the purpose of income diversification.

Income diversification into rain-fed and irrigated crop farming

Crop farming is another on-farm diversification strategy that may be pursued by farmers. The major crop produced is white maize (Atlas of Namibia Project, 2002: 146; Mendelsohn, 2006: 63), minor crops are vegetables, fruits and olives (Mendelsohn, 2006: 63). Crop farming is conducted in two systems as rain-fed and irrigated farming (Atlas of Namibia Project, 2002: 146; Mendelsohn, 2006: 60).

Both types of crop farming may be used to manage a range of cattle specific risks, specifically the wildlife grazing risk, wildlife predation risks, cattle diseases risk, cattle reproduction risk, output prices risk, trade risk and cattle theft risk. In addition, rain-fed crop farming may also be used to manage the groundwater risk and irrigated crop farming may be used to manage the precipitation/grass production risk. Altogether, output from crops produced in the CCFR amounts to less than N$ 80 million[28] and thus to less than 10% of the N$ 819 million that derives from cattle farming (MAWF, 2009: Table 2.1). Again, these aggregated figures alone do not tell who is producing crops. Mendelsohn (2006), p. 59, notes that crop farming is pursued both by specialized and cattle farmers, and as such I conclude that crop farming is indeed used as a diversification strategy. However, this strategy is not available to all cattle farmers as either an adequate microclimate or a productive aquifer is a prerequisite (Atlas of Namibia Project, 2002: Figure 5.24; Mendelsohn, 2006). As such, rain-fed and irrigated crop farming are conducted in the 'Otavi-Grootfontein-Tsumeb' triangle that has a local micro-climate with sufficient rainfall as well as productive aquifers, and irrigated crop farming is also conducted above productive aquifers in the Hochfeld (Otjiozondjupa) and Stampriet (Omaheke) areas (Atlas of Namibia Project, 2002: 146; Mendelsohn, 2006: 60).

Vaccination, hunting and game fences

Farmers pursue a variety of risk management strategies that deal with disease and wildlife risks. The disease risk may be managed by vaccination, and farmers routinely appear to pursue this strategy (Mendelsohn, 2006: 45).[29] The wildlife grazing risk may be managed by hunting wildlife grazers or by excluding them from the farmland through the construction of special game fences. To what extent hunting is used for the management of the wildlife

[28] Similar to wild-life related activities, there is no data available on crop output for the CCFR only. National output from maize averages N$ 65 million (MAWF, 2009: Table 2.1), which is predominantly white maize produced in the commercial cattle farming region. Output from other crops, excluding wheat and grapes that are not produced in the CCFR, amounts to N$ 15 million and these are only partly produced in the CCFR. Both figures add up to N$ 80 million and thus constitute the upper boundary for output from crop in the CCFR.

[29] The VCF is itself a risk management strategy, pursued by the Namibian government, to keep the CCFR free of food-and-mouth disease and contagious bovine pleuropneumonia. As of yet, this is successful and farmers thus do not vaccinate against these diseases.

grazing risk is unclear, but game fences are common in the CCFR. Finally, farmers may manage the predation risk by hunting mammalian predators or by keeping guard animals such as donkeys and dogs in cattle herds (Schumann et al., 2008). Hunting appears to be common, and guard animals are used by at least some farmers.

4.2 Financial management

Insurance

Insurances against a variety of environmental risks exist, but appear to be seldom pursued by farmers. Santam Agriculture, a branch of the insurance company Santam, offers individually negotiated contracts against environmental risks including bush fire risk, wildlife predation risk, disease risk and reproduction risk (NAU, 2011; Santam, 2011).[30] However, uptake by farmers appears to be low since premiums are perceived to be too high or conditions to be too unattractive (Caspers, 2007; Workshop, 2007; Bayer, 2010). The precipitation/grass production risk is presently uninsurable in Namibia (Horsthemke, 2010) even though suitable insurance products in the form of index insurance exist in other countries like Ethiopia, Mexico or India (Müller et al., 2011). One reason appears to be an insufficient coverage by official weather stations (Horsthemke, 2010) which precludes a meaningful calculation of premiums.

Bank account, agricultural derivatives and future contracts

Farmers typically own bank accounts which they use to build up financial buffers in case revenues from cattle farming are temporarily low (de Bryn et al., 2007; Horsthemke, 2010) and may thus use this as a strategy against essentially all risks. Owning a bank account is common among farmers. Investment into derivatives on suitable agricultural products may principally be used to manage the output price risk. Derivatives are traded at the South African Futures Exchange but it is unclear whether suitable derivatives and agricultural products exist. In any case, farmers appear not to pursue this strategy (Schutz, 2010), for unknown reasons. Finally, MeatCo offers future contracts on ox sales to manage the output price risk, but these contracts are complex and inflexible and thus unattractive for farmers (Horsthemke, 2010).

[30] The available information is somewhat vague and other risks may be insurable with Santam.

Income diversification into off-farm sources

Farmers may also diversify into income from off-farm sources such as financial assets, property or off-farm occupations. No information is available to what extent farmers pursue these off-farm sources.[31]

4.3 Collective management

Risk management may be conducted by membership in various groups. Firstly, locally operating fire management groups may provide risk management against bush fires by organizing coordinated actions to swiftly suppress any bushfires emerging on a members' farm. Secondly, local wildlife management groups target local wildlife, specifically large herbivorous mammals by investing into game fences, and may thus manage the wildlife grazer risk. To what extent these two types of local groups exit, is not known. Thirdly, national groups like the NAU or the Emerging Farmers' Support Programme lobby in the interest of farmers and may thus manage political risks. As described in Section 2.4, membership is open to commercial cattle farmers and it is common among farmers to actually hold a membership (Hager and Marggraff, 2007).

5. Issues of sustainability

5.1 Bush encroachment

As detailed in Section 2.1, the Acacia-Tree-and-Scrub savanna that covers the CCFR is characterized by a coexistence of grass and bushes. The relative proportion of both vegetation components hereby varies considerably across the region (CCA, 2010: Figure 1). From the farmers' perspective, a high bush density is undesirable, as it negatively affects grazing capacity (discussed in this section) as well as biodiversity (discussed in Section 5.2) and groundwater depletion (Section 5.3).

Densities of below 1,000 bush/ha are considered unproblematic (de Klerk, 2004: 77). However, the majority of the CCFR is subject to bush encroachment, defined as an "invasion and/or thickening of aggressive undesired woody vegetation, resulting in an imbalance of the grass:bush ratio" (de Klerk, 2004: 2), and densities in these areas are above 2,000 bush/ha (Figure 6) (de Klerk, 2004: 77). Specifically which bush species is responsible for bush encroachment varies locally. Dominant species are Sickle bush (*Dichrostachys cineria*) in the

[31] Many farmers conduct farming only part-time on the weekend. However, I do not consider these farmers as pursuing income diversification since for them farming is more a hobby than an occupation (Sherbourne, 2004).

north-east of the CCFR, Mopane (*Colophospermum mopane*) in the north-west, Black thorn (*Acacia mellifera*) in the center-south and Silver terminalia (*Terminalia sericea*) in the south-east (de Klerk, 2004: 4; CCA, 2010: Figure 1).

In encroached areas, grass productivity is markedly depressed and may be 55% or even less of the amount that characterizes non-encroached areas (CCA, 2010: 15)[32], and dense bush vegetation bars cattle from reaching what grass is still left between bushes (Atlas of Namibia Project, 2002: 107). As a consequence, grazing capacity is nowadays as low as 0.033–0.05 LSU/ha (de Klerk, 2004: 60) in areas where it used to be 0.1 LSU/ha until the mid 1960s (de Klerk, 2004: 21) when bush encroachment was largely absent. This decrease in grazing capacity is reflected in a decrease of the number of cattle that can be kept in the CCFR, which is now only 840,000 instead of the historic 2,300,000 cattle (de Klerk, 2004: 20; CCA, 2010: 16), and is ultimately reflected in a decrease in farmers' income (Lubbe, 2007; Steir, 2007).[33]

Bush encroachment appears to be caused on the one hand by environmental factors such as certain inter-annual precipitation patterns (Asner et al., 2004; de Klerk, 2004: xi, 31–32) : 28). However, anthropogenic factors may also be important drivers (Asner et al., 2004), and this may include at least four risk management strategies: Firstly, suppression of bush fires, such as by fire breaks and fire management groups, avoids the destruction of grass, but also of bush seedlings and saplings (de Klerk, 2004: 17–18; similarly: Mendelsohn, 2006: 42). Secondly, choice of stocking rates that are too high leads to overgrazing of pastures and causes seriously damage to the grass layer (de Klerk, 2004: 19). Thirdly, exclusion of wildlife grazers from farms by game fences has the side effect of also excluding browsers and thus prevents these animals from feeding on bush saplings and seed pods (de Klerk, 2004: 23–24; Zimmermann et al., 2008: 28). The result is a reduction of the competitive ability of the grass layer and facilitate the establishment of bush cover until it ultimately dominates in a given area (de Klerk, 2004).

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[32] CCA (2010), p. 15, cites three comparative studies, none of which I could obtain, to demonstrate the difference of grass production between encroached and non-encroached areas. He reports that the first study by IDC (2006) was conducted in Namibia near Otjiwarongo and finds that grass production in an encroached area (no bush density given) is only 55% of that in a partly encroached area (1,500 bush/ha) with 1.20 kg/(ha*mm precipitation) and 2.17 kg/(ha*mm precipitation), respectively. CCA (2010) notes that the difference in productivity would be even higher if the former area would be completely debushed. The two other studies by Snyman (1988) and by Snyman and Rensburg (1990) were conducted in South Africa and apparently find even larger decreases in production, albeit no precise information is given on the properties of the compared areas. Thus, the aforementioned 55% decrease in production is a conservative estimate, and production like decreases even more in encroached areas.

[33] One might think that bush encroachment would benefit browsers and greatly contribute to the viability of wildlife-related activities. However, such an effect is not as large as it appears at first glance. Due to structural defenses of adult encroaching bushes they are unpalatable for browsers and only 30-40% of total bush qualifies as good fodder for browsers in encroached areas (CCA, 2010: 17, 97).

5.2 Biodiversity loss

Terrestrial biodiversity in Namibia, in the sense of species richness[34], is highest in the wet and semi-tropical areas of the Caprivi Strip, but it is also elevated in CCFR (Atlas of Namibia Project, 2002: Figure 4.12). Relatively high levels in the latter region are partly due to structural habitat diversity (Meik et al., 2002) provided by the Tree-and-Scrub savanna with its coexistence of grass and bush vegetation and partly due the topographic features in the Windhoek and Tsumeb highlands that support specialized species (Maggs et al., 1998).

Namibia's biodiversity is considered to be "largely intact" (MET, 2006: 31), but lack of data is a serious obstacle for any assessment of its state (Loots, 2005; MET, 2006). Indeed, there is evidence that biodiversity loss has already occurred or may occur soon, including in the CCFR: Approximately 2% of higher plant taxa (Loots, 2005: 4), 21% of reptile species (MET, 2006: 34) and 4% of bird species[35] (Atlas of Namibia Project, 2002; MET, 2006) are vulnerable, threatened or extinct. In addition, several large mammal species such as buffaloes, elephants or lions that may still be found in other regions of Namibia are nowadays absent in the CCFR (Atlas of Namibia Project, 2002: 121–122; Barnes et al., 2009: Table 4).

Biodiversity loss is problematic since it is linked to a reduction in local provision of ecosystem services (MEA, 2005b), including those that contribute to the "capacity of the local system to function over a range of environmental and market conditions" (Perrings et al., 2009: 230). That this specifically also holds for grassland communities has been demonstrated, for example, by Tilman (1996). Given the large variability of environmental conditions in the CCFR's savanna system, loss in biodiversity may thus threaten the functionality of the system and ultimately farmers' livelihood.

One driver for biodiversity loss appears to be bush encroachment (Maggs et al., 1998; de Klerk, 2004; MET, 2006), with the relationship being non-linear for many taxa (e.g. Blaum et al., 2007; Blaum et al., 2009; Sirami et al., 2009). Specifically, the relationship between species richness and bush density is often hump-shaped, with species richness peaking at intermediate levels of bush density. The reason is that the structural habitat diversity is highest

[34] Beyond species richness there exist other measures of biodiversity that also take into account relative abundance for each species (e.g. the Simpson Index, Simpson, 1949), but, for simplicity sake, I will in this chapter only refer to biodiversity loss as measured by a reduction in species richness.

[35] The figure for birds was calculated as follows: MET (2002), p. 109, estimates that 658 bird species may be found in Namibia. MET (2006), citing an unobtainable paper from Simmons (2003) notes that 40 bird species "fall in the following categories: extinct, critically endangered, endangered, vulnerable, near-threatened, rare/peripheral, or data-deficient" (MET, 2006: 32). Excluding the latter two categories which represent 32% of the 40 species (MET, 2006: Figure 2.15) leaves me with 27 bird species that are in some way extinct, endangered, vulnerable or threatened. These 27 species constitute 4% of the 658 estimates bird species in Namibia.

at these intermediate levels and may thus attract the highest number of species (Sirami et al., 2009).[36] In Southern African savannas such a hump-shaped relationship has been demonstrated for birds (Sirami et al., 2009), small carnivores (Blaum et al., 2007) and ground-dwelling arthropods (Blaum et al., 2009), while species richness of rodents was found to decrease linearly with bush density (Blaum et al., 2006).

Along these lines, risk management may contribute to indirectly to biodiversity loss, especially those aforementioned strategies that may causes severe bush encroachment (c.f. Section 5.1). But strategies may also directly contribute to biodiversity loss as in the case of hunting or exclusion of large herbivorous and predating mammals to the point of local absence. This applies, for example, to elephants and lions which may no longer be found in the CCFR, or to game species which are locally absent on farms due to game fences (Griffin, 1998; Barnes et al., 2009).

5.3 Groundwater depletion

Supply of water used for farming, household and industries in Namibia is, on average, higher than its demand. Christelis and Struckmeier (2011), p. 11, estimate total supply from all water sources – that is surface water, rechargeable[37] groundwater and reused water – to amount to 660 million m³/year. In contrast, only 355 million m³/year are presently demanded by all consumer groups (CCA, 2010: Table 11). Inspecting only groundwater, the water source that is mainly used by commercial cattle farming, reveals the same picture: Sustainable yield of rechargeable groundwater is 300 million m³/year (Christelis and Struckmeier, 2011: 11) while demand by all consumer groups is 156 million m³/year (CCA, 2010: Table 11)[38], of which communal and commercial livestock farming accounted for only 61 million m³/year (CCA, 2010: Table 11). Albeit groundwater is locally over-abstracted in the CCFR near Okahandja (Christelis and Struckmeier, 2011: 82), Leonardville (Christelis and Struckmeier, 2011: 91) and Otavi (CCA, 2010: 29–31), commercial cattle farming has thus at present generally sufficient groundwater.

This will likely change soon. Projections indicate that by 2030 total water demand across Namibia will amount to 772 million m³/year (CCA, 2010: Table 10), which exceeds the total

[36] Sirami et al. (2009) as well as the subsequent cited references in this paragraph use bush *cover* in percent instead of bush *density* as an indicator of bush encroachment. I assume here that higher bush cover implies higher bush density and use, for consistency, only bush density as a measure of bush encroachment.

[37] No estimate exists for supply or demand of water from fossil aquifers. Thus, this type of groundwater is excluded in the further discussion.

[38] Table 11 in CCA (2010) reports figures from IWRM (2010). The latter reference could not be obtained and is thus not directly cited.

supply of 660 million m³/year. While no detailed figures exit for groundwater only, the rising total water demand implies, *ceteris paribus*, that groundwater will be depleted[39] as other water sources cannot meet demand. The main driver for this increase in total demand is demand by irrigated crop farming while demand by livestock farming will remain unchanged from present demand.[40]

Notwithstanding that livestock farming, including commercial cattle farming, appears not to contribute to demand increase, one may still question if the present demand particularly by commercial cattle farming is not already too high. Furthermore, one may question how risk management is linked to this demand. Here, it is choice of stocking rate that is linked directly to local demand since the amount of necessary cattle drinking water is determined by cattle density. However, the more significant link is not through an increase in demand but through a reduction of recharge of aquifers. Specifically, bush encroachment with its increasing bush densities reduces recharge since i) bush leaves intercept precipitation, ii) roots intercept percolating water and iii) roots tap directly into the groundwater (CCA, 2010: Figure 7). A pilot study suggests that the difference in recharge in a non-encroached rangeland versus the typical Namibian rangeland (that is encroached to some degree) may be considerable: While an aquifer below debushed rangeland near Otjiwarongo was recharged by 8% of recent precipitation (CCA, 2010: 37), aquifers across Namibia are typically recharged by only 1% of precipitation (Christelis and Struckmeier, 2011: 36). Thus, those risk management strategies that may entail bush encroachment (c.f. Section 5.1) may (indirectly) contribute considerably to future groundwater depletion through a reduction in recharge.

6. Conclusion

I find that commercial cattle farming in Namibia is subject to at least 13 environmental, economic, social and political risks. Many of these risks are heterogeneous across farmers, either because they are spatially heterogeneous as in the case of most environmental risks and the cattle theft risk, or because they affect only certain segments of the farmer population such as in the case of the trade risk or the expropriation risk. Beyond merely compiling and describing these risks, it would be desirable to assess the magnitude of each risk. Available information allows such an assessment only for five risks, that is the precipitation/grass production risk, the input and the output price risks, the wildlife grazer risk and the

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[39] In the case of rechargeable aquifer, depletion means that groundwater abstraction is higher than its recharge.

[40] Demand from all water sources by livestock is expected to remain stable at 87 million m³/year. By contrast, demand by irrigated crop farming is expected to increase from 144 in 2009 to 497 million m³/year in 2030.

expropriation risk. I assess the first four to be high risks as they may have a considerably negative impact on the livelihood of many farmers. In comparison to these risks, I assess the expropriation risk to be low.

Risks can typically be managed by alternative strategies or by a combination of strategies. The only exceptions appear to be two political risks, the expropriation and labor legislation risks, which may only be managed by interest group membership. It appears that from among the various strategies, farmers predominantly employ on-farm management strategies. In contrast, most financial strategies appear to be used only marginally due to an insufficient supply of suitable financial products but possibly also due to farmers' skepticism of these strategies. Finally, I note that several risk management strategies may be employed to manage multiple risks simultaneously. This may entail synergies or trade-offs, but an analysis thereof is beyond this review.

Farmers' risk management appears to contribute, both directly and indirectly, to bush encroachment, biodiversity loss and the projected groundwater depletion, specifically the choice of a high stocking rate and the exclusion of wildlife grazers from farms, which inevitable also excludes browsers. Suppression of bush fires appears also to be a very important contributing factor, but it is unclear whether farmers at all apply risk management strategies that aim at bush fire suppression (c.f. Sections 4.1 and 4.3). Finally, I wish to emphasize that it are not the risk management strategies *pre se*, but rather their configuration that contributes to issues of sustainability: Stocking rate, for example, may very well be set to a level that does not result in bush encroachment, but may also be set to such a high level that overgrazing and ultimately bush encroachment are inevitable.

To my knowledge, this review is the first compiled description of risk, management and sustainability for commercial cattle farming in Namibia and is as such a useful foundation for future research. However, scarcity of information on risks, on what risk management strategies farmers actually do employ and on the precise link between strategies and issues of sustainability is a serious limitation. Therefore, I overall conclude that it is of principal importance to establish a better data base. Only with such data can the link between risk, management and sustainability be adequately analyzed and can meaningful recommendations be given to farmers and policy makers.

Acknowledgements

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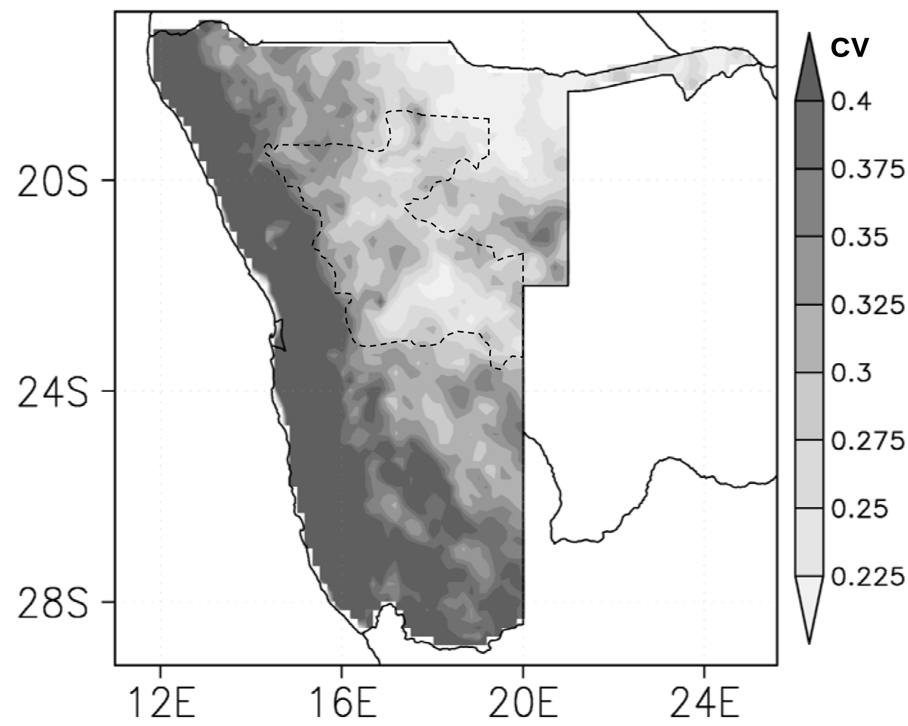

Figure 1: Cattle farming region and precipitation risk in Namibia. This figure is a slightly modified reprint of Figure 1 in Olbrich et al. ({Olbrich 2011 #91/yearonly}). Dashed lines denote the commercial cattle farming area as adapted from ({Mendelsohn 2006 #7}: Figure 20). Shading denotes the inter-annual coefficient of variation (CV) of total rainy season precipitation for the period 1978–2008 as simulated by the atmospheric circulation model REMO ({Olbrich 2011 #91}: 12). CVs of simulated and actual precipitation data are highly correlated ({Olbrich 2011 #91}: 16).

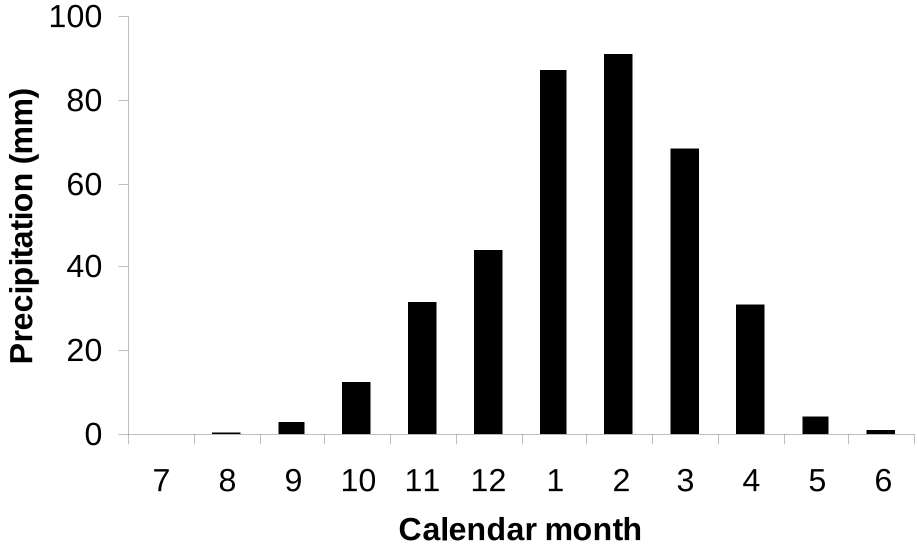

Figure 2: Average monthly precipitation for the commercial cattle farming region. Data is provided by the Namibian Meteorological Service as described in Section 3.1 (NMS, unpublished). The rainy season is commonly denoted as the period November (11) to April (4).

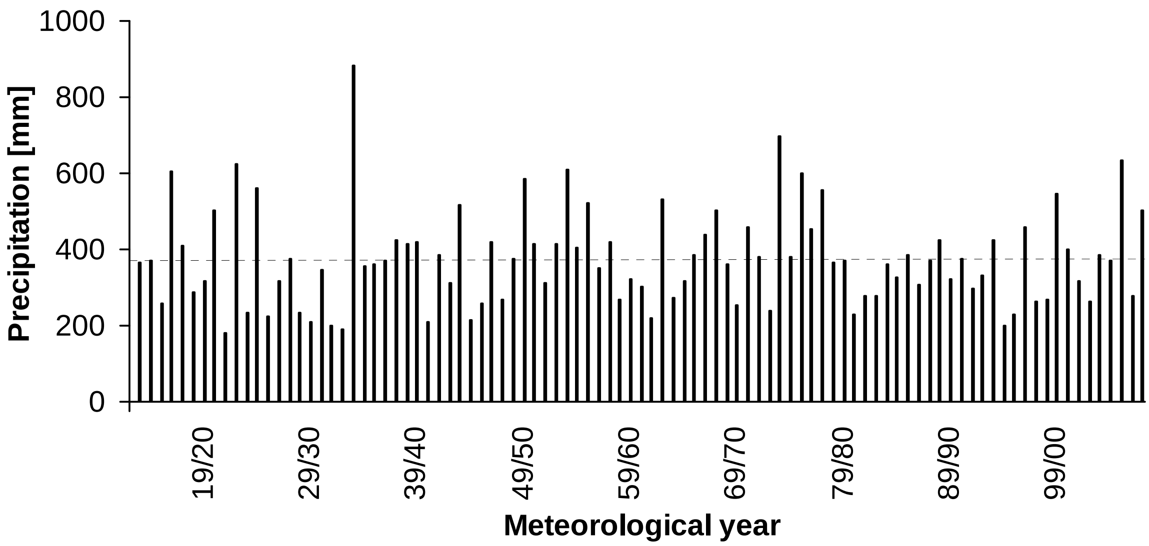

Figure 3: Annual precipitation of the meteorological year (July to June) for the period 1913-2008. Data is provided by the Namibian Meteorological Service as described in Section 3.1 (NMS, unpublished). A dashed trendline is indicated and has the function y = 0.0027x * 372.2, $R^2 = 0.00$.

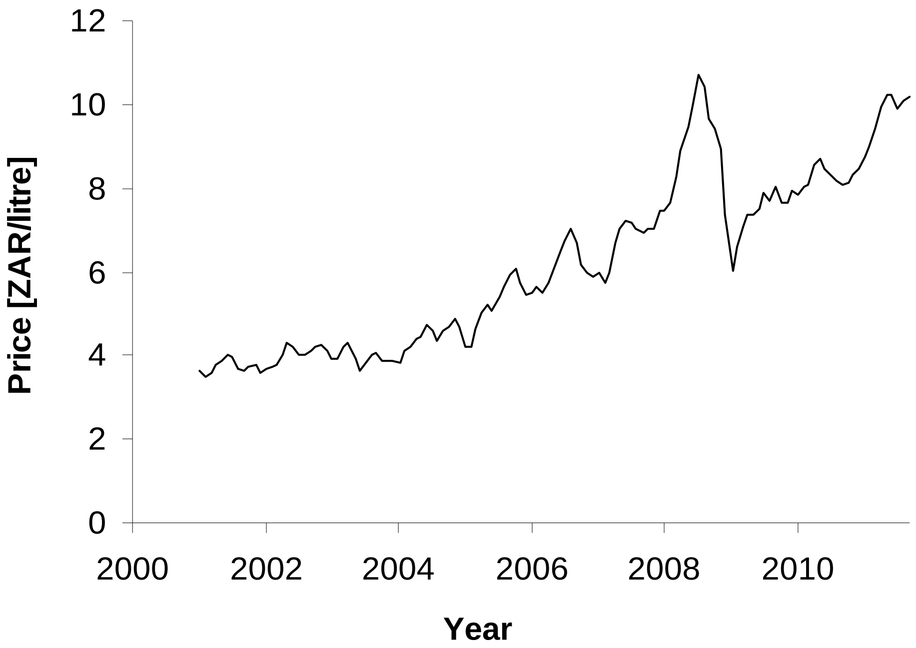

Figure 4: Monthly prices for Petrol 95 Unleaded sold in South Africa. Data is provided by the South African Department of Energy (DE, 2011). The price unit is Rand per litre [ZAR/litre]. The Namibian Dollar is tied to the South African Rand on a one-to-one basis.

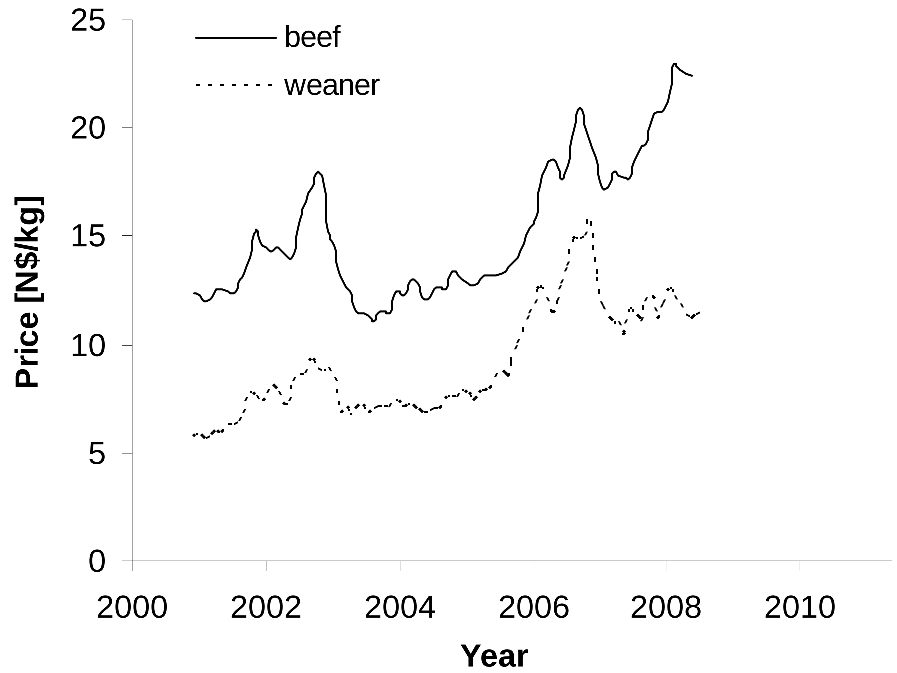

Figure 5: Monthly prices for weaners and ox carcasses for the period January 2001 to August 2008. Weaner data is provided by Agra Co-operative Ltd. (Agra, unpublished), ox carcass price data provided by Meat Board of Namibia (Meat Board, unpublished) as described in Section 3.2

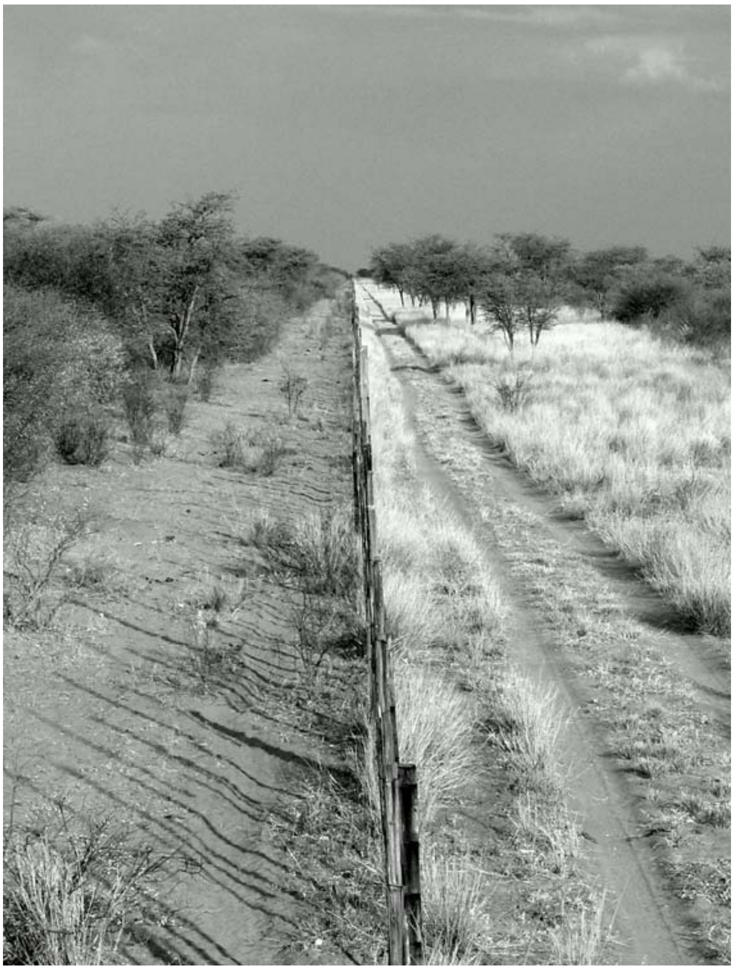

Figure 6: Fence line between two cattle farms in central Namibia. Bush encroachment afflicts the left farm while grass and bush vegetation is balanced on the right farm.

Table 1: Risks and respective risk management strategies. Bank account as financial buffer and income diversification into off-farm sources are not listed as they may essentially be used to manage all risks listed below.

Risks	**Risk management strategies**		
	On-farm	**Financial**	**Collective**
Environmental risks			
Precipitation/grass production	Spatial diversification Stocking rate Forage reserves Production system Income diversification (wildlife, irrigated crop)		
Groundwater	Spatial diversification Income diversification (rain-fed crop)		
Bush fire	Fire breaks	Insurance	Fire management group
Wildlife grazing	Spatial diversification Income diversification (irrigated and rain-fed crop) Hunting Game fences		Wildlife management group
Wildlife predation	Spatial diversification Income diversification (irrigated and rain-fed crop) Hunting Guard animals	Insurance	
Cattle diseases	Cattle breed Herd organization Income diversification (wildlife, irrigated and rain-fed crop) Vaccination	Insurance	
Cattle reproduction	Production cycle Cattle breed Income diversification (wildlife, irrigated and rain-fed crop)	Insurance	

Risks	Risk management strategies		
	On-farm	**Financial**	**Collective**
Economic risks			
Input prices (only petrol)			
Output prices	Production system Production cycle Income diversification (wildlife, irrigated and rain-fed crop)	Agricultural derivatives Future contracts (only for ox carcass price)	
Trade	Production system Income diversification (wildlife, irrigated and rain-fed crop)		
Social and political risks			
Expropriation			National interest group
Labor legislation			National interest group
Cattle theft	Spatial diversification Income diversification (wildlife, irrigated and rain-fed crop)		National interest group

Appendix: Interview partners

The following list contains the name of the interview partner, their function, their affiliation, place of the interview and date of the interview:

Komwill Bayer, Manager: Credit, *Agribank of Namibia*, Windhoek (Namibia), 01. March 2010

Dana Beukes, Registrar of Deeds, Deeds Registry, *Ministry of Lands and Resettlement*, Windhoek (Namibia), 15. March 2010

Hermann Caspers, Audit Manager, *Grant Thornton Neuhaus*, Windhoek (Namibia), 28. March 2007

Marina Coetzee, Chief Agricultural Researcher, *Ministry of Agriculture, Water & Forestry*, Windhoek (Namibia), 19. October 2007

Flip de Bruyn, General Manager: Finance, *Agra Co-operative Ltd.*, Windhoek (Namibia), 30. March 2007 & 11. October 2007 & 05. March 2010

Vera de Cauwer, Lecturer, Land Management Department, *Polytechnic of Namibia,* Windhoek (Namibia), 23. July 2008

Volker Dieckhoff, Chairman, *Water Management Group Okakarara, Farm La Paloma,* Okahandja (Namibia), 15. October 2007 & 31. July–01. August 2008

Peter Eichhoff, *Farm Vergenoeg*, Summerdown (Namibia), 17. October 2007

Celeste Espach, Agricultural Researcher, Remote Sensing & GIS, *Ministry of Agriculture, Water & Forestry*, Windhoek (Namibia), 19. October 2007 & 23. July 2008 & 25. July 2008 & 05. August 2008

Ben Fuller, *Independent Expert on Social and Economic Research and Policy Analysis*, Windhoek (Namibia), 28. March 2007

Arne Gressmann, Chairman of Board of Directors, *MeatCo*, Chairman, *Study Group Karsfeld*, *Farm Klein-Huis*, Grootfontein (Namibia), 13.–14. October 2007

Claus-Peter Hager, Coordinator: Land Management Desk, *Desert Research Foundation of Namibia*, Windhoek (Namibia), 02. April 2007 & 24. July 2008

Birgit Hoffmann, Senior Manager: Marketing, *Agra Co-operative Ltd.*, Windhoek (Namibia), 08. October 2007

Jürgen Hoffmann, Senior Trade Advisor, *Namibian Agricultural Trade Forum*, Windhoek (Namibia), 01. April 2007 & 09. October 2007 & 22. July 2008 & 22. August 2008

Oliver Horsthemke, Head: Agri Division, *First National Bank of Namibia*, Windhoek (Namibia), 29. March 2007 & 04. March 2010

Peter H. Hugo, Senior Manager: Livestock, *Agra Co-operative Ltd.*, Windhoek (Namibia), 11. October 2007 & 05. March 2010

Dave Joubert, Lecturer, Department of Nature Conservation, *Polytechnic of Namibia,* Windhoek (Namibia), 21. July 2008 & 04. March 2010

Gift Kamupingene, Lecturer, Department of Animal Science, *University of Namibia,* Windhoek (Namibia), 04. August 2008

Arnold Klein, General Manager: Retail and Wholesale, *Agra Co-operative Ltd.*, Windhoek (Namibia), 30. March 2007 & 08. October 2007

Bertus Kruger, Project Coordinator, *Emerging Commercial Farmers' Support Programme*, Windhoek (Namibia), 29. March 2007 & 02. March 2010 & 04. March 2010

Judith und Ekkehard Külbs, *Farm Springbockvley*, Windhoek (Namibia), 08.–09. August 2008

Tobie Le Roux, Manager, *Namibian Stud Breeders Association,* Windhoek (Namibia), 29. July 2008

Leon Lubbe, Agricultural Researcher, Pasture Science, *Ministry of Agriculture, Water & Forestry*, Windhoek (Namibia), 19. October 2007 & 05. August 2008 & 04. March 2010

Harald Marggraff, Manager: Commodities, *Namibia Agricultural Union*, Windhoek (Namibia), 02. April 2007 & 08. October 2007 & 04. March 2010

Salomo Mbai, Head of Department, Department of Agriculture, *Polytechnic of Namibia*, Windhoek (Namibia), 04. March 2010

Manuel Mbuende, Agrometeorologist, *Ministry of Agriculture, Water & Forestry*, Windhoek (Namibia), 25. July 2008

Joseph Minnaar, Statistician, Agricultural Statistics, Central Bureau of Statistics, *National Planning Commission*, Windhoek (Namibia), 29. March 2007

Jeniffer Moety, Chief Meteorological Technician, *Namibia Meteorological Service,* Windhoek (Namibia), 24. July 2008

Sepiso Mwangala, Chief Meteorological Technician, *Namibia Meteorological Service,* Windhoek (Namibia), 25. July 2008 & 06. August 2008

Norbert Neumann, Chief Agricultural Extension Officer, *Ministry of Agriculture, Water & Forestry*, Windhoek (Namibia), 30. July 2008

Wilfried Pack, Board Member, *Conservancies Association of Namibia, Farm Grünental*, Witvlei (Namibia), 26. July 2008

Thomas Peltzer, Board Member, *Conservancy Association of Namibia*, *Farm Onjossa*, Okahandja (Namibia), 18.–19. October 2007 & 28.–29. July 2008

Gunther Roeber, Technical Advisor, Professional Service Division, *Agra Co-operative Ltd.*, Windhoek (Namibia), 05. March 2010

Axel Rothauge, Lecturer, Department of Animal Science, *University of Namibia,* Windhoek (Namibia), 24. July 2008

Argo Rust, *Farm Sonnleiten,* Windhoek (Namibia), 04. August 2008

Klaus Schade, Acting Director, *The Namibian Economic Policy Research Unit*, Windhoek (Namibia), 09. October 2007

Robert Schultz, Member of Energy Desk, *Desert Research Foundation of Namibia*, Windhoek (Namibia), 29. March 2007 & 22. July 2007

Willie Schutz, Manager Information Systems, *Meat Board of Namibia*, Windhoek (Namibia), 29. March 2007 & 22. July 2008 & 07. August & 01. March 2010

Elaine Smith, Manager: Research & Development, *Namibia Agricultural Union*, Windhoek (Namibia), 19. October 2007 & 09. March 2010

Elsabe Steenkamp, Manager: Finance, *Namibia Agricultural Union*, Windhoek (Namibia)

Helmut Stehn, Rangeland Consultant, *Farm Smalhoek,* Windhoek (Namibia), 09. August 2008

Hans-Günter Stier, Chairman of Board of Directors, *Agribank of Namibia*, Partner, *Stier Vente Associates*, Windhoek (Namibia), 12. October 2007

Piet Stomann, Chairman, *Grootfontein/Otavi/Tsumeb Regional Farm Association*, Otavi (Namibia), 11. March 2010

Ben Strohbach, Coordinator, *National Botanical Research Institute of Namibia,* Windhoek (Namibia), 25. July 2008

Paul Strydom, General Manager, *Meat Board of Namibia*, Windhoek (Namibia), 29. March 2007

Mogos Teweldemedhin, Deputy Head of Department, Department of Agriculture, *Polytechnic of Namibia*, Windhoek (Namibia), 04. March 2010

Vehaka Tjimune, Chairman, *Namibian National Farmers' Union*, Senior Manager: Procurement, *MeatCo of Namibia*, Windhoek (Namibia), 29. March 2007 & 23. July 2008

Justus Tjituka, Senior Manager Finance, *Agribank of Namibia*, Windhoek (Namibia), 11. October 2007

Wessel Visser, Manager: Karakul, *Agra Co-operative Ltd.*, Windhoek (Namibia), 30. March 2007

Gerd Wölbling, *Farm Hebron*, Otjiwarongo (Namibia), 07. August 2008

Peter Zensi, Member, *Study Group Karsfeld*, *Farm Hamburg*, Grootfontein (Namibia), 14.–15. October 2007

Ibo Zimmermann, Chair of Steering Committee, *BIOTA Namibia*, Deputy Director, Department of Agriculture, *Polytechnic of Namibia*, Windhoek (Namibia), 31. March 2007 & 04. March 2010

Chapter 3: Sustainable use of ecosystem services under multiple risks – A survey of commercial cattle farmers in semi-arid rangelands in Namibia

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Abstract

Studying the sustainable use of ecosystem services under uncertainty requires the consideration of the stochastic dynamics of the system under study, risk and time preferences, risk management strategies and normative views pertaining to sustainability. To gather this information for an important ecological-economic system, we conducted a survey of commercial cattle farmers in semi-arid rangelands of Namibia, a system that features risks on various space and time scales. Here we present a description of the research aims, design and conduction of the survey, and analyze and discuss the homogeneity and representativeness of our survey population. The survey consisted of a mail-in questionnaire and in-field experiments. We combined two existing farm-address databases, reaching 77% of the estimated 2,500 cattle farmers. The return rate of questionnaires exceeded 20%, and response rate to individual questions surpassed 95% and 90% for the majority of non-sensitive and sensitive questions, respectively. Distinct sub-sample groups within the survey population did not differ in the analyzed characteristics with the exception of ethnicity, regional location of farmland and an intentionally induced bias for residency on farm. It has turned out that we have undersampled distinct population segments of farmers, such as indigenous farmers or farmers not belonging to the main interest group of commercial cattle farming. Notwithstanding, we consider the survey to be highly successful, yielding a rich dataset which allows diverse analyses.

Keywords: survey, cattle farming, semi-arid, rangeland management, sustainability, risk
JEL-classification: Q12, Q15, Q24, Q56, Q57

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1. Introduction

Ecosystem users depend upon the specific spatio-temporal provision of ecosystem services. The provision of many of these services is influenced by risks acting on various space and time scales. To what extent users are affected by these risks depends on the risks' characteristics, users' risk and time preferences and their endowment (Gollier, 2001; Machina and Rothschild, 2008). Many of these risks are endogenous, i.e. users may employ strategies to lessen risk (Shogren and Crocker, 1999; Perrings, 2004). These risk management strategies have a long history in human civilization (Covello and Mumpower, 1985) and are ubiquitous in the everyday life (Shogren and Crocker, 1999).

In a coupled ecological-economic system, different ecological and socio-economic management strategies may be substitutes in regards to risk reduction, but may differ profoundly in regards to their sustainability (Quaas and Baumgärtner, 2008). Generally speaking, users may employ ecological risk management strategies to alter the probability distribution of ecosystem service provision. For example, conservative pasture management may be employed as a form of natural insurance to reduce the variance in forage provision and thus dampen income risk from livestock production (Quaas et al., 2007). Alternatively, users may resort to socio-economic management strategies to hedge risk arising from uncertain provision of ecosystem services. For example, a (hypothetical) financial insurance may indemnify users when income from livestock production falls below a certain threshold. Depending on the properties of the ecological-economic system as well as on the specific design of insurance contracts, financial insurance indeed provides the same risk reduction as natural insurance but leads to a degradation of the ecosystem (Quaas and Baumgärtner, 2008; Müller et al., 2009). Thus, one approach to promote sustainable use of ecosystem services under uncertainty may be to design policies and institutions to encourage the employment of sustainable risk management strategies.

Furthermore, any meaningful assessment of sustainability of risk management strategies faces issues on a fundamental level: the necessity to address uncertainty about the system dynamics in the criterion used for the assessment. Services may cease to exist due to stochastic events that are beyond human control. For grazing in semi-arid rangelands, for example, the system might be irreversibly degraded through a long-term drought despite the best human efforts at conservation.

A novel operational criterion for strong sustainability under uncertainty that captures uncertainty about the system dynamics is ecological-economic viability (Baumgärtner and

Quaas, 2009). Viability, in short, specifies that components and functions of a dynamic, stochastic system remain at any time in a domain where their future existence is guaranteed with a sufficiently high probability. To this end, the criterion requires normative judgments that have to be made by society pertaining to object and scope of sustainability, to appraisal of risk and to the relevant time horizon.

Against this background, our research is aimed firstly at characterizing what risks affect individual ecosystem users in a coupled ecological-economic system with stochastic dynamics. Secondly, we explore ecosystem users' risk and time preferences and the relationship of preferences with personal, economic and environmental characteristics. Thirdly, we study what views of sustainability in the sense of viability are present among ecosystem users. And lastly, we characterize what risk management strategies are employed and how the choice and extent of strategies relate to individual risk and time preferences and views of sustainability. Results of this research should be useful for assessing ecological and socio-economic risk management strategies in general, and natural and financial insurance in specific, in regards to risk reduction and sustainability. Ultimately, we aim at contributing to an understanding of how economic policies and institutions have to be designed to effectively and efficiently promote sustainable use of ecosystem services.

We focus on ecosystem users that derive their income predominantly from ecosystem services. As a case study we have chosen commercial cattle farming in semi-arid rangelands of Namibia. This tightly coupled ecological-economic system is of high economic importance, contributing one-third of the agricultural output in Namibia (MAWF, 2005), is subject to a variety of environmental, economic, political and social risks (Olbrich et al., 2011c) and is therefore a prime object of study for ecological economics (e.g. Janssen et al., 2004; Perrings and Walker, 2004; Quaas et al., 2007; Baumgärtner and Quaas, 2009). Approximately 2,500 commercial farmers conduct cattle farming in Namibia. Predominant among the risks farmers face is uncertain precipitation and the resulting uncertain production of forage. Namibia has a mean annual rainfall of approximately 270 mm, and precipitation is highly variable across the country with the coefficient of variation of annual precipitation ranging from below 30% to over 100% (Sweet, 1998).

In addition to these scientific reasons, commercial cattle farming in Namibia also lends itself as an empirical case study for practical reasons. Infrastructure is comparatively well developed, allowing a relatively easy data collection. Furthermore, information systems are likewise well developed, permitting extended analyses by combining collected data with existing databases on various economic and environmental aspects.

In August 2008 we conducted a survey of 2,119 commercial cattle farmers. In line with the research aims described above, we collected information about (i) risks faced by farmers, (ii) individual risk and time preferences and their determinants, (iii) risk management strategies and (iv) normative views towards sustainability in the sense of viability.

This paper explains the design and conduction of the survey. Since our survey population was a subset of all Namibian commercial cattle farmers and was comprised of two distinct groups, we also analyze this population for homogeneity and discuss its representativeness for the overall group of Namibian commercial cattle farmers. Section 2 describes the survey's design and Section 3 its conduction. Analyses of participation and population homogeneity are presented in Section 4. Finally, we discuss the results in Section 5 and draw conclusions.

2. Survey design

The survey consisted of two parts: a mail-in questionnaire was sent to farmers and in-field experiments were conducted with a subset of those farmers who received a questionnaire (see Appendix B and C for questionnaire and experimental documentation). In these experiments we elicited risk and time preferences involving payments of real money which were designed to complement corresponding hypothetical experiments in the questionnaire.

2.1 Qualitative interviews and pre-testing

In order to acquire a sound understanding of system dynamics, decision making, management strategies and issues of sustainability in commercial cattle farming, we conducted a series of qualitative interviews with farmers, experts and decision makers of the agricultural, political and financial sector (Appendix A lists interview partners; see also Olbrich et al. 2011c). These interviews were held in person in March and October 2007 in Namibia. Following the March interviews we designed a first version of the questionnaire. In October, we discussed this version in a second set of interviews and also during a workshop with 14 farmers which we organized with our cooperating organization *Namibia Agricultural Union* (NAU), the main interest group for commercial farmers. Based on the feedback gained, we revised the questionnaire. We distributed the questionnaire for pre-testing to a group of ten farmers and experts in June 2008. Subsequently, we made last modifications to the questionnaire based on the group's comments and produced the final version which was sent-out to the entire survey population in August 2008.

From the qualitative interviews it became clear that a considerable challenge would be the general skepticism of farmers towards surveys and distrust regarding promises of feedback and confidentiality. Farmers were confronted with a number of surveys in the previous years, but hardly ever were findings made accessible to them. Even worse, there was a serious breach of confidentiality in at least one survey which was advertised as anonymous but contained a hidden identification code. In addition, almost all white farmers – who constitute the majority of commercial farmers – are worried about the political situation and especially about possible expropriation, which contributes to their unwillingness to take part and reveal sensitive data in surveys. As a consequence, the return rate to surveys in previous years was frequently lower than 5%. We paid tribute to this in the elicitation format for sensitive questions, as described below in Sections 2.6 and 2.7, and in the conduction of the survey, as discussed in Section 3.2.[41]

We complemented the questionnaire with a cover letter and more detailed descriptions of our research aims (Appendix D). Farmers usually converse in Afrikaans among themselves but are by and large fluent in English. We therefore formulated the questionnaire in English with only selected terms and section headings also supplied in Afrikaans, and we supplied the accompanying documents both in English and in Afrikaans[42].

2.2 Elicitation of perception and characteristics of risks

In the survey, we elicited farmers' perception of a number of risks. To this end we identified the 13 most important environmental, economic, political and social risks during our qualitative interviews (Olbrich et al., 2011c). We then listed these risks in the questionnaire and asked farmers to rate their importance on a six-item Likert-scale, ranging from "no risk" to "very high risk" (Part II of the questionnaire, Appendix B). Since precipitation risk was identified as the dominant environmental risk we specifically collected additional information on on-farm monthly precipitation for the previous two rainy seasons and assessments of the previous five rainy season (Part V).

2.3 Elicitation of risk and time preferences

Both risk and time preferences were elicited for each farmer. We view risk preferences in the sense of von-Neumann-Morgenstern expected utility theory (von Neumann and Morgenstern, 1944) and time preferences in the sense of the discounted utility model, i.e. as pure preference for utility in the present versus utility at some future point in time (Samuelson, 1937).

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[41] In addition, we will hold a series of workshops in Namibia in February/March 2010 to inform farmers about our results as well as supply NAU with our research papers stemming from this survey.

[42] Translation from English into Afrikaans was courtesy of Marietjie van Staden of AgriForum, the monthly newsletter published by NAU.

We elicited preferences by an adapted multiple price list format both in a hypothetical scenario within the questionnaire (Part IV) and through in-field experiments involving payments of real money (Appendix C). This method was pioneered in the elicitation of preferences for risk and time by Binswanger (1980) and Coller and Williams (1999), respectively, and has since been regularly employed (e.g. Holt and Laury, 2002; Harrison et al., 2005a; Andersen et al., 2008a). Subjects choose for a number of scenarios between taking part in a lottery or receiving a certain payment instead ("risk experiments"), or between receiving a payment at a certain point in time or a higher payment later ("time experiments"). Scenarios differ with regard to the certain amount and the amount of the later payment, respectively, which increases from the first to the last scenario. Subjects in these experiments typically prefer the lottery when the certain amount is low and the earlier payment when the later payment is likewise low. They switch once the certain amount or the later payment are deemed high enough. From the switch point, interval measures of risk aversion such as the constant relative risk aversion (CRRA) and of the discount-rate, respectively, can be inferred.

In the elicitation of risk preferences we aimed at analyzing how different farmers value the same lotteries, thus income from and probabilities of occurrence of each lottery were objectively defined and communicated to the participants. In the hypothetical risk experiments we presented farmers with six scenarios, where we framed the lottery in the context of selling cattle at an auction. The auction had two possible outcomes, N$90,000[43] and N$130,000, each occurring with equal probability of 1/2. The expected value of the auction (N$110,000) corresponds to about 1/3 of the annual net income of the average farmer. Instead of taking part in the uncertain auction, farmers could chose to sell to a trader for a certain amount which started at N$100,000 in the first scenario and increased in steps of N$2,500 to N$112,500 in the sixth scenario. The six scenarios corresponded to intervals of the coefficient of CRRA the lowest of which was [-∞;-1.40] in the sixth and the highest of which was [6.32; ∞] in the first scenario.

In the in-field experiments the lottery was context-free with an expected value of N$1,500, which corresponds to the value of a calf. The certain amount started at N$550 and increased to N$1,900. For a higher resolution of risk aversion measures 16 scenarios were presented corresponding to intervals of the coefficient of CRRA from [-∞; -1.46] in the last to [8.27; ∞] in the first scenario. After the subject had made their choices for all scenarios one scenario

[43] On the 1st of August 2008, N$1,000 equalled €88.14 or US$137.50.

was chosen at random and played out, i.e. the subject either received the certain amount or the lottery in turn was played out. Payments were made in cash instantly.

In the elicitation of time preferences we focused on the long-term behavior of farmers and consequently eliminated the possibility of short-term considerations to influence the farmers' decision making. We considered this approach appropriate as 1) the relevant outcomes of farming decisions rarely manifest immediately, but rather months or even longer into the future, and 2) we are especially interested in analyzing the relationship between long-term behavior and sustainable use of ecosystem services. Subjects in the time experiments had to choose between receiving a payment in one month or a higher payment in seven months. Both hypothetical and in-field experiments were framed context-free and values were in a similar range as in the risk experiments. In the hypothetical experiments we elicited discount rates in five scenarios, with a payment in one month of N$100,000 and a payment in seven months which increased from N$104,881 in the first to N$122,474 in the last scenario. The scenarios corresponded to discount rate intervals from [-∞; 10%] to [50%; ∞]. In the in-field experiments 20 scenarios were presented with a payment in one month of N$2,000 and a payment in seven months which increased from N$2,025 in the first to N$2,449 in the last scenario. Corresponding discount-rate intervals ranged form [-∞; 2.5%] to [50%; ∞]. Scenario selection for payout corresponded to that in the risk experiments. Payments in the in-field experiment were guaranteed by the NAU which would transfer the money to the farmer's account with the respective delay chosen by the farmer. Due to monetary constraints we could pay only 10% of farmers in the in-field risk and time experiments which were randomly selected by letting farmers draw lots.

Through the conceptual separation of risk and time preferences and the corresponding experimental set-up we implicitly assumed that farmers were not influenced by time preferences in the elicitation of risk preferences since lotteries had a time scale of effectively zero (i.e. they were resolved immediately after the farmers had made their decisions). Conversely, we assumed that risk preferences were irrelevant in the elicitation of time preferences since later payments were guaranteed by the NAU and thus deemed certain.

Risk and time preferences were also elicited in the questionnaire in an alternative format involving self-assessment through nine-item Likert-scales (Part IV), ranging from "completely avoid taking risks" to "very willing to take risk" for risk and from "not at all willing to wait" to "very willing to wait" for time preferences. We calibrated answers to these questions through the in-field experiments involving real monetary payments, a strategy which has been successfully applied in a survey of the German Socio-Economic Panel (Dohmen et al., 2005).

2.4 Elicitation of risk management strategies

Farmers employ a range of different risk management strategies, which can be distinguished into ecological strategies which alter the production process (termed "on-farm risk management" in the questionnaire) and socio-economic strategies which make use of financial instruments ("financial risk management") or group membership ("collective risk management") (Olbrich et al., 2011c).

Again, we selected the 16 most relevant strategies based on the information gained in the qualitative interviews, and asked farmers to rate the importance of each strategy on a six-item Likert-scales ranging from "not at all important" to "very important" (Part II). Given the dominance of precipitation risk, we framed the elicitation of on-farm and financial – but not collective – strategies in the context of that risk. In addition, we elicited quantitative information on the following risk management strategies: legal organization for the farm (Part I), spatial diversification of farmland (Part I), structural organization of the farm (Part V), diversification of cattle production system (Part V), and diversification of income (Part V).

2.5 Elicitation of normative views of sustainability

We consider normative views of sustainability in the context of a specific operational criterion for strong sustainability under uncertainty, namely ecological-economic viability (Baumgärtner and Quaas, 2009). The viability-criterion enables an *ex-ante* assessment of the ecological-economic sustainability of a given action within a system under study. To this end, the criterion requires a number of normative judgments in order to adequately assess such an action. More specifically, it requires judgments on the object and scope of sustainability. In this regard, viability reflects the properties of traditional notions of strong sustainability, including that various stocks or services have to be conserved separately. However, owing to the explicit consideration of uncertainty the criterion also requires judgments on the appraisal of risk and the relevant time horizon. This appraisal is conceptually separate of any valuation of risks and their time scales due to preferences.

Hence, the following questions have to be answered prior to a sustainability assessment under uncertainty using the viability-criterion:

(i) What should be preserved, i.e. what ecological or economic stocks or services should be maintained?

(ii) How much of it should be preserved, i.e. at what level should the selected stocks and service be maintained?

(iii) For how long should it be preserved, i.e. over what time horizon should the stocks and service be maintained?

(iv) To what extent of uncertainty, i.e. what are the minimum probabilities that the stocks and services are above their respective threshold levels at each point in time?

We based the elicitation of normative views of sustainability on these questions. We pre-selected the main ecological stock (grass biomass) and economic service (income) within the system and asked farmers about their views of threshold levels, time horizon and extent of uncertainty (Part III). In addition, we inquired in an open question which other stocks and services farmers considered important for preservation, but without inquiring for threshold levels, time horizon or extent of uncertainty.

2.6 Elicitation of farm business and personal characteristics

Finally, we recorded information on a variety of variables which possibly impact on farmers' behavior under uncertainty. We enquired about additional farm business characteristics such as quantity of farmland (Part I), degradation status and carrying capacity of farmland (Part V), size of cattle herd (Part V) and household income. Because of the sensitivity of income information and farmers' skepticism, we elicited income only in categories. We also collected information on personal characteristics such as gender, age, ethnicity, education and experience with farming (Part VI). As we suspect a connection between some of the aforementioned behavioral determinants and one's outlook into the future, we asked farmers for their expectations regarding the future development of their farm business (Part VI).

2.7 Linkage with other databases

In general, data collection is extensive in Namibia, and a number of organizations maintain comprehensive databases on various aspects of cattle farming, such as precipitation recordings, price data for live cattle on auctions or beef exports. To allow spatial analyses of our survey data and linkage with the existing databases we concluded the questionnaire with a question for the farm number. The farm number is an official and unique label of each commercial farm in Namibia, the knowledge of which allows identification of the owner and farm location. Due to the sensitivity of this information we left this question optional. Since we expected a majority of farmers to not answer this question we also acquired at least a broad indication of the farm's location by eliciting the district location of the farm (Part V).

3. Conduction of the survey

3.1 Survey population

No up-to-date database containing all commercial cattle farmers in Namibia exists. As a consequence, the total number of farmers is unknown, though it is estimated at 2,500 by experts (H. Marggraff, W. Schutz, V. Tjimune; pers. communication). For this survey we compiled an address database that was as comprehensive as possible by requesting access to and combining databases of various Namibian organizations.

One source was the NAU database which contains about 2,500 members but no additional information on the kind of agricultural production. We therefore selected only those members who lived in the commercial cattle farming regions (the states Erongo, Khomas, Omaheke, Otjozondjupa, and adjoining districts of neighboring states) which amounted to 1,324 members. We estimate that 1,121 (84.7%)[44] of these are actually producing cattle.

The other source was *MeatCo of Namibia* (MeatCo), Namibia's largest slaughterhouse. MeatCo has a database of all those farmers[45] who had delivered cattle to MeatCo in the period 2004–2008. This database contains 1,484 entries. After removing 689 entries which were already contained in the NAU-database, 795 remained. The survey populations thus comprised 2,119 farmers of which we estimate 1,916 to be producing cattle. The survey population thus makes up for 77% of the estimated total number of commercial cattle farmers in Namibia.

Based on the assessment of experts (H. Marggraff, W. Schutz, V. Tjimune), we suspected that NAU members and farmers delivering to MeatCo would differ from each other and from the whole population of commercial cattle farmers in the characteristics ethnicity and production system pursued. White commercial farmers are overrepresented among NAU-members for historical reason, while there was no previous indication that this should also hold for farmers delivering to MeatCo. These should be representative in ethnicity for the overall group of commercial cattle farmers. Conversely, NAU-members are thought to be representative for all commercial cattle farmers in regard to production system pursued – i.e. production for beef, production for sale of live animals or stud breeding – while farmers who concentrate on beef production are thought to be overrepresented among those delivering to MeatCo. To avoid a

[44] This estimation is based on our selection of experimental participants among NAU-members: 61 (84.7%) of the contacted 72 members produce cattle.

[45] Both farmers and legal entities deliver cattle to MeatCo. The latter numbered 67 (8.4%) in the MeatCo database. For simplicity reasons we will use the term 'farmer' throughout this paper to refer to both individual farmers and legal entities.

possible bias in production system pursued among the experimental participants, we selected these only among NAU-members.

The whole survey population was thus divided into two mutually exclusive subpopulations: NAU-members living in cattle producing regions (which we label *"NAU-members"* in the following) and MeatCo-customers who delivered cattle and were not simultaneously NAU-members (labeled *"MeatCo-customers"* in the following). Survey participants constituted three samples of these two subpopulations, labeled as follows (Figure 1):

- *Sample "NAU-respondents"* of the *subpopulation "NAU-members"*: NAU-members who returned a mail-in questionnaire,
- *Sample "experimental participants"* of the *subpopulation "NAU-members"*: NAU-members who participated in the experiments,
- *Sample "MeatCo-respondents"* of the *subpopulation "MeatCo-customers"*: MeatCo-customers who returned a mail-in questionnaire

We marked all those questionnaires that were sent to MeatCo-customers, in order to allow some identification of group membership of responding farmers.[46]

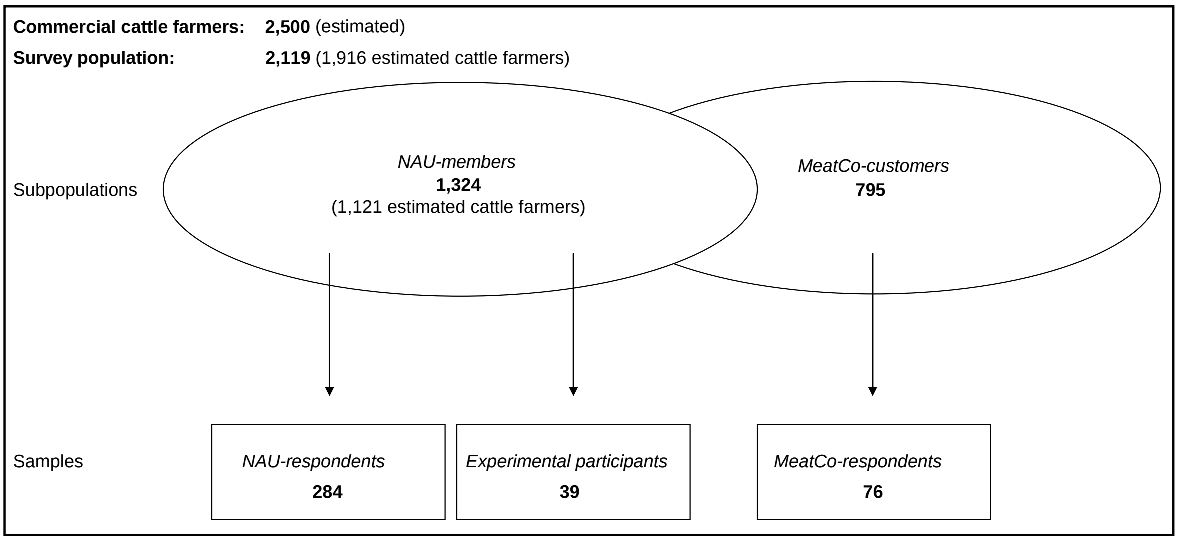

Figure 1: Survey population with subpopulations and samples as defined in Section 3.1. Overlap in subpopulations indicates 695 double entries in the two source databases which were assigned to the subpopulation *NAU-members.*

[46] We received the MeatCo database after the questionnaires destined for NAU-members had already been prepared. Thus, it was not possible for logistic reasons to also separately mark those questionnaires that were sent to MeatCo-farmers who were simultaneously NAU-members.

3.2 Promotion of survey

As noted in Section 2, farmers are generally skeptic towards surveys, and the possibility of low participation was thus very high. Therefore, we put considerable effort into trust-building and into the promotion of the survey. One strategy was the utilization of NAU's organizational structure by contacting responsible decision makers (farm convention chairmen, regional chairmen and national board members) and asking for their support. A similar strategy was not feasible with regard to MeatCo-customers since they lack any specific coherent organization.

NAU is a hierarchically organized interest group. At the local level, individual farmers are organized in about 70 farm conventions, each headed by a local chairman. At the regional level, farm conventions are grouped into 10 regional divisions, each in turn headed by a regional chairman. A national board consisting of regional chairmen, deputies of various committees and the administrative directorate is representing the organization at the national level. We succeeded in personally reaching all national and regional representatives, as well as half of the local chairmen, and contacted the remaining local chairmen by email or phone.

We also aimed our promotion directly at farmers, and again made special use of NAU's organization. To this end we gave an interview about the survey in the NAU-affiliated monthly magazine "AgriForum" (AgriForum 21(7), August 2008), and placed advertisements in the weekly online NAU-newsletter for several weeks (22nd and 29th of August, 12th of September). Both NAU members and MeatCo-customers were addressed through a radio interview transmitted by the Namibian Broadcasting Corporation (23rd and 25th of August 2008) and through an advertisement in the "Ring" (The Ring, September 2008), the monthly newsletter of Agra Co-operative Ltd., Namibia's largest retailer for farm equipment. In addition, we extensively spoke with many farmers, assuming (correctly) that word about our survey would spread between individual farmers.

3.3 Send-out of questionnaires and conduction of experiments

We mailed out a first batch of questionnaires in the period 19th – 21st of August 2008, and a second batch as a follow-up on the 15th of September 2008. Return address for the questionnaires was the NAU which forwarded all incoming questionnaires to Leuphana University of Lüneburg. Owing to delays in the Namibian postal system, where delivery of mail can take weeks, we set the 28th of February 2009 as a cut-off date for questionnaires to be included in our analysis.

In-field experiments were conducted with 39 commercial cattle farmers.[47] To this end, 72 farmers were randomly selected, and a session was scheduled if the farmer produced cattle and worked on his farm full-time. This applied to 57 (79.1%) of the contacted farmers. 44 sessions were set of which 39 were actually conducted.[48] [49]

We visited the majority of participants (79.4%) on their respective farm, and the remaining ones at pubic locations in major cities. With one exception,[50] each session of experiments started with the participants filling in the questionnaire. We then conducted the experiments and subsequently determined whether the farmer had won money by letting him draw a lot. Duration of sessions varied between one and two-and-a-half hours.

4. Data quality and homogeneity of samples

4.1 Return rate of questionnaires and response rate of individual questions

We received 399 questionnaires, 360 of which were sent to us and 39 of which were filled out during experimental sessions. Of the 360 questionnaires sent in, 284 came from NAU members and 76 from MeatCo-customers (Figure 1). This makes a return rate of 20.8% in regard to the estimated number of cattle farmers within the survey population.[51] Return rate was much higher among NAU-members than MeatCo-customers, with 28.8%[52] and 9.6%, respectively.

In the returned questionnaires, response rate for non-sensitive questions exceeded 95% for most questions, the exception being cattle production system (91.9%), the risk management strategies 'purchase of extra rangeland for scale effects' and 'investment into agricultural

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[47] The in-field experiments were conducted by one of us (Roland Olbrich).

[48] Three sessions were cancelled by farmers on short notice and no alternative session could be set, during one session filling in of the questionnaire lasted so long that no time remained for the conduction of experiments and one session had to be cancelled by the researcher due to a tire break.

[49] During one session it became obvious that the participant was a part-time farmer. Thus, of the 39 sessions conducted, only 38 were with full-time farmers. We have included data on the part-time farmer in our subsequent analysis in this paper as inclusion of these data does not change our results.

[50] Upon arrival at the meeting the farmer remarked that his time would not permit both filling-in of the questionnaire and conducting experiments. We thus chose to elicit only selected data in the questionnaire and directly proceeded to the experiments. After the experiments, we asked the farmer to mail or fax us a completed questionnaire, but unfortunately the farmer never sent a complete questionnaire.

[51] This rate is the fraction of returned questionnaires to the number of the 1,916 farmers that we have estimated to be cattle farming (see Section 3.1). This rate drops to 18.8% if return rate is instead calculated as a fraction of the 2,119 farmers that had received a questionnaire.

[52] Again, the rate was calculated as a fraction to the number of the 1,121 NAU-members that we have estimated to be farming cattle and drops to 24.4% if calculated as a fraction of all of the 1,324 NAU-members that had received a questionnaire.

derivatives on the stock market' (both 90%) and on-farm monthly rainfall (83.5%). Response rate was also high among the sensitive questions regarding normative views of sustainability (94.7%), size of cattle herd (93.6%) and income (91.9%). The optional question for identification of the farm was answered by 75.1% of survey participants, while the more general question for district location of the farm was answered by 99%. Only a single questionnaire was discontinued after the initial questions.

4.2 Population homogeneity

As discussed in Section 3.1, NAU-members and MeatCo-customers were expected to differ in the characteristics ethnicity and production system pursued. We thus tested for homogeneity of samples in respect to the these characteristics, as well as for further basic farm business and personal characteristics which we deemed to be possibly distinct in both groups. We aimed at revealing evidence which would prohibit us from 1) generalizing results from the in-field experiments to either subpopulation and 2) pooling samples in future analyses. The descriptive statistics of personal and farm business characteristics are reported in Table 1.

Production system was recorded by five variables representing percentages of cattle herd allocated to live cattle production, cattle speculation, beef production, stud breeding and other production types. We examined differences by employing a one-way multivariate analysis of variance (MANOVA) using the Wilks' Lambda criterion. Comparisons for other farm business and personal characteristics were performed with Student's t-tests assuming unequal variances in case of continuous variables, with Mann-Whitney-tests in case of ordinal variables and with Fisher's exact tests in case of nominal variables. As a significance threshold for group difference we took the 5%-level.

4.3 Differences between experimental participants and respondent samples

Table 2 (third column) reports the comparison of experimental participants with NAU-respondents. Since both samples originated from the same subpopulation, any detected difference would have been an indication for a bias in sampling procedure, and generalization of in-field experimental evidence to the subpopulation would thus have to be restricted. We found no difference in production system pursued ($F(4, 254)=0.98$, $p=0.42$), or most of the other farm business or personal characteristic. The only exception was residency on farm ($p=0.003$) where 97.4% of experimental participants but only 79.9% of NAU-respondents lived on the farm.

Table 1: Descriptive statistics for *experimental participants*, *NAU-respondents*, *all NAU-members* (pooled from experimental participants and NAU-respondents), *MeatCo-respondents* – all as classified in Section 3.1 – and for *all farmers* who participated in the survey. For continuous variables, mean and standard deviation (in brackets) are noted, for ordinal and nominal variables proportions in each category. Cattle production system depicts the allocation to each branch of production for the average farm business in each group, irrespective of actual number of cattle.

Variable	Experi-mental participants	NAU-respondents	All NAU-members	MeatCo-respondents	All farmers
Personal characteristics					
age	52.5 y	55.5 y	55.2 y	56.5 y	55.4 y
	(12.1 y)	(11.5 y)	(11.6 y)	(13.3y)	(11.9 y)
male	94.9%	94.7%	94.7%	94.7%	94.7%
ethnicity					
Afrikaans	41.0%	46.5%	45.8%	51.3%	46.9%
German	59.0%	49.1%	50.3%	30.3%	46.4%
Herero	0%	0.4%	0.3%	15.8%	3.4%
Ovambo	0%	0.7%	0.6%	1.3%	0.8%
Nama/Damara	0%	0.4%	0.3%	1.3%	0.5%
English	0%	1.8%	1.6%	0%	1.3%
other indigenous	0%	1.1%	1.0%	0%	0.8%
education					
no high school graduation	7.7%	2.5%	3.1%	12.0%	4.8%
high school graduation	12.8%	23.4%	22.1%	29.3%	23.5%
trade / apprenticeship certificate	28.2%	14.5%	16.2%	8.0%	14.7%
diploma or bachelor	41.0%	45.7%	45.2%	37.3%	43.7%
master	10.3%	10.3%	10.3%	12.0%	10.6%
Ph.D	0%	3.6%	3.1%	1.3%	2.8%
farming experience	24.7 y	25.2 y	25.1 y	26.7 y	25.4 y
	(12.7 y)	(14.2 y)	(14.0 y)	(15.3 y)	(14.3 y)
annual net household income					
< N$ 50.000	7.7%	16.2%	15.1%	20.0%	16.0%
N$ 50,001 – 150,000	28.2%	26.3%	26.5%	31.4%	27.5%
N$ 150,001 – 250,000	25.6%	27.0%	26.9%	15.7%	24.7%
N$ 250,001 – 350,000	12.8%	12.0%	12.1%	11.4%	12.0%
> N$ 350,001	25.6%	18.5%	19.5%	21.4%	19.8%
income from cattle farming					
0%	0%	6.9%	6.1%	6.9%	6.2%
1-20%	10.8%	12.0%	11.8%	13.9%	12.2%
21-40%	2.7%	14.5%	13.1%	13.9%	13.3%
41-60%	24.3%	18.5%	19.2%	12.5%	17.9%
61-80%	32.4%	19.9%	21.4%	20.8%	21.3%
81-100%	29.7%	28.3%	28.4%	31.9%	29.1%
residency on farm	97.4%	79.9%	81.9%	72.4%	80.1%

Variable	Experi-mental participants	NAU-respondents	All NAU-members	MeatCo-respondents	All farmers
Farm business characteristics					
cattle production system					
weaner production	29.1%	26.4%	26.8%	29.0%	27.1%
beef production with weaner breeding	6.3%	11.2%	10.5%	16.7%	11.5%
beef production without weaner breeding	56.8%	48.4%	49.6%	39.6%	48.0%
stud breeding	6.7%	10.5%	9.9%	8.0%	9.6%
other	1.1%	3.6%	3.2%	6.6%	3.8%
ownership status					
owner	87.2%	93.2%	92.5%	86.7%	91.4%
hired manager	7.7%	1.8%	2.5%	4.0%	2.8%
tenant	2.6%	3.2%	3.1%	6.7%	3.8%
other	2.6%	1.8%	1.9%	2.7%	2.0%
legal organization of farm					
single owner	69.2%	72.7%	72.3%	58.9%	69.8%
partnership	2.6%	4.7%	4.5%	8.2%	5.2%
cooperative	2.6%	1.8%	1.9%	2.7%	2.1%
corporation	25.6%	19.6%	20.4%	26.0%	21.5%
other	0%	1.1%	1.0%	4.1%	1.6%
area for cattle farming	8,472 ha	8,000 ha	8,056 ha	7,551 ha	7,962 ha
	(4,324 ha)	(5,257 ha)	(5,151ha)	(6,896 ha)	(5,511ha)
number of own cattle in Nov '07	489	451	456	425	450
	(307)	(354)	(349)	(448)	(369)
regional location of main farmland					
Erongo	0%	7.5%	6.6%	1.3%	5.6%
Hardap	2.6%	2.1%	2.2%	5.3%	2.8%
Karas	0%	0.4%	0.3%	2.6%	0.8%
Khomas	28.2%	20.6%	21.6%	15.8%	20.5%
Kunene	5.1%	9.6%	9.1%	13.2%	9.9%
Omaheke	18.0%	21.7%	21.3%	26.3%	22.2%
Oshikoto	2.6%	2.1%	2.2%	5.3%	2.8%
Otjozondjupa	43.6%	35.9%	36.9%	30.3%	35.6%

Table 2 (fourth column) reports the comparison between experimental participants and MeatCo-respondents. Again, we found no difference in production system pursued (F(4, 83)=2.06, p=0.09)), or in most of the other farm business or personal characteristic. We found differences in ethnicity (p=0.003). This was mainly due to 18.4% of indigenous farmers among MeatCo-respondents while no indigenous farmers were present among experimental participants. We also detected a difference in residency on farm (p=0.001) with only 72.4% of MeatCo-respondents living on the farm as opposed to 97.4% of experimental participants.

Table 2: Comparison of personal and farm business characteristics between *experimental participants* and both *NAU-respondents* and *MeatCo-respondents*. Analyses were performed with Student's t-tests assuming unequal variances for continuous, with Mann-Whitney tests for ordinal and with Fisher's exact tests for nominal variables. Production system was analyzed with a MANOVA using the Wilks' Lambda criterion. p-Values significant at the 5%-level are indicated by an asterisk (*).

Variable	Statistical test	p-Value	
		NAU-respondents	MeatCo-respondents
Personal characteristics			
age	t-test	0.15	0.11
gender	Fisher's exact test	0.66	0.67
ethnicity	Fisher's exact test	0.82	0.003*
education	Mann-Whitney test	0.47	0.46
farming experience	t-test	0.85	0.48
total household income	Mann-Whitney test	0.20	0.14
income from cattle farming	Mann-Whitney test	0.11	0.30
residency on farm	Fisher's exact test	0.003*	0.001*
Farm business characteristics			
cattle production system	MANOVA	0.42	0.09
ownership status	Fisher's exact test	0.13	0.77
legal organization of farm	Fisher's exact test	0.78	0.62
area for cattle farming	t-test	0.54	0.39
total number of own cattle	t-test	0.49	0.38
regional location of main farmland	Fisher's exact test	0.47	0.39

4.4 Differences between subpopulations

Given that experimental participants did not differ from NAU-respondents except for residency on farm we pooled both samples for a second comparison of subpopulations using the whole dataset for the subpopulation of NAU-members (Table 3). Excluded in this comparison was residency on farm since we detected a significant difference in this characteristic between both samples. In regard to this characteristic, we tested between subpopulations using only the sample NAU-respondents for the subpopulation NAU-members.

We detected no difference in production system pursued ($F(4, 304)=1.47$, $p=0.21$) and in the majority of farm business or personal characteristics. Again, we detected a difference in ethnicity ($p<0.001$) due to higher proportions of indigenous farmers among MeatCo-respondents which amounted to only 2.2% in the pooled NAU-sample. A test for differences in regional location was significant (p=0.03), but no clear picture in distribution of the pooled sample versus MeatCo-respondents emerged. Educational difference was barely insignificant (p=0.054) with a lower proportion of MeatCo-respondents having a trade certificate or some form of university education (46.6% versus 75.1% in the pooled sample). Likewise, a test for legal organization of the farm business was barely insignificant (p=0.06), with a smaller percentage of MeatCo-respondents conducting the farm business as single owners (58.9% versus 72.3% in the pooled sample). A test for differences in farm residency using only the sample NAU-respondents for the subpopulation of NAU-members detected no difference.

Table 3: Comparison of personal and farm business characteristics between the subpopulations *NAU-members* and *MeatCo-customers*. Both samples of the subpopulation *NAU-members* were pooled for the analyses except for residency on farm which was performed only with the sample *NAU-respondents*. Analyses were performed with Student's t-tests assuming unequal variances for continuous, with Mann-Whitney tests for ordinal and with Fisher's exact tests for nominal variables. Production system was analyzed with a MANOVA using the Wilks' Lambda criterion. p-Values significant at the 5%-level are indicated by an asterisk (*).

Variable	**Statistical test**	**p-Value**
Personal characteristics		
age	t-test	0.43
gender	Fisher's exact test	0.63
ethnicity	Fisher's exact test	< 0.001*
education	Mann-Whitney test	0.054
year of farming experience	t-test	0.43
total household income	Mann-Whitney test	0.41
income from cattle farming	Mann-Whitney test	0.91
residency on farm	Fisher's exact test	0.08
Farm business characteristics		
cattle production system	MANOVA	0.21
ownership status	Fisher's exact test	0.28
legal organization of farm	Fisher's exact test	0.06
area for cattle farming	t-test	0.56
total number of own cattle in November	t-test	0.58
regional location of main farmland	Fisher's exact test	0.03*

5. Discussion and conclusion

In this paper we describe a survey that we conducted among commercial cattle farmers in Namibia. The survey was designed on the basis of a comprehensive conceptual framework reflecting the current state of knowledge in sustainability and risk economics. The survey's actual specification was adapted to the specific situation of commercial cattle farmers in Namibia through information gained in qualitative interviews and pre-tests. An analysis of participation and homogeneity of the survey population confirmed the existence of single biases while refuting the majority. In this concluding section we discuss our findings.

5.1 Farmer's skepticism towards surveys

A considerable challenge was to overcome farmers' skepticism towards surveys in general and to specific sensitive questions. We successfully addressed this challenge, resulting in an overall return rate of 20.8%, and 28.8% and 9.6% among NAU-members and MeatCo-customers, respectively.

We attribute the high return rate in part to our transparency in explaining our research aims by attaching detailed FAQ-pages to the questionnaire and by explaining these in interviews and advertisements in major Namibian magazines and radio broadcasts. Moreover, we assume that high participation principally reflects our effort in trust-building through prior discussions with individual farmers and with decision makers at all hierarchical levels in the well-connected NAU organization. This is indicated by a striking difference in return rates between NAU-members and MeatCo-customers. During our discussions, decision makers showed a keen interest in our study and were willing to motivate their constituencies to participate. In addition, word-of-mouth on our survey spread between individual farmers originating from discussions that followed the in-field experiments and that took place during our preceding research journeys. As anecdotic evidence we can cite that frequently farmers unknown to us had heard about our study from already visited farmers. Thus, given the general trust of NAU-members towards decision-makers and a well-connected network within the organization, we assume that our effort in trust-building produced a 'snowball effect' in ensuring participation.

In addition to high participation, farmers also proved to be less skeptic than expected towards specific sensitive questions. Response rates for the sensitive questions income, size of cattle herd (which is a proxy for wealth) and normative views of sustainability was high with values between 91% and 95%. Furthermore 75.1% of all survey participants identified their farm, which will allow us to conduct extended analyses for a significant portion of participants by including information from other databases.

For the majority of non-sensitive questions response rate was very high, exceeding 95%. Fewer farmers responded to the questions concerning the risk management strategies 'land increase for scale effects' and 'investment into agricultural derivative' (both 90% response rate). From question marks set in a few cases of non-response it seems that this was due to a lack of understanding of the terms 'scale effect' and 'agricultural derivatives'. Even fewer farmers indicated on-farm monthly rainfall. This is likely due to some farmers not keeping precipitation records, which was the case among the personally interviewed experimental participants where response rate to these questions was likewise low with only 77.5%. We cannot conclusively explain why response rate for cattle production system was only 91.9%; possible reasons are incomplete records or an unexpected sensitivity of the question.

5.2 Generalizing experimental results to subpopulations

A possible bias was introduced through the creation of the survey address databases from the two databases of NAU and of MeatCo. Participants in this survey thus belonged to two distinct subpopulations of commercial cattle farmers.

Generalizing results from the in-field experiments to either subpopulation requires the absence of sampling biases and suitably similar subpopulations. In our analysis of farm business and personal characteristics between both samples of the subpopulation NAU-members we found no indication for a sampling bias, except for residency on farm (a proxy for full-time farming). We intentionally had induced this bias as we wanted to specifically elicit risk preferences from farmer that are primarily dependent on the farm business for the provision of income.

Owing to our sampling design we could not test for sampling biases in the sampling of MeatCo-customers and simply assumed that random sampling was sufficient. With regard to similarity of subpopulations when comparing the samples experimental participants and MeatCo-respondents we found both to be similar in most characteristics. The only exceptions were ethnicity and the intentionally induced bias in residency on farm.

Thus, we will consider these restrictions when generalizing results from the in-field experiments and will certainly perform more detailed analyses when we approach the respective research questions, but at this point we find no general adverse indication for generalization of results. One future challenge which might arise is the comparatively low number of experimental participants owing to the logistic challenges in collecting these data. If and to what extent this will impose further restrictions is a matter that we will address in future analyses.

5.3 Differences between subpopulations

It will be desirable to pool questionnaire data and it was thus necessary to determine to what extent the subpopulations NAU-members and MeatCo-customers differ. In addition to the comparison between the samples experimental participants and MeatCo-respondents we therefore performed a further comparison between subpopulations by pooling the samples experimental participants and NAU-respondents for the subpopulation NAU-members.

One likely difference between subpopulations was the production system pursued, which we suspected to be biased towards beef production among MeatCo-customers. We detected no such difference between both groups in our data. Furthermore, a large share (30.6%) of MeatCo-respondents indicated that they exclusively pursue production systems other than beef production. Thus, farmers seem to deliver to MeatCo regardless of production system pursued, where even farmers that do not focus on beef production likely deliver the occasionally unproductive or old animals for slaughtering.

The difference in ethnicity that already manifested in the comparison using only the sample experimental participants was also detected when using the pooled sample. This difference in ethnicity is not unexpected since indigenous farmers were reported to be underrepresented among NAU-members. We also detected a difference in regional location of farmland, but no clear pattern emerged which would allow us to give a reasonable explanation at this point. We found no further significant difference in other characteristics. However, because of the small proportion of indigenous farmers and the lack of a pattern in regional location of farmland, respectively, we consider the significant difference in ethnicity and regional location no general reason for not pooling samples from both subpopulations. In future analyses we will evaluate differences in farm location more precisely by using the farm identifier – when provided by the respective survey participants – and we will taken care in any analysis that explicitly involves ethnicity.

5.4 Representativeness of survey population

Assuming the estimate of 2,500 commercial cattle farmers is accurate we will not have reached 23% of farmers. The question remains whether the survey population is representative for all commercial cattle farmers or if we have undersampled distinct subpopulations.

Since we had access to a complete database of NAU-members our sample will be biased with regard to membership in this interest group. The bias was probably amplified by our selective promotion among NAU-members. Furthermore, NAU-members are reported to be distinct regarding ethnicity, which was also indicated in our comparison with the subpopulation MeatCo-customers. A likely secondary bias induced is thus undersampling of indigenous farmers. Less obviously, membership to an organization that lobbies for the continuance of cattle farming may indicate a certain predisposition in Weltanschauung, among which may also be specific normative views of sustainability. We will take this possible bias into account in future analyses.

A further possible bias could have been introduced through MeatCo-customers being distinct in production system pursued. We found no indication for this in our comparison with NAU-members. In addition, none of the other analyzed characteristics revealed any difference. We also found no further indication for any undersampling of distinct subpopulations, nor do we suspect any such bias.

Ultimately, however, due to lack of quantitative data on characteristics of the general commercial cattle farmer population we cannot conclusively answer the questions of representativeness. We will therefore be very careful in considering if and how we can generalize any of our future results to the whole population of commercial cattle farmers.

5.5 Conclusion

Notwithstanding the aforementioned limitations, the survey was very successful, and given the resulting extensive dataset we expect that future analyses advance our understanding of sustainability under uncertainty in coupled ecological-economic systems. Overall, we take the comparatively high return and response rate as a confirmation of what became already apparent during the qualitative interviews – that issues of sustainable use of ecosystem services under uncertainty are highly relevant for the agricultural sector in Namibia, and that our research can contribute to producing relevant solutions.

Acknowledgements

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Appendix A: Qualitative expert interviews conducted in preparation of the survey

Hermann Caspers, Audit Manager, *Grant Thornton Neuhaus*, Windhoek (Namibia), 03/28/2007

Marina Coetzee, Chief Agricultural Researcher, *Ministry of Agriculture, Water & Forestry*, Windhoek (Namibia), 10/19/2007

Flip de Bruyn, General Manager Finance, *Agra Co-operative Ltd.*, Windhoek (Namibia), 03/30 & 10/11/2007

Volker Dieckhoff, Chairman of *Water Management Group Okakarara, Farm La Paloma,* Okahandja (Namibia), 10/15/2007

Peter Eichhoff, *Farm Vergenoeg*, Summerdown (Namibia), 10/17/2007

Celeste Espach, Agricultural Researcher, Remote Sensing & GIS, *Ministry of Agriculture, Water & Forestry*, Windhoek (Namibia), 10/19/2007

Dr. Ben Fuller, Independent expert on Social and Economic Research and Policy Analysis, Windhoek (Namibia), 03/28/2007

Arne Gressmann, Chairman of Board of Directors, *MeatCo*, Chairman, *Study Group Karsfeld*, *Farm Klein-Huis*, Grootfontein (Namibia), 10/13–10/14/2007

Claus Hager, Manager Research and Development, *Namibia Agricultural Union*, Coordinator: Land Management Desk, *Desert Research Foundation of Namibia*, Windhoek (Namibia), 04/02/2007

Birgit Hoffmann, Senior Manager Marketing, *Agra Co-operative Ltd.*, Windhoek (Namibia), 10/08/2007

Jürgen Hoffmann, Senior Trade Advisor, *Namibian Agricultural Trade Forum*, Windhoek (Namibia), 04/01 & 10/09/2007

Oliver Horsthemke, Manager Agricultural Development, *First National Bank of Namibia*, Windhoek (Namibia), 03/29/2007

Peter H. Hugo, Senior Manager Livestock, *Agra Co-operative Ltd.*, Windhoek (Namibia), 10/11/2007

Arnold Klein, General Manager Retail and Wholesale, *Agra Co-operative Ltd.*, Windhoek (Namibia), 03/30 & 10/08/2007

Bertus Kruger, Head of Land Desk, *Desert Research Foundation of Namibia*, Windhoek (Namibia), 03/29/2007

Glenn-Marie Lange, Senior Researcher, Center on Globalization and Sustainable Development, The Earth Institute, *Columbia University,* New York (USA), 10/09 & 10/12/2007

Leon Lubbe, Agricultural Researcher, Pasture Science, *Ministry of Agriculture, Water & Forestry*, Windhoek (Namibia), 10/19/2007

Harald Marggraff, Manager Commodities, *Namibia Agricultural Union*, Windhoek (Namibia), 04/02 & 10/08/2007

Joseph Minnaar, Statistician, Agricultural Statistics, Central Bureau of Statistics, *National Planning Commission*, Windhoek (Namibia), 03/29/2007

Thomas Peltzer, Board Member, *Conservancy Association of Namibia*, *Farm Onjossa*, Okahandja (Namibia), 10/18–10/19/2007

Klaus Schade, Acting Director, *The Namibian Economic Policy Research Unit*, Windhoek (Namibia), 10/09/2007

Robert Schultz, Member of Energy Desk, *Desert Research Foundation of Namibia*, Windhoek (Namibia), 03/29/2007

Willie Schutz, Manager Information Systems, *Meat Board of Namibia*, Windhoek (Namibia), 03/29/2007

Elaine Smith, Manager Research & Development, *Namibia Agricultural Union*, Windhoek (Namibia), 10/19/2007

Hans-Günter Stier, Chairman of Board of Directors, *Agribank of Namibia*, Partner, *Stier Vente Associates*, Windhoek (Namibia), 10/12/2007

Paul Strydom, General Manager, *Meat Board of Namibia*, Windhoek (Namibia), 03/29/2007

Vehaka Tjimune, Chairman, *Namibian National Farmers' Union*, Senior Manager: Procurement, *MeatCo of Namibia*, Windhoek (Namibia), 03/29/2007

Justus Tjituka, Senior Manager Finance, *Agribank of Namibia*, Windhoek (Namibia), 10/11/2007

Wessel Visser, Manager Karakul, *Agra Co-operative Ltd.*, Windhoek (Namibia), 03/30/2007

Peter Zensi, Member, *Study Group Karsfeld*, *Farm Hamburg*, Grootfontein (Namibia), 10/14–10/15/2007

Ibo Zimmermann, Chair of Steering Committee, *BIOTA Namibia*, Deputy Director, Department of Agriculture, *Polytechnic of Namibia*, Windhoek (Namibia), 03/31/2007

APPENDIX B: Questionnaire

Leuphana University of Lüneburg

Sustainability of commercial cattle farms and the natural environment in Namibia

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Volhoubaarheid van kommersiële beesplase en die natuurlike omgewing in Namibië

A scientific study by the *Leuphana University of Lüneburg*, Germany, in cooperation with the *Namibia Agricultural Union*.

Important

⇨ Questionnaire may be filled in in English, Afrikaans or German.

⇨ All information collected will remain **strictly confidential.**

⇨ Please return the questionnaire even if you cannot answer all questions.

Who should complete this questionnaire?

⇨ We kindly ask any commercial farm business that farms cattle to complete one questionnaire only.

⇨ We kindly ask the principal operator / *hoof* of each farm business to complete the questionnaire, i.e. the person that is responsible for the on-site, day-to-day operation of the farm business.

How to complete this questionnaire?

Please follow these guidelines when you complete this questionnaire:

- **check white boxes**

  Example: **Gender:** Male .... ☒
  Female .... ☐

- **enter numbers in the larger white fields**

  Example: Farm size .... [5 000] ha

- **write text on the continuous lines**

  Example: Other: *Cattle* .. ☒

For some questions we provide you with additional explanations. This is indicated by the ➔ symbol.

How to contact us?

Prof. Dr. Stefan Baumgärtner
Leuphana University of Lüneburg, Germany
Sustainability Economics Group
phone: +49.4131.677-2715
email: sustainabilityeconomics@uni-lueneburg.de

Harald Marggraff
Namibia Agricultural Union
Manager Commodities
tel.: 061.237838
email: meat@agrinamibia.com.na

Or visit our web site at http://www.uni-lueneburg.de/seg

➔ *Continue to STEP 1*

I. Business basics / Basiese boerdery-inligting

STEP 1

1. **What is your status as the principal operator / *hoof* of the farm business?**

➔ *Please check only one box.*

I'm an owner .... ☐
I'm a hired manager .... ☐
Other: ____ ☐

2. **How would you characterize your farm business structure?**

Sole proprietorship .... ☐	Partnership .... ☐	Cooperative .... ☐
Family corporation ..... ☐	Non-family corporation . ☐	Other: _____________ . ☐

STEP 2

3. **What area of land (in hectares) did your farm business own, lease, or use free of charge on April 30, 2008?**

3.1	Owned by your farm business	☐ ha
3.2	Rented or leased <u>from</u> others for 1 year or less	☐ ha
3.3	Rented or leased <u>from</u> others for more than 1 year	☐ ha
3.4	Used free of charge <u>from</u> others	☐ ha
3.5	**Total area of land owned, leased or used free of charge** ➔ *Total of questions 3.1 to 3.4*	☐ ha

4. **What area of land was owned by your farm business but used <u>by others</u> on April 30, 2008?**

4.1	Rented or leased <u>to</u> others for 1 year or less	☐ ha
4.2	Rented or leased <u>to</u> others for more than 1 year	☐ ha
4.3	Entrusted <u>to</u> others free of charge	☐ ha
4.4	**Total area of land used by others** ➔ *Total of questions 4.1 to 4.3*	☐ ha

5. **What total area of land was <u>operated</u> by your farm business on April 30, 2008?**

➔ *Question 3.5 minus 4.4* .... ☐ ha

6. **What area of land operated by your farm business on April 30, 2008 was designated for cattle farming, hereafter in the questionnaire referred to as your RANGELAND?**

➔ *Include all land available for cattle farming even if it is used at the same time for other purposes such as game farming; include also areas with bush encroachment; exclude land used <u>solely</u> for other purposes* .... ☐ ha

II. Risks and management strategies / Risiko en bestuurstrategieë

STEP 3

7. How would you rate the risk of low rainfall resulting in low grass production for your farm business?

➔ *Please check the box on the scale that best describes your rating.*

no risk ☐ ☐ ☐ ☐ ☐ ☐ **very high risk**

8. Considering only the risk of low rainfall resulting in low grass production, we would ask you to rate the importance of each of the following individual "On-Farm" and "Financial" management strategies.

➔ *For each strategy, please check the box on the scale that best describes the importance.*

ON-FARM management strategies …	**not at all important**					**very important**
- purchase of supplementary feed / *voer en lek*	☐	☐	☐	☐	☐	☐
- choice of cattle production system such as oxen production	☐	☐	☐	☐	☐	☐
- choice of breed adapted to high variability in grass production .	☐	☐	☐	☐	☐	☐
- resting part of your RANGELAND in good rainy seasons to build up buffers for bad seasons	☐	☐	☐	☐	☐	☐
- purchase/lease of extra RANGELAND in areas with different rainfall patterns	☐	☐	☐	☐	☐	☐
- purchase/lease of extra RANGELAND for scale effects	☐	☐	☐	☐	☐	☐

- other ON FARM management strategies:

____

FINANCIAL management strategies …	**not at all important**					**very important**
- forward contracts for fixing a good price	☐	☐	☐	☐	☐	☐
- advances on livestock sales	☐	☐	☐	☐	☐	☐
- savings/checking account as a financial buffer	☐	☐	☐	☐	☐	☐
- uptake of loans for covering operating losses	☐	☐	☐	☐	☐	☐
- income from off-farm employment and off-farm assets	☐	☐	☐	☐	☐	☐
- investment into agricultural derivatives on the stock market	☐	☐	☐	☐	☐	☐

- other FINANCIAL management strategies:

____

9. **The following is a list of other risks that may impact on your cattle farming. How would you rate each risk?**

➔ *For each risk, please check the box on the scale that best describes your rating.*

How would you rate the NATURAL RISK of …	**no risk**					**very high risk**
- low groundwater levels due to low rainfall …………………………	☐	☐	☐	☐	☐	☐
- unintentional bush fires striking your RANGELAND …………………	☐	☐	☐	☐	☐	☐
- cattle contracting diseases or parasites …………………………………	☐	☐	☐	☐	☐	☐
- cattle loss from predators ………………………………………………………	☐	☐	☐	☐	☐	☐

How would you rate the ECONOMIC RISK of …	**no risk**					**very high risk**
- unfavourable prices for live cattle/slaughter sales …………………	☐	☐	☐	☐	☐	☐
- unfavourable prices for farming inputs such as feed or licks ……	☐	☐	☐	☐	☐	☐
- rising living expenses …………………………………………………………………	☐	☐	☐	☐	☐	☐

How would you rate the POLITICAL RISK of …	**no risk**					**very high risk**
- unfavourable trade agreements on export of cattle meat ………	☐	☐	☐	☐	☐	☐
- changing labour market conditions …………………………………………	☐	☐	☐	☐	☐	☐
- expropriation ………………………………………………………………………………	☐	☐	☐	☐	☐	☐

How would you rate OTHER RISKS such as …	**no risk**					**very high risk**
- cattle theft …………………………………………………………………………………	☐	☐	☐	☐	☐	☐
- failure of machinery or other farm equipment ………………………	☐	☐	☐	☐	☐	☐

10. **Apart from individual management strategies, there are also collective management strategies. How important in general (not just for the risk of low rainfall) are the following collective management strategies for your cattle farming?**

➔ *For each strategy, please check the box on the scale that best describes the importance.*

	not at all important					**very important**
Cooperative ownership of farmland ………………………………………………	☐	☐	☐	☐	☐	☐
Governmental support such as subsidies or drought relief ………	☐	☐	☐	☐	☐	☐
Interest groups on a local level such as conservancy groups ……	☐	☐	☐	☐	☐	☐
Interest groups on a national level such as NAU or parties ………	☐	☐	☐	☐	☐	☐

III. Sustainability / Volhoubaarheid

STEP 4

11. **Sustaining the livelihood of farmers by sustaining income: How much annual net income (gross revenues from farming minus operating expenses, taxes and interest on loans), expressed in today's N$, should you yourself and future generations at least derive from cattle farming?**

➔ *Please enter an amount in the box. Assume that there is no rise in prices or living expense over time.*

☐ N$

12. **Sustaining the natural environment by sustaining the grazing capacity of your RANGELAND: How high should the grazing capacity of your RANGELAND, expressed in hectares per large stock unit, be during your own and future generations?**

☐ hectares per large stock unit

13. **For how many generations should cattle farming be sustained, i.e. both net income and grazing capacity of your RANGELAND stay at or above the levels you have specified in *Questions 11* and *12*?**

➔ *Please enter a number into the box, where **'0'** denotes the current generation, **'1'** the following generation, **'2'** the generation thereafter etc.*

☐ generations

14. **Income from cattle farming is always risky to some degree. It may not be possible to obtain the net income at or above the level you have specified (*Question 11*) in every year .**

In how many out of every 10 years is it manageable that income falls below the level specified?

➔ *Please enter the number of years between **'0'** and **'10'** into the box.*

☐ years out of 10 years

15. **Grazing capacity of your RANGELAND is always risky to some degree. It may not be possible to obtain the grazing capacity at or above the level you have specified *(Question 12)* in every year.**

In how many out of every 10 years is it manageable that grazing capacity falls below the level specified?

➔ *Please enter the number of years between **'0'** and **'10'** into the box.*

☐ years out of 10 years

16. **We assumed that sustaining livelihood means sustaining income, and that sustaining the natural environment means sustaining the grazing capacity of RANGELAND.**

In regard to livelihood or the natural environment, it may also be important to sustain things other than income or grazing capacity of RANGELAND. In your opinion, what else should be sustained?

____

____

IV. Attitude towards risk / Benadering tot risiko

STEP 5

17. In general, how would you rate your willingness to take risks?

➔ *Please check the box on the scale that best describes your willingness to take risks.*

completely avoid to take risks ☐–☐–☐–☐–☐–☐–☐–☐–☐ **very willing to take risks**

18. In the following question, we would like you to respond to a hypothetical situation.

Let's assume you are forced to sell fifty weaners (due to financial or grazing reasons) and can do so at auction. However, you are uncertain about the amount of money they will fetch. You have a 50% chance that the fifty weaners combined will fetch N$ 90 000 and a 50% chance that they will fetch N$ 130 000.

Instead of selling at auction, you can sell the weaners to a reputable trader for a fixed amount of money. The trade procedures (i.e. driving to the venue, paperwork, etc.) are similar regardless of whether you sell at auction or to the trader.

For each of the following six scenarios, please choose whether you prefer to take part in the auction having a 50% chance of fetching either N$ 90 000 or N$ 130 000, or prefer to sell to the trader offering you increasing higher amounts of money.

➔ *Please check only one box for each of the six scenarios.*

Scenario	Auction	Trader
1: The trader offers you **N$ 100 000**. What would you prefer?	Sell at auction ☐	or sell to trader ☐
2: The trader offers you **N$ 102 500**. What would you prefer?	Sell at auction ☐	or sell to trader ☐
3: The trader offers you **N$ 105 000**. What would you prefer?	Sell at auction ☐	or sell to trader ☐
4: The trader offers you **N$ 107 500**. What would you prefer?	Sell at auction ☐	or sell to trader ☐
5: The trader offers you **N$ 110 000**. What would you prefer?	Sell at auction ☐	or sell to trader ☐
6: The trader offers you **N$ 112 500**. What would you prefer?	Sell at auction ☐	or sell to trader ☐

STEP 6

19. In your present situation, what would you prefer: a payment of N$ 100 000 in one month or a higher amount in seven months (therefore six months later)?

➔ *Please check only one box for each of the five scenarios. For your convenience, we have indicated for each scenario the corresponding effective annual interest rate with quarterly compounding.*

Scenario	Payment in one month		Payment in seven months	Annual interest rate
1: What would you prefer?	**N$ 100 000** in one month ☐	or	**N$ 104 881** in seven months ☐	10%
2: What would you prefer?	**N$ 100 000** in one month ☐	or	**N$ 109 545** in seven months ☐	20%
3: What would you prefer?	**N$ 100 000** in one month ☐	or	**N$ 114 018** in seven months ☐	30%
4: What would you prefer?	**N$ 100 000** in one month ☐	or	**N$ 118 322** in seven months ☐	40%
5: What would you prefer?	**N$ 100 000** in one month ☐	or	**N$ 122 474** in seven months ☐	50%

20. **How would you rate your willingness to wait for a larger payment?**

➔ *Please check the box on the scale that best describes your willingness to wait.*

not at all willing to wait ☐—☐—☐—☐—☐—☐—☐—☐—☐ **very willing to wait**

V. Your farm management / Jou plaasbestuur

STEP 7

21. **How much rainfall did you receive at the farm house in the rainy seasons of 2006/07 and 2007/08?**

➔ *Please enter the total amount of rainfall for the respective periods in **mm**.*

Oct ´06	Nov ´06	Dec ´06	Jan ´07	Feb ´07	Mar ´07	Apr ´07	May – Sept ´07
Oct ´07	Nov ´07	Dec ´07	Jan ´08	Feb ´08	Mar ´08	Apr ´08	May – July ‘08

22. **How would you characterize each rainy season (November 1 to April 30) on your farm in the period 2003 to 2008?**

➔ *Please check only one box for <u>each</u> season.*

	very poor					**very good**
2007/08 rainy season	☐	☐	☐	☐	☐	☐
2006/07 rainy season	☐	☐	☐	☐	☐	☐
2005/06 rainy season	☐	☐	☐	☐	☐	☐
2004/05 rainy season	☐	☐	☐	☐	☐	☐
2003/04 rainy season	☐	☐	☐	☐	☐	☐

STEP 8

23. **How would you rate the quality of your RANGELAND (see *question 6*)?**

➔ *Please check the box on the scale that best describes the quality.*

very poor quality ☐—☐—☐—☐—☐—☐ **very good quality**

24. **What percentage of your RANGELAND was covered by bushes on April 30, 2008 ?**

0 % .... ☐ 1 to 20 % .... ☐ 21 to 40 % .... ☐

41 to 60 % .... ☐ 61 to 80 % .... ☐ 81 to 100 % .... ☐

25. What percentage would be the optimum level of bush cover for your RANGELAND?

[ ] %

26. What was the grazing capacity of your RANGELAND as measured as hectares per large stock unit on April 30, 2008?

[ ] hectares per large stock unit

27. How many camps is your RANGELAND divided into?

➔ *If you have not divided your RANGELAND, please enter **'0'** in the box.*

[ ] camps

STEP 9

28. How many of <u>your own</u> cattle did you have on your RANGELAND at the start (November 1, 2007) and the end (April 30, 2008) of the rainy season of 2007/08?

➔ *Please report the number for each cattle group. Only include cattle that you own.*

	Cows	Weaners	Heifers	Oxen	Bulls
November 1, 2007					
April 30, 2008					

29. In addition to your own cattle, how many cattle that did not belong to your farm business did you have on your RANGELAND on April 30, 2008?

	Cows	Weaners	Heifers	Oxen	Bulls
April 30, 2008					

30. For each of the following production systems of cattle farming, please indicate the percentage of <u>your own</u> cattle herd assigned to each production system.

➔ *Please enter the percentage in the box. If you don't pursue a specific production system, enter **'0'** in the box. Please bear in mind that the percentages should add up to **100**.*

Percentage of total herd

Weaner breeding for sale but not for slaughter.. [ ] %

Slaughter animal production from weaners that you have bought .... [ ] %

Weaner breeding for slaughter .... [ ] %

Stud breeding .... [ ] %

Other: ____ ... [ ] %

STEP 10

31. Including yourself and your spouse (if married), how many people are in your household?

➔ *Include in 'household' anyone who is living on your farm and with whom you share at least one meal per day, but exclude anyone whom you pay a salary to and you are not related to (e.g. farm workers).*

Number of people in your household: ☐

32. Adding up the income from all sources and all household members, which best describes your annual household net income (gross revenues from farming minus operating expenses, taxes and interest on loans) in the period March 1, 2007 to February 29, 2008?

N$ 0 to N$ 50 000 .... ☐ N$ 50 001 to N$ 150 000 ..... ☐ N$ 150 001 to N$ 250 000 .. ☐

N$ 250 001 to N$ 350 000 ..... ☐ N$ 350 001 or more .... ☐

33. What percentage of your annual household net income came from cattle farming in the period March 1, 2007 to February 29, 2008?

0 % .... ☐ 01 to 20 % .... ☐ 21 to 40 % .... ☐

41 to 60 % .... ☐ 61 to 80 % .... ☐ 81 to 100 % .... ☐

34. What other products do you farm, and what percentage of your annual household net income came from farming these products in the period March 1, 2007 to February 29, 2008?

➔ *For each product, please enter the percentage in the box. If you don't farm it, enter '**0**' in the box.*

	Percentage of annual household net income
Small stock	☐ %
Game (for meat production)	☐ %
Tourism (e.g. accommodation, hunting)	☐ %
Maize	☐ %
Bioenergy	☐ %
Other products: ____ ...	☐ %

35. What percentage of your annual household net income came from off-farm employment, off-farm business or other off-farm sources in the period March 1, 2007 to February 29, 2008?

0 % .... ☐ 01 to 20 % .... ☐ 21 to 40 % .... ☐

41 to 60 % .... ☐ 61 to 80 % .... ☐ 81 to 100 % .... ☐

STEP 11

36. Do you live on the farm during the week?

Yes .... ☐ No .... ☐

37. In which district is the majority of your RANGELAND located? ___________________________________

VI. Personal information / Persoonlike inligting

STEP 12

38. What is your year of birth and gender?

Year of birth: 19 ☐

Male .... ☐

Female .... ☐

39. Which of the following best describes your ethnic background?

Afrikaans .... ☐ German .... ☐ Herero .... ☐ Ovambo .... ☐

Kavango ...... ☐ Nama/Damara ..... ☐ English .... ☐ Other: _____________ .. ☐

40. What is the highest level of education that you have completed?

No high school graduation .... ☐

High school graduation .... ☐

Trade or apprenticeship certificate ..... ☐

University/Polytech Diploma or Bachelor .. ☐

University/Polytech Master .... ☐

University Doctoral .... ☐

Other: _________________________ ... ☐

41. What is the main field of study for your highest certificate, diploma or degree?

____

STEP 13

42. How many years of experience do you have with operating a farm business?

As farm owner: ☐ years As manager: ☐ years Other: _____________ ☐ years

43. Since what calendar year have you been operating this particular farm business? .... ☐

44. How many years do you plan to continue cattle farming? .... ☐

45. If you retire from cattle farming, what do you expect would be the reason?

____

46. What do you think is most likely going to happen with your farm business if you would retire?

____

STEP 14

47. Are you an Emerging Commercial Farmer?

Yes .... ☐ No .... ☐

STEP 15

48. And finally, could we ask you to give us your farm number?

Please consider carefully if you are willing to disclose this information. By giving us your farm number your responses to these questions will no longer be anonymous to us!

Knowing the farm number will enable us to perform additional scientific analysis because we can link the information you provide to information on local environmental conditions such as rainfall or soil quality.

Your information will remain strictly confidential, we will not share this information with others, and nobody will be able to identify you or your farm from any information we include in our reports.

Your farm number: ☐

Do you have any suggestions or comments to add to this questionnaire? Are there important aspects of management or sustainability of cattle farming that we have not considered? We are grateful for any comment or suggestion.

____

____

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➔ ***Please put the completed questionnaire in the enclosed postage-paid envelope and mail it to the NAU who will forward the envelope unopened to the Leuphana University of Lüneburg.***

➔ ***If you have any questions, feel free to contact us at the addresses provided on the second page.***

Thank you for your cooperation.

Dankie vir u samewerking.

NAU NLU

Leuphana University
of Lüneburg

Sustainability of commercial cattle farms and the natural environment in Namibia

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Volhoubaarheid van kommersiële beesplase en die natuurlike omgewing in Namibië

Experiment of attitude towards risk and time, conducted by the *Leuphana University of Lüneburg* in cooperation with the *Namibia Agricultural Union*.

What is this about?

In the following, we would like to conduct with you an scientific experiment about your attitude towards risk (Section I) and time (Section II). Each section consists of one question where we would like to ask you to rate your respective attitude and one question where we would like to ask you to respond to a hypothetical situation. Each section concludes with a task that involves real money.

When you have completed all questions and tasks we would ask you to draw a lot for both tasks having each a 10% change to win whatever you have chosen in the respective task.

We wish you good luck!

I. Risk

I.1 In general, how would you rate your willingness to take risks?

➔ *Please check the box on the scale that best describes your willingness to take risks.*

completely avoid to take risks ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ **very willing to take risks**

I.2 In the following question, we would like you to respond to a hypothetical situation.

Let's assume you are forced to sell fifty weaners (due to financial or grazing reasons) and can do so at auction. However, you are uncertain about the amount of money they will fetch. You have a 50% chance that the fifty weaners combined will fetch <u>N$ 90 000</u> and a 50% chance that they will fetch <u>N$ 130 000</u>.

Instead of selling at auction, you can sell the weaners to a reputable trader for a fixed amount of money. The trade procedures (i.e. driving to the venue, paperwork, etc.) are similar regardless of whether you sell at auction or to the trader.

For each of the following six scenarios, please choose whether you prefer to take part in the auction having a 50% chance of fetching either <u>N$ 90 000</u> or <u>N$ 130 000</u>, or prefer to sell to the trader offering you increasing higher amounts of money.

➔ *Please check only one box for <u>each</u> of the six scenarios.*

Scenario	Auction	Trader
1: The trader offers you **N$ 100 000**. What would you prefer?	Sell at auction ☐	or sell to trader ☐
2: The trader offers you **N$ 102 500**. What would you prefer?	Sell at auction ☐	or sell to trader ☐
3: The trader offers you **N$ 105 000**. What would you prefer?	Sell at auction ☐	or sell to trader ☐
4: The trader offers you **N$ 107 500**. What would you prefer?	Sell at auction ☐	or sell to trader ☐
5: The trader offers you **N$ 110 000**. What would you prefer?	Sell at auction ☐	or sell to trader ☐
6: The trader offers you **N$ 112 500**. What would you prefer?	Sell at auction ☐	or sell to trader ☐

I.3 In the following we would like to present you with a task that involves real money.

Below is list of sixteen scenarios. Each scenario gives you the choice between taking part in a lottery or accepting a certain amount instead. The lottery is same throughout the scenarios offering a 50% chance to win N$ 2 500 and a 50% chance to win N$ 500, but the certain amount increases from one scenario to the next.

We would like to ask you to consider every scenario and indicate whether you would prefer to take part in the lottery or accept the certain amount. After you have made your choices for all scenarios we will randomly select one scenario for which your choice becomes relevant, i.e. either taking part in the lottery or receiving the certain amount. Finally, will make a second random selection where you have a 10% chance of being the lucky winner of whatever you have chosen in the selected scenario. If you win you will receive the money straight away.

Scenario	**Lottery**				**Certain amount**	**Your choice**	
	Probability of N$ 2.500		***Probability of N$ 500***			***Lottery***	***Certain amount***
1	50%	N$ 2.500	50%	N$ 500	N$ 550	☐	☐
2	50%	N$ 2.500	50%	N$ 500	N$ 600	☐	☐
3	50%	N$ 2.500	50%	N$ 500	N$ 650	☐	☐
4	50%	N$ 2.500	50%	N$ 500	N$ 700	☐	☐
5	50%	N$ 2.500	50%	N$ 500	N$ 800	☐	☐
6	50%	N$ 2.500	50%	N$ 500	N$ 900	☐	☐
7	50%	N$ 2.500	50%	N$ 500	N$ 1.000	☐	☐
8	50%	N$ 2.500	50%	N$ 500	N$ 1.100	☐	☐
9	50%	N$ 2.500	50%	N$ 500	N$ 1.200	☐	☐
10	50%	N$ 2.500	50%	N$ 500	N$ 1.300	☐	☐
11	50%	N$ 2.500	50%	N$ 500	N$ 1.400	☐	☐
12	50%	N$ 2.500	50%	N$ 500	N$ 1.500	☐	☐
13	50%	N$ 2.500	50%	N$ 500	N$ 1.600	☐	☐
14	50%	N$ 2.500	50%	N$ 500	N$ 1.700	☐	☐
15	50%	N$ 2.500	50%	N$ 500	N$ 1.800	☐	☐
16	50%	N$ 2.500	50%	N$ 500	N$ 1.900	☐	☐

II. Time

II.1 In your present situation, what would you prefer: a payment of N$ 100 000 in one month or a higher amount in seven months (therefore six months later)?

➔ *Please check only one box for each of the five scenarios. For your convenience, we have indicated for each scenario the corresponding effective annual interest rate with quarterly compounding.*

Scenario	Payment in one month			Payment in seven months		Annual interest rate
1: What would you prefer?	**N$ 100 000** in one month	☐	or	**N$ 104 881** in seven months	☐	10%
2: What would you prefer?	**N$ 100 000** in one month	☐	or	**N$ 109 545** in seven months	☐	20%
3: What would you prefer?	**N$ 100 000** in one month	☐	or	**N$ 114 018** in seven months	☐	30%
4: What would you prefer?	**N$ 100 000** in one month	☐	or	**N$ 118 322** in seven months	☐	40%
5: What would you prefer?	**N$ 100 000** in one month	☐	or	**N$ 122 474** in seven months	☐	50%

II.2 How would you rate your willingness to wait for a larger payment?

➔ *Please check the box on the scale that best describes your willingness to wait.*

not at all willing to wait ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ **very willing to wait**

II.3 In the following we would like to present you with a task that involves real money.

Below is list of twenty scenarios. Each scenario gives you the choice between a payment of N$ 2 000 in one month and larger payment in seven months (therefore six months later). The payment in one month is the same for all scenarios, but the payment in seven months increases from one scenario to the next.

We would like to ask you to consider every scenario and indicate whether you would prefer the payment in one month or in seven months. After you have made your choices for all scenarios we will randomly select one scenario for which your choice becomes relevant, i.e. receiving the payment in one month or in seven months. Finally, will make a second random selection where you have a 10% chance of being the lucky winner of whatever you have chosen in the selected scenario. If you win you will receive a guarantee backed by the Namibia Agricultural Union over the time and amount you have chose in the selected scenario.

Scenario	Payment in one month	Payment in seven months	Effective annual interest rate	Your choice *One month*	 *Seven months*
1	N$ 2 000	N$ 2 025	2,5%	☐	☐
2	N$ 2 000	N$ 2 049	5,0%	☐	☐
3	N$ 2 000	N$ 2 074	7,5%	☐	☐
4	N$ 2 000	N$ 2 098	10,0%	☐	☐
5	N$ 2 000	N$ 2 121	12,5%	☐	☐
6	N$ 2 000	N$ 2 145	15,0%	☐	☐
7	N$ 2 000	N$ 2 168	17,5%	☐	☐
8	N$ 2 000	N$ 2 191	20,0%	☐	☐
9	N$ 2 000	N$ 2 214	22,5%	☐	☐
10	N$ 2 000	N$ 2 236	25,0%	☐	☐
11	N$ 2 000	N$ 2 258	27,5%	☐	☐
12	N$ 2 000	N$ 2 280	30,0%	☐	☐
13	N$ 2 000	N$ 2 302	32,5%	☐	☐
14	N$ 2 000	N$ 2 324	35,0%	☐	☐
15	N$ 2 000	N$ 2 345	37,5%	☐	☐
16	N$ 2 000	N$ 2 366	40,0%	☐	☐
17	N$ 2 000	N$ 2 387	42,5%	☐	☐
18	N$ 2 000	N$ 2 408	45,0%	☐	☐
19	N$ 2 000	N$ 2 429	47,5%	☐	☐
20	N$ 2 000	N$ 2 449	50,0%	☐	☐

APPENDIX D: Cover letters and FAQ-pages

NAU NLU

Leuphana University of Lüneburg

Prof. Dr. Stefan Baumgärtner
Sustainability Economics Group

July 31st, 2008

Dear *Cattle Farmer*:

You have chosen a tough job! Variable rainfall and fluctuating cattle prices cause commercial cattle farming to be a risky enterprise. Moreover, the natural environment is degrading in many areas of Namibia making farming even more challenging. Nonetheless, commercial cattle farmers have been employing well-suited management strategies to make cattle farming successful.

Who are we?

The *Sustainability Economics Group* at the *Leuphana University of Lüneburg*, Germany, along with the *Namibia Agricultural Union* (NAU), is conducting a study of commercial cattle farming in Namibia. We want to know how under risky conditions both the livelihood of farmers and the natural environment can be sustained for present and future generations. Your perspective on this issue will be unique and extremely valuable to us.

We are asking just a few minutes of your time.

The enclosed questionnaire has been sent to more than two thousand commercial cattle farmers in Namibia. It includes questions about the risks you face as a commercial cattle farmer, your management strategies and your views on sustainability. We kindly ask you to answer these questions and return the questionnaire in the postage-paid envelope. **The questionnaire may be filled in in Afrikaans, English or German.** *'N70'* on this envelope is the business reply license for all envelopes of this study; it is not unique to your envelope. Of course, your answers will be strictly confidential. We will use the information only anonymously and only for scientific purposes.

We know you are busy. So why should you participate?

Findings from this study may help to achieve long-term economic success of cattle farming in Namibia and contribute to sustaining the natural environment that enables farming. To this end we will invite you to workshops throughout Namibia in the summer of 2009/10. The findings will also be available from the NAU as a written report, and we will gladly send you an electronic version upon request.

If you have any questions or concerns about completing the questionnaire, please contact us at the *Sustainability Economics Group*. The contact address is provided below. You may also contact Harald Marggraff at the *NAU* (phone: 061.237838, email: meat@agrinamibia.com.na).

We are looking forward to your participation!

Yours sincerely,

Prof. Dr. Stefan Baumgärtner

P.O. Box 2440
D-21314 Lüneburg, Germany

phone: +49.4131.677-2715
fax: +49.4131.677-1381

email: sustainabilityeconomics@uni-lueneburg.de
http://www.uni-lueneburg.de/seg

Leuphana Universiteit
van Lüneburg

Prof. Dr. Stefan Baumgärtner
Volhoubaarheid Ekonomie Groep

31 Julie 2008

Geagte *Beesboer*:

U het dit nie maklik nie! Wisselende reënval en beespryse bring mee dat kommersiële beesboerdery ondernemings met risiko's geword het. Intussen gaan die natuurlike omgewing in baie gebiede agteruit, wat boerdery in Namibië nog meer uitdagend maak. Tog span kommersiële beesboere geskikte bestuurstrategieë in om suksesvol met bees te boer.

Wie is ons?
Die *Volhoubaarheid Ekonomie Groep* aan die *Leuphana Universiteit van Lüneburg*, Duitsland, onderneem in samewerking met die *Namibia Landbou Unie* (NLU) 'n studie na kommersiële beesboerdery in Namibië. Ons probeer vasstel hoe volhoubaar boere hul bestaan op plase en die natuurlike omgewing bestuur ten einde 'n goeie lewe te maak – vir huidige en toekomstige geslagte. U siening oor hierdie aspek sal uniek en van groot waarde vir ons wees.

Ons vra net 'n paar minute van u tyd
Die ingeslote vraelys is aan meer as tweeduisend kommersiële beesboere in Namibië gestuur. Dit sluit in vrae oor risiko's, bestuurstrategieë en u standpunt oor volhoubaarheid. Ons versoek u vriendelik om hierdie vrae te beantwoord en dit terug te stuur in die ingeslote koevert. **Vraelyste kan ook in Afrikaans en Duits ingevul word.** Die posgeld daarvoor is reeds betaal. Die kode *"N70"* op die koevert is 'n identfikasie-kenmerk en vir die uitsluitlike doel van die studie. Alle antwoorde is streng vertroulik. Inligting word anoniem vir 'n suiwer wetenskaplike doel gebruik.

Ons weet u is besig. So waarom moet u deelneem?
Bevindinge van die studie kan help om die langtermyn ekonomiese sukses van beesboerdery in Namibië te bepaal en kan bydra om die omgewing volhoubaar te onderhou ten einde te kan boer. Aan die einde van die navorsing in die somer van 2009/10 sal ons die bevindinge by werkwinkels regoor Namibië waarheen u genooi sal word, bekend maak. Teen daardie tyd sal bevindinge van die studie in verslagvorm (ook elektroniese formaat) by die NLU beskikbaar wees.

Indien u enige vrae rondom die invul van die vraelys het, kontak die *Volhoubaarheid Ekonomie Groep* deur middel van Harald Marggraff by die NLU (tel: 061-237838 of e-pos: meat@agrinamibia.com.na).

Ons sien uit na u deelname.

Groete,

Prof. Dr. Stefan Baumgärtner

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Leuphana University of Lüneburg

Sustainability of commercial cattle farms and the natural environment in Namibia

Additional information

Who are we?

The *Sustainability Economics Group* at the *Leuphana University of Lüneburg*, Germany, carries out research on how human economic actions depend upon and affect the natural environment. Research about sustainability of the Namibian agriculture is conducted since 2004. For this study, the group cooperates with the *Namibian Agricultural Union* (NAU).

Why management of risk and sustainability?

Sustainability is generally understood as sustaining both the livelihood of humans and the natural environment – for present and for future generations. Due to risks such as variable rainfall or fluctuating cattle prices, livelihood and the natural environment are always risky to some degree. When considering sustainability, those involved have to specify how much of both they wish to sustain for how long and how much risk is acceptable. Once specified, actions for achieving sustainability can be devised which may include management strategies aimed at reducing risk.

What is the purpose of this questionnaire?

We conduct a scientific study on how sustainability of commercial cattle farming in Namibia may be achieved under risky condition. Farmers know best how to deal with these conditions, and we want to find out how risk, management strategies, and the assessment of what sustainability is differ across farmers. We aim at identifying economic and institutional obstacles that prevent farmers from applying sustainable management strategies. We also aim at deriving potential solutions of how to overcome these obstacles – so that the livelihood of farmers and Namibia's natural environment can be sustained for present and future generations.

What is your benefit from participating and how will you be informed about the results?

Findings from the analyses of your answers may help to achieve long-term economic success of commercial cattle farming. Moreover, with your answers you will contribute to the conservation of the natural environment that enables farming. At the end of our study in summer 2009/10 we will present our findings in workshops throughout Namibia that you will be invited to attend. In addition, the findings will be available as a free report from the NAU, and we will gladly send you an electronic version upon request.

Sensitive information is asked in the questionnaire. What will happen with these data?

We ask you to return the questionnaires in the enclosed business-reply envelope to the NAU who will forward the envelopes to us unopened. *'N70'* on this envelope is the business-reply license for all envelopes of this study; it is not unique to your envelope. Your data stays anonymous and we will treat it as strictly confidential. Under no circumstances will we pass personal data to any governmental institution.

Leuphana Universiteit van Lüneburg

Volhoubaarheid van kommersiële plase en die natuur in Namibië

Addisionele inligting

Wie is ons?

Die *Volhoubaarheid Ekonomie Groep* van die *Leuphana Universiteit van Lüneburg*, Duitsland, doen navorsing oor hoe menslike ekonomiese optrede bepaal en beïnvloed word deur die natuur. Navorsing oor die volhoubaarheid van Namibiese landbou word sedert 2004 gedoen. Vir hierdie studie werk die groep saam met die *Namibia Landbou Unie* (NLU).

Hoekom moet risiko en volhoubaarheid bestuur word?

Volhoubaarheid word algemeen verstaan as die volhou van die lewensbestaan van die mens en die natuur vir die huidige en toekomstige generasies. Weens risiko's soos wisselende reënval en beespryse is lewensbestaan en die natuurlike omgewing altyd tot 'n mate riskant. Wanneer volhoubaarheid in aanmerking geneem word, moet diegene wat daarby betrokke is, spesifiseer hoeveel van beide hulle wil volhou, vir hoe lank en hoeveel risiko's aanvaarbaar is. Wanneer dit gespesifiseer is, kan aksies vir die bereik van volhoubaarheid opgestel word wat bestuurstrategieë kan insluit en daarop gemik is om die risiko te verminder.

Wat is die doel van hierdie vraelys?

Ons doen wetenskaplike navorsing oor hoe volhoubaarheid van kommersiële beesboerdery in Namibië onder riskante toestande onder riskante toestande bereik kan word. Boere weet die beste hoe om hierdie toestande te hanteer en ons wil vasstel hoe risiko, bestuurstrategieë en die begrip van volhoubaarheid tussen boere verskil. Ons poog om ekonomiese en institusionele struikelblokke te identifiseer wat boere verhinder om volhoubare bestuurstrategieë toe te pas. Ons poog ook om moontlike oplossings te vind om hierdie hindernisse te oorkom sodat die lewensbesaan van boere en Namibië se natuurlike omgewing vir die huidige en toekomstige generasies behoue kan bly.

Watter voordeel hou deelname aan hierdie studie vir u in en hoe gaan u ingelig word oor die bevindinge?

Die bevindinge van die ontledings van u antwoorde kan help om langtermyn ekonomiese sukses vir kommersiële beesboere te bereik. Soveel te meer sal u antwoorde bydra tot die bewaring van die natuur wat boerdery moontlik maak. Aan die einde van die navorsing in die somer van 2009/10 sal ons die bevindinge by werkwinkels regoor Namibië waarheen u genooi sal word, bekend maak. Bykomend hiertoe sal die bevindinge gratis by die NLU verkry kan word. Ons sal ook graag vir u by navraag 'n elektroniese weergawe aanstuur.

Sensitiewe inligting word in die vraelys gevra. Wat gaan met hierdie inligting gedoen word?

Ons vra u om die vraelys in die ingeslote koevert aan die NLU terug te besorg wat dit dan onoopgemaak na ons sal aanstuur. Die kode N70 op hierdie koeverte is 'n kode wat die inligting vir hierdie studie identifiseer en is nie uniek aan die koevert wat u ontvang het nie. U inligting bly anoniem en ons sal dit streng vertroulik hanteer. Onder geen omstandighede sal u persoonlike inligting aan enige regeringsinstelling gegee word nie.

Chapter 4: Characterizing commercial cattle farms in Namibia: Risk, management and sustainability

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Abstract

Commercial cattle farming in Namibia, a prime example of livestock farming in semi-arid rangelands, is subject to a variety of risks, predominant among which is precipitation risk. At the same time it suffers from degradation that is at least partly due to inadequate management. We characterize cattle farms through descriptive statistics and cluster analysis using data that we elicited in August 2008 through mail-in questionnaires and in-field experiments. We find that cattle farms are heterogeneous in the majority of individual characteristics. Heterogeneity is also observed when analyzing characteristics jointly through the cluster analysis which suggests classification of farms into three distinct clusters. This classification is predominantly driven by environmental condition and financial risk management, and to a lesser extent by organizational structure of farms and ethnicity. Overall, our study is the first to provide a comprehensive characterization of this system in respect to risk, management and sustainability.

Keywords: cattle farming, semi-arid rangelands, Namibia, empirical survey, perceived risk, management, risk and time preferences, normative views, sustainability

JEL-Classification: Q12, Q15, Q57

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1. Introduction

Livestock farming is the dominant land use in semi-arid areas. These areas are globally very important, covering 15% of the Earth's surface and housing approximately 900 million people (MEA, 2005a: 627). The demanding environmental conditions, chiefly among them low and highly risky precipitation, place serious constraints on rain-fed crop farming. Thus, land is instead used as rangeland for livestock farming, as this offers sufficient flexibility to adapt to the environmental conditions. Livestock farming is conducted on 1.2 billion hectares in semi-arid areas which accounts for more than 60% of the land surface used for agricultural purposes (MEA, 2005a: 627). However, while livestock farming is intended to deal with the variable environmental conditions it is frequently unsustainable with at least 10–20% of semi-arid areas, including rangelands, being degraded (MEA, 2005a: 637, 640). One reason is the use of inadequate management strategies (e.g. Fynn and O'Connor, 2000; de Klerk, 2004; Wiegand, 2010). This is the case not only in communal livestock farming where rangeland is a common pool resource and where it may be rational for farmers to "produce outcomes that are not in anyone's long-term interest" (Ostrom, 1999: 279); it is also in the case in commercial livestock farming (de Klerk, 2004) where property-owning farmers exclusively manage rangeland and may do so for decades.

In this paper we empirically characterize one prime example of commercial livestock farming in semi-arid rangelands, which is commercial cattle farming in Namibia. Like other semi-arid rangelands, those in Namibia are also subject to high precipitation risk (Sweet, 1998) and suffer from degradation which comes in the form of bush encroachment (de Klerk, 2004). At the same time, commercial cattle farming is economically important, contributing the largest share to Namibia's agricultural output (MAWF, 2009: 7). Some aspects of commercial cattle farming have been studied extensively, such as bush encroachment (e.g. de Klerk, 2004), but many other aspects relating to (environmental) risk, management and sustainability have been examined to a much lesser extent (see Olbrich (2011) for a review). We take a first step to fill this gap by presenting comprehensive descriptive statistics for farmers and farms on 1) personal and farm features, 2) risk perception, 3) risk management strategies, 4) individual risk and time preferences, and 5) normative views of sustainability. We also conduct a cluster analysis to determine whether cattle farms may be classified into similar groups. Data for this study derives from a survey, consisting of a mail-in questionnaire and in-field experiments, that we conducted among commercial cattle farmers in Namibia in August/September 2008 (Olbrich et al., 2009). Altogether, we reached 1,916 of an estimated 2,500 farmers. 399 questionnaires were returned, equaling a return rate of 20.8%. We complement this quantitative data by qualitative ones that we collected in personal interviews during the period 2007–2010.

Our results show that cattle farms are heterogeneous in the majority of individual characteristics as indicated by high standard deviations. A cluster analysis reveals that cattle farms are also heterogeneous when considering characteristics jointly as exemplified by the identification of three clusters. Classification is predominantly driven by environmental conditions and financial risk management and to a lesser extent by organizational structure of the farms and ethnicity: the most distinct of the three identified clusters is best characterized by high grazing capacity, low perceived rainfall risk and low self-reported financial risk management; of the remaining two clusters, one is best characterized by a high proportion of multiple owners, the other by a high proportion of Afrikaans farmers. Risk and time preferences and normative views of sustainability play only a marginal role for classification. Income does not drive classification and neither does weekend farming, a commonly used classification characteristic in Namibia.

The paper is organized as follows: Section 2 gives a brief description of the background of commercial cattle farming in Namibia. Section 3 describes the data collection. Section 4 details the analytical procedure and results for the descriptive statistics, while Section 5 does so for the cluster analysis. Finally, Section 6 discusses and concludes. Due to the large number of figures and tables we do not present them interspersed in the text, but have instead relegated them to Appendices A to C (for the descriptive statistics) and D (for the cluster analysis).

2. Background on commercial cattle farming in Namibia

Giving a comprehensive background of commercial cattle farming is beyond the scope of this paper, but is given by Olbrich (2011). The commercial cattle farming area covers approximately 14.5 million hectares (ha) (Mendelsohn, 2006: 42) and is located in the northern half of Namibia (Figure 1), confined to the south and west by areas to dry for farming and in the north and east by communal lands. On average, the commercial farming area receives an annual precipitation of 374 mm, with 95% (352 mm) of precipitation falling during the rainy season (NMS, unpublished).[53] Precipitation is highly variable from one rainy season to the next: the coefficient of variation of total rainy season precipitation amounts to

[53] We refer here to the meteorological year, which is commonly defined from July to June in southern Africa (e.g. Unganai, 1996; Burke, 1997). We define the rainy season as the period 01st of November until 30th of April.

0.35 (NMS, unpublished).[54] The area is partly degraded, with many farms nowadays having a grazing capacity which is worse than historic value of above 0.1 Large Stock Unit per hectare (LSU/ha) (below 10 ha/LSU)[55] that was encountered on average across Namibia until the mid 1960s (de Klerk, 2004: 21).

Commercial cattle farming is economically the dominant livestock farming system in Namibia: it contributes by far the largest share of total agricultural output and approximately 1–2% directly to GPD (MAWF, 2009: 7, 9).[56] An estimated 2,500 commercial cattle farmers[57] keep an average of 840,000 cattle (MAWF, 2009: 13). Of the 298,961 cattle that are on average marketed each year, roughly half (49%) of the cattle are sold as live cattle (almost exclusively as weaners) whereas the other half (51%) are converted to beef (MAWF, 2009: 14). Almost all weaners are exported as live cattle to feed lots in South Africa (Schutz, 2010). Beef is primarily sold to South Africa (45%), overseas (37%) and other markets (3%) with only a fraction consumed domestically (15%) (MAWF, 2009: 14, 15). Politically, the majority of commercial cattle farmers are organized in the Namibia Agricultural Union (NAU) which is the main interest group of commercial farmers. The Emerging Commercial Farmers' Support Programme is a smaller interest group that specifically represents indigenous commercial farmers which are typically referred to as "emerging commercial farmers".

3. Data collection

3.1 Quantitative data collection

In August 2008, we conducted a survey consisting of a mail-in questionnaire and in-field risk and time experiments among commercial cattle farmers in Namibia. We elicited characteristics in respect to 1) personal and farm features, 2) risks faced by farmers, 3) risk management strategies, 4) individual risk and time preferences, and 5) normative views of sustainability. Within the questionnaire we employed a variety of question formats, including Likert-scales, multiple-choice questions and open questions. In addition, the questionnaire contained risk and time experiments over hypothetical rewards, parallel to in-field risk and

[54] The coefficient of variation for total annual precipitation is with 0.35 very similar. As a reference, we note that for countries in central and northern Europe this coefficient of variation is between 0.1 and 0.2 (Chapman, 2010: Map 2).

[55] Throughout this paper, we report grazing capacity in the unit LSU/ha which more intuitive since higher values then denote better grazing capacity. However, we always also report in brackets the more commonly used inverted value in the unit ha/LSU.

[56] All subsequent figures from MAWF (2009) are calculated as averages over the period 2000–2007.

[57] No census data is available that gives the exact number of commercial cattle farmers. The estimate comes from experts of the Namibia Agricultural Union and the Meat Board of Namibia.

time experiments with monetary rewards. A detailed description of the survey and its conduction can be found in Olbrich et al. (2009) which also has the questionnaire attached.

We sent out questionnaires to all cattle farming members of the NAU and to all farmers that deliver cattle to MeatCo, the largest slaughterhouse in Namibia. We mailed out a first batch of questionnaires in the period 19th – 21st of August 2008, and a second batch as a follow up on the 15th of September 2008. In addition, we randomly selected 39 NAU members for participation in in-field risk and time experiments. We visited the majority of participants (79.4%) on their respective farms, and the remaining ones at pubic locations in major cities.

Altogether, we reached 1,916 of the estimated 2,500 commercial cattle farmers (76.6%). 399 questionnaires were returned, equaling a return rate of 20.8%. In the returned questionnaires, the response rate for non-sensitive questions exceeded 95% for most questions, and the response rate was greater than 90% for sensitive questions such as income. An optional question for identification of the farm was answered by 75.1% of survey participants.

3.2 Qualitative data collection

In addition to the quantitative survey, we conducted qualitative interviews with farmers and decision makers in the agricultural, political and financial sector throughout four research visits in March/April 2007, October 2007, July/August 2008 and February/March 2010. During the last research visit we also conducted a series of workshops with farmers and decision makers to discuss preliminary results of this paper. We will not report findings from qualitative interviews and workshops as such but draw on these findings for the interpretation of some results of the quantitative survey.

4. Descriptive statistics

In a first step, we analyze data through the use of descriptive statistics. Results are presented in the form of figures, summary and frequency tables. Due to the large number of figure and tables we have relegated these to the Appendices: Appendix A contains figures, Appendix B a table of summary statistics and Appendix C frequency tables. In this section, we will explicitly refer to figures and frequency tables, but not to summary statistics (Table 1).

4.1 Personal and farm features

Personal features

We find that the majority of principal decision makers on farms are male (94.7%) (Table 2). Household size is on average 3.7 members with most households (38.2%) consisting of two members (Table 3). A small percentage of households (1.5%) report to consist of eleven or more members, with the largest household indicated as having 46 members. However, we deem it likely that very large figures for household size, i.e. 20 members or higher, are artefacts that arose from a misunderstanding of the question.

Farmers are very heterogeneous in respect to age and the distribution is centred within the advanced age: mean age of farmers is 55.4 years with a standard deviation of 11.9 years.. The proportion of farmers that are 35 years or younger amounts to only 4.3%, while the proportion of those older than the typical Namibian retirement age of 65 years is with 20.3% relatively high (Figure 2, Table 4). One possible explanation that emerged in our qualitative data collection is that farmers are accustomed to work until old age which in turn entails that their offspring take over businesses typically at an age well beyond 30 years.

The age distribution is also reflected in the distribution of both farm experience and expected duration until retirement. Average farm experience is 25.4 years with a standard deviation of 14.3 years. At the tails of the distribution we find that only 16.5% of farmers have experience of 10 years or less whereas an almost equally sized proportion (13.2%) has experience of 41 years or more (Table 5). Farmers acquired the majority of their farm experience on their own farms: on average, farmers operated their farm for 21.1 years. Regarding retirement, we find that a third of farmers (31.9%) plan to retire within the next 10 years and almost another third (29.6%) plan to do so in the next 11 to 20 years (Table 6). 20.7% of farmers did not specify a precise duration until retirement but stated that they will continue until they either die or their children take over the business.[58]

Expected reasons for retirement (an open question) are predominantly age-related ones (82.5%) such as frailty or death (Table 7). In contrast, political (9.7%), economic (8.3%) or environmental (2.4%) conditions as well as crime (1.9%) are of only minor importance. Correspondingly, the majority of farmers expect a regular transition of the farm to the next owner (another open question) which is expected to be a family member (68.2%), an

[58] Mean age of these 20.7% of farmers is 54.4 years. Thus, we consider it likely that some of these farmers will likewise quit farming within the next 20 years. Thus, the fraction of farmers that expect to quit within this timeframe is probably even higher than the 61.5% who explicitly indicated this.

unrelated person who purchases the farm (16.6%) or a new manager (3.5%) (Table 8). Only a minority expects to be expropriated (2.7%), and an even smaller fraction expects the business to be dissolved (2.2%). The low percentage of farmers expecting expropriation of their own farm is at odds with farmers' high rating of this risk in general (see below in Section 4.2) as well as with findings from our qualitative data collection where the possibility of expropriation commands considerable attention among farmers. It thus appears as if farmers feel this risk but do not expect to be personally affected.

Farmers are almost exclusively of Afrikaans (46.1%) or German (45.3%) descent, with indigenous farmers accounting for only 5.3% (Table 9). This distribution of ethnicity reflects that commercial cattle farming was the domain of white famers until Namibia's independence in 1991, and moreover that settlement of commercial farmers occurred historically during German colonial rule and South African administration (Mendelsohn, 2006). Closely connected to the distribution of ethnicity is the classification of farmers as being emerging commercial farmers (13.8%) or not (86.2%) (Table 10). However, we acknowledge a possible bias in both ethnicity and classification as emerging commercial farmer due to our sample design: the main channel for promoting the survey was the NAU in which indigenous farmers are underrepresented. This in turn implies that indigenous farmers (and thus also emerging commercial farmers) may be underrepresented in our sample (see Olbrich et al. (2009) for a detailed discussion).[59] Finally, 80.9% of farmers are NAU members.

Education is of high importance among farmers (Table 11). In a sector where the next generation of farmers may learn the essential farm management skills by growing up on a farm, we find that only 28.4% of farmers did not receive any post-secondary education. 14.7% have learned a trade and 57% have attended college or university. Among the fields of post-secondary education, agriculture ranks highest (34.8%), followed by engineering (20.3%) and business related studies (12.3%) (Table 12). Education (4.3%) and health (3.6%) are fields of minor importance. Partly responsible for the high level of education may be that 19.9% of farmers operate only on the weekend, i.e. consider farming a secondary occupation or hobby, while earning their livelihood primarily in a field that requires post-secondary education (Table 13).[60]

[59] Based on the definition of emerging commercial farmers, the fraction of emerging commercial farmers (13.8%) should not exceed the fraction of indigenous famers (5.3%). This again suggests an artifact where part of the farmers may have misunderstood either the question referring to ethnicity or, more likely, the question referring to classification as emerging commercial farmers.

[60] Indeed, the distribution of education is shifted towards higher education among the so called "weekend farmers" as compared to fulltime farmers.

Farm features

Cattle farms in our sample are well distributed throughout the area considered to be the main commercial cattle farming area (Figure 1) (Mendelsohn, 2006: 43). Most farms are located in the regions Otjozondjupa (35.4%), Omaheke (22.3%) and Khomas (20.5%), as well as in Kunene (9.9%) (Table 14). Only few farms are in Erongo (5.6%), Hardap (2.8%) and Karas (0.8%), which are regions where precipitation conditions are very low and variable (Mendelsohn, 2006). The region Oshikoto (2.8% of farms) is largely communal farmland.

Farmer's assessments of the previous five rainy seasons show temporal variability across seasons. Average ratings on a six-item Likert-scale are above the mean of 3.5 for all seasons except for 2006/07 which was rated at only 2.9. The 2007/08 rainy season, which directly preceded the survey data collection, was rated with 4.7 as very good. Precipitation data which we elicited for the individual farms for the seasons 2006/07 and 2007/08 confirmed the above assessment: the subpar-rated 2006/07 season had an average rainfall of 270 mm which is well below the long-term average of 352 mm for the commercial cattle farming region (NMS, unpublished). In contrast, the highly rated 2007/08 season had on average 439 mm of rainfall. All in all, the temporal pattern in rainy season assessments and on-farm precipitation data conform to the pattern found the precipitation data set collected by the Namibia Meteorological Service (NMS, unpublished). In addition to temporal variability, seasons were also spatially variable: the standard deviations of the season assessments were 1.2 or higher for all seasons, and the standard deviations of on-farm precipitation were 134 mm and 136 mm for the 2006/07 and 2007/08 seasons, respectively.

Most farms are operated by an owner (91.4%), and only a small fraction by tenants (3.8%) or managers (2.8%) (Table 15). The ownership structure of farms is predominantly ownership by a single owner (69.7%) (Table 16). However, a considerable fraction of farms is organized in some form of joined ownership, which includes corporations (21.5%), partnerships, trusts or foundations (5.2%) and cooperatives (2.1%).

Farms are large, with area of *owned* farmland averaging 7,178 ha. Even the area of *owned* farmland is not sufficient for a substantial fraction of farmers: extra land is rented or used free of charge by a third of land owning farmers (32.5%)[61], resulting in *operated* farmland (i.e. *owned* farmland plus net *rented / used free of charge* farmland) averaging 8,401 ha.[62] Finally,

[61] This figure combines the fraction of farmers that have rented land for one year or less and the fraction that have rented land for more than one year.

[62] Curiously, whereas 553,986 ha of land is *rented / used free of charge*, only 74,944 ha are *rented out / given free of charge*. The discrepancy in area of 479,042 ha corresponds in turn to the difference in average owned and

not all of the operated farmland is used as *rangeland* for cattle farming but on average only 7,949 ha with the remaining 452 ha set aside for other farming purposes.[63] The large average size of *rangeland* reflects the extensive nature of cattle farming which requires large areas due to the demanding environmental conditions. At the same time, there is considerable heterogeneity in *rangeland* area with a standard deviation of 5,512 ha (Figure 3, Table 25); the same is true for *owned, rented / used free of charge* and *operated* farmland (Table 17 to Table 24). Small farms with *rangeland* area of 2,500 ha or less are relatively uncommon (7.7%) whereas farms above 7,500 ha constitute more than two fifths (42.9%) of all farms. This large heterogeneity may reflect a variety of causes such as spatial heterogeneity in environmental conditions or heterogeneity in individual farm management practices. In terms of internal organization, the *rangeland* of a farm is on average divided into 31.5 camps, which is the basic grazing unit on which cattle are kept for a period of days to weeks.

Not only the quantity of rangeland is heterogeneous across farms, but also its quality. This is less obvious when analysing overall quality of rangeland which is on average rated to be high (4.3 on a six-item Likert-scale) with an intermediate level of the standard deviation of 1.0. A different picture emerges when analysing bush cover: only one farm is classified in the lowest category of bush cover (i.e. no bushes) and only 3.8% of farms in the highest category (i.e. 81 to 100% of rangeland covered), but all other categories from low to high cover are well represented (Table 26). Almost half of the farms (48.2%) have bush cover that is intermediate or higher (i.e. 41% or more of the farm covered by bushes), but only 12.1% of farmers consider this cover to be optimal (Table 27). The majority (58.9%) instead prefers low or no cover (i.e. 0 to 20%). Indeed, 62% of farmers consider the bush cover on their farm to be too high (Table 28). A high bush cover negatively impacts the amount of grazing that is available to cattle. Consequently average grazing capacity is 0.080 LSU/ha (14.8 ha/LSU) which is less favourable than the historic 0.01 LSU/ha (10 ha/LSU) that were found on average prior to the mid 1960s (de Klerk, 2004: 21) (Table 29). Like bush cover, grazing capacity is also spatially variable across farms with a standard deviation of 0.040 LSU/ha.

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operated farmland. We cannot conclusively explain this discrepancy but one possible explanation is that we have undersampled certain segments of the commercial farmer population, specifically the emerging commercial cattle farmers. If indeed emerging commercial farmers rent out part of the "missing" area, this might suggest the existence of an informal market for renting out farmland as land acquired under the land-reform-act (by way of which many emerging commercial farmers acquired their land) may not be rented out.

[63] For all farms combined we find that total *owned* farmland amounts to 2,806,503 ha, total *rented / used free of charge* farmland to 553,986 ha, total *operated* farmland to 3,293,045 ha and total *rangeland* to 3,116,073 ha. Total *rangeland* thus constitutes 21.5% of the area of 14,500,000 ha that Mendelsohn (2006), p.42, estimated for commercial cattle farmland in Namibia, a fraction which is remarkably similar to our estimated questionnaire-return rate of 20.8%.

Finally, heterogeneity in farms is also reflected in cattle numbers (Figure 4, Table 30 to Table 32). 458 cattle were on average on each farm in April 2008, i.e. at the end of the rainy season 2007/2008, but the standard deviation is with 377 cattle considerable. Cattle owned by third persons that were kept on the farm constitute with 32 cattle on average roughly 7% of total cattle. Farmers owned with 445 cattle slightly less at the beginning of the rainy season in November 2007 but the difference in cattle numbers between beginning and end of the season was statistically significant (t-test, $p<0.05$). Without further data it is, however, impossible to tell if this difference i) is specific to the year of data collection where a drought season was followed by a good rainy season, ii) is a regular pattern or iii) has an altogether different explanation.

In terms of production systems, the sector is dominated by oxen production (47.7%), i.e. the production for sale to a slaughterhouse of 18–24 month old oxen reared from a stock of mother cows (Table 33). Of less importance is weaner production (26.9%), i.e. the production for live sales on auctions of eight months old weaners reared from a stock of mother cows, and speculation production (12.0%), i.e. the production for sale to a slaughterhouse of oxen reared from purchased weaners. Thus, even though environmental conditions are fairly unstable in Namibia, farmers focus on the production system that has the most demanding requirements on environmental condition as feed has to be available throughout the whole production cycle of 27–33 months (which includes the mother cow's pregnancy of 9 months). The likely explanation is that this production system also offers the highest profits (Olbrich, 2011).

Farmers predominantly belong to the top Namibian income groups. To conclude this we compare our income data to the latest available national income data that was elicited in 2003/2004 (CBS Namibia, 2006: 38). In order to make this comparison we have to express our data in 2004 prices which we do by adjusting for the consumer price inflation rate of 20% in the period 2004–2008 (CIA, 2011). We then find that those 83.9% of farm households who report an annual net income of more than N$ 50,000 in 2008 (Table 34) have a corresponding income of N$ 41,666 in 2004 prices which places them considerably above the median income (i.e. N$ 29,361). Those 19.6% of farmers that report an income of above N$ 350,000 have a corresponding income of above N$ 291,666 in 2004 prices which places them somewhere in the top five percentiles (i.e. those 5% of households that earn more than N$ 183,227).[64] In terms of income diversification we find that most farmers only partly rely on

[64] The top percentile is located at N$ 339,455.

cattle farming for income, with 70.8% of farmers deriving 80% or less from cattle farming (Table 35). Alternative income sources are on-farm services and products such as tourism (7.8%), small stock (5.9%) and game farming (3.3%) (Table 36), as well as off-farm income which 61.1% of farmers obtain to some degree (Table 37).

4.2 Risks faced by farmers

Of all risks, farmers are most concerned with economic risks. The risk of unfavourable trade agreements on beef export is rated highest (5.3 on a six-item Likert-scale), followed by the risk of unfavourable input prices (5.2), of unfavourable cattle output prices (5.1) and of rising living expenses (5.0). The high ratings of these risks may in part be influenced by events occurring prior to the survey, which included the renegotiation of Namibia's trade agreements to the EU (Meyn, 2007), volatile petrol prices (DE, 2011) and living expenses (CBS Namibia, 2010: 3) and volatile beef and weaner prices (Meat Board, unpublished), but may also indicate a general wariness of economic risks.

Environmental risks are in part assessed to be high such as the risk of bush fire striking the farm (4.8), the rainfall risk (4.6) or the risk of low groundwater level (4.5), and in part assessed to pose an intermediate threat such as the risk of cattle diseases (3.7) or of cattle losses from predators (3.6). We presume that the latter two risks are rated relatively low since techniques like vaccination or hunting predators exit to mitigate these risks.

Risks pertaining to the political or social situation are likewise assessed to be high. The risk of changing labour market conditions (4.8) might hereby reflect a concern with further restriction on the labour market that make employing and laying-off farm workers more difficult after similar laws have already been passed in recent years. The risk of expropriation is also rated to be high (4.8), reflecting the uncertain situation on how the land reform in Namibia will evolve. However, as already discussed above, the high rating of this risk in general is at odds with what famers expect in regards to the future of their own farm (c.f. Table 8). Risk of cattle theft (4.4) is also high and matches information from qualitative interviews as well as regular media reports of such incidents (e.g. Isaacs, 2007).

Lastly, failure of machinery or infrastructure (3.3) is rated lowest of all risk. The likely reason is again that techniques exit to specifically mitigate this risk.

Heterogeneity in risk rating across farmers differs considerably between risks. Standard deviations of ratings for environmental risk such as low groundwater level (standard deviation: 1.7), cattle diseases (1.6) or cattle losses from predators (1.6) are relatively heterogeneous while others such as the market price risks (1.0 to 1.1) are much more homogenous. One explanation is that some risks may differ in their exogenous characteristics at the local scale, which fits well to our findings for most environmental risks. Other risk may be fairly homogenous at the national scale, which in turn may be what we are seeing in the high homogeneity of ratings of economic risks.[65]

4.3 Risk management strategies

Farmers predominantly consider on-farm management strategies to be important in the management of risky pasture production. Especially those on-farm strategies where the decision process is in the hand of farmers are rated high, i.e. resting part of the rangeland as a reserve in good rainy seasons (4.7 on a six-item Likert-scale), purchase of supplementary feed (4.7), choice of breed adapted to high variability in grass production (4.5) and choice of cattle production system (4.4). In contrast, the two remaining on-farm strategies, i.e. purchase/lease of rangeland for spatial diversification (3.3) or scale effects (3.3), are rated considerably lower. We cannot conclusively explain these latter two findings.

Financial risk management strategies are of less importance. Checking accounts as a financial buffer (4.7), income from off-farm employment or assets (4.0) and forward contracts (3.9) are all rated relatively high, which is unsurprising since farmers generally have a checking account, derive at least some off-farm income (see Section 4.1) and frequently conclude forward contracts for cattle sales with MeatCo. In contrast, farmers seem to be sceptic towards the remaining financial management strategies: advances on livestock sales (3.1), loans for covering operating losses (3.0) and investment into agricultural derivatives (2.4) are among the lowest rated strategies.

Collective risk management strategies are a mixed bag. Highest rated among these, and indeed among all risk management strategies, are interest groups at a national level such as the NAU (5.0), presumably because they may address a variety of economic, social and political risks. Government support (3.9) and interest groups at a local level (3.8) are rated at intermediate importance. Cooperative ownership of farmland (2.4) is of low importance, which agrees with the result that this organizational form of farms is adapted for only a small fraction of farms (see Section 4.1 above).

In regards to heterogeneity in ratings across farmers, we find considerable heterogeneity for most risk management strategies (standard deviation of 1.6 to 1.8). Our interpretation of this

[65] For completeness, we note that not only the exogenous characteristics but also a variety of factors relating to endogeneity of risks may determine heterogeneity of risk ratings across farmers (Shogren and Crocker, 1999).

finding is firstly that farmers differ in the general extent in which they employ risk management and secondly that many individual strategies may be substitutes which leaves the individual farmer considerable leeway in the choice of specific strategies.

4.4 Risk and time preferences

Farmers are predominantly risk averse, as indicated by responses in hypothetical risk experiments in the questionnaire as well as in the in-field experiments (Table 38 and Table 39). In a detailed analysis of the risk experiments, Olbrich et al. (2011d)) calculate for the average farmer a point estimate for the coefficient of relative risk aversion (CRRA) of 0.78.[66] This estimate is slightly higher than the value of 0.54 reported for a field study of semi-subsistence farmers in Ethiopia, India and Uganda by Harrison et al. (2010), but in range with the value of 0.79 provided for the Danish population by Andersen et al. (2006). In an alternative approach for eliciting risk preferences through a self-assessment question on a nine-item Likert-scale ranging from very risk averse (1) to very risk loving (9), farmers indicate on average a value of 5.3. If one assumes that risk neutrality is located in the exact middle of the Likert-Scale, at a value of 5, then the average value of 5.3 would indicate slight risk attraction. This is at odds with above findings from the risk experiments. However, a detailed analysis on the location of risk neutrality on the Likert-Sale is beyond the scope of this publication and we thus cannot conclude in how far average values calculated from both elicitation approaches agree. Finally, in regards to heterogeneity of risk preferences we find intermediate levels of variability in both the hypothetical and in-field experiments, where the majority of farmers are placed in a few closely connected categories (Table 38 and Table 39), and in the self-assessment question, where the standard deviation amounts to 2.1. Such heterogeneity is not unexpected and has been frequently demonstrated in studies of risk preferences (e.g. Andersen et al., 2006).

Farmers are of intermediate impatience. Responses of farmers in the hypothetical as well as in the in-field time preference experiments are centred on discount rates between 10% and 30% (Table 40 and Table 41). The distribution of discount rates is shifted towards slightly higher discount rates as compared to findings from other field studies, such as for the Danish population (Harrison et al., 2005c). Calculating point estimates of discount rates is again beyond the scope of this publication. Hence, we do not report these here. Intermediate impatience is also reflected by responses to an alternative self-assessment question on a nine-

[66] In Olbrich et al. (2011d), as well as in the subsequently cited papers, a positive value of the CRRA indicates risk aversion, a negative value risk attraction and a value of zero risk neutrality.

item Likert-scale ranging from very impatient (1) to very patient (9) with an average value of 5.5. In regards to heterogeneity of time preferences we find the same picture as for risk preferences: intermediate variability may be found in responses to both hypothetical and in-field time experiments as well as in the self-assessment question. Heterogeneity of time preferences has likewise been demonstrated in previous studies (e.g. Harrison et al., 2005c).

4.5 Normative views of sustainability

Our conceptualization and operationalization of sustainability is detailed in Baumgärtner and Quaas (2009) and Olbrich et al. (2011b), and we briefly summarize it here. We *conceptualize* sustainability as a norm, i.e. as an obligation to "pass on a world of undiminished life opportunities to members of future generations" (Howarth, 2007). From this rather abstract norm, individuals derive normative views (also called personal norms) of sustainability that are heterogeneous across individuals and provide concrete guidance on how to act. We *operationalize* these normative views through ecological-economic viability (Baumgärtner and Quaas, 2009), a criterion for strong sustainability under uncertainty. Normative views of sustainability then pertain to i) what should be sustained ("objects"), ii) how much at least of each of them ("thresholds"), iii) to what extent of risk ("acceptable risk") and iv) for how long ("time horizon").

Prior to the survey we had already identified in our qualitative interviews that grazing capacity (which may be viewed as a proxy for ecosystem condition) and income are the most relevant objects that should be sustained. Consequently, we elicited in the survey

- sustainable grazing capacity (sustainable income) as the threshold at or above which grazing capacity (income) should be sustained,
- acceptable grazing capacity risk (acceptable income risk) as the acceptable risk that grazing capacity (income) falls below the threshold, and
- time horizon over which grazing capacity and income should be sustained at the respective thresholds.

We find that farmers consider on average that grazing capacity should be sustained at or above a threshold of 0.082 LSU/ha[67] and annual net income at or above a threshold of N$ 275,791. Even though these values are close to actual values for grazing capacity and income

[67] In the questionnaire we elicited the characteristic in the unit ha/LSU. We report the inverted value because higher values then denote more demanding norms. For example, it is more demanding to require that grazing capacity is 0.08 LSU/ha instead of only 0.04 LSU/ha.

(see Section 4.1), the respective correlation coefficients are of only intermediate to high values with 0.65 for the correlation between actual and sustainable grazing capacity (Spearman correlation, $p<0.001$) and of only intermediate values with 0.42 for the correlation between actual and sustainable income (Spearman correlation, $p<0.001$). Thus, it is not just the actual conditions that determine normative views of grazing capacity and income. We will not pursue this question here as it is treated in more detail in Olbrich et al. (Olbrich et al., 2011b). Heterogeneity for both sustainable grazing capacity and income is high with standard deviations of 0.045 LSU/ha and N$ 206,897 and, respectively.

In regards to the time horizon for sustaining grazing capacity and income we find that 8.7% of farmers do not care about the future beyond their own generation, whereas 16.1% of farmers have a very long outlook, i.e. ten generations or more (Table 42). Most farmers (56.1 %) indicated that grazing capacity and income ought to be sustained for the two generations following their own generation, i.e. for the generations of their children and grandchildren, which is the timeframe that most farmers will be expected to experience in their lifetime.

Acceptable grazing capacity risk and acceptable income risk are both centred at an intermediate value of 0.6.[68] Distributions of both probability thresholds are, however, spread out over the whole range of possible values, as exemplified a standard deviation of 0.2 for both characteristics, revealing large heterogeneity across the farmers' population.

In addition to these normative views pertaining to grazing capacity and income, we asked in an open question what should be sustained besides those two objects. Farmers predominantly indicated groundwater level (36.7%) and ecosystem quality (27.6%), reflecting farmers' worries about falling groundwater levels (see Section 4.2) and about degrading ecosystems (Table 43). Furthermore, the sustainability of the social order in an encompassing way appears to be important as farmers also indicated that social conditions (15.4%), the political conditions (14.3%) and infrastructure (10.5%) should be preserved.

[68] In the questionnaire we elicited acceptable grazing capacity risk (acceptable income risk) as in how many out of every ten years it is manageable that income (grazing capacity) falls *below* the specified income (grazing capacity) threshold. We make two adjustments in the way we report these characteristics here: firstly, we recalibrate them so that they now specify the still acceptable risk that grazing capacity (income) is *above* the threshold. Secondly, we express values as probabilities where one year out of every ten years is expressed at a probability value of 0.1, two years as a probability value of 0.2, and so forth.

5. Cluster analysis

5.1 Statistical methods

In the previous section we characterized commercial cattle farms by describing individual characteristics separately. We now analyze characteristics jointly through a cluster analysis to explore whether we may classify farms into similar groups. In regards to risks and risk management strategies we focus on the dominant precipitation risk and the on-farm and financial risk management strategies. Thus, we will omit all other risks as well as collective risk management strategies.[69]

Specifically, we conduct a hierarchical cluster analysis. We use Ward's method for agglomeration over an N x N dissimilarity matrix, where N is the number of observations (Ward, 1963). The matrix contains as elements the Gower dissimilarity measure between observations which is designed to accommodate both continuous and binary characteristics (Gower, 1971). It is defined as

$$D_{ij} = \frac{\sum_k w_{ijk} d_{ijk}}{\sum_k w_{ijk}}$$

where D_{ij} is the dissimilarity between observation i and j as the sum of the dissimilarities d_{ijk} between observation i and j with respect to each characteristic $k = \{1, \ldots, K\}$ (StataCorp, 2007; Everitt et al., 2011). w_{ijk} is a binary indicator that takes on the value 1 if observations i and j have non-missing entries for characteristic k and is 0 otherwise. We only include observations that have non-missing entries for all K characteristics since all D_{ij} are then calculated over the same set of characteristics. Thus, w_{ijk} always takes on the value 1, and the denominator equals K.

The specification of d_{ijk} differs between binary and continuous characteristics. For binary characteristics,

$$d_{ijk} = \begin{cases} 0 & if\ x_{ik} = x_{jk} \\ 1 & otherwise \end{cases},$$

where x_{ik} and x_{jk} are the values that characteristic k takes on for observations i and j, respectively. For continuous characteristics,

[69] Including these other risks and collective management strategies, which are altogether 16 characteristics, would exact the cluster analysis to classify at least partly according to them instead of only according to the more relevant other characteristics.

$$d_{ijk} = \frac{\left| x_{ik} - x_{jk} \right|}{\max(x_k) - \min(x_k)},$$

which standardizes the absolute distance between x_{ik} and x_{jk} by the range of values that characteristic k takes on over all observations.

We chose the number of clusters by calculating the pseudo F index (Calinski and Harabasz, 1974), where large values indicate a good number of clusters, and the pseudo T squared Je(2)/Je(1) index ("pseudo T squared index") (Duda and Hart, 1973), where low values indicated a good number of clusters, and by subsequently identifying local maxima and minima, respectively. As a robustness check we require that both indices display local optima at the same number of clusters. Subsequent to the cluster analysis, we examine in regards to which characteristics the clusters differ significantly overall and exactly which clusters are responsible for the significant difference. For continuous characteristics, we thereto conduct one-way analyses of variance (ANOVA) followed by pair-wise, Bonferroni-corrected t-tests. For binary characteristics, we conduct Chi-square tests followed by pair-wise, Bonferroni-corrected Chi-square tests. All analyses are performed using the Stata/SE 10.1 statistical software package.

5.2 Data processing

Not all characteristics we describe in Section 4 are suitable for the cluster analysis in the way we measured them, and we have to transform, aggregate and exclude several characteristics.

We transform categorical measured characteristics into binary characteristics where the values '1' denotes the most frequent category.[70] We transform ordinal measured characteristics into interval-scaled discrete characteristics with the artificial unit "index point" where the value '1' denotes the first category, the value '2' the second category and so forth.[71] In regards to the time horizon characteristic we set all values greater than ten generations, such as "forever", to the value ten generations. In regards to risk and time preferences we construct indices for risk and time preference out of the raw responses to the respective hypothetical experiments in the questionnaire: subjects typically prefer in the risk experiments the lottery (which is in our case the cattle auction) when the certain amount is low and in the time experiments the earlier payment when the later payment is likewise low. They switch once the

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[70] For example, the categorical measured characteristic 'ownership structure' (Table 16) is transformed in such a way that the value '1' denotes single owners (the most frequent category, indicated by 69.7% of respondents) whereas the value '0' denotes the other structures that involve multiple owners.

[71] For example, the ordinal measured characteristic 'actual bush cover' that has six categories is transformed into a discrete characteristic that takes on the values 1, 2, …, 6.

certain amount or the later payment are deemed high enough, and we take this switch point as an index for risk and time preference, respectively. We thus construct a risk preference index as a discrete characteristics with values in {1, 2, …, 7} where low values denote high risk aversion, i.e. those farmers who already switch to the certain amount when it is still low. Conversely, high values denote risk attraction, i.e. those farmers who only switch to the certain amount when it is high. For the time preference index we construct a discrete characteristic with values in {1, 2, …, 6} where low values denotes patience, i.e. those farmers who only already switch to the later amount when it is low. Conversely, high values denote impatience, i.e. those farmers only never if the later amount is high.[72]

We aggregate all characteristics that denote area of land rented and land rented out, regardless of duration of rental period, into a single characteristic that denotes net rented land, i.e. land rented minus land rented out. We also aggregate the characteristics that denote the rainy season assessment of the previous five seasons into one characteristic that denotes the average assessment across the five seasons.

We exclude those measures for risk and time preferences that we elicited in the in-field risk experiments since they are available for only 39 farmers. We also exclude the measure that we elicited as self-assessed preferences through the Likert-scales since we wish to include only one type of preference measures. Furthermore, we exclude all characteristics that were elicited in open questions. Finally, when calculating the Gower dissimilarity measure, highly correlated characteristics may bias results as the impact of these characteristics on the measure is overemphasized with respect to the remaining characteristics (Backhaus et al., 2006: 550). We alleviate this issue by excluding characteristics that display a correlation coefficient of 0.6 or higher to any other characteristic. After all exclusions, we retain a set of 33 characteristics over which we conduct the cluster analysis (Table 45).[73] We report the most important omitted characteristics in the table that displays the results alongside the included characteristics but will not explicitly discuss them in the text. Due to exclusion of any farm that has a missing value for at least one included characteristic, we remain with 108 farms for the analysis.

[72] As Olbrich et al. (2011d) detail, we encountered irregularities for some farmers in the risk experiments, which we treated as artifacts and excluded in our further analyses. Similar irregularities were encountered in the time experiments and the respective observations were likewise excluded.

[73] After exclusion, the vast majority of characteristics are weakly correlated: out of the 528 unique characteristics pairs, only 11 show a correlation coefficient of 0.4 or larger.

5.3 Results

In reporting results, we upfront note that we make three language simplifications for convenience sake: firstly, we talk about characteristics of clusters when we of course actually refer to characteristics of the farmers or farms included in the respective clusters; secondly, the values we report are cluster-averaged values, but we do not explicitly refer to them as "averaged"; thirdly, when we state that a cluster is "different" we always mean, unless otherwise noted, that the discussed clusters differ significantly from *all* other clusters.

Both the pseudo F- and the pseudo T-index have optima jointly at a number of three and nine clusters (Figure 5, Table 44). At three clusters the pseudo T-index has a global minimum while the pseudo F-index has only a local maximum. Conversely, at nine clusters the pseudo F-index has a global maximum and the pseudo T-index' only a local minimum. Examining both indices thus does not give a unique solution to the optimal number of clusters. Nonetheless, we report the three cluster solution as the nine cluster solutions has two disadvantages: firstly, it is not very insightful as the number of clusters is so large that individual clusters are distinct in only very few characteristics; secondly, under this solution we encounter clusters with fewer than 7 observations, making the validity of the analysis doubtful due to the low number of observations.

Cluster EnFiMa

This cluster is the smallest in that it contains 26 out of the 108 analyzed farms, but is also the most distinct cluster. It differs significantly from each of the two other clusters in 10 out of the 33 analyzed characteristics (Table 45). It is best described by favourable environment and low financial risk management ("EnFiMa"), for the following reasons: in regards to environmental characteristics, it has the highest grazing capacity (0.089 LSU/ha; $p<0.05$) and the lowest rating of rainfall risk (4.4 on a six-item Likert-scale; $p<0.1$), but differs in the latter only at the significance level of 10% and only from one other cluster. It also has the most favourable values for average rainy season assessment and actual bush cover, but differences to the other clusters are not significant. Thus, of the aforementioned environmental characteristics it is mainly grazing capacity and to a lesser extent (perceived) rainfall risk that makes this cluster distinct.

In regards to risk management, it has the lowest ratings of the three clusters for all financial risk management strategies, albeit the differences are significant only for the strategies *advances on livestock sales* (1.4 on a six-item Likert-scale; $p<0.05$) and *loans for covering operating losses* (1.5; $p<0.01$). In contrast, it does not have the lowest ratings of the three clusters for all on-farm strategies but only for three of these strategies: for *purchase/lease of rangeland for scale effects* (2.7; $p<0.1$), albeit at only the 10% significance level; and for *choice of production system* and *choice of breed* (both 3.9; $p<0.05$), albeit differing in both strategies only from one other cluster. Thus, as differences are more pronounced and consistent for financial risk management strategies we consider them, and not on-farm management strategies, as the distinctive characteristics of this cluster.

Cluster EnFiMa also has the most demanding normative views pertaining to acceptable grazing capacity risk (probability threshold of 0.7; $p<0.05$), possibly because farmers in this cluster experience low environmental risk and can thus “afford” this more demanding normative view. Other normative views are not significantly different. Finally, it is distinct in two characteristics which are not obviously related to environmental condition and management: it has the lowest number of household members (2.7 members; $p<0.1$) and it is the most patience (2.6 index points out of 6, $p<0.1$), albeit it is again significantly distinct in the latter characteristics from only one other cluster. It does not differ in any other personal and farm features or in risk preferences.

Cluster MultOwn

Based on the distinctive characteristics of cluster EnFiMa, the remaining two clusters are accordingly characterized by relatively unfavourable environmental conditions and relatively high financial risk management. Beyond this distinction, however, they also have their own distinct characteristics. The next largest cluster with 36 farms is significantly distinct in five such characteristics and best characterized by multiple owners (“MultOwn”) as it has the highest proportion of them (41.7% of single owners, corresponding to 58.3% multiple owners; $p<0.01$). It also has the highest area of net rented land (2,587 ha, $p<0.05$) and the highest area of rangeland, although the difference to the other clusters is not significant. We may interpret this as a tenuous indication that multiple owners have the means to operate altogether larger farms. This cluster also differs from the other clusters in characteristics that are less obviously associated with multiple ownership: it has the highest rating of the strategy *advances on livestock sales* (3.6; $p<0.05$), the lowest rating of the strategy *resting part of the rangeland* (4.1; $p<0.05$) and the youngest farmers (46.9 years; $p<0.01$), albeit it is in the latter two characteristics distinct from only one cluster.

Cluster "Afrikaans"

The largest cluster with 46 farms is distinct in four characteristics. It is difficult to describe this cluster as we see no obvious connection between these characteristics; we opt to describe it as Afrikaans farmers ("AFRIKAANS") as it exclusively consists of farmers of this ethnicity ($p<0.01$). Beyond this distinction, it has an intermediate rating of the strategy *advances on livestock sales* (2.6; $p<0.05$) and, differing significantly from one other cluster, has the lowest proportion of oxen production (42.3%; $p<0.01$) and the lowest education level (3.4 index points; $p<0.05$). Both clusters MULTOWN and AFRIKAANS are not distinct in preferences or normative views.

Altogether, we thus also observe heterogeneity of cattle farms when classifying them, albeit only one cluster of farms is very distinct. Accordingly to the key distinctive characteristics of this cluster, classification is predominantly driven by environmental characteristics and farmer's management, in the form of financial risk management. To a lesser extent, classification is driven by organizational structure and ethnicity, the defining characteristics of the remaining two clusters. Overall, preferences and normative view play only a marginal role for classification.

6. Discussion and conclusion

We characterize farms for commercial cattle farming in Namibia, a prime example of livestock farming in semi-arid rangelands. We find that cattle farms are heterogeneous in a wide range of characteristics, as indicated by high standard deviations. When classifying farms in a cluster analysis according to personal and farm features, perceived rainfall risk, self-reported risk management, risk and time preferences and normative views of sustainability, we also find heterogeneity as exemplified by the identification of three separate clusters. Classification is driven predominantly by environmental conditions and financial risk management and to a lesser extent by organizational structure of farms and ethnicity.

It is interesting to note which characteristics are *not* driving farm classification. Firstly, risk and time preferences and normative views of sustainability are only marginally important for classification. Based on the observed concomitant differences in management one might hypothesize that preferences and normative views, which are key behavioural determinants, are at least for our case study not related to management behaviour. Regarding preferences, this is controversial and we do not expect that such a hypothesis will be uphold under more in-depth scrutiny than can be achieved through a cluster analysis. Regarding normative views, however, we find indeed no evidence that they impact on farm management in an in-depth analysis (Olbrich et al., 2011b). Secondly, weekend farming, a characteristic typically employed by local farmers and decision makers for farm classification, also does not drive our classification. It thus seems that it is of minor importance in comparison to the farms' environment and management. Finally, income does not differ across clusters. This is curious in the light of the observed differences in environmental condition, specifically in grazing capacity, and in financial risk management, as one might expect that differences in income are associated with differences in the latter characteristics. One possible explanation is that increased financial risk management, while stabilizing income, negatively impacts on grazing condition and thus ultimately leads to a degradation of the system (Quaas and Baumgärtner, 2008).

By means of the last observation we note the limitations of the cluster analysis: it cannot be used to make definite statements concerning the causal relationship between single characteristics and thus cannot be a substitute for an in-depth analysis. Thus, we cannot clarify the exact relationship between environmental condition, financial risk management and income without further analysis, as we have for example done in respect to normative views (Olbrich et al., 2011b).

Altogether, this study is the first to provide a comprehensive characterization of Namibian commercial cattle farms in respect to risk, management and sustainability. It provides the basis for more in-depth analyses of the system, in particular by identifying issues that may warrant close attention. It furthers the understanding of the system and may ultimately contribute to the development of policies that promote sustainability of commercial cattle farming in Namibia.

Acknowledgements

Many scientist, experts and farmers contributed with their comments and discussion to the design of this survey, and we wish to express our gratitude to all of them. Special thanks go to Volker and Ursula Dieckhoff, Arne Gressmann, Claus Hager, Jürgen Hoffmann, Harald Marggraff, Thomas and Heidrun Peltzer, Elsabe Steenkamp, Peter Zensi and Ibo Zimmermann. We also thank our cooperating organizations Agra Co-operative Ltd., Namibia Agricultual Union and Namibian Agronomic Board. Finally, we are grateful to the German

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Appendix A: Descriptive statistics, figures

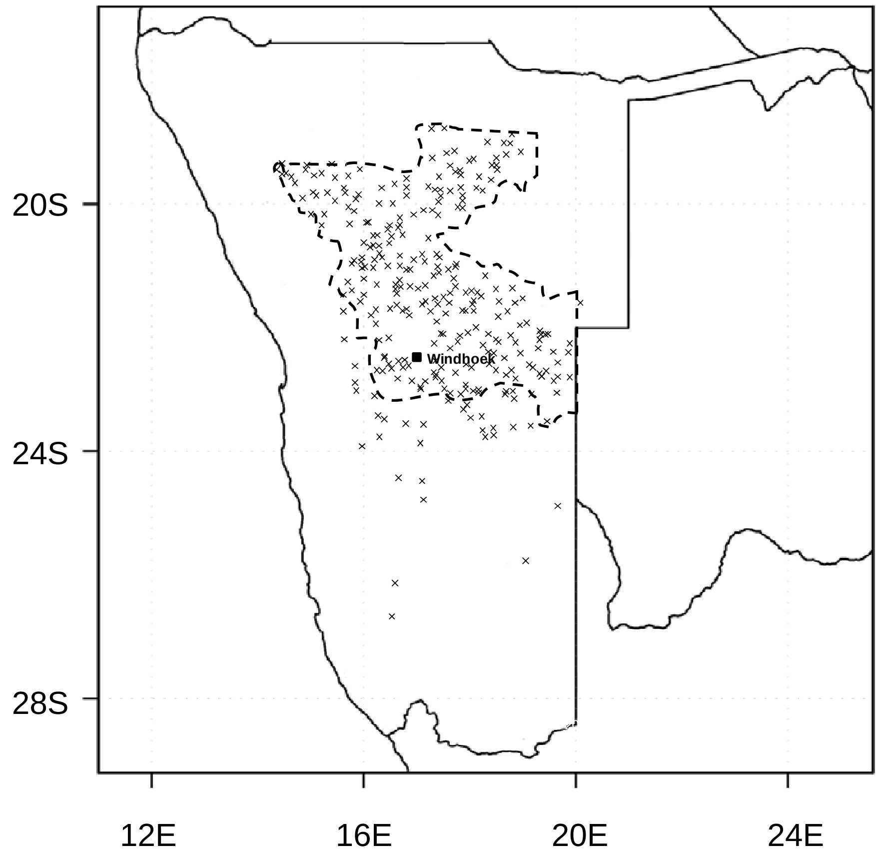

Figure 1: Commercial cattle farms in Namibia. Dashed line denotes what is considered the commercial cattle farming area (Mendelsohn, 2006). Crosses denote position of all 299 farms which were identified in our mail-in questionnaire.

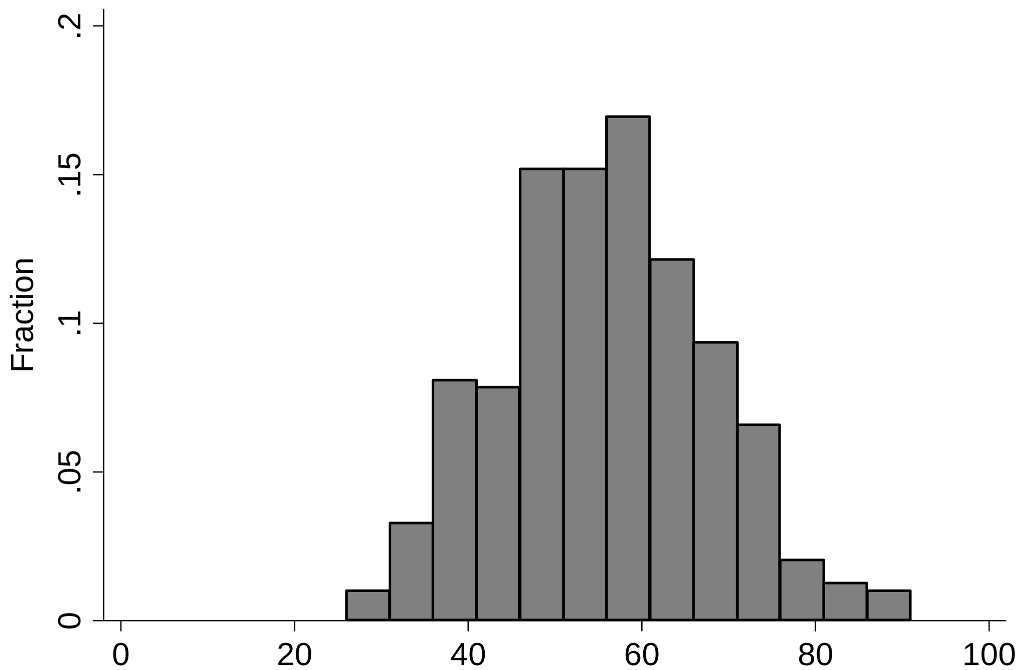

Figure 2: Distribution of age. N = 395.

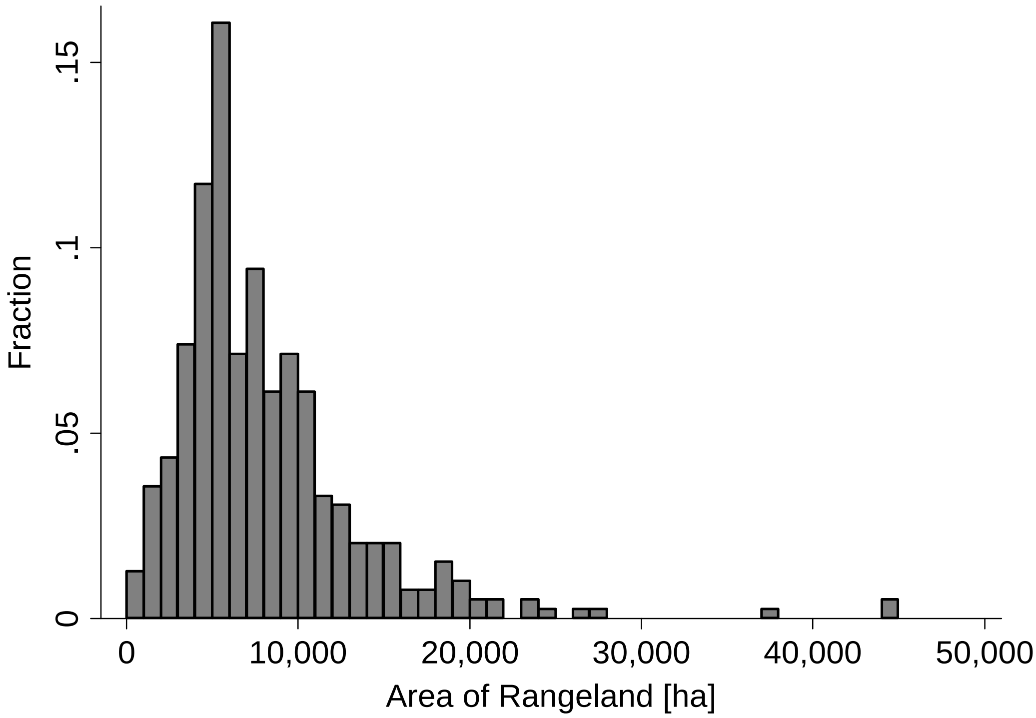

Figure 3: Distribution of area of rangeland. N = 392.

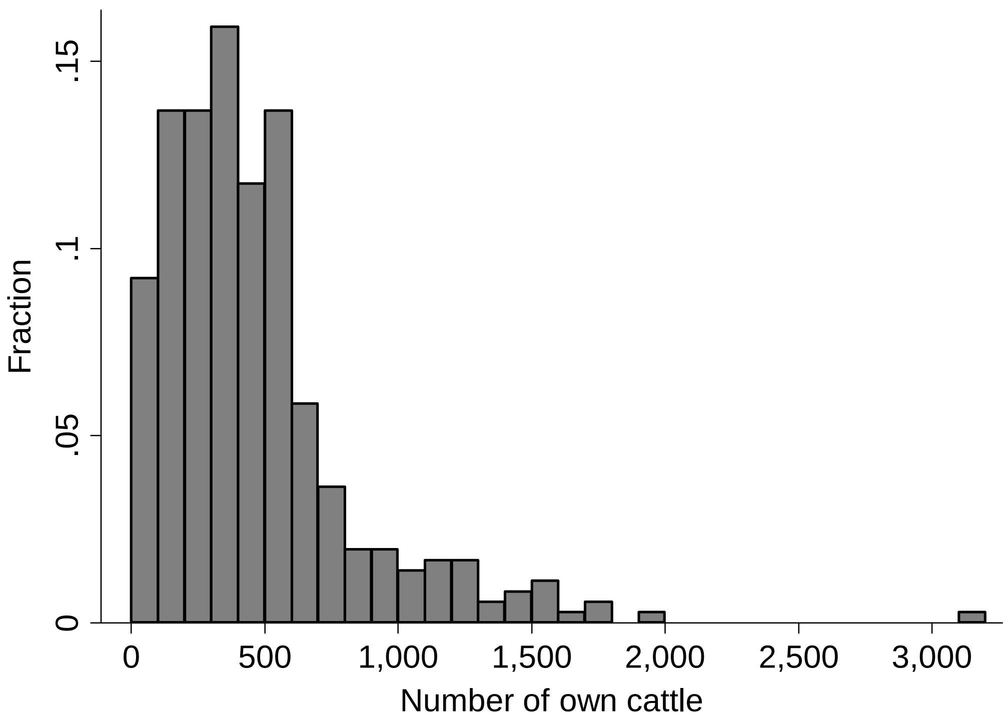

Figure 4: Distribution of own cattle on farm in April 2008. N = 358.

Appendix B: Descriptive statistics, table of summary statistics

Table 1: Summary statistics for the areas 1) personal and farm features, 2) risks faced by farmers, 3) risk management strategies, 4) individual risk and time preferences and 5) normative views of sustainability. Displayed are mean, median, standard deviation, minimum and maximum for all continuous and Likert-scale measured characteristics. Characteristics are listed in the order in which they are discussed in the text.

Characteristics	Mean	Median	Std. dev.	Min	Max
1) Personal and farm features					
Household size *[number of members]*	3.7	3.0	3.7	1.0	46.0
Age *[years]*	55.4	55.0	11.9	27.0	90.0
Farm experience *[years]*	25.4	24.0	14.3	0.3	84.0
Duration for operating own farm *[year]*	21.1	20.0	13.3	0.0	69.0
Rainy season assessment					
[1=very poor, 6=very good]					
2003/04	3.6	4.0	1.2	1.0	6.0
2004/05	3.7	4.0	1.2	1.0	6.0
2005/06	5.0	6.0	1.2	1.0	6.0
2006/07	2.9	3.0	1.5	1.0	6.0
2007/08	4.7	5.0	1.2	1.0	6.0
On-farm precipitation [millimetre]					
Oct 2006	34	29	30	0	200
Nov 2006	36	31	30	0	180
Dec 2006	54	43	46	0	188
Jan 2007	62	55	46	0	330
Feb 2007	44	31	47	0	227
Mar 2007	49	37	46	0	415
Apr 2007	26	19	28	0	230
May–Sept 2007	1.2	0	7	0	73
Total rainy season[74] 2006/07	270	259	134	13	815
Oct 2007	15	11	17	0	140
Nov 2007	15	11	17	0	102
Dec 2007	26	18	28	0	152
Jan 2008	102	90	70	0	374
Feb 2008	165	155	79	0	463
Mar 2008	113	109	53	0	520
Apr 2008	18	10	28	0	200
May–Sept 2008	3	0	7	0	62
Total rainy season[17] 2007/08	439	429	136	89	980

[74] The rainy season is defined as 1st of November until 30th of April the following year.

Characteristics (continued)	Mean	Median	Std. dev.	Min	Max
Size of farmland [hectare]					
Land owned	7,178	6,000	5,472	0	57,000
Land rented for one year or less	137	0	654	0	5000
Land rented for more than one year	1,151	0	2,731	0	14,000
Land used free of charge	130	0	923	0	10,500
Land rented out for one year or less	66	0	492	0	5017
Land rented out for more than one year	72	0	433	0	4,600
Land entrusted to others	53	0	497	0	8,500
Land operated	8,401	7,000	6,172	0	64,000
Rangeland	7,949	6,765	5,512	0	44,244
Camps *[number of camps]*	31.5	24	24.3	1	152
Land quality *[1=very poor quality, 6=very good quality]*	4.3	4.0	1.0	1.0	6.0
Grazing capacity *[Large Stock Unit per hectare]*	0.080	0.077	0.040	0.012	0.500
Cattle on farm [number of cattle]					
Own cattle, Nov 2007	445	368	369	0.0	3200
Own cattle, Apr 2008	458	370	377	0.0	3200
Cattle of third person on farm, Apr 2008	32	0	102	0.0	1238
2) Risks faced by farmers *[1=no risk, 6=very high risk]*					
Environmental risks					
Rainfall	4.6	5.0	1.2	1.0	6.0
Low groundwater level	4.5	5.0	1.7	1.0	6.0
Bush fire	4.8	5.0	1.4	1.0	6.0
Cattle diseases	3.7	4.0	1.6	1.0	6.0
Cattle losses from predators	3.6	4.0	1.6	1.0	6.0
Economic risks					
Unfavourable cattle output prices	5.1	5.0	1.1	1.0	6.0
Unfavourable input prices	5.2	6.0	1.0	1.0	6.0
Rising living expenses	5.0	5.0	1.1	1.0	6.0
Unfavourable trade agreements on beef export	5.3	6.0	1.0	1.0	6.0
Political risks					
Changing labour market conditions	4.8	5.0	1.2	1.0	6.0
Expropriation	4.8	5.0	1.3	1.0	6.0
Cattle theft	4.4	5.0	1.4	1.0	6.0
Failure of machinery or farm equipment	3.3	3.0	1.5	1.0	6.0

Characteristics (continued)	Mean	Median	Std. dev.	Min	Max
3) Risk management strategies *[1=not at all important, 6=very important]*					
On-farm management strategies					
Purchase of supplementary feed	4.7	5.0	1.5	1.0	6.0
Choice of cattle production system	4.4	5.0	1.4	1.0	6.0
Choice of breed adapted to high variability in grass production	4.5	5.0	1.3	1.0	6.0
Resting part of rangeland in good rainy seasons	4.7	5.0	1.5	1.0	6.0
Purchase/lease of rangeland for spatial diversification	3.3	3.0	1.7	1.0	6.0
Purchase/lease of rangeland for scale effects	3.3	3.0	1.7	1.0	6.0
Financial management strategies					
Forwards contracts	3.9	4.0	1.8	1.0	6.0
Advances on livestock sales	3.1	3.0	1.8	1.0	6.0
Checking account as financial buffer	4.7	5.0	1.4	1.0	6.0
Loans for covering operating losses	3.0	3.0	1.7	1.0	6.0
Income from off-farm employment or assets	4.0	4.0	1.7	1.0	6.0
Investment into agricultural derivatives	2.4	2.0	1.6	1.0	6.0
Collective management strategies					
Cooperative ownership of farmland	2.4	2.0	1.7	1.0	6.0
Governmental support	3.9	4.0	1.8	1.0	6.0
Interest groups on a local level	3.8	4.0	1.6	1.0	6.0
Interest groups on a national level	5.0	5.0	1.3	1.0	6.0
4) Individual risk and time preferences					
Self-assessment of risk preferences *[1=avoid to take risks, 9=willing to take risks]*	5.3	6.0	2.1	1.0	9.0
Self-assessment of time preferences *[1=not willing to wait, 9= willing to wait]*	5.5	6.0	2.5	1.0	9.0
5) Normative views of sustainability					
Sustainable annual net income *[N$]*	275,791	240,000	206,896	4,000	2,000,000
Sustainable grazing capacity *[LSU/ha]*	0.082	0.077	0.045	0.013	0.05
Acceptable income risk *[probability]*	0.6	0.4	0.2	0.0	1.0
Acceptable grazing capacity risk *[probability]*	0.6	0.4	0.2	0.0	1.0

Appendix C: Descriptive statistics, frequency tables

Each table contains frequencies per category, give as number of observations, column percentages and cumulative percentages. The exceptions are tables for binary characteristics and for those elicited by open questions which do not contain cumulative percentages.

Table 2: Gender.

Gender	No.	Col. %
Female	21	5.3
Male	376	94.7
Total	**397**	**100.0**

Table 3: Household size.

Household size	No.	Col. %	Cum. %
One member	26	6.6	6.6
Two members	150	38.2	44.8
Three members	49	12.5	57.3
Four members	78	19.8	77.1
Five members	41	10.4	87.5
Six to ten members	43	10.9	98.5
Eleven members or more	6	1.5	100.0
Total	**393**	**100.0**	

Table 4: Age.

Age	No.	Col. %	Cum. %
25 to 30 years	4	1.0	1.0
31 to 35 years	13	3.3	4.3
36 to 40 years	32	8.1	12.4
41 to 45 years	31	7.8	20.3
46 to 50 years	60	15.2	35.4
51 to 55 years	60	15.2	50.6
56 to 60 years	67	17.0	67.6
61 to 65 years	48	12.2	79.7
66 to 70 years	37	9.4	89.1
71 to 75 years	26	6.6	95.7
76 to 80 years	8	2.0	97.7
81 to 85 years	5	1.3	99.0
86 to 90 years	4	1.0	100.0
Total	**395**	**100.0**	

Table 5: Farm experience. Characteristic is calculated as the sum of years spent as owner, manager and in other functions on the farm.

Farm experience	**No.**	**Col. %**	**Cum. %**
10 years or less	65	16.5	16.5
11 to 20 years	109	27.6	44.1
21 to 30 years	96	24.3	68.4
31 to 40 years	73	18.5	86.8
41 to 50 years	35	8.9	95.7
51 to 60 years	11	2.8	98.5
61 to 70 years	4	1.0	99.5
71 years or more	2	0.5	100.0
Total	**395**	**100.0**	

Table 6: Duration until retirement.

Duration until retirement	**No.**	**Col. %**	**Cum. %**
10 years or less	122	31.9	31.9
11 to 20 years	113	29.6	61.5
21 to 30 years	34	8.9	70.4
21 to 40 years	15	3.9	74.3
40 years or more	6	1.6	75.9
Until death	73	19.1	95.0
Until children take over	6	1.6	96.6
Do not know	13	3.4	100.0
Total	**382**	**100.0**	

Table 7: Expected reasons for retirement. This was an open question in the survey, where more than one answer was possible. 372 farmers gave at least one answer. Reported are the five most frequent answers.

Reasons for retirement	**No.**	**Col. %**
Age related (e.g. frailty, death)	307	82.5
Political conditions	36	9.7
Economic conditions	31	8.3
Environmental conditions	9	2.4
Crime	7	1.9

Table 8: Fates of farm at retirement. This was an open question in the survey, where more than one answer was possible. 368 farmers gave at least one answer. Reported are the five most frequent answers.

Fates of farm	No.	Col. %
Continued by family	251	68.2
Sold	61	16.6
New manager	13	3.5
Expropriated	10	2.7
Dissolved	8	2.2

Table 9: Ethnicities.

Ethnicities	No.	Col. %	Cum. %
Afrikaans	182	46.1	46.1
German	179	45.3	91.4
Other Caucasian	13	3.3	94.7
Indigenous	21	5.3	100.0
Total	**395**	**100.0**	

Table 10: Classification as emerging commercial farmer.

Emerging commercial farmer	No.	Col. %
Yes	53	13.8
No	331	86.2
Total	**384**	**100.0**

Table 11: Education levels.

Education levels	No.	Col. %	Cum. %
No high school graduation	19	4.8	4.8
High school graduation	93	23.5	28.4
Trade/apprenticeship	58	14.7	43.0
Diploma/Bachelor	172	43.5	86.6
Master	42	10.6	97.2
Doctoral	11	2.8	100.0
Total	**395**	**100.0**	

Table 12: Main fields of study.

Main fields of study	No.	Col. %	Cum. %
Agriculture	96	34.8	34.8
Business	34	12.3	47.1
Education	12	4.3	51.4
Engineering	56	20.3	71.7
Health	10	3.6	75.4
Other fields	68	24.6	100.0
Total	**276**	**100.0**	

Table 13: Weekend farmers. Those farmers are denoted as weekend farmers who do not live on the farm during the week.

Weekend farmer	No.	Col. %
Yes	79	19.9
No	317	80.1
Total	**396**	**100.0**

Table 14: Regional locations of farms.

Regional locations of farms	No.	Col. %	Cum. %
Erongo	22	5.6	5.6
Hardap	11	2.8	8.4
Karas	3	0.8	9.2
Khomas	81	20.5	29.7
Kunene	39	9.9	39.6
Omaheke	88	22.3	61.9
Oshikoto	11	2.8	64.6
Otjozondjupa	140	35.4	100.0
Total	**395**	**100.0**	

Table 15: Status of principal operator.

Status of operator	No.	Col. %	Cum. %
Owner	360	91.4	91.4
Manager	11	2.8	94.2
Tenant	15	3.8	98.0
Other status	8	2.0	100.0
Total	**394**	**100.0**	

Table 16: Ownership structures.

Ownership structures	**No.**	**Col. %**	**Cum. %**
Single owner	269	69.7	69.7
Partnership/trust/ foundation	20	5.2	74.9
Cooperative	8	2.1	76.9
Corporation	83	21.5	98.4
Other structures	6	1.6	100.0
Total	**386**	**100.0**	

Table 17: Owned farmland. Area is measured in hectare (ha).

Owned farmland	**No.**	**Col. %**	**Cum. %**
0 ha	23	5.9	5.9
1 to 2,500 ha	23	5.9	11.8
2,501 to 5,000 ha	90	23.0	34.8
5,001 to 7,500 ha	115	29.4	64.2
7,501 to 10,000 ha	72	18.4	82.6
10,001 to 20,000 ha	62	15.9	98.5
20,001 or more	6	1.5	100.0
Total	**391**	**100.0**	

Table 18: Farmland rented for one year or less. Area is measured in hectare (ha).

Farmland rented for one year or less	**No.**	**Col. %**	**Cum. %**
0 ha	366	93.6	93.6
1 to 2,500 ha	17	4.3	98.0
2,501 to 5,000 ha	8	2.0	100.0
Total	**391**	**100.0**	

Table 19: Farmland rented for more than one year. Area is measured in hectare (ha).

Farmland rented for more than one year	**No.**	**Col. %**	**Cum. %**
0 ha	299	76.5	76.5
1 to 2,500 ha	31	7.9	84.4
2,501 to 5,000 ha	33	8.4	92.8
5,001 to 7,500 ha	9	2.3	95.1
7,501 to 10,000 ha	4	1.0	96.2
10,001 to 20,000 ha	15	3.8	100.0
Total	**391**	**100.0**	

Table 20: Farmland used free of charge. Area is measured in hectare (ha).

Farmland used free of charge	**No.**	**Col. %**	**Cum. %**
0 ha	381	97.4	97.4
1 to 2,500 ha	2	0.5	98.0
2,501 to 5,000 ha	4	1.0	99.0
5,001 to 7,500 ha	3	0.8	99.7
10,001 to 20,000 ha	1	0.3	100.0
Total	**391**	**100.0**	

Table 21: Farmland rented out for one year or less. Area is measured in hectare (ha).

Farmland rented out for one year or less	**No.**	**Col. %**	**Cum. %**
0 ha	380	97.2	97.2
1 to 2,500 ha	7	1.8	99.0
2,501 to 5,000 ha	3	0.8	99.7
5,001 to 7,500 ha	1	0.3	100.0
Total	**391**	**100.0**	

Table 22: Farmland rented out for more than one year. Area is measured in hectare (ha).

Farmland rented out for more than one year	**No.**	**Col. %**	**Cum. %**
0 ha	375	95.9	95.9
1 to 2,500 ha	13	3.3	99.2
2,501 to 5,000 ha	3	0.8	100.0
Total	**391**	**100.0**	

Table 23: Farmland entrusted to others free of charge. Area is measured in hectare (ha).

Farmland entrusted to others free of charge	**No.**	**Col. %**	**Cum. %**
0 ha	381	97.4	97.4
1 to 2,500 ha	8	2.0	99.5
2,501 to 5,000 ha	1	0.3	99.7
7,501 to 10,000 ha	1	0.3	100.0
Total	**391**	**100.0**	

Table 24: Operated farmland. Area is measured in hectare (ha).

Operated farmland	No.	Col. %	Cum. %
0 ha	1	0.3	0.3
1 to 2,500 ha	26	6.6	6.9
2,501 to 5,000 ha	88	22.4	29.3
5,001 to 7,500 ha	101	25.8	55.1
7,501 to 10,000 ha	75	19.1	74.2
10,001 to 20,000 ha	87	22.2	96.4
20,001 or more	14	3.6	100.0
Total	**392**	**100.0**	

Table 25: Rangeland. Area is measured in hectare (ha).

Rangeland	No.	Col. %	Cum. %
0 ha	1	0.3	0.3
1 to 2,500 ha	29	7.4	7.7
2,501 to 5,000 ha	97	24.7	32.4
5,001 to 7,500 ha	97	24.7	57.1
7,501 to 10,000 ha	77	19.6	76.8
10,001 to 20,000 ha	81	20.7	97.4
20,001 or more	10	2.6	100.0
Total	**392**	**100.0**	

Table 26: Actual bush cover. Cover measured as percentage of rangeland covered.

Actual bush cover	No.	Col. %	Cum. %
0%	1	0.3	0.3
1 to 20%	79	20.3	20.5
21 to 40%	122	31.3	51.8
41 to 60%	107	27.4	79.2
61 to 80%	66	16.9	96.2
81 to 100%	15	3.8	100.0
Total	**390**	**100.0**	

Table 27: Optimal bush cover. Cover measured as percentage of rangeland covered.

Optimal bush cover	No.	Col. %	Cum. %
0%	9	2.4	2.4
1 to 20%	215	56.6	58.9
21 to 40%	110	28.9	87.9
41 to 60%	34	8.9	96.8
61 to 80%	11	2.9	99.7
81 to 100%	1	0.3	100.0
Total	**380**	**100.0**	

Table 28: Actual versus optimal bush cover. Cover measured as percentage of rangeland covered. Cells report frequencies in percent. Shaded are cells where actual exceeds optimal bush cover.

		Actual bush cover						
		0%	**1 to 20%**	**21 to 40%**	**41 to 60%**	**61 to 80%**	**81 to 100%**	**Total**
Optimal bush cover	**0%**	0.3	0.5	0.8	0.5	0.3	0.0	**2.4**
	1 to 20%	0.0	18.0	18.5	13.5	5.3	1.3	**56.6**
	21 to 40%	0.0	1.9	9.8	9.5	6.3	1.3	**28.8**
	41 to 60%	0.0	0.0	1.9	2.9	3.4	0.8	**9.0**
	61 to 80%	0.0	0.0	0.0	1.3	1.6	0.0	**2.9**
	81 to 100%	0.0	0.0	0.0	0.0	0.0	0.3	**0.3**
	Total	**0.3**	**20.4**	**31.0**	**27.8**	**16.9**	**3.7**	**100.0**

Table 29: Grazing capacity. Grazing capacity is measured as hectare per Large Stock Unit (ha/LSU).

Grazing capacity	No.	Col. %	Cum. %
5 ha/LSU or less	4	1.1	1.1
6 to 10 ha/LSU	110	29.0	30.1
11 to 15 ha /LSU	157	41.4	71.5
16 to 20 ha /LSU	69	18.2	89.7
21 to 25 ha/LSU	18	4.7	94.5
25 to 30 ha/LSU	16	4.2	98.7
30 ha/LSU or more	5	1.3	100.0
Total	**379**	**100.0**	

Table 30: Own cattle in November 2007.

Own cattle in November 2007	**No.**	**Col. %**	**Cum. %**
No cattle	3	0.8	0.8
100 or less cattle	36	9.6	10.4
101 to 250 cattle	84	22.4	32.8
251 to 500 cattle	135	36.0	68.8
501 to 750 cattle	64	17.1	85.9
750 or more cattle	53	14.1	100.0
Total	**375**	**100.0**	

Table 31: Own cattle in April 2008.

Own cattle in April 2008	**No.**	**Col. %**	**Cum. %**
No cattle	4	1.1	1.1
100 or less cattle	30	8.4	9.5
101 to 250 cattle	75	20.9	30.4
251 to 500 cattle	122	34.1	64.5
501 to 750 cattle	78	21.8	86.3
750 or more cattle	49	13.7	100.0
Total	**358**	**100.0**	

Table 32: Cattle of third persons on farm in April 2008.

Cattle of third persons on farm in April 2008	**No.**	**Col. %**	**Cum. %**
No cattle	277	72.3	72.3
25 or less cattle	35	9.1	81.5
26 to 50 cattle	17	4.4	85.9
51 to 100 cattle	17	4.4	90.3
101 to 250 cattle	26	6.8	97.1
251 or more cattle	11	2.9	100.0
Total	**383**	**100.0**	

Table 33: Production systems.

Production systems	No.	Col. %	Cum. %
Weaner	87	26.9	26.9
Speculation	39	12.0	38.9
Oxen	154	47.7	86.6
Stud breeding	32	9.8	96.4
Other systems	12	3.6	100.0
Total	**324**	**100.0**	

Table 34: Annual net income. Income is measured as annual net income in Namibian dollar (N$) in the period 1st March 2007 to 29th February 2008, which is the Namibian tax year.

Annual net income	No.	Col. %	Cum. %
< N$ 50,000	59	16.1	16.1
N$ 50,001 to N$ 150,000	101	27.5	43.6
N$ 150,001 to N$ 250,000	91	24.8	68.4
N$ 250,001 to N$ 350,000	44	12.0	80.4
> N$ 350,000	72	19.6	100.0
Total	**367**	**100.0**	

Table 35: Income derived from cattle farming. Displayed is the fraction of annual net income in the period 1st March 2007 to 29th February 2008, which is the Namibian tax year.

Fraction of income from cattle farming	No.	Col. %	Cum. %
0%	24	6.3	6.3
1 to 20%	47	12.2	18.5
21 to 40%	50	13.0	31.5
41 to 60%	69	18.0	49.5
61 to 80%	82	21.4	70.8
81 to 100%	112	29.2	100.0
Total	**384**	**100.0**	

Table 36: Income deriving from non-cattle on-farm income sources. Displayed is the fraction of annual net income averaged across all farmers, thus only percentages and not number of observations are given for each category. 398 farmers responded to this question. The relevant period is 1st March 2007 to 29th February 2008, which is the Namibian tax year.

Non-cattle on-farm income sources	Col. %	Cum. %
Bioenergy	1.2	1.2
Game farming	3.3	4.5
Maize	1.2	5.7
Small stock	5.9	11.6
Tourism	7.8	19.4
Other sources	2.9	22.3
Total		

Table 37: Income deriving from off-farm sources. Displayed is the fraction of annual net income in the period 1st March 2007 to 29th February 2008, which is the Namibian tax year.

Income fraction from off-farm sources	No.	Col. %	Cum. %
0%	146	38.9	38.9
1 to 20%	85	22.7	61.6
21 to 40%	35	9.3	70.9
41 to 60%	43	11.5	82.4
61 to 80%	31	8.3	90.7
81 to 100%	35	9.3	100.0
Total	**375**	**100.0**	

Table 38: Responses from risk experiments with hypothetical rewards in the questionnaire. The experiments are detailed in Olbrich et al. (2009). Denoted are raw intervals of the coefficient of relative risk aversion (CRRA) which are calculated without considering any individual characteristics. Raw data contained an artefact where many farmers who received a mail-in questionnaire indicated extreme responses, i.e. the highest or lowest category of CRRA-intervals. In contrast, farmers who complete the questionnaire in the presence of a researcher while participating in the in-field experiments did not show this behaviour. The issue is discussed at greater length in Olbrich et al. (2011d). We here display corrected data where the highest and lowest category contain only responses of farmers who participated in the in-field experiments, scaled up to the number of respondents who did not indicate extreme responses.

Open CRRA-interval	No.	Col. %	Cum. %
6.32, ∞	22	8.7	8.7
4.38, 6.32	4	1.6	10.3
2.79, 4.38	9	3.6	13.8
1.37, 2.79	56	22.1	36.0
0.00, 1.37	93	36.8	72.7
-1.40, 0.00	52	20.6	93.3
-∞, -1.40	17	6.7	100.0
Total	**253**	**100.0**	

Table 39: Responses from in-field risk experiments with monetary reward. The experiments are detailed in Olbrich et al. (2009) . Denoted are raw intervals of the coefficient relative risk aversion (CRRA) which are calculated without considering any individual characteristics.

Open CRRA-interval	No.	Col. %	Cum. %
8.27, ∞	7	17.9	17.9
4.79, 8.27	0	0.0	17.9
3.58, 4.79	0	0.0	17.9
2.93, 3.58	0	0.0	17.9
2.18, 2.93	1	2.6	20.5
1.70, 2.18	0	0.0	20.5
1.35, 1.70	10	25.6	46.2
1.05, 1.35	2	5.1	51.3
0.78, 1.05	6	15.4	66.7
0.52, 0.78	2	5.1	71.8
0.27, 0.52	1	2.6	74.4
0.00, 0.27	6	15.4	89.7
-0.29, 0.00	2	5.1	94.9
-0.61, -0.29	0	0.0	94.9
-0.99, -0.61	0	0.0	94.9
-1.46, -0.99	0	0.0	94.9
-∞, -1.46	2	5.1	100.0
Total	**39**	**100.0**	

Table 40: Responses from time experiments with hypothetical rewards in the questionnaire. The experiments are detailed in Olbrich et al. (2009) . Denoted are raw intervals of the discount rate which are calculated without considering any individual characteristics. Similar to the hypothetical risk experiments, raw data also contained an artefact. We thus present corrected data as discussed in Table 38.

Open discount rate interval	No.	Col. %	Cum. %
0%, 10%	32	11.4	11.4
10%, 20%	63	22.5	33.9
20%, 30%	89	31.8	65.7
30%, 40%	48	17.1	82.9
40%, 50%	42	15.0	97.9
50%, ∞%	6	2.1	100.0
Total	**280**	**100.0**	

Table 41: Responses from in-field time experiments with monetary rewards. The experiments are detailed in Olbrich et al. (2009) . Denoted are raw intervals of the discount rate which are calculated without considering any individual characteristics.

Open discount rate interval	No.	Col. %	Cum. %
0.0%, 2.5%	0	0.0	0.0
2.5%, 5.0%	0	0.0	0.0
5.0%, 7.5%	0	0.0	0.0
7.5%, 10.0%	4	10.3	10.3
10.0%, 12.5%	3	7.7	17.9
12.5%, 15.0%	7	17.9	35.9
15.0%, 17.5%	6	15.4	51.3
17.5%, 20.0%	3	7.7	59.0
20.0%, 22.5%	3	7.7	66.7
22.5%, 25.0%	3	7.7	74.4
25.0%, 27.5%	3	7.7	82.1
27.5%, 30.0%	3	7.7	89.7
30.0%, 32.5%	2	5.1	94.9
32.5%, 35.0%	1	2.6	97.4
35.0%, 37.5%	0	0.0	97.4
37.5%, 40.0%	0	0.0	97.4
40.0%, 42.5%	0	0.0	97.4
42.5%, 45.0%	0	0.0	97.4
45.5%, 47.5%	0	0.0	97.4
47.5%, 50.0%	0	0.0	97.4
50.0%, ∞%	1	2.6	100.0
Total	**39**	**100.0**	

Table 42: Time horizon over which grazing capacity and income should be sustained. Denoted is the number of generations beyond the own generation of the farmer.

Time horizon	No.	Col. %	Cum. %
Only current generation	32	8.7	8.7
One generation	60	16.4	25.1
Two generations	145	39.6	64.8
Three generations	32	8.7	73.5
Four generations	15	4.1	77.6
Five generations	20	5.5	83.1
Six to nine generations	3	0.8	83.9
Ten generations or more	59	16.1	100.0
Total	**366**	**100.0**	

Table 43: Other objects that should be sustained on farm besides grazing capacity and income. This was an open question in the survey, where more than one answer was possible. 286 farmers gave at least one answer. Reported are the five most frequent answers.

Objects to be sustained	No.	Col. %
Groundwater level	105	36.7
Ecosystem quality	79	27.6
Social conditions	44	15.4
Political conditions	41	14.3
Infrastructure	30	10.5

Appendix D: Cluster analysis

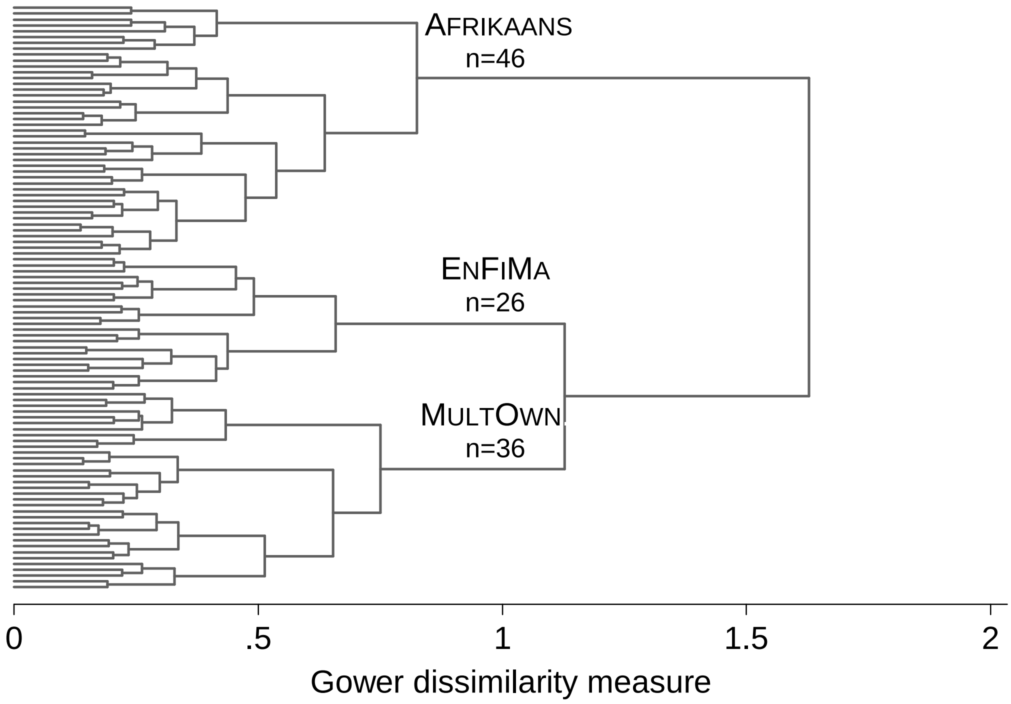

Figure 5: Dendrogram for three cluster solution. Cluster labels and observations per cluster are indicated above the respective branch. Clusters are MULTOWN (multiple owners), ENFIMA (favorable environment / low financial risk management) and AFRIKAANS (Afrikaans farmers). N=108.

Table 44: Results for pseudo F- and pseudo T square-indices for different numbers of clusters. Good number of clusters are indicated by high values for pseudo F-index and by low values for pseudo T-square index.

Number of clusters	pseudo F	pseudo T square
1		0.30
2	0.30	0.98
3	0.57	0.00
4	0.38	0.99
5	0.53	1.26
6	0.59	1.48
7	0.79	3.07
8	1.22	2.43
9	1.59	0.15
10	1.41	1.44
11	1.43	0.35
12	1.31	0.07
13	1.20	0.02
14	1.09	1.56
15	1.03	0.17

Table 45: Cluster-averaged values of characteristics for clusters MULTOWN (multiple owners), ENFIMA (favorable environment / low financial risk management) and AFRIKAANS (Afrikaans farmers). p-values for cluster differences calculated for each characteristic by one-way ANOVA for continuous and Chi-square test for binary characteristics. Shading indicates cluster responsible for differences as calculated by Bonferroni-corrected t-tests for continuous and pair-wise Chi-square test for binary characteristics, with the significance levels: *** p<0.01, ** p<0.05, * p<0.1. Dark shading denotes that cluster differs from both other clusters, light grey shading that it differs from only one other cluster (the one most different in averaged values). N=108.

Clusters:	**MULTOWN**	**ENFIMA**	**AFRIKAANS**	**p-value**
1) Personal and farm features				
Household size *[number of members]*	3.6	2.7*	3.6	0.036
Age *[years]*	46.9***	55.5	51.4	0.010
Afrikaans *[%]*	19.4	7.7	95.7***	0.000
Education level *[1=no high school graduation, 6=Doctorate]*	3.8	4.0	3.4**	0.035
Weekend farmer *[%]*	83.3	80.8	87.0	0.773
Average rainy season assessment *[1=very poor, 6=very good]*	3.9	4.1	3.9	0.328
Single owners *[%]*	41.7***	84.6	89.1	0.000
Rangeland *[hectare]*	9,448	7,980	8,181	0.483
Land net rented *[hectare]*	2,587**	512	919	0.010
Land quality*[1=very poor quality, 6=very good quality]*	4.0	4.2	4.4	0.342
Actual bush cover *[1=0%, 6=81 to 100%]*	3.7	3.3	3.6	0.392
Optimal bush cover *[%]*	23.8	19.3	26.5	0.115
Grazing capacity *[Large Stock Unit per hectare]*	0.071	0.089*	0.074	0.016
Oxen production *[%]*	68.3	60.5	42.3***	0.008
Annual net income *[1= <N$50,000, 6= >N$350,000]*	2.9	3.4	3.2	0.358
2) Risks faced by farmers ***[1=no risk, 6=very high risk]***				
Rainfall	4.9	4.4*	5.0	0.067
3) Risk management strategies ***[1=not at all important, 6=very important]***				
On-farm management strategies				
Purchase of supplementary feed	4.3	4.8	4.5	0.371
Choice of cattle production system	4.9	3.9**	4.5	0.039
Choice of breed adapted to high variability in grass production	4.8	3.9**	4.6	0.032
Resting part of rangeland in good rainy seasons	4.1**	4.7	5.0	0.025
Purchase/lease of rangeland for scale effects	4.1	2.7*	3.3	0.004
Financial management strategies				
Advances on livestock sales	3.6**	1.4**	2.6**	0.000
Checking account as financial buffer	4.8	4.3	4.8	0.327
Loans for covering operating losses	3.0	1.5***	3.4	0.000
Income from off-farm employment or assets	3.9	3.6	3.8	0.803
Investment into agricultural derivatives	2.4	1.9	2.0	0.392

Characteristics (continued)	MULTOWN	ENFIMA	AFRIKAANS	p-value
4) Individual risk and time preferences				
Risk preference index *[1=very risk averse, 7=very risk attracted]*	4.6	5.0	4.7	0.416
Time preference index *[1=very patient, 7=very impatient]*	3.1	2.6*	3.2	0.069
5) Normative views of sustainability				
Sustainable annual net income *[N$]*	292,806	251,539	294,000	0.567
Sustainable grazing capacity *[Large Stock Unit per hectare]*	0.074	0.086	0.076	0.217
Acceptable income risk *[probability]*	0.6	0.5	0.6	0.801
Acceptable grazing capacity risk *[probability]*	0.6	0.7**	0.6	0.009
Time horizon *[generations]*	3.3	4.1	3.5	0.671
Selected characteristics not included in cluster analysis				
Female *[%]*	2.8	3.9	4.3	
Farm experience *[years]*	17.8	22.7	23.7	
Regional location of farm *[%]*				
Khomas	19.4	23.1	17.4	
Omaheke	8.3	26.9	23.9	
Otjozondjupa	58.3	38.4	30.4	
Total on-farm precipitation rainy season 2006/07 *[mm]*	241.6	291.4	242.2	
Total on-farm precipitation rainy season 2007/08 *[mm]*	439.2	441.0	395.7	
Land owned *[ha]*	7,651	7,352	7,696	
Land operated *[ha]*	10,187	8,028	8,600	
Own cattle, Apr 2008	521	492	454	
Income from cattle farming *[1= 0%, 6= 81-100%]*	4.3	4.6	4.4	
NAU member [%]	91.7	92.3	82.6	
Emerging commercial farmer [%]	16.6	8.3	2.2	
Risk management strategies [1=not at all important, 6=very important]				
Purchase/lease of rangeland for spatial diversification	3.7	2.4	3.0	
Forwards contracts	4.1	2.7	3.3	

Chapter 5: Risk preferences under heterogeneous environmental risk[75]

By Roland Olbrich, Martin F. Quaas, Andreas Haensler and Stefan Baumgärtner[76]

Abstract

We study risk preferences and their determinants for commercial cattle farmers in Namibia who are subject to high precipitation risk that is heterogeneous across farms. We use data on risk preferences from questionnaire and field experiments, simulated data for on-farm precipitation risk and data on famers' previous place of residence. We find that, on average, less risk-averse farmers operate farms with higher precipitation risk. Moreover, the longer farmers experience a given precipitation risk in early life the more risk-averse they are. These findings suggest self-selection and endogeneity of risk preferences, respectively.

Keywords: risk preferences, environmental risk, experimental elicitation, endogenous preferences, self-selection, field experiment

JEL-Classification: D81, Q12

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1. Introduction

Behavior towards risk, as the interplay between risk preferences and the risky opportunity set, plays an important role in economic life. Everybody experiences risks in one's every-day economic life. But few people continuously experience the same type of risk throughout their entire life. Rangeland farmers in semi-arid regions are among them, with their livelihood essentially depending on environmental risks. These farmers are therefore particularly well suited to study the determinants that drive risk behavior, especially the interplay between risk preferences and environmental risk.

Previous studies on the interplay between risk preferences and environmental risk assumed risk preferences to be stable and then examined how a change in risk constraints induces a behavioral change (e.g. Rosenzweig and Binswanger, 1993). Recent studies demonstrate that risk preferences endogenously change with external cues such as market arrangements (Palacios-Huerta and Santos, 2004), civil war shocks (Voors et al., 2011) and possibly macroeconomic shocks (Malmendier and Nagel, 2011). In this paper, we empirically study risk preferences and their determinants, with a specific focus on whether and how risk preferences are shaped by environmental risk.

Our case study is commercial cattle farming in semi-arid rangelands of Namibia. Farmers in these areas experience a variety of socio-economic and environmental risks, predominant among which is precipitation risk. Annual precipitation in Namibia is low with an average of approximately 270 mm, and spatially and temporally highly variable (Sweet, 1998; Ward et al., 2004; Wiegand et al., 2005; Chapman, 2010; Figure 1). In addition to precipitation risk, farmers face price risks for inputs and outputs. These prices may be very volatile. For example, prices for auction sales for cattle may increase or decrease by more than 50% from one year to the next (Olbrich et al., 2011c). Commercial cattle farmers own land property rights.[77] The market for farmland is well developed which allows the purchase and sale of farms anywhere within the commercial farming region. Roughly half of the farmer population operates on a farm that they purchased, whereas the other half stays on the farm where they grew up and which they took over from their parents.

We experimentally elicited risk preferences both in questionnaire experiments with hypothetical payouts and in-field experiments with real payouts in August 2008. The farms operated by the participants in the experiments are distributed over the whole region in

[77] In this respect, commercial cattle farming differs from communal farming, the other main farming system performed in Namibia, where rangelands are used as a common property resource mainly for subsistence farming.

Namibia where commercial cattle farming is common (Figure 1; Mendelsohn, 2006: 43). We complement our survey data with actual and simulated on-farm precipitation data and by farm records of the Deed's Office of Namibia which detail farm ownership since 1920. We investigate the impact of precipitation risk[78] and experience with this risk during childhood and adolescence on the coefficient of relative risk aversion by maximum-likelihood estimation, controlling for socio-demographic variables, liquidity constraint and price background risk.

We find that, on average, risk aversion and environmental risk are negatively related. This observation is consistent with self-selection where *more* risk-averse farmers occupy *less* risky farms. However, among farmers who grew up on the farm they currently operate, we find that prior experience with environmental risk during childhood and adolescence influences risk preferences in such a way that farmers are *more* risk-averse the more years they have spent on their farm prior to age 18 years. We also find that risk preferences are no longer endogenous during adulthood. These findings are consistent with the hypothesis that risk preferences are endogenous with respect to environmental risk experienced in early life. Past risk experience even is the dominant feature of the relationship between risk preferences and environmental risk for farmers who grew up on their farm for at least 9 years during childhood or adolescence: these farmers are the *more* risk-averse the higher the precipitation risk is on their farm, i.e. the *more* risky their farm is.

We can exclude alternative explanations for our results. Firstly, precipitation risk may act as a background risk to choices in our risk experiments, but we can exclude its possibly confounding influence based on previous findings on the sign of its effect on risk aversion. Secondly, all price-background risks are homogenous across farmers and therefore cannot explain individual heterogeneity in behavior towards risk. Thirdly, we found that liquidity constraints have no significant influence on risk aversion.

The paper is organized as follows. Section 2 explains the conceptual background. Section 3 describes the data and methods. Results are presented and discussed in Section 4 and Section 5 concludes. In addition, we provide four Appendices A.1–A.4 of which the latter three are available online only.

[78] One might argue that the relevant risk is profits from cattle farming and not precipitation. However, from qualitative interviews with farmers we infer that they are preoccupied with precipitation of which they keep very detailed records. Conversely, data on profits are seldom recorded. We thus assume that precipitation is indeed the relevant risk and that the profit risk (in the mindset of farmers) is linearly related to precipitation risk.

2. Conceptual background and hypotheses

The relationship between an individual's risk preferences and risk can be driven by formation of risk preferences through given risk conditions ("endogeneity of risk preferences") or by choice of risk conditions according to given risk preferences ("self-selection"). In this section, we explain these two mechanisms and derive testable hypotheses concerning endogeneity of preferences and self-selection that pertain to commercial cattle farming in Namibia.

2.1 Endogeneity of risk preferences

One possible mechanism driving the relationship between risk preferences and risk is that preferences are formed by given risk conditions that individuals experience. Endogeneity of risk preferences has been studied for a variety of contexts. Risk preferences are found to be relatively stable over time (Harrison et al., 2005b; Andersen et al., 2008b; Sahm, 2008), with respect to changes in income and wealth (Brunnermeier and Nagel, 2008; Sahm, 2008), and under major shocks like job displacement (Sahm, 2008). However, they change with age (Dohmen et al., 2005; Sahm, 2008; Harrison et al., 2010) and are endogenous with respect to external cues. Palacios-Huerta and Santos (2004), assuming a general-equilibrium model in which preferences are endogenous with respect to market arrangements, observe that individuals are less risk-averse when markets are incomplete and provide less institutional risk mitigation which consequently leave those individuals more vulnerable to risk. Voors et al. (2011) study how risk preferences are affected by civil war shocks. They find that those individuals who experienced higher violence, in the sense that their community has suffered a higher number of casualties, are more risk seeking. Finally, Malmendier and Nagel (2011) find that individuals who have experienced worse stock and bond market conditions, in the form of low returns, take less financial risks. They attribute this relationship to formation of more pessimistic beliefs about future returns, but cannot discard the possibility of endogeneity of risk preferences. As of yet, no economic study considered environmental risk as an external cue that may form risk preferences. Moreover, to our knowledge no economic study has yet examined childhood or adolescence as a period of risk preference formation, even though this period is well known to be critical for the formation of a variety of preferences (e.g. Cunha and Heckman, 2007; Borghans et al., 2008; Cunha et al., 2010).

Insights on the requirements and processes for formation of risk preferences are provided by the psychological literature. Firstly, important cognitive requirements for risk preferences such as logical reasoning are in place at the end of childhood (e.g. Boyer, 2006; Reyna and Farley, 2006), meaning that older children and adolescents do indeed have risk preferences that allow a rational evaluation of risky alternatives. Secondly, these preferences may change during childhood and adolescence through a variety of processes. One of these processes is a systematic preference shift with age in response to certain external cues an individual experiences (Bowles, 1998; Loewenstein and Angner, 2003) – a process called *maturation* (Loewenstein and Angner, 2003). In maturation, preferences may shift more strongly the longer the cue is experienced, but eventually 'different types of preferences tend to become "frozen" at different periods in one's life … [and thereby people] become increasingly inoculated against external influences' (Loewenstein and Angner, 2003: 363; similarly Holbrook and Schindler, 2003). For example, people prefer throughout their life the movie-star-photographs of their teens (Holbrook and Schindler, 1994) and the music of their mid-twenties (Holbrook and Schindler, 1989), and political party preferences are usually quite stable once young adulthood has been reached (Gerber and Green, 1998).

Turning to commercial cattle farming in Namibia we first note that such farming is driven by precipitation risk. Along the lines of *maturation,* precipitation risk may constitute a strong external cue that acts on farmers' risk preferences throughout childhood and adolescence. Thus, we hypothesize that farmers' risk preferences are endogenous with respect to the precipitation risk experienced during childhood and adolescence, and that precipitation risk influences preferences more strongly the longer farmers experience this risk.

2.2 Self-selection on the land market

Another possible mechanism driving the relationship between risk preferences and environmental risk is that individuals self-select themselves into risk conditions according to their given risk preferences, with more risk-averse individuals choosing less risky conditions. Evidence conforming with self-selection has been observed, for example, in regards to occupational choice (Dohmen et al., 2005; Guiso and Paiella, 2005; Bellemare and Shearer, 2010; Jaeger et al., 2010), investment choice (Dohmen et al., 2005; Guiso and Paiella, 2005) and health behavior (Dohmen et al., 2005).

For commercial cattle farmers in Namibia the land market is the main institution that may lead to a self-selection of farmers onto farms differing in precipitation risk according to their risk preferences. To be precise about how self-selection on such a land market works, consider the following model of rangeland farming and the market for farms. The grazing capacity (i.e. the state of the grass vegetation) of the rangeland is described by a stock variable x_t that follows a geometric Brownian motion with zero mean growth rate (i.e. we consider a steady state) and a standard deviation σ of the growth rate that is determined by precipitation risk. Using x_0 to denote the state of vegetation at time $t=0$, the state x_t at time t follows a log-normal distribution with mean x_0 and variance $x_0^2\left(\exp(\sigma^2 t)-1\right)$ (Dixit and Pindyck, 1994). Annual rents derived from rangeland farming are proportional to the grazing capacity of the rangeland in the year under consideration. To keep notation simple, we normalize annual income from rangeland farming such that it equals x_t. The farm, in this simple model, is characterized by the expected annual state of the vegetation x_0 and by the standard deviation σ that is determined by precipitation risk at the farm's location. We denote this farm (x_0,σ). We specify farmers' preferences by the instantaneous utility function $U(x)=x^{1-r}/1-r$ which exhibits constant relative risk aversion with r as the coefficient of constant relative risk aversion. Further, we use δ to denote the farmer's time preference rate, and assume $1/2\,r(1-r)\sigma^2+\delta>0$ and $1/2\,\sigma^2<\delta$ to ensure the existence of an interior solution to the farmer's optimization problem. The condition $1/2\,\sigma^2<\delta$ states that uncertainty should not grow faster than the discount rate. The condition $1/2\,r(1-r)\sigma^2+\delta>0$ is always fulfilled for farmers with a coefficient of risk aversion $r<1$. For more risk-averse farmers, $r>1$, a farm that is very risky compared to the farmer's discount rate would be of no use (the present value of utility would be $-\infty$). The condition $1/2\,r(1-r)\sigma^2+\delta>0$ thus means that we consider only farms for which a risk-averse farmer would offer a positive bid.

There is a land market where farmers bid for farms. The bidders differ with regard to their risk and time preferences and with regard to their reservation utility levels. We use y_0 to denote the certain and constant income stream that would give rise to the reservation utility level of the farmer under consideration, and ϕ to denote the maximal constant fraction of annual income that the farmer is willing to bid for a farm.

The allocation on this land market is characterized by the following result.

Proposition: *If two farmers with identical discount rates bid the same constant fraction ϕ of annual income for a farm (x_0,σ), then the more risk-averse farmer outbids the less risk-averse farmer for all less risky farms $(x_0,\underline{\sigma})$ with $\underline{\sigma}<\sigma$ and the less risk-averse farmer outbids the more risk-averse farmer for all riskier farms $(x_0,\bar{\sigma})$ with $\bar{\sigma}>\sigma$.*

Proof: see Appendix A.1.

Based on this proposition, we hypothesize that farmers self-select themselves onto farms according to their given risk preferences in such a way that more risk-averse farmers operate farms with less risky precipitation conditions.

3. Data and methods

3.1 Data sources

Description of the survey

In August 2008, we elicited risk preferences as well as personal, farm business and environmental characteristics of commercial cattle farmers in Namibia in a quantitative survey, consisting of a mail-in questionnaire and in-field experiments. A detailed description of the survey, its conduction and an analysis of representativeness of the survey population can be found in Olbrich et al. (2009).

We sent out questionnaires to all 1,121 cattle farming members of the Namibia Agricultural Union (NAU), the main interest group of commercial farmers in Namibia, and to all 795 farmers that deliver cattle to MeatCo, by far the largest slaughterhouse in Namibia. We mailed out a first batch of questionnaires in the period 19th–21st of August 2008, and a second batch as a follow up on the 15th of September 2008.

In addition, we randomly selected 39 NAU members for participation in in-field risk experiments. We visited the majority of these participants (79.4%) on their respective farms, and the remaining ones at pubic locations in major cities. Each session of experiments started with the participant filling in the questionnaire and was followed by the experiments. Duration of sessions varied between one and two-and-a-half hours.

Altogether, we reached 1,916 of an estimated total number of 2,500 commercial cattle farmers (77%).[79] 399 questionnaires were returned, equaling a return rate of 21%. In the returned questionnaires, the response rate for non-sensitive questions exceeded 95% for most questions, and it was greater than 90% even for sensitive questions such as income. An optional question for identification of the farm was answered by 75% of respondents. This question enabled us to pinpoint the location of the farm and link survey data to data from external sources such as precipitation data from the REMO climate model and the farm records of the Deed's Office of Namibia (see below).

In addition to the quantitative survey, we conducted 62 qualitative interviews with farmers and decision makers in the agricultural, financial and political sector in which we discussed various aspects of commercial cattle farming. Interviews took place throughout four research visits in March/April 2007, October 2007, July/August 2008 and February/March 2010.

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[79] No census data is available that gives the exact number of cattle farmers. The estimate is that of experts of the Namibia Agricultural Union and the Meat Board of Namibia.

Elicitation of risk preferences

We elicited risk preferences in the sense of von-Neumann-Morgenstern expected utility theory (von Neumann and Morgenstern, 1944) by an adapted multiple price list format (Binswanger, 1980; Holt and Laury, 2002; Andersen et al., 2006; Harrison et al., 2010), both through experiments with hypothetical payouts within the questionnaire ("questionnaire experiments") and through in-field experiments ("field experiments") with payouts of real money. In the questionnaire experiments we offered farmers six scenarios, where we framed the lottery in the context of selling cattle at an auction (Table 1a). The auction had two possible outcomes, N$90,000[80] and N$130,000, each occurring with equal probability of 1/2. The expected value of the auction (N$110,000) corresponds to about one third of the annual net income of the average farmer. Instead of taking part in the risky auction, farmers could chose to sell to a trader for a certain amount which started at N$100,000 in the first scenario and increased in steps of N$2,500 to N$112,500 in the sixth and last scenario.

In the field experiments the lottery was context-free with two possible outcomes, N$500 and N$2,500, each occurring with equal probability of 1/2. The expected value of N$1,500 corresponds to the value of a calf. To achieve a higher resolution of risk aversion measures, 16 scenarios were presented. The certain amount started at N$550 in the first scenario and increased to N$1,900 in the last scenario (Table 1b). After the subject had made their choices one of the chosen scenarios was randomly picked (by throwing a dice) and paid out, i.e. the subject either received the certain amount or the lottery in turn was played out (again by throwing a dice). Due to monetary constraints we could pay only 10% of farmers which were randomly selected by letting farmers draw lots. Payments were made in cash instantly.

Based on the choices observed in each scenario we estimated the risk-aversion parameter of a constant-relative-risk-aversion (CRRA) specification of an expected utility function (Andersen et al., 2006; Harrison et al., 2010).[81] In this specification $U(y) = y^{(1-r)} / (1-r)$, y denotes lottery pay-out and r the coefficient of constant relative risk aversion. Based on this function, indifference between the lotteries and the certain amount in the different scenarios corresponds to values of r in the range -1.40 and 6.32 for the questionnaire experiments, and -1.46 and 8.27 in the field experiments.

[80] N$ denotes Namibian dollars. On 1st of August 2008, N$1,000 equaled €88.14 or US$137.50.

[81] Both lab and field studies have shown that CRRA is for a given income domain at least locally a plausible assumption (e.g. Holt and Laury, 2002; Harrison et al., 2007a).

Farmers' life history

To infer since when farmers lived on their farm, we examined records of farm deeds from the Deed's Office of Namibia. For a given farm these records denote every transaction, reaching as far back in time as 1920, and include the transaction date, the transferred area and the names of transferors and transferees. Matching this information with survey information for those farmers who identified their farm allowed us to identify these present farmers' names and for how long previous farm owners shared the same surname. This, in turn, allowed us to infer since when the farm was in family possession.[82] Comparing the year since when a farm was in family possession with the year of birth of the present farmer, we can infer whether the farmer grew up on his farm or whether he acquired it at some later time.

Precipitation data

Precipitation data from the Namibia Meteorological Service is available for the period 1913–2008. However, these data are collected at only few weather stations across Namibia and the time series have many gaps. To overcome these deficiencies, we used simulated precipitation data for our analysis. These data were generated by the three-dimensional, hydrostatic atmospheric circulation model REMO (REgional MOdel) (Jacob and Podzun, 1997; Jacob, 2001). The model is forced at the lateral boundaries with historical climate data and with output from the global climate model ECHAM4 (Roeckner et al., 1996) every six simulated hours. REMO data is available for the period 1978–2008. We use output data of REMO with a temporal resolution of six hours and a spatial resolution of 18km * 18km to calculate total precipitation per rainy season (November till April) for individual farms as a weighted mean over nine adjacent model gridboxes. These simulated precipitation data closely conform to weather-station data in respect to the precipitation risk measure we employ (see Section 3.3).

Input and output price data

Prices for inputs are temporally variable, but homogenous across farmers since all commercial farmers buy from the same few companies.[83] Farmers produce two main outputs which are (1) cattle sold to the slaughterhouse for meat production and (2) cattle sold at auctions for further rearing by other farmers. Prices for the first output are also homogenous across

[82] There is a chance that transferors and transferees share the same surname even though they are not related. However, diversity of surnames among Namibian cattle farmers is high. Even when considering the most common surnames, there are never more than 19 individuals per surname in our survey population. Given the size of the survey population (1,916 farmers), the chance of transferor and transferee sharing the same surname even though they are not related is less than 1%.

[83] Inputs are purchased from Agra Co-operative Ltd. as well as from a few companies who exclusively distribute specialized products (de Bryn et al., 2007). All these companies have nationally homogeneous prices.

farmers since 95% of cattle sold to the slaughterhouse are sold to MeatCo in 2007, the latest available record (MAWF, 2009). We thus will not consider price risks of inputs and of cattle sold to the slaughterhouse as they cannot explain individual differences in risk behavior.

In contrast, output prices for cattle sales at local auctions may be spatially heterogeneous and therefore also heterogeneous across farmers since cattle are typically sold at auctions close to the farm. To examine this risk, we obtained price data for cattle sales on 2,083 commercial auctions across Namibia for the period 2000–2008 from Agra Co-operative Ltd, the largest retailer for farm equipment in Namibia and organizer of almost all cattle auctions. Data contain the location of auctions, the auction date, the number of sold cattle with average weight and average price per head and per kilogram.

3.2 Confounding influence of precipitation and price risks as background risks

In the risk experiments it was not feasible to elicit farmer's risk preferences by experimentally varying precipitation risk, our primary risk of interest. We were therefore relegated to introduce an additional, artificial risk in the experiments and to examine endogeneity of preferences and self-selection in respect to precipitation risk by way of controlling for these two mechanisms. The downside of this approach is that precipitation risk may influence choices in the risk experiment by acting as a background risk. This may confound our inferences on those mechanisms by which precipitation risk may impact on risk preference that we are primarily interested in, i.e. endogeneity of preferences and self-selection. To better pinpoint potentially confounding influences we propose the following two-stage process in which the different mechanisms may act:

- first stage, *before* the risk experiments:

  i) endogeneity of preferences where precipitation risk influences risk preferences contingent on life history,

  ii) self-selection where farmers sort themselves, *ceteris paribus*, into local precipitation risk according to their risk preferences, and

- second stage, *in* the risk experiments:

  iii) precipitation background risk where the previously chosen local precipitation risk now acts as a constraint to choices in the experiments with the artificial risk.

We will control for endogeneity of preferences with respect to past experience with precipitation risk by examining different subpopulations (methodically resolved by an interaction effect, cf. Section 3.3). Statements about this mechanism will therefore not be confounded by the presence of precipitation background risk.

We cannot pursue a similar approach to discriminate the precipitation background risk mechanism from the self-selection mechanism. However, theoretical (Eeckhoudt et al., 1996), experimental (Harrison et al., 2007b) and field findings (Guiso and Paiella, 2008) suggest that the impact of background risk on risk aversion is positive and thus of opposite sign to the negative impact of self-selection (Guiso and Paiella, 2008; Jaeger et al., 2010), at least when utility functions are characterized by non-increasing prudence which is implied by our CRRA assumption. Accordingly, a *positive* impact of local precipitation risk on risk aversion would then indicate a background risk mechanism with an unclear contribution of self-selection while a *negative* impact would indicate self-selection with an unclear contribution of background risk. Thus, while it is impossible in our experimental setup to make statements on both self-selection and background risk simultaneously, we may – contingent on finding a significant non-zero impact – make at least unambiguous statements in respect to one of these mechanisms.

In addition to the precipitation background risk (iii), the price risk of cattle sales at auctions may also act as a background risk in the risk experiments. However, we find that prices between auction locations are highly correlated with Pearson correlation coefficients being no smaller than 0.97 and significant at the 0.1%-level for correlation between any two locations.[84] Thus, this price background risk is effectively identical for all farmers. Like price risks for inputs and cattle sold to the slaughterhouse it may not explain individual differences in behavior, and we do not consider in the further course of the paper.

3.3 Statistical specification

Precipitation risk measure

We employ the definition of risk by Rothschild and Stiglitz (1970): a distribution of precipitation is more risky than another distribution if it is a mean-preserving spread of the latter. If distributions are log-normal, a mean-preserving spread is – for a given mean – equivalent to a higher coefficient of variation (CV) (Levy, 2006). Rainfall in Namibia is indeed log-normally distributed (Sandford, 1982).[85] Thus, to measure precipitation risk, we

[84] The reason is that a small number of buyers purchase the majority of cattle sold on auctions (Schutz, 2010).

[85] We tested all distributions of total rainy season precipitation that were simulated by the REMO model and that we use in our analysis for log-normality using the Shapiro-Wilk-W test. The hypothesis of log-normality cannot

employ the inter-annual coefficient of variation (CV) of total rainy season precipitation while controlling for the inter-annual mean of total rainy season precipitation.

We calculate the inter-annual CV and mean of total rainy season precipitation for individual farms from REMO data. Furthermore, as we are interested in the precipitation risk that individual farmers have experienced, to measure the precipitation risk we only use the precipitation data of the period that a given farmer was holding the farm. For some farmers this period is longer than the period of 1978–2008 for which REMO data is available. However, the precipitation risk is fairly stable over time and we use the risk measure calculated for the period 1978-2008 as a proxy for the risk of all longer periods.[86] Since CV estimates fluctuate wildly if based on only few observations we require that farmers lived on their farm for at least three years prior to the survey in order to be included in the analysis. We calculated the risk measure of precipitation risk for all farmers that are risk-averse, indicated their farm location and lived on the farm for at least three years.

Finally, we validate risk measures calculated from simulated data with the corresponding risk measures calculated from weather-station data by matching REMO data with data for the nearest weather station of the Namibia Meteorological Service (requiring a distance of less than 5km). Measures are highly correlated between both data sets and significant at the 0.1%-level, with a Pearson correlation coefficient of 0.76 ($p<0.001$, $n = 26$) and 0.74 ($p<0.001$, $n = 26$) for CV and mean, respectively. We thus conclude that simulated precipitation data closely conform to actual weather-station data in respect to our risk measure.

Socio-demographics, experimental type and life history

We control for various socio-demographic characteristics: gender (female vs. male), education (no college or apprenticeship education vs. higher education), area of rangeland (as a proxy for wealth), ownership structure (farm operated by single owner vs. multiple owners such as corporations, cooperatives or trusts), farm residence (living on the farm vs. off the farm, as a proxy for full-time farming versus part-time farming) and liquidity constraint (measured as the importance of loans for farm business operation, where more reliance on

be rejected for the vast majority (95 out of 99) of distributions at the 5%-level. We thus treated all distributions as log-normal.

[86] We exemplarily analyzed actual rainfall data from the Namibia Meteorological Service to investigate how closely the risk measure derived from the period 1978–2008 conforms to the measure derived from the period 1930 (the year of birth of the oldest farmer included in our analyses) –2008. We chose all those weather stations for which at least 10 observations for total rainy season precipitation were available in both the periods 1930–1978 and 1978–2008, which applies to 79 stations, and calculated the respective risk measures. Pearson correlation coefficients are 0.93 ($p<0.001$) and 0.98 ($p<0.001$) for the CV and mean, respectively. We conclude that the risk measure derived from the period 1978–2008 can serve as a proxy for the risk measure of the period 1930–2008 as well as for all other periods Z –2008 where Z is an integer in the interval [1930, 1978].

loans implies more liquidity constraint).[87] We represent life history by a continuous variable that denotes the number of years farmers have spent on their farm prior to adulthood, i.e. prior to age 18 years.[88] The idea behind this approach is to measure how long farmers could have experienced the precipitation risk on their farm during childhood and adolescence. Finally, we also include an experimental control variable that denotes payout type (real payout in field experiments vs. hypothetical payout in questionnaire experiments). Table 2 lists the respective variables with sample mean, standard deviation and range.

Maximum-likelihood specification

In our econometric specification of the expected utility function we follow the approach applied in previous studies in semi-arid areas by Harrison et al. (2010) and which is detailed in Harrison (2008). The expected utility of the lottery, i.e. the auction in the questionnaire experiments and the lottery in the field experiments, is defined as

(1) $$EU^L = p_1 U(y_1) + p_2 U(y_2) \ ,$$

where p_1 and y_1 denote the probability and payoff for outcome 1, p_2 and y_2 denote probability and payoff for outcome 2. Since probabilities and incomes were the same for all scenarios, it follows for the questionnaire experiments that

(2) $$EU^L = 0.5\ U(N\$90{,}000) + 0.5\ U(N\$130{,}000)$$

and for the field experiments that

(3) $$EU^L = 0.5\ U(N\$500) + 0.5\ U(N\$2{,}500) \ .$$

The expected utility for income from the certain amount is defined accordingly. Since this income is certain, the expected utility function reduces to $EU^C_i = U(y_{ci})$ where y_{ci} is the certain income for scenario *i* from the trader in the questionnaire experiments and the certain payout in the field experiments, respectively. Here, *i* as an index for the scenario (i=1,…,6 in the questionnaire experiment and i=1,…,16 in the field experiment).

We think of individuals as assessing the difference between expected utility derived from the lottery and the utility derived from the certain payoff when making their choices. They may, however, perform a processing error when evaluating the alternatives. This error can be

[87] Two commonly used socio-demographic control variables, age and ethnicity, are not included in our analyses. We ran specifications with these variables but found that they were not significant and that their inclusion did not change our results. In order to avoid over-specification we tried to use as few control variables as possible and consequently excluded both age and ethnicity.

[88] We assume that farmers stayed on the farm ever since it came into family possession or since he acquired it.

specified as a Fechner error ε which is an additive error term that is normally distributed with mean zero and standard deviation σ (Fechner, 1860/1966; Hey and Orme, 1994; Loomes and Sugden, 1995). The EU-difference the individuals evaluate is then

(4) $\Delta EU_i = EU^L - EU^C{}_i + \varepsilon$.

Employing maximum-likelihood estimation, we estimate the constant relative risk aversion (CRRA)-coefficient *r* and the Fechner error's standard deviation σ as parameters of a log-likelihood function.[89] This estimation assumes a cumulative standard normal distribution Φ defined over EU difference for the observed choices in each scenario. Thus, the log-likelihood function, conditional on the observed choices, is

(5) $$\ln L(r,\sigma;z,X) = \sum_i \left[(\ln(\Phi(\frac{\Delta EU}{\sigma})) \mid z_i = 1) + (\ln(1-\Phi(\frac{\Delta EU}{\sigma})) \mid z_i = 0) \right]$$

where z_i = 1 (0) denotes whether the subject choses the lottery (certain income) in scenario *i* and *X* is a vector of determinants. Due to an experimental artifact (many farmers indicated extreme responses) we did not include the responses of all farmers in the analysis (for details see Appendix A.2).

We model *r* as a linear function of the determinants and, following Harrison et al. (Harrison et al., 2007b) assume that σ is influenced by gender. We may then analyze the hypothesis that precipitation risk influences farmers differently contingent on life history through an interaction effect between risk and life history. The estimate $\hat{r}$ of *r* is

(6) $$\hat{r} = \hat{r}_o + \hat{r}_{MEAN} \cdot MEAN + \hat{r}_{CV} \cdot CV + \hat{r}_{YFPA18} \cdot YFPA18 + \hat{r}_{CV \times YFPA18} \cdot (CV \times YFPA18) + \hat{r}_X \cdot X$$

where *MEAN* is the inter-annual mean of total rainy season precipitation, *CV* the respective coefficient of variation which captures the precipitation risk, *YFPA18* the continuous life history variable denoting the number of years spent on the present farm prior to age 18 years, *CV* x *YFPA18* the interaction between risk and life history, and *X* a vector of control variables (see Table 2). We are interested in the value not only of the coefficients, but also of the constant $\hat{r}_o$.. In order to interpret it as the CRRA of the "typical" farmer – contingent on the chosen independent variables – we define binary variables (i.e. real payout, female, low education, multiple ownership, off-farm residence) in such way that the value zero indicates the most frequent category. We redefine continuous independent variables (i.e. area of

[89] Harrison et al. (2007b) discuss in detail why the estimation of the Fechner error reduces to estimating σ.

rangeland, liquidity constraint, mean of precipitation, CV of precipitation) by centering them through subtraction of their respective means. Thus, for redefined continuous variables the value zero now represents the sample average. We do not redefine the life history variable because the value zero is of special importance as it indicates those farmers who did not grow up on their farm.[90]

Finally, we assume that a farmer's responses in different scenarios are correlated, i.e. that the choice in one scenario is not independent of those in the other scenarios. We thus correct the standard errors by clustering all responses for a single farmer.

4. Results and discussion

We present our results in the form of three different model specifications which employ samples of different size and composition (Table 3). Specification (1) includes only the socio-demographic and experimental control variables, but not the risk and life-history variables. The sample for this specification consists of 1,782 choices by 216 farmers. Specification (2) additionally includes the risk and life-history variables, and Specification (3) the interaction effect between both variables. The sample for the latter two specifications is restricted to 977 choices by 99 farmers since we exclude farmers that are not risk-averse, did not reveal their farm location, lived on the farm for fewer than three years, or for whom we could not identify since when they lived on their present farm. We begin our discussion with findings on the causal mechanisms between risk preferences and precipitation risk (Section 4.1), proceed with findings on the impact of socio-demographic and experiment control variables (Section 4.2) and close with robustness checks (Section 4.3).

4.1 Causal mechanisms between risk preferences and precipitation risk

Both Specifications (2) and (3) indicate that risk preferences are significantly related to local precipitation risk. Specification (3), which we will discuss unless otherwise noted, indicates that the relationship is additionally contingent on life history: the total effect of risk on risk aversion comprises a significant main effect of risk and a significant interaction effect between risk and life history. The main effect is negative, with CRRA decreasing by 0.748 per unit of inter-annual CV of total rainy season precipitation. The interaction effect is positive with each year spent on the farm prior to age 18 years increasing the total effect of

[90] If we define the life history variable in such a way, then the interaction effect between risk and life history is zero for farmers who did not grow up on the farm. We will use this property in the discussion of our results (cf. Section 3.1).

precipitation risk on CRRA by 0.084. Although it does not concern the relationship between risk preferences and risk, we note for completeness that the main effect of life history on risk aversion is small but also significant, with CRRA decreasing by 0.003 for each year spent on the farm prior to age 18 years.

To examine which causal mechanisms are at play we discriminate between two subpopulations of farmers. The first subpopulation consists of farmers who did not grow up on their farm, i.e. who acquired their farm as adult. For them, the total effect equals the main effect as *YFPA18* is zero (i.e. they have spent no year on their farm prior to age 18 years). These farmers are *less* risk-averse the higher the precipitation risk on their farm. The second subpopulation consists of farmers who grew up on their farm for at least one year prior to age 18 years. For them, *YFPA18* and the interaction effect are positive and (partly) offset the negative main effect. For a given precipitation risk, those farmers are more risk-averse than farmers who did not grow up on their farm, and this increment in risk aversion is larger the longer they have experienced the risk during childhood and adolescence. For farmers of this second subpopulation who have spent less than 9 years on their farm prior to age 18 years, the total effect remains negative as the interaction effect offsets the main effect only partially. They are still less risk-averse under higher precipitation risk. In contrast, for farmers of who have spent at least 9 years on their farm prior to age 18 years the total effect becomes positive: the interaction effect then amounts to at least 0.756 and completely offsets the main effect of -0.748. They are *more* risk-averse under higher precipitation risk.

Endogeneity of risk preferences

In Section 2.1 we derived the hypothesis that risk preferences are endogenous with respect to precipitation risk experienced during childhood and adolescence and that formation of preferences is stronger the longer a farmer has experienced this risk. We have no information on early-life experience of risk for the first subpopulation of farmers who did not grow up on their farm. However, we do have such information for the second subpopulation of farmers who grew up on their farms, as we may approximate the precipitation risk during their childhood and adolescence by the precipitation risk on the very same farm that we may calculate for the period 1978–2008 (c.f. Section 3.3). For them, our estimation results support our hypothesis: the interaction effect is non-zero and the total effect of risk on risk aversion consequently contingent on *YFPA18*. Thus, the relationship between risk preferences and risk changes with experience of this risk during childhood and adolescence, and the change is more profound the longer this risk was experienced. We can exclude the possibility of reverse causality, i.e. risk aversion impacting on precipitation risk, as precipitation is, of course, exogenous to the actions of the individual farmer.

We may interpret the positive sign of the interaction effect, i.e. that risk aversion is increasing with early-life experience of a risk, as a more general indication that experience with adverse risk conditions results in more risk-averse behavior. In this regard, our observations are in line with those of Malmendier and Nagel (2011) who observe more risk-averse behavior for stock and bond market investors who have experienced worse macro-economic conditions. We differ from their study in our interpretation of the results. Malmendier and Nagel (2011) propose endogeneity of risk beliefs as the causal mechanism. For Namibian cattle farmers there is qualitative evidence that farmers' subjective beliefs about the precipitation distribution conform to the objective distribution. Thus, we rule out endogeneity of beliefs as a possible explanation and instead propose endogeneity of risk preferences.[91] However, our results are not in line with those by Voors et al. (2011) who find that adverse experience of civil war shocks makes people more risk-averse.

Self-selection

In Section 2.2 we derived the hypothesis that farmers self-select themselves according to risk preferences with more risk-averse farmers operating on less risky farms. Our estimation results for the first subpopulation of farmers who did not grow up on their farm support this hypothesis: the total effect is negative and equal to the main effect of -0.748. Thus, within this subpopulation farmers are indeed less risk-averse under higher precipitation risk. This result also conforms to previous findings of a negative relationship between risk aversion and riskiness of prospects, e.g. on choice of occupations with risky income (e.g. Bellemare and Shearer, 2010) or investment portfolios (e.g. Guiso and Paiella, 2005), which are likewise explained by self-selection.

Precipitation background risk

Finally, we note in Section 3.2 that precipitation risk may act as a background risk. In contrast to endogeneity of preferences, we cannot control for this separately. The main effect of risk on risk aversion may thus reflect *both* self-selection and precipitation risk acting as a background risk. We therefore have to consider whether precipitation background risk may confound our findings on self-selection.

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[91] Even though Malmendier and Nagel (2011) propose endogeneity of beliefs as the underlying mechanism, they cannot rule out the possibility of endogeneity of risk preferences occurring simultaneously.

There are three cases. In the first case, precipitation risk does not act as a background risk. Then our estimate of -0.748 for the main effect solely reflects self-selection. In the second case, precipitation risk acts as a background risk and impacts positively on risk aversion, i.e. in the opposite direction of self-selection. Then we can only estimate a negative coefficient for the main effect if the positive effect due to precipitation background risk is completely offset by a considerably larger and negative effect due to self-selection. In the third case, precipitation risk again acts as a background risk but now impacts negatively on risk aversion, i.e. in the same direction as self-selection. Then we can make no statement on whether only self-selection, only background risk, both or neither are causal mechanisms that explain the negative impact of risk on risk aversion.

Based on previous literature findings (cf. Section 3.2), we can exclude the third case. That still leaves the first two cases and it is not possible to state which one holds true. We therefore cannot make any statement on whether precipitation risk is indeed acting as a background risk. However, we can state that the observed negative relationship between risk aversion and risk is at least partly due to self-selection. Thus, the possibility of precipitation risk acting as a background risk does not confound our findings on self-selection.

Price background risks and liquidity constraint

Finally, we note that our results are neither confounded by price background risks or by liquidity constraints. As mentioned above, the price risks are homogenous across farmers and cannot explain individual differences in risk behavior. Liquidity constraints are heterogeneous across famers but do not impact on risk aversion as the coefficient is with -0.005 small and not significant.

4.2 Constant, socio-demographic and experimental control variables

Results on the socio-demographic and experimental control variables are identical in regards to sign, and similar in regards to magnitude and significance for Specifications (2) and (3). All estimates that are significant in Specification (1) are also significant in Specifications (2) and (3), but absolute values of the constant and almost all variables are higher in the latter two specifications. At least for the constant, this is due to exclusion of risk-loving farmers. Finally, gender is significant only in Specifications (2) and (3). In the further course, unless otherwise noted, we will discuss the constant and control variables exemplarily for Specification (1).

We find that the "typical" farmer is risk-averse with a CRRA-coefficient of 1.029 (Table 3). This value is close to the 0.951 reported for field experiments with American coin collectors by Harrison et al. (2007b) who employ the same utility function and error specification. The Fechner error is not significant and only marginally different from zero. If we rerun the analysis without independent variables and error specification, we estimate a CRRA-coefficient of 0.790 (1845 choices by 227 farmers, $p<0.001$).[92] Thus, risk aversion for the "typical" farmer is confirmed over alternative model specifications, and this agrees with findings from other studies in semi-arid areas, such as Binswanger (1980) for India, Nielsen (2001) for Madagascar, Wik et al. (2004) for Zambia, Bezabih (2009) for Ethiopia, Yesuf and Bluffstone (2009) for Ethiopia and Harrison et al. (2010) for Ethiopia, India and Uganda).

Specifications (2) and (3), but not Specification (1), show that female farmers are less risk-averse than male farmers with CRRA being lower by 0.318 and 0.347, respectively. This result echoes what Harrison et al. (2010) found in India, Uganda and Ethiopia, but is at odds with other results from semi-arid regions (e.g. Wik et al., 2004). Low education is positively related to risk aversion with an increase in CRRA by 0.063, and these findings are in accordance with, for example, Binswanger (1980). Farmers who operate in some form of joint ownership are with 0.028 units CRRA significantly less risk-averse than farmers who are single owners. Area of rangeland is not related to risk aversion, which is in contrast to Yesuf and Bluffstone (2009) who find a negative relationship. Likewise, part-time farming and liquidity constraint do not significantly affect risk aversion. Altogether, comparing the relationship between risk preferences and socio-demographic variables across studies does not reveal a clear picture on the sign of many of these variables. Our findings are thus best viewed in the specific context of commercial cattle farming in Namibia.

Turning to the experimental control variable we find that choices in field experiments (which involve real payouts) are associated with an increase in risk aversion by 0.427. The observed difference in risk aversion may be due to payout structure, i.e. real payouts in field experiments and hypothetical payouts in questionnaire experiments, or framing, i.e. the number of scenarios, elicitation procedure and the specific context in which the experiments were phrased. In regards to payout structure, Holt and Laudry (2002) reported subjects behaved more risk-averse when confronted with real instead of hypothetical payouts. In

[92] This coefficient is higher than values reported from other field studies that assume the same utility function and no error specification, but not out of range of values that can be found in laboratory experiments. For example, Harrison et al. (2010) find a CRRA-coefficient of 0.536 in a field study in India, Uganda and Ethiopia, and Harrison et al. (2007a) a coefficient of 0.67 in a field study in Denmark, while Andersen et al. (2006) reported a value of 0.79 for laboratory experiments in Denmark.

regards to framing, Harrison et al. (2007b) found the CRRA-estimate differs by up to 0.756 across frames. In light of this number, the difference in CRRA-estimates between field and questionnaire experiments in our study is reasonably small. Altogether, our finding that the CRRA-coefficient is sensitive to experimental type is not surprising, but the exact reason remains elusive since our experiments were not designed to clarify this aspect.

4.3 Robustness check

In order to ensure that our results in Section 4.1 are not driven by certain assumptions or model specifications we perform robustness checks. We briefly summarize these checks here while we treat them at length in Appendices A.3 and A.4.

Life history as a binary variable

Our results on endogeneity of preferences may depend on the way we code life history. In this robustness check (Appendix A.3), we code life history not as a continuous variable as in Specification (3), but instead as a binary variable that indicates whether farmers were present on their farm at a certain threshold age. We estimate three separate specifications in which we vary the threshold age. In the first one, we set the threshold to age 0 years. The binary variable then indicates whether farmers were born on their farm. In the second and third one, we set the threshold to age 9 years and age 18 years, respectively, to indicate farmers who lived already on their farm at age 9 years and 18 years.

Estimating these alternative specification we find that the main effect of precipitation risk on risk aversion is negative, while the interaction effect is positive and increases if farmers have spent more time on their farm during childhood and adolescence (i.e. if we lower the age threshold in the binary life history variable). In addition, our results show that preferences are no longer endogenous with respect to environmental risk once adulthood has been reached. Thus, using these alternative specifications we again find evidence for endogeneity of preferences during childhood and adolescence, and self-selection during adulthood, acting as causal mechanisms.

Heterogeneous time preferences

According to the farm market model (Section 2.2) time preference in the form of a discount rate influences the bids farmers are willing to offer for a farm and thus ultimately self-selection onto farms. We assume in the previous analysis that time preferences are homogenous across farmers. However, we elicited time preferences along with risk preferences in the survey. We did not include them before due to an experimental artifact akin to what we described for risk experiments in Appendix A.2 which invalidates elicited data from time experiments for 32% of farmers. As a consequence, if we control for time preferences the number of farmers over which results are estimated decreases to only 79.

In this robustness check we include time preference as an additive control variable in the form of a time preference index (Appendix A.4). Estimation yields qualitatively the same results as in Specification (3): coefficients remain in the same order of magnitude and retain their sign, and (in)significant coefficients remain (in)significant. The index itself is significant at the 1%-level and has a coefficient of -0.027. Thus, the parsimonious model we estimate in Specification (3) adequately captures the relationship between risk preferences and risk.

5. Conclusion

We find that, on average, more risk-averse farmers operate less risky farms. We have shown that this finding may be explained by a farm market that allocates farms to farmers according to their risk preferences. Even for farmers who never purchased a farm (i.e. who grew up and stayed on their farm) we observe evidence suggesting self-selection. More importantly, our analysis also shows that risk preferences endogenously depend on experience with environmental risk during childhood and adolescence, but not during adulthood. Finally, if early-life experience with environmental risk is long enough, endogeneity becomes the dominant mechanism for the relationship between risk preferences and environmental risk. Our results are robust to alternative model specifications and are not confounded by precipitation risk acting as a background risk, by price background risks or by liquidity constraints.

Our results have general implications since risk preferences play a fundamental role in economic theory. For example, (Harsanyi, 1953, 1955, 1977) justifies the Utilitarian social welfare function based on an argument where an impartial observer chooses social states behind a veil of ignorance according to von-Neumann-Morgenstern risk preferences. Endogeneity of risk preferences poses an obvious challenge to this argument.

Our results also have implications for the management of ecosystems and natural resources in the context of climate change. Climate change is considered to entail an increase in environmental risks, such as of storms, fires, floods or droughts, which already affect many regions worldwide (Schneider et al., 2007). This alters peoples' opportunity sets and, *ceteris paribus* (given risk preferences, in particular), increases the demand for insurance against environmental risks. According to our results, however, an increase in experienced environmental risk might make future generations ever more risk-averse. This additionally increases future insurance demand. It also poses a challenge to the actuarial calculation of insurance premiums, and the functioning of competitive insurance markets over the long-run. Thus, development of well-functioning insurance markets in developing regions may become even more important, but also more challenging, with ongoing climate change in the coming decades.

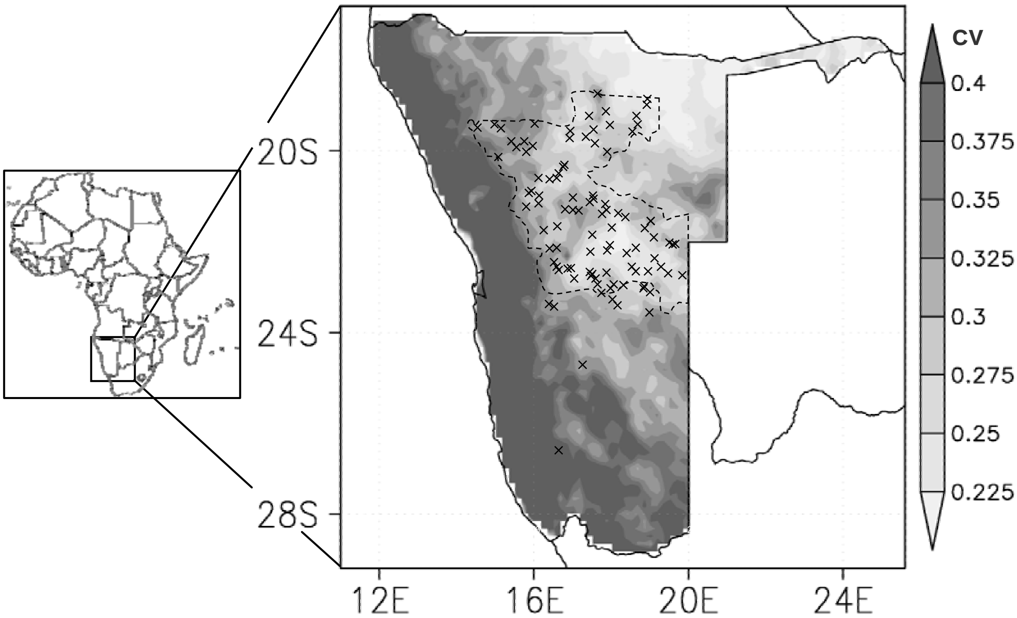

Figure 1: Precipitation risk in Namibia and study area. Shading denotes the inter-annual coefficient of variation (CV) of total rainy season precipitation for the period 1978–2008, as calculated by the Regional Model (REMO). Crosses depict locations of those surveyed farms that were included in Specifications (2) and (3). Dashed lines indicate main commercial cattle farming area as adapted from Mendelsohn (2006: 43). Map of Africa copyrighted by Graphic Maps.

Table 1: Experimental design for risk preference elicitation: a) questionnaire experiments with context of sales at a cattle auction, b) field experiments without context. For context and instructions provided see Olbrich et al. (2009).

a) Questionnaire experiments

Scenario	Lottery		Certain amount
	Outcome 1	Outcome 2	
1	N$ 90,000; ½	N$ 130,000; ½	N$ 100,000
2	N$ 90,000; ½	N$ 130,000; ½	N$ 102,500
3	N$ 90,000; ½	N$ 130,000; ½	N$ 105,000
4	N$ 90,000; ½	N$ 130,000; ½	N$ 107,500
5	N$ 90,000; ½	N$ 130,000; ½	N$ 110,000
6	N$ 90,000; ½	N$ 130,000; ½	N$ 112,500

b) Field experiments

Scenario	Lottery		Certain amount
	Outcome 1	Outcome 2	
1	N$ 500; ½	N$ 2,500; ½	N$ 550
2	N$ 500; ½	N$ 2,500; ½	N$ 600
3	N$ 500; ½	N$ 2,500; ½	N$ 650
4	N$ 500; ½	N$ 2,500; ½	N$ 700
5	N$ 500; ½	N$ 2,500; ½	N$ 800
6	N$ 500; ½	N$ 2,500; ½	N$ 900
7	N$ 500; ½	N$ 2,500; ½	N$ 1,000
8	N$ 500; ½	N$ 2,500; ½	N$ 1,100
9	N$ 500; ½	N$ 2,500; ½	N$ 1,200
10	N$ 500; ½	N$ 2,500; ½	N$ 1,300
11	N$ 500; ½	N$ 2,500; ½	N$ 1,400
12	N$ 500; ½	N$ 2,500; ½	N$ 1,500
13	N$ 500; ½	N$ 2,500; ½	N$ 1,600
14	N$ 500; ½	N$ 2,500; ½	N$ 1,700
15	N$ 500; ½	N$ 2,500; ½	N$ 1,800
16	N$ 500; ½	N$ 2,500; ½	N$ 1,900

Table 2: Variable list and descriptive statistics for Specifications (2) to (3). N = 99.

Variable	Definition	Mean	Standard deviation	Min	Max
Real payout	Participation in field experiment with real payout	0.25	0.44	0	1
Female	Female	0.04	0.20	0	1
Low education	No college or apprenticeship education	0.18	0.39	0	1
Area of rangeland	Area of rangeland in hectares	7,952	4,693	0	26,000
Multiple ownership	Farm owned by a more than one individual	0.32	0.47	0	1
Off-farm residence	Living off farm during the week, proxy for part-time farming	0.21	0.41	0	1
Liquidity constraint	Self-reported liquidity constraint, measured as importance of loans for farm business operation on a six-item Likert scale where higher values indicate more liquidity constraint	2.92	1.63	1	6
YFPA18	Number of years farmers have spent on their farm prior to age 18 years	8.19	8.56	0	18
Mean of precipitation	Inter-annual mean of total rainy season precipitation in mm	286.9	85.3	67.4	508.6
CV of precipitation	Inter-annual coefficient of variation (CV) of total rainy season precipitation	0.29	0.04	0.22	0.47
CV x YFPA18	Interaction effect between CV of precipitation and YFPA18	2.30	2.42	0	6.18

Table 3: Maximum-likelihood estimation of coefficient of constant relative risk aversion (r) and Fechner error (σ) for three different model specifications (1, 2, 3). Standard errors are reported in parentheses. Confidence levels: *** p<0.01, ** p<0.05, * p<0.1.

Parameter	Variable	(1)	(2)	(3)
r	Constant	1.029***	1.376***	1.386***
		(0.114)	(0.138)	(0.126)
	Real payout	0.427***	0.664***	0.673***
		(0.085)	(0.114)	(0.108)
	Female	0.023	–0.318***	–0.347***
		(0.082)	(0.116)	(0.116)
	Low education	0.063***	0.056**	0.069**
		(0.020)	(0.027)	(0.027)
	Area of rangeland	–0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)
	Multiple ownership	–0.028*	–0.059**	–0.067***
		(0.015)	(0.025)	(0.024)
	Off-farm residence	0.001	–0.045	–0.041
		(0.023)	(0.029)	(0.030)
	Liquidity constraint	–0.002	–0.001	–0.005
		(0.005)	(0.006)	(0.006)
	YFPA18		–0.004**	–0.003**
			(0.001)	(0.002)
	Mean of precipitation		0.000	0.000
			(0.000)	(0.000)
	CV of precipitation		–0.499*	–0.748**
			(0.269)	(0.291)
	CV x YFPA18			0.084**
				(0.038)
σ	Female	–0.012	0.002	0.002
		(0.018)	(0.002)	(0.002)
	Constant	0.018	0.000	0.000
		(0.024)	(0.001)	(0.001)
	Log-likelihood	–667.9	–322.2	–318.8
	Chi-square	42.97	58.71	65.15
	Model significance	0.000	0.000	0.000
	Observations	1,782	977	977
	Clusters	216	99	99

Appendix

A.1. Bids on the land market

The expected present value of utility from rangeland farming for a farm (x_0,σ) is given by

$$E\left[\int_0^\infty \frac{x_t^{1-r}}{1-r}\exp(-\delta t)dt\right]=\int_0^\infty \frac{x_0^{1-r}}{1-r}\exp(-\frac{1}{2}r(1-r)\sigma^2 t)\exp(-\delta t)dt \tag{7}$$
$$=\frac{x_0^{1-r}}{1-r}\frac{1}{\frac{1}{2}r(1-r)\sigma^2+\delta}.$$

The maximal constant fraction ϕ of annual income that a farmer with reservation utility

$$\int_0^\infty \frac{y_0^{1-r}}{1-r}\exp(-\delta t)dt=\frac{y_0^{1-r}}{1-r}\frac{1}{\delta}$$

is willing to bid is determined by the condition

$$\frac{\left((1-\phi)x_0\right)^{1-r}}{1-r}\frac{1}{\frac{1}{2}r(1-r)\sigma^2+\delta}=\frac{y_0^{1-r}}{1-r}\frac{1}{\delta}.$$

Solving for ϕ leads to

$$\phi=1-\frac{y_0}{x_0}\left(1+\frac{r(1-r)\sigma^2}{2\delta}\right)^{\frac{1}{1-r}}. \tag{8}$$

Differentiating (8) with respect to r and σ, we obtain

$$\frac{d\phi^2}{drd\sigma}=-\frac{y_0}{x_0}\frac{\sigma}{\delta}\left(1+\frac{r(1-r)\sigma^2}{2\delta}\right)^{\frac{r}{1-r}-1}\cdot$$
$$\left(1+\frac{r(1-r)\sigma^2}{2\delta}+\frac{r^2(1-2r)\sigma^2}{(1-r)2\delta}+\frac{r}{(1-r)^2}\left(1+\frac{r(1-r)\sigma^2}{2\delta}\right)\ln\left(1+\frac{r(1-r)\sigma^2}{2\delta}\right)\right)$$

The expression in brackets is positive, as we shall prove in the following. We consider the cases $r>1$ and $r<1$ separately. For $r>1$, the third term is positive. The sum of the first two terms is positive by assumption $1/2\,r(1-r)\sigma^2+\delta>0$. The last term is positive by the same assumption. The sum of these positive terms must be positive as well. For $r<1$, we use

$$\ln\left(1+\frac{r(1-r)\sigma^2}{2\delta}\right)<\frac{r(1-r)\sigma^2}{2\delta}\left(1-\frac{1}{2}\frac{r(1-r)\sigma^2}{2\delta}\right)$$

which holds as by assumption $1/2\,\sigma^2<\delta$. Hence, we have

$$\left(1+\frac{r(1-r)\sigma^2}{2\delta}+\frac{r^2(1-2r)\sigma^2}{(1-r)2\delta}+\frac{r}{(1-r)^2}\left(1+\frac{r(1-r)\sigma^2}{2\delta}\right)\ln\left(1+\frac{r(1-r)\sigma^2}{2\delta}\right)\right)$$

$$<1+\frac{r(1-r)\sigma^2}{2\delta}+\frac{r^2(1-2r)\sigma^2}{(1-r)2\delta}+\frac{r^2\sigma^2}{(1-r)2\delta}\left(1+\frac{1}{2}\frac{r(1-r)\sigma^2}{2\delta}-\frac{1}{2}\left(\frac{r(1-r)\sigma^2}{2\delta}\right)^2\right)$$

$$=1+\frac{\sigma^2}{2\delta}\left(r(1-r)+\frac{r^2(1-2r)}{1-r}+\frac{r^2}{1-r}\right)+\frac{r}{2}\left(\frac{r\sigma^2}{2\delta}\right)^2\left(1-\frac{r(1-r)\sigma^2}{2\delta}\right) \quad .$$

$$=1+\frac{\sigma^2}{2\delta}\frac{r-2r^2+r^3+r^2-2r^3+r^2}{1-r}+\frac{r}{2}\left(\frac{r\sigma^2}{2\delta}\right)^2\left(1-\frac{r(1-r)\sigma^2}{2\delta}\right)$$

$$=1+\frac{\sigma^2}{2\delta}\frac{r-r^3}{1-r}+\frac{r}{2}\left(\frac{r\sigma^2}{2\delta}\right)^2\left(1-\frac{r(1-r)\sigma^2}{2\delta}\right)>0$$

Overall, we have $\frac{d\phi^2}{drd\sigma}<0$ which proves the proposition.

The following Appendices A.2 to A.4 are for online publication only.

A.2 Elimination of experimental artifacts

About one quarter (23.4%) of farmers who mailed in questionnaires never or always chose the lottery in the questionnaire experiment, i.e. they made choices that characterize them as extremely risk-averse or extremely risk-attracted. Such a pattern was not apparent for those 39 farmers that completed the questionnaire experiment in the presence of a researcher (during our experimental sessions) where only 17.5% never or always chose the lottery. A two sample Kolmogorov-Smirnov test for equality of distributions reveal significant differences between both groups ($p = 0.032$). In the sessions where a researcher was present we observed that it frequently took farmers a long time to complete the hypothetical risk experiment in the questionnaire. After having filled in the questionnaire some of those farmers who were characterized as extremely risk-averse or extremely risk-attracted remarked that they had a personal dislike for selling at auctions or to a trader, respectively.

Based on these observations, we consider the extreme responses of those farmers who mailed-in questionnaires likely to be experimental artifacts that do not reflect risk taking behavior. We therefore exclude these farmers in our analyses. After exclusion, a two sample Kolmogorov-Smirnov test is no longer significant ($p = 0.332$). The above described maximum likelihood-estimation is thus at the tails defined only over responses from the 39 experimental participants for which we are certain that they indicated risk taking behavior.

A.3. Robustness check: life history as a binary variable

In Specification (3) we examine for endogeneity of risk preferences by coding life history as the continuous variable *YFPA18* and by calculating the interaction effect with precipitation risk. In this robustness check, we code life history as the binary variable *GREWUP* which indicates whether farmers lived already on their farm at a certain threshold age (*GREWUP* = 1) or not (*GREWUP* = 0). We then calculate the interaction effect between the precipitation risk farmers have experienced and *GREWUP* accordingly and estimate the model:

(9) $$\hat{r} = \hat{r}_o + \hat{r}_{MEAN} \cdot MEAN + \hat{r}_{CV} \cdot CV + \hat{r}_{GREWUP} \cdot GREWUP + \hat{r}_{CV \times GREWUP} \cdot (CV \times GREWUP) + \hat{r}_X \cdot X$$

where *GREWUP* is the binary life history variable and *CV* × *GREWUP* the interaction effect between precipitation risk and life history. Estimation results obviously depend on the precise value we select for the threshold age of *GREWUP*. We exemplarily report below estimations for the three values 0, 9 and 18 years, but we arrive at the same qualitative results if we choose other values in the interval [0 years, 18 years]. Accordingly, in Specification (4) we set the threshold age to 0 years. *GREWUP* then indicates whether farmers were born on their farm. In Specification (5) and (6) we set the threshold to 9 years and 18 years, respectively, to indicate farmers who lived already on their farm at age 9 years and age 18 years.

Estimation results show that the main effect of risk on risk aversion is significant, negative and similar between Specifications (4) to (6) with a value between -0.546 and -0.735 (Table 4). The interaction effect is positive in all specifications, but significant only in the first two. Its value decreases from 1.756 to 1.343 and 0.392 in Specifications (4), (5) and (6), respectively.

These results confirm our previous findings on endogeneity of preferences. The positive interaction effect indicates that, for a given risk, farmers who grew up on their farm are more risk-averse than those who did not grow up on their farm. Furthermore, the interaction effect is larger in magnitude the lower we set the age threshold, indicating that the relationship between risk aversion and risk is impacted on more strongly the longer farmers have experienced the risk. Finally, the interaction effect is no longer significant if we set the threshold age to 18 years, suggesting that risk must be experienced in early life in order to shape preferences.

The results also confirm our finding on self-selection. For the subpopulation of farmers whom we designated as not having grown on their farm, i.e. for whom *GREWUP* and the interaction effect take on the value zero, the total effect of risk on risk aversion equals the negative main effect. In Specification (6), the composition of this subpopulation corresponds to that in Specification (3), i.e. comprises of farmers who came to the farm at age 18 years or old and thus presumably by their own choice. Thus, the negative relationship between risk aversion and risk suggests self-selection according to risk preferences. In Specification (5) and (4) the composition is different: farmers designated as not having grown up on their farm comprise all farmers who came to the farm of their own choice as well as those who came there with their parents between age 10 to 18 years and age 1 to 18 years, respectively. The negative relationship suggests self-selection even if farmers are included who never changed farms on their on choice.

Altogether, results in this alternative approach with a binary life history variable confirm our previous finding on endogeneity of preferences and self-selection that we estimated with a continuous life history variable. These previous findings are thus not sensitive to the concrete model specification we employed in Specification (3).

A.4. Robustness check: heterogeneous time preferences

Correspondingly to the elicitation of risk preferences, we elicited time preferences by a multiple price list format with hypothetical payouts, as detailed in Olbrich et al. (2009). In a context free frame, farmers had to choose in five scenarios between receiving a payment in one month or a higher payment in seven months. The payment in one month of N\$100,000 was constant throughout all scenarios. The payment in seven months increased from N\$104,881 in the first scenario, which corresponds to an annual interest rate with quarterly compounding of 10%, to N\$122,474 in the fifth and last scenario, which corresponds to an interest rate of 50%. Values for later payments in the scenarios in between the first and the last were chosen in such a way that the corresponding interest rate increased by 10% per scenario.

In these kind of experiments, subjects typically prefer the earlier payment when the later payment is low and switch once the later payment is deemed high enough. Out of the switch point we constructed a time preference index as an integer variable with values in {1, 2, …, 6} where high values denote high impatience and thus imply a high discount rate, i.e. those farmers who only switch to the later amount when it is high. The highest possible value '6' denotes very high impatience, i.e. those farmers who never switch to the later amount.

Including the time preference index as an additive control variable in regression Equation (6) yields the following augmented equation:

$$(10) \quad \hat{r} = \hat{r}_o + \hat{r}_{MEAN} \cdot MEAN + \hat{r}_{CV} \cdot CV + \hat{r}_{YFPA18} \cdot YFPA18 + \hat{r}_{CV \times YFPA18} \cdot (CV \times YFPA18) + \hat{r}_{TPI} \cdot TPI + \hat{r}_X \cdot X$$

where *TPI* is the time preference index. Including the index reduces the sample size to 868 choices from 79 farmers due to an experimental artifact akin to what we observed in the risk experiments (cf. Appendix A.2).

Estimating this regression as Specification (7) confirms our results in Specification (3): all coefficients remain in the same order of magnitude and retain the sign, and significant (insignificant) coefficients remain significant (insignificant) (Table 4). The time preference index itself is significant at the 1%-level and has a coefficient of -0.027. Thus, farmers who are less impatient (have a lower implied discount rate) are more risk-averse. These findings on the time preference index conform to Andersen et al. (2008a) who study both risk and time preferences and who estimate a lower discount rate if they consider that experimental participants are risk-averse instead of risk neutral. Altogether, control for time preferences does not change our findings on the relationship between risk preferences and precipitation risk, and the parsimonious model we estimated in Specification (3) thus captures adequately the relationship between risk preferences and environmental risk.

Table 4: Maximum-likelihood estimation of coefficient of constant relative risk aversion (r) and Fechner error (σ). Specification (3) as in Table 3. Specification (4), (5) and (6) denote life history by the binary variable *GREWUP* with the age threshold set at 0 years, 9 years and 18 years, respectively. The interaction effects between life history and precipitation risk are calculated correspondingly. Specification (7) is as (3) but includes a time preference index. Standard errors are reported in parentheses. Confidence levels: *** p<0.01, ** p<0.05, * p<0.1.

Parameter	Variable	(3)	(4)	(5)	(6)	(7)
r	Constant	1.386***	1.383***	1.388***	1.369***	1.398***
		(0.126)	(0.129)	(0.129)	(0.153)	(0.155)
	Real payout	0.673***	0.673***	0.675***	0.653***	0.685***
		(0.108)	(0.109)	(0.109)	(0.123)	(0.134)
	Female	–0.347***	–0.327***	–0.352***	–0.306***	–0.326***
		(0.116)	(0.110)	(0.118)	(0.108)	(0.107)
	Low education	0.069**	0.064**	0.069**	0.051*	0.079***
		(0.027)	(0.026)	(0.027)	(0.028)	(0.025)
	Area of rangeland	0.000	0.000	0.000	–0.000	0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Multiple owners	–0.067***	–0.065***	–0.065***	–0.053**	–0.043*
		(0.024)	(0.022)	(0.024)	(0.023)	(0.022)
	Off-farm residence	–0.041	–0.056*	–0.031	–0.052*	–0.027
		(0.030)	(0.031)	(0.030)	(0.030)	(0.029)
	Liquidity constraint	–0.005	–0.004	–0.005	0.002	–0.006
		(0.006)	(0.006)	(0.006)	(0.006)	(0.005)
	YFPA18	–0.003**				–0.003***
		(0.002)				(0.001)
	GREWUP		–0.041	–0.054**	–0.030	
			(0.027)	(0.023)	(0.022)	
	Mean of precipitation	0.000	0.000	0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	CV of precipitation	–0.748**	–0.646**	–0.735**	–0.546*	–0.543**
		(0.291)	(0.281)	(0.287)	(0.292)	(0.258)
	CV x YFPA18	0.084**				0.109***
		(0.038)				(0.042)
	CV x GREWUP		1.756**	1.343**	0.392	
			(0.769)	(0.636)	(0.625)	
	Time preference index					–0.027***
						(0.008)
σ	Female	0.002	0.001	0.002	0.001	0.001
		(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
	Constant	0.000	0.000	0.000	0.000	0.000
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	Log-likelihood	–318.8	–320.1	–318.8	–327.7	–292.5
	Chi-square	65.15	67.76	66.29	69.85	56.10
	Model significance	0.000	0.000	0.000	0.000	0.000
	Observations	977	977	977	977	868
	Clusters	99	99	99	99	79

Chapter 6: Personal norms of sustainability and their impact on management – The case of rangeland management in semi-arid regions

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Abstract

We empirically study personal norms of sustainability, conceptualized according to the norm-activation theory and operationalized under the notion of strong ecological-economic sustainability, for commercial cattle farmers in semi-arid rangelands of Namibia, a system that is subject to extensive degradation. We characterize farmers' personal norms, study their determinants, and analyze their impact on actual management based on the dual-preferences model. We find personal norms of sustainability that are heterogeneous across farmers but vary little with socio-demographic or environmental characteristics. We find no evidence for a significant impact of personal norms on actual management behavior, which may be due to farmers not feeling capable for averting adverse long-term consequences of their management. This may contribute to the observed degradation of rangelands in Namibia.

Keywords: commercial cattle farming, Namibia, norm-activation theory, personal norms, dual-preferences model, semi-arid rangelands, sustainability

JEL-classification: D63, Q12, Q57

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1. Introduction

Sustainability is often viewed as a moral obligation to "pass on a world of undiminished life opportunities to members of future generations" (Howarth, 2007: 656; similarly: Solow, 1993). As such, sustainability is a norm which is an independent determinant of individual behavior besides egoistic preferences and the opportunity set (Brekke et al., 2003; Young, 2008; Young and Burke, 2010). More specifically, it is a type of norms that determines behavior affecting the well-being of others through changes in the environment (Harland et al., 1999; Stern, 2000; Nordlund and Garvill, 2002). A crucial aspect of norms is that people are not bound to comply. People may have distinct norms but might not be aware of adverse, interpersonal consequences of their behavior or might not belief themselves capable of averting these consequences (Schwartz, 1973, 1977; Stern et al., 1999), and thus act as if these norms were non-existent. In this paper, we empirically characterize norms of sustainability for the case study of commercial cattle farming in semi-arid rangelands of Namibia, study their determinants, and analyze their impact on actual management behavior.

Previous studies of norms that determined environmentally significant behavior, such as recycling (e.g. Hopper and Nielsen, 1991; Thogersen, 1999), waste reduction (e.g. Thogersen, 1999) or renewable energy consumption (e.g. Ek and Söderholm, 2008) often equate these norms with norms of sustainability. However, it remains questionable whether this equation is valid as important aspects of sustainability are not explicitly clarified, such as what specific notion of sustainability is employed or whether the behavior at hand targets indeed sustainability. Furthermore, the typically studied economic actors are consumers, which may not be the ideal objects for studying norms of sustainability. Consumer behavior is only indirectly linked to the environment, while the direct impact on the environment is exerted by production, in particular in agriculture.

In this paper, we properly conceptualize, operationalize and analyze norms of sustainability. We conceptualize norms according to the norm-activation theory (Schwartz, 1973, 1977). Accordingly, sustainability may be viewed as an abstract social norm from which individuals derive concrete personal norms of sustainability which are heterogeneous across individuals. These personal norms provide guidance on how to act sustainably in specific situations only if they are activated, that is if individuals are aware of conditions that entail adverse consequences for others and feel capable for averting these consequences. We operationalize personal norms under the notion of strong ecological-economic sustainability (Pearce et al., 1989; Daly et al., 1994; Ekins et al., 2003; Baumgärtner and Quaas, 2009). For sustainability of an ecological-economic system, it is important to maintain both the condition of the ecosystem, so that it may continue to provide essential services to humans, and to maintain the income of the actors, so that their livelihood is secured (Baumgärtner and Quaas, 2009). Accordingly, we examine two specific personal norms of sustainability which are the level at or above which ecosystem quality should be sustained ("personal ecosystem norm") and the level at or above which income should be sustained ("personal income norm"). We analytically relate these personal norms to behavior using the dual-preferences model (Brekke et al., 2003; Conlin et al., 2003; Young and Burke, 2010). Herein, they constitute an independent determinant of behavior besides egoistic preferences and are traded-off against egoistic preferences by a non-negative weighting factor. This factor may be interpreted as the activation of a personal norm: if the factor is positive (zero) then the norm impacts (does not impact) on behavior since it is activated (not activated).

We chose commercial cattle farming in semi-arid rangelands of Namibia as a case study since we previously identified critical components for the system's sustainability (Quaas et al., 2007; Olbrich et al., 2011c; Quaas and Baumgärtner, 2011), among them the aforementioned condition of the ecosystem and the income of farmers. Furthermore, farmers as the main economic actors are closely linked to the environment. Namibian rangelands suffer from degradation in the form of bush encroachment where the historical coexistence of grass and bush vegetation is replaced by a dense bush vegetation (de Klerk, 2004). Bush encroachment does not only impair the ecosystem's condition, such as by reducing biodiversity (e.g. Griffin, 1998; Maggs et al., 1998), but also severely reduces farmer's income as it limits cattle production. It is frequently hypothesized that inadequate farm management contributes to bush encroachment (de Klerk, 2004).

Against this background, we pursue the following research questions: 1) What personal ecosystem and income norms can be found among commercial cattle farmers in Namibia? 2) What determines these norms? 3) Do these norms impact on actual management? We approach these questions empirically based on a large-scale, representative mail survey of 1.916 farmers that we conducted in August 2008 (Olbrich et al., 2009). Herein, we elicited personal ecosystem and income norms, management employed by farmers as well as socio-demographic and environmental characteristics.

We find firstly that farmers have personal ecosystem and income norms that are heterogeneous across individuals. Secondly, these norms are independent of each other and vary only little with socio-demographic or environmental characteristics. Thirdly and most importantly, we find no evidence for a significant impact of personal norms on actual management. This suggests that the weighting factors of the dual-preferences model are zero, indicating that the personal norms of sustainability are not activated. We hypothesize that personal norms are not activated because farmers do not feel capable of averting adverse long-term management consequences and thus do not pursue sustainable management.

This paper is organized as follows. Section 2 details the conceptual background of our analysis – norm-activation theory, notion of sustainability, system description and dual-preferences model. Section 3 describes the methods used to collect and analyze our data. Results are presented in Section 4, and Section 5 discusses and concludes.

2. Conceptual background

2.1 Norm-activation theory

Several approaches have been developed to conceptualize norms, which may broadly be divided into two strands. The first strand views norms as "a standard, customary, or ideal form of behavior to which individuals in a social group try to conform" (Young and Burke, 2010), and thus views norms to be homogenous across individuals within a population (Elster J., 1989; Hausman and McPherson, 2006; Young and Burke, 2010).

The second strand emphasizes the individual nature of norms, which are viewed to be heterogeneous across individuals (Schwartz, 1973; Ajzen, 1991). In order to account for individual differences in norms we follow this second strand, and more specifically, the norm-activation theory (Schwartz, 1973, 1977). This theory was originally developed to explain social behavior, where "other people are directly affected by the consequences of one's behavioral choices" (Harland et al., 1999: 2508). It has been extended to environmentally significant behavior that indirectly affects others through "[changing] the availability of materials or energy from the environment or [altering] the structure and dynamics of ecosystems or the biosphere itself" (Stern, 2000: 408) As such it has been frequently employed in the environmental psychological literature (e.g. Hopper and Nielsen, 1991; Stern et al., 1999; Stern, 2000; Bamberg and Schmidt, 2003), but has also been applied in the economic literature (Thogersen, 1999; Brekke et al., 2010). It distinguishes norms at two levels: *social norms* are abstract and only vague guides to behavior, but are shared by all individuals of a group; *personal norms* as "expectations that people hold for themselves" (Schwartz, 1973), which derive from social norms, are concrete determinants of behavior, but are heterogeneous across individuals. They are learned in and modified through social interaction. Furthermore, they are tied to a person's self-image and are thus enforced through mechanisms such as guilt or pride (Schwartz, 1973). A crucial aspect of the norm-activation theory is that personal norms must be activated in order to affect behavior. To this end, individuals must firstly be aware of specific conditions that entail adverse consequences for others. Secondly, they must feel capable for averting these interpersonal consequences (Schwartz, 1973; Stern et al., 1999).[93]

Sustainability as a moral obligation to confer undiminished life opportunities to future generations (Solow, 1993; Anand and Sen, 2000; Howarth, 2007) is a norm that prescribes a form of environmentally significant behavior as this behavior affects the well-being of future generations through changes in the environment. Defined in such a general way, it is rather vague on how to act in specific situations and we consequently conceptualize it as a social norm in the sense of the norm-activation theory. Individuals may then be imagined to hold concrete expectations for themselves on how to act sustainably in specific situation. For example, a farmer may have expectations on how he should utilize rangeland so that future generations may still make a living of it. We conceptualize these expectations as personal norms of sustainability.

2.2 Notion of sustainability

We operationalize these personal norms under the notion of strong ecological-economic sustainability. According to this notion, relevant natural and economic stocks and services have to be conserved at or above specified thresholds, and have to be conserved independently[94] of each other (Pearce et al., 1989; Daly et al., 1994; Ekins et al., 2003). A given behavior, such as a farm management behavior, is sustainable if it ensures this conservation of stocks and services.[95]

What to conserve, i.e. which stocks and services, and how much of it, i.e. the respective thresholds, are normative expectations that we consider at the individuals level. Thus, we operationalize personal norms in the way that each individual holds separate norms for each

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[93] Individuals balance compliance with the norms with fulfillment of egoistic needs. As such they may not feel capable for complying with the norm (and thus not feel capable for averting adverse consequences) for ethically sound and less sound reasons.

[94] In this respect, strong sustainability differs from weak sustainability which only requires that the aggregate value of stocks and services has to be conserved (e.g. Pearce and Atkinson, 1993; Pezzey and Withagen, 1998).

[95] Strong sustainability may also be operationalized under conditions of uncertainty where the conservation of stocks and services is not deterministic with respect to a behavior due to stochastic system dynamics. For example, (Baumgärtner and Quaas, 2009) develop an operational criterion for strong sustainability under uncertainty, termed ecological-economic viability. The criterion expands on the traditional notion of strong sustainability by also requiring that the acceptable risk has to be specified that conservation fails due to the stochastic system dynamics.

relevant stock and service in a given ecological-economic system where each norm specifies the threshold at which the respective stock or service should be conserved. As mentioned above, personal norms may be heterogeneous across the population and thus different individuals may ascribe different thresholds for a given stock or service.

Finally, we note that since farmers in our case study own their farms and typically pass it on to their children (Olbrich et al., 2011a), we will not consider sustainability towards all members of the future generation in general, but rather dynastic sustainability that specifically is concerned with one's own children, their children's children and so forth.

2.3 System description

Commercial cattle farming in semi-arid rangelands of Namibia is a rain-fed grazing system (Mendelsohn, 2006; Quaas et al., 2007). The dominant biome is tree-and-scrub savannah (Atlas of Namibia Project, 2002) which is characterized by a competition between grass and woody bush vegetation. Annual precipitation is on average 374 mm and the majority of rainfall occurs in a rainy season from November to April (Olbrich et al., 2011c). On the rangeland, grass grows during the rainy season and serves as the main feed for cattle. Cattle have to feed continuously and thus grass production in the rainy season has to maintain cattle throughout the following dry season and, if a drought occurs, also during the rainy and dry season thereafter. Finally, cattle production provides income to farmers who may in addition receive income from alternative on- and off-farm sources (Olbrich et al., 2011a).

The farmer has several management strategies at his disposal by which he can impact on the various system components and ultimately cattle production (Olbrich et al., 2011a). Firstly, farmers may manage the land by adjusting land size for scale effects of cattle production ("rangeland size increase") and by adjust land distribution to achieve spatial diversification ("spatial diversification"). Secondly, farmers may manage cattle feed. They may respond to the seasonality in grass production by resting part of their rangeland in order to provide continuous feed for cattle ("resting rangeland"). They may also compensate for brief shortages in feed as well as for insufficient nutrients by providing cattle with supplementary feed in the form of purchased hay and licks ("additional feed"). Finally, farmers may directly manage the cattle herd. They may choose cattle breeds adapted to local environmental conditions from among a variety of breeds that differing both in ecological requirements and productivity ("breed adaptation"). They may also choose one of various cattle production systems, such as weaner (selling cattle at age 9 months) or ox (selling at age 18-24 months) production, which differ in their requirements for environmental condition and profits ("production system adaptation").

A sustainability problem arises at least partly from inadequate farm management (de Klerk, 2004) that has two main adverse ecosystem and economic consequences. In regards to the ecosystem consequence, inadequate managements may impacts on the natural grass-bush coexistence by increasing the proportion of bushes. This bush encroachment in turn entails, for example, a decrease in biodiversity (Griffin, 1998; Maggs et al., 1998). A proxy for bush encroachment is the capacity to support grazing cattle ("grazing capacity"), and the time series of grazing capacity demonstrates that bush encroachment is indeed a major concern in the cattle farming region: nowadays, the grazing capacity is on average only 0.08 Large Stock Units[96] per hectare (LSU/ha)[97] (Olbrich et al., 2011a) which is much lower than the historic value of above 0.1 LSU/ha that characterized a largely undisturbed ecosystem (de Klerk, 2004). In regards to the economic consequences, bush encroachment results in a given farm being able to support only a low cattle production due to insufficient forage. This in turn results in farm income being too low to meet operating and living cost (Lubbe, 2007; Peltzer, 2007).

Based on this sustainability problem and on the aforementioned system dynamics, we consider ecosystem condition of the rangeland, measured as grazing capacity, as well as income received from cattle farming as the relevant services that have to be conserved for strong ecological-economic sustainability. In accordance with our description of personal norms of sustainability from Section 2.2 we postulate that farmers have personal ecosystem and income norms that specify the threshold at or above which ecosystem condition and income have to be conserved, respectively. Those farmers who comply with the norms then chose management among the aforementioned strategies in such a ways as to conserve ecosystem conditions and income above the thresholds specified in their personal norm.

2.4 Dual-preferences model

Our analytical approach integrates personal norms into a behavioral model while maintaining individual optimization, which is a crucial aspect for an economic analysis of the impact of norms on behavior (Postlewaite, 2010). Specifically, we relate personal norms to behavior

[96] A Large Stock Unit (LSU) is a standard measure for livestock quantity in Namibia. In the case of cattle, one cattle equals one LSU.

[97] Typically, grazing capacity is reported as hectare per Large Stock Unit. We report the inverse here and use it throughout this paper as our later interpretation of results will then be more intuitive.

using the dual-preferences model (Brekke et al., 2003; Conlin et al., 2003; Young and Burke, 2010), which in its original form is specified as

$$U(a) = u(y) - \frac{\gamma}{2} \cdot (\overline{g} - g(a))^2 \,. \tag{1}$$

Here, utility depends on egoistic preferences *u*(.) over private income *y* as well as on self-image which captures the deviation of an individual behavioral consequence *g*(.) from a norm $\overline{g}$. If the individual does not comply to the norm, i.e. if $\overline{g} \neq g(.)$, then he receives a penalty to overall utility. Egoistic preferences and self-image are traded-off against each other by the factor γ which weights how strongly the individual wishes to comply to the norm.

We apply this model to commercial cattle farming in Namibia and include the aforementioned personal norms of sustainability. Equation (1) then expands to

$$\begin{aligned} U(a) &= u(y(a)) - \frac{\gamma}{2} \cdot \{\max(\overline{g} - g(a),0)\}^2 - \frac{\upsilon}{2} \cdot \{\max(\overline{y} - y(a),0)\}^2 \\ &= u(pf(g(a)) - c(a)) - \frac{\gamma}{2} \cdot \{\max(\overline{g} - g(a),0)\}^2 - \frac{\upsilon}{2} \cdot \{\max(\overline{y} - [pf(g(a)) - c(a)],0)\}^2 \end{aligned} \,. \tag{2}$$

Self-image now capture the deviation of behavior consequences from two norms that pertaining to ecosystem condition and income which we realize by two separate terms. For the term denoting self-image in respect to ecosystem condition, we consider as a specific behavioral consequence *g*(.) the *actual* ecosystem condition of the rangeland which dependent on the farmer's management choice *a*. $\overline{g}$ is then the farmer's personal ecosystem norm, i.e. how high the ecosystem condition *should* be, and the weighting factor γ capture how strongly the farmer wishes to comply to the personal ecosystem norm. For the term denoting self-image with respect to income, we consider as a specific behavioral consequence *y*(.) the *actual* income a farmer receives form cattle farming that likewise depends on the management choice *a*. $\overline{y}$ is then the farmer's personal income norm, i.e. how high income *should* be, and the weighting factor υ captures how strongly the farmer wishes to comply to the personal income norm. We can rewrite income as a function of cattle production *f*(.) sold at market price *p* minus costs *c*(.) that are incurred during the production process. Furthermore, cattle production may be viewed to depend only indirectly on *a*, instead having ecosystem condition as a direct input. Thus, *f*(.) becomes a function of *g*(a).

Following our conceptualization of personal norms of sustainability, we allow for heterogeneity of both personal norms across farmers. We also capture two crucial aspects of strong ecological-economic sustainability. Firstly, we realize the idea that services should be conserved independently by introducing both personal norms additively and separately. Secondly, as services should be conserved at or above thresholds we model compliance with the norms piecewise: farmers only receive a penalty to overall utility if actual ecosystem condition or actual income are below the respective personal norms, not if they are above.

Having formulated the model, we are now interested in how a change in the norms $\bar{g}$ and $\bar{y}$ impacts on the management choice a. We approach this by calculating the first order condition of Equation (2) with respect to the choice variable and by subsequently solving for this variable. To this end, we need to specify the involved function. We specify a quadratic utility function as $u(y) = \alpha \cdot y - \frac{\beta}{2} \cdot y^2$ with $\alpha > 0$, $\beta > 0$ and $u'(y) = \alpha - \beta \cdot y > 0$ which is increasing and concave in y. We also specify grazing capacity as linear and increasing in management choice, i.e. $g(a) = g \cdot a$ with $g > 0$, constant returns to scale, i.e. $f(g(a)) = f \cdot g(a) = \phi \cdot a$ with $\phi > 0$ and constant marginal costs, i.e. $c(a) = c \cdot a$ with $c > 0$.[98] Furthermore, we standardize prices to unity. Profit y(a) may then be rewritten as $y(a) = f(a) - c(a) = (\phi - c) \cdot a \equiv \varphi \cdot a$ and is increasing for all a if we assume that $\phi > c > 0$ and thus $\varphi > 0$.

Considering only the case that the farmer does not already comply to the norms, i.e. that $\bar{g} - g(a) > 0$ and that $\bar{y} - y(a) > 0$, it is then straightforward to show that the optimal management choice a can be expressed as

$$a^* = \psi_1 + \gamma \cdot \psi_2 \cdot \bar{g} + \upsilon \cdot \psi_3 \cdot \bar{y} \tag{3}$$

with constants ψ_1, ψ_2, $\psi_3 > 0$ (for proof, see the Appendix A.1).

Hence, one finds that a change in optimal management choice a^* for a change in the personal ecosystem norm $\bar{g}$ or in the personal income norm $\bar{y}$ is zero if and only if γ or υ, respectively, equal zero. Thus, a change in the norms always leads to a change in management if the farmer is concerned with self-image in respect to ecosystem condition or income. Conversely, even if

[98] We tested the validity of the specifications regarding the grazing capacity function and production function in our data using simple OLS regressions. Regarding the grazing capacity function we cannot reject a linear relationship between extent of the strategy and the actual grazing capacity at the 5% significance level for three out of the six management strategies noted in Section 2.3 (i.e. for spatial diversification, resting rangeland and additional feed) and deem it likely that we might find the same for the remaining three strategies if relevant covariates are included in a multiple regression. In regards to the production function, we likewise cannot reject a linear relationship between actual grazing capacity and number of cattle at the 5% significance level. Thus, we deem our specifications to be realistic concerning those two functions. We could not perform a similar analysis for the cost function as we do not have data on production costs.

the farmer has distinct ecosystem and income norms a change will not affect management if he is not concerned with self-image, i.e. if γ or υ equal zero. This latter case may be interpreted in line with the norm-activation model: the farmer has distinct personal norms, but the norms are not activated.

3. Data

3.1 Data sources

Description of data collection

In August 2008, we elicited personal norms of sustainability, management strategies and socio-demographic characteristics of commercial cattle farmers in Namibia through a mail-in questionnaire. A detailed description of the survey can be found in (Olbrich et al., 2009), which also includes a copy of the questionnaire.

We sent out questionnaires to all cattle farming members of the Namibia Agricultural Union (NAU), the main interest group of commercial farmers, and to all farmers that deliver cattle to MeatCo, the largest slaughterhouse in Namibia. We mailed out a first batch of questionnaires in the period 19th – 21st of August 2008, and a second batch as a follow up on the 15th of September 2008. We reached 1,916 of an estimated total number of 2,500 farmers. 399 questionnaires were returned, equaling a return rate of 20.8%.

In addition to the quantitative data collection, we conducted qualitative interviews with farmers, local scientists and decision makers in the agricultural, political and financial sector throughout four research visits in March/April 2007, October 2007, July/August 2008 and February/March 2010.

Elicitation of personal norms

As detailed in Section 2.2, we operationalize personal norms of sustainability under the notion of strong ecological-economic sustainability. Prior to designing the questionnaires we inquired in our qualitative interviews with farmers and local agricultural scientists which services are critical for the sustainability of the farming system. On the basis of these interviews we preselected the already in Section 2.3 noted ecosystem condition of the rangeland and income as the two most critical services, and elicited the personal ecosystem norm, i.e. the minimum threshold at or above which ecosystem condition should be sustained, and the personal income norm[99], i.e. the minimum threshold at or above which income should be sustained. We measured the ecosystem norms as grazing capacity in the unit hectare per Large Stock Unit and the income norm as net annual income[100] in the unit Namibian Dollar (N$).

Elicitation of management strategies, ecosystem condition, income and further characteristics

In regards to farmers' management, we elicited self-reported extent of various on-farm management strategies. On the basis of our qualitative interviews we selected the six most relevant management strategies that pertain to on-farm management choices (c.f. Section 2.3): rangeland size increase, spatial diversification, resting rangeland, additional feed, breed adaptation and production system adaptation. For each strategy we asked farmers to self-report the extent of the strategy on a six-item Likert-scale ranging from "not at all important" to "very important". We elicited actual ecosystem condition as grazing capacity in the unit ha/LSU. For confidentiality reasons we elicited total net annual income only as interval data where farmers indicated which of the following income intervals they belong to: [N$ 0, N$ 50.000], [N$ 50.001, N$ 150.000], [N$ 150.001, N$ 250.000], [N$ 250.001, N$ 350.000], [N$ 350.001, ∞[. Finally, we elicited the fraction of total income that derives from cattle farming.

We also elicited a variety of socio-demographic characteristics: gender, age, experience on present farm (i.e. number of years operating the present farm), ethnicity (i.e. Afrikaans or other ethnicities)[101], education (high school graduation at most vs. some sort of apprenticeship or college/university education), household size, ownership structure of the farm (single owner or multiple owners), living off farm (as a proxy for part-time farming vs. full-time farming), NAU membership, area of rangeland, net area of rented land (area of land rented minus area of land rented out), and cattle quantity. Finally, we elicited as additional environmental characteristics the deviation of actual from optimal bush cover as well as the regional location of the farm in Namibia (Erongo, Hardap/Karas, Khomas, Kunene, Omaheke, Oshikoto, Otjozondjupa) to cover a variety of environmental characteristics that are not captured in the grazing capacity. A list of all elicited variables along with their summary statistics is given in Table 1.

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[99] Strictly speaking, we elicited the personal income norm in respect to income from cattle farming only and not in respect to total income, i.e. income from cattle farming plus income from other sources. However, we will refer to this income from cattle farming simply as "income" for the remainder of the paper.

[100] We define net annual income as gross revenues minus operating expenses, taxes and interest on loans.

[101] Afrikaans is the most common ethnicity. Other ethnicities are predominantly German.

3.2 Calibration of variables and statistical specification

Calibration of variables

For our subsequent analysis, we calibrate personal norm variables in such a way that higher values denote more demanding personal norms. For example, the personal norm that income should be sustained at or above N$200,000 is more demanding, in the sense that it is more difficult to comply with, than the personal norm that income should be sustained at or above N$100,000. The respective variable for the personal income norm is already correctly calibrated in the way it was elicited, but we have to make adjustments to the personal ecosystem norm. We inverse the elicited variable, i.e. we use now a variable measured in Large Stock Unit per hectare (LSU/ha) instead of hectare per Large Stock Unit. Correspondingly, we also invert the variable for actual ecosystem condition which is now likewise used in the unit LSU/ha. In regards to income data which we elicited in the form of interval data we convert these data to discrete data by using the interval midpoints as income. We then multiply this variable by the fraction of total income that derives from from cattle farming to acquire the income that derives from cattle farming.[102]

Statistical specification

We generate results for Research Question 1 (characterization of personal norms) through descriptive statistics. We approach Question 2 (determinants of personal norms) firstly by analyzing whether both norms are correlated by employing a Pearson correlation. We then model the personal norms as being dependent on actual income, actual ecosystem condition and on the other socio-demographic and environmental characteristics. Thus, for each of the two elicited personal norms, we estimate

$$N_{ji} = \lambda_0 + \lambda_Z Z + \varepsilon_i \quad (4)$$

where N_j is one of the j = 1, 2 elicited personal norms (i.e. the personal ecosystem or income norm), Z a vector of socio-demographic and environmental characteristics and ε_i are unobserved factors. Even though personal norms may impact on each other, we do not include the respective other norm in the equation since we then incur an endogeneity problem that we cannot adequately address as we cannot construct suitable instrumental variables. However, we perform robustness checks in which we include the respective other norm and show that

[102] We do this so that what we measure by the actual income variable corresponds to what we measure by the personal income norm variables (which in the strict sense measures the income norm in respect to income from cattle farming).

its inclusion does not change our results (Appendix B.1, Equation 4a). Thus, we conclude that we do not incur an omitted variables bias by not including the respective other norm in Equation (4).

We analyze Question 3 (impact of personal norms on management) by modeling each of the six management strategies as a function of the personal ecosystem and income norm while controlling for socio-demographic and environmental characteristics. For each strategy we estimate the equation

$$S_{ki} = \nu_0 + \nu_{\bar{g}} G[\bar{g}_i] + \nu_{\bar{y}} Y[\bar{y}_i] + \nu_x X_i + \chi_i \tag{5}$$

with

$$G[\bar{g}_i] = \begin{cases} \bar{g}_i - g_i & \text{for } \bar{g}_i > g_i \\ 0 & \text{otherwise} \end{cases}, \qquad Y[\bar{y}_i] = \begin{cases} \bar{y}_i - y_i & \text{for } \bar{y}_i > y_i \\ 0 & \text{otherwise} \end{cases}$$

where S_k is the self-reported extent of management strategy k = 1, …, 6, $\bar{g}$ the personal ecosystem norm, g the actual ecosystem condition, $\bar{y}$ the personal income norm, y the actual income, X a vector of socio-demographic and environmental characteristics and χ_i are unobserved factors. Similar to Equation (4), the different management strategies may impact on each other but we do not include the respective other strategies in Equation (5) since we then incur an endogeneity problem that we likewise cannot adequately address as we cannot construct suitable instrumental variables. However, we perform robustness checks in which we include the respective other strategies and show that their inclusion does not change our results (Appendix B.2, Equation 5a). Thus, we conclude that we do not incur an omitted variables bias by not including the respective other strategies in Equation (5).

With the term G[.] and Y[.] we achieve a piecewise regression over the personal ecosystem norm $\bar{g}$ and income norm $\bar{y}$, respectively, which is a reduced form of the standard piecewise regression function (for proof, see Appendix A.2). For farmers who do not comply with the ecosystem (income) norm, i.e. for whom the actual ecosystem condition (income) is lower the ecosystem (income) norm, G[.] (Y[.]) is positive. Conversely, for farmers who comply with the ecosystem (income) norm, i.e. for whom actual ecosystem condition (income) is at least as high as the ecosystem (income) norm, G[.] (Y[.]) is zero. This corresponds to properties of the behavioral model of Equation (2) that states that personal norms only impact on utility if the actual values are below the respective norms. Finally, rescaling $\bar{g}$ and $\bar{y}$ by subtracting the actual values g and y ensures that the pieces are joined together at the respective breakpoints.

We are especially interested in the coefficients $\nu_{\bar{g}}$ and $\nu_{\bar{y}}$ that describes the effect of a change in the ecosystem and income norms on the extent of management for a given strategy (conditional on the actual ecosystem condition and income being lower than the respective norms). In order to interpret these coefficients we draw on the result for optimal management a^* that we have developed in Equation (3). Specifically, we see that non-zero values for these coefficients imply that the weighting factors γ and υ are non-zero, i.e. that self-image with respect to ecosystem condition and income indeed impact on utility. Conversely, if the coefficients are zero, this implies that γ and υ equal zero, i.e. that self-image does not play a role in utility maximization. In the latter case, farmers may have distinct personal norms, but they do not factor into their choices regarding management.

Robustness checks

We have already mentioned two robustness checks above that we perform for Equation (4) and (5). In addition, we perform various other checks for Equation (5) since this equation is used to produce our most relevant results. These checks involve different definition of income, the application of different regression models and expansion of Equation (5) that includes the effect of social interactions on compliance with personal norms. These robustness checks are explained in detail in Appendix B.2.

4. Results

4.1 Characterization of personal norms

For the norm pertaining to sustainable ecosystem condition of the rangeland, we find that grazing condition should on average be at or above 0.08 LSU/ha with a standard deviation of 0.03 LSU/ha (Figure 1a, Table 1). For the personal norm pertaining to sustainable income, farmers indicated on average that annual net income should be at or above N$275,107 with a standard deviation of N$206,991 (Figure 1b, Table 1).

Thus, we find personal norms of sustainability that are heterogeneous across individuals with both norms unimodally distributed and clustered around intermediate values. This heterogeneity of personal norms can be explained by the norm-activation theory, which predicts that individuals differ in the concrete specification of personal norms. Indeed, such heterogeneity has been demonstrated for a variety of personal norms such as those pertaining to littering (Kallgren et al., 2000), recycling (Hopper and Nielsen, 1991; Thogersen, 1999) and environmentally friendly transportation (Widegren, 1998; Bamberg and Schmidt, 2003).

4.2 Determinants of personal norms

When examining determinants of personal norms we firstly find that both personal norms are not correlated with each other as indicated by a Pearson's correlation (r=0.03, p=0.59). Thus, farmers seem to attain these norms independently from each other. Only few previous studies have analyzed the interrelation between personal norms, but found that different norms are positively correlated (Widegren, 1998; Thogersen, 1999). Thogersen (1999) examined the underlying reason for this correlation and hypothesized that the "correlation may indeed be caused by them [i.e. personal norms] having shared [mental] antecedents" (Thogersen, 1999: 67). Such antecedents may be a person's values, which Thørgersen (1999) could indeed demonstrate, but a person's values explained only a small share of variability in personal norms. This suggests that the determination of norms through mental antecedents is much more complex. In the light of this we find it not unsurprising that the specific norms we elicited are not correlated. However, our survey was not design to examine in depth the relationship between different norms and their antecedents, and we thus may not hypothesize on the reasons of norms being uncorrelated.

We find little evidence of socio-demographic and environmental characteristics impacting on personal norms (Table 2). Both ecosystem and income norm are significantly positively related to actual ecosystem condition and actual income, respectively: for each unit increase in actual ecosystem condition the ecosystem norm increases by 0.60 LSU/ha, and for each unit increase in actual income the income norm increases by 0.69 N$. This positive relationship conforms to predictions of the behavioral model of Equation (2), where an increase in ecosystem condition (income) leads to an increase in the ecosystem (income) norm and vice versa.[103]

Area of rangeland is significantly related to both norms but in opposite direction: each hectare of rangeland is associated with a decrease in the ecosystem norm by 1.4e-06 LSU/ha and an increase in the income norm by N$ 6.8. If we interpret area of rangeland as a proxy of wealth then these findings indicate that more wealthy farmers have lower ecosystem norms but higher income norms. Farm experience is significantly negatively related to both norms. For each additional year of experience, the ecosystem norm decreases by 8.3e-04 and the income norm by N$ 3,400. We find no other socio-demographic or environmental characteristic that is related with both norms. The remaining characteristics are at most related to only one norm

[103] Calculating the first order condition of Equation (2) (c.f. in Appendix A.1) and solving for $\overline{g}$ and $\overline{y}$, respectively, yields this prediction.

with the majority of characteristics not being related to either norm. Thus, by and large, we do not find that personal norms of sustainability vary systematically across subpopulations.

4.3 Impact of personal norms on management

We find no significant interaction even at the 10% significance level between the personal norms and self-reported management for any of the six analyzed strategies, regardless of whether covariates are excluded (Table 3) or included (Table 4). Thus, we find no evidence that the factors weighting self-image versus egoistic preferences in the dual-preferences model are non-zero. This means that there is no evidence that personal norms impact on actual behavior. These results agree with previous findings that even distinct norms may have little or no impact on behavior, as for example demonstrated for helping behavior (Schwartz, 1977) or car use (Bamberg and Schmidt, 2003).

Socio-demographic and environmental characteristics have only a sporadic effect on management with only two strategies, *spatial diversification* and *additional feed*, showing any significant relation with more than three characteristics. Reversely, only one characteristic, rented rangeland area, is related to more than two strategies, i.e. *rangeland size increase, spatial diversification* and *production system adaptation*. As one would expect, we find that *rangeland size increase* is positively related to rented rangeland area, where each ha increases the extent of this management strategy by 7.5e-05, and that *spatial diversification* is related to both rangeland area and rented rangeland area, where each ha increases the extent by 7.2e-05 and 9.7e-05, respectively. Beyond this observation we cannot discern any other expected relationship. We conclude that choice of management does by and large not systematically vary across subpopulation.

4.4 Robustness checks

To test the sensitivity of our results, we perform a variety of robustness checks which are detailed in Appendix B.1 and B.2.

Robustness check for analysis of Research Question 2 (determinants of personal norms)

We examine whether estimation results for the coefficients of determinants of a given personal norm are sensitive to the inclusion of the respective other norm (which we previously excluded to avoid a potential endogeneity problem). Results for this check show that almost all coefficients previously significant (insignificant) remain significant (insignificant) in the robustness check. Furthermore, all coefficients that are significant in the original equation retain sign and order of magnitude in the robustness check, and vice versa. We thus conclude that we can exclude the respective other norms without incurring an omitted variable bias for almost any variable.

Robustness check for analysis of Research Question 3 (impact of personal norms on management)

We perform several checks for this Research Question. In the first check we examine whether estimation results for the coefficients of personal norms on a given management strategy are sensitive to the inclusion of the respective other management strategies (which we previously excluded to avoid a potential endogeneity problem). Results show that coefficients are unchanged and we conclude that we can exclude the respective other management strategies without incurring an omitted variable bias in respect to the personal norm coefficients.

A series of three checks involve alternative specifications of the income variables as logarithmic income – where we simultaneously also use the logarithm of the personal income norm –, and as the lower and upper bound of the income interval elicited in the questionnaire (whereas we previously used the mid-points of the intervals). Estimating results confirm our previous results in that we do not find evidence that personal norms impact on management.

In three further checks we employ alternative regression models, namely ordered probit and ordered logit models as well as a Zellner's seemingly unrelated regression system (Zellner, 1962) where we estimate all six management strategies jointly. Again, estimate results confirm our previous results in that we do not find evidence that personal norms impact on management.

Finally, in two checks we test whether other farmers' management and personal norms, respectively, impact on compliance with personal norms. We assume that farmer know about management and norms of other farmers in their region through exchange with these farmers on a variety of regional platforms provided by the NAU. Thus, for those farmers who are members of the NAU and operate full-time (many part-time farmers do not live in their farms' region and can attend these platforms only rarely), we calculate regional averages of the extent of management and of the level of personal norms, respectively. In one check, we then interact individual farmers' personal norms with the regional averages of the management strategy that is currently estimated. In the other check, we interact the individual farmers' personal norms with the respective regional averages of the personal norms. We find no evidence that either the management or personal norms of other farmers influences compliance with the personal norms.

5. Discussion and conclusion

For the empirical case study of commercial cattle farming in semi-arid rangelands of Namibia, where farmers as the main economic actors are closely linked to the environment, we have conceptualized personal norms of sustainability according to the norm-activation theory, operationalized them under the notion of strong ecological-economic sustainability and analyzed them with an adapted dual-preferences model. We find that 1) farmers have personal norms of sustainability that are heterogeneous across individuals, 2) these norms are uncorrelated with each other and vary only little with socio-demographic and environmental characteristics, and 3) there is no evidence that these norms have an impact on actual management.

The last conclusion is of particular relevance, as it may explain the observed degradation of rangelands in Namibia. Some discussion is needed, however. Firstly, it is theoretically impossible to demonstrate that an impact of norms on management does not exist: we cannot accept the null hypothesis but only fail to reject it. In reality, norms may impact on management but a sample bias or an inappropriate choice of econometric methods might preclude the detection of this impact. We have no indication that our sample might be biased in those characteristics that are crucial for this study (Olbrich et al., 2009),[104] and rerunning our analysis with common alternative regression models as well as with alternative specifications of variables and equations demonstrates that results are robust. Thus, even though we may not make a definite statement, we consider it at least highly probable that norms do not impact on management. Secondly, we cannot estimate management strategies jointly in a simultaneous equation model, even though strategies are significantly interrelated, as we cannot construct suitable instrumental variables. Instead, we estimate each management strategy separately without including the respective other management strategies. Robustness checks show that we do not incur an unobserved variable bias for the coefficients of primary interest, that is the personal norm coefficient, and we thus conclude that this approach is justified. Thirdly, we formulate the behavioral model under certainty and may thus only consider deterministic sustainability. Given that semi-arid rangelands are subject to a variety of risks (Olbrich et al., 2011c), a more realistic approach would be the use of a model that describes behavior under uncertainty where we then would consider sustainability under

[104] No database exists that contains all commercial cattle farmers and their key socio-demographic characteristics. We thus compared samples from two subpopulations, NAU members and MeatCo customers, but found no difference in important socio-demographic characteristics (Olbrich et al., 2009). We add here that samples also do not differ in personal norms and on-farm management strategies (t-tests, $p>0.1$ for all personal norms and strategies).

uncertainty. However, we cannot estimate such a model as we could not elicit all the required information with our cross-sectional survey, specifically the individual, on-farm distributions of ecosystem condition and income.

Notwithstanding these limitations, we believe that our analysis provides novel insights into why farmers' management behavior may contribute to the pervasive degradation in Namibia: farmers have personal norms but they do not impact on behavior, presumably because they are not activated. This in turn suggest that activation may promote behavioral changes that may entail sustainability of cattle farming, which is similar to suggestions voiced in the environmental psychology literature for promoting pro-environmental behavior (Stern, 2000). To this end, one first has to clarify why norms are not activated. From our qualitative interviews we have anecdotic evidence that farmers are aware that inadequate management degrades the environment and thus has adverse consequences to future generations (Joubert, 2008; Neumann, 2008). Moreover, farmers may feel incapable of averting adverse consequences of their management as they rather pursue short-term profit (Pack, 2008). Thus, we hypothesize that norms are not activated because farmers feel not capable of averting adverse consequences of their behavior. A next question then is why this might be the case. This information is required to decide whether taking measures for norm activation is justified (farmers may have ethically sound reasons for not feeling capable) and exactly what measures to take. Clearly, this requires more study, and we consider it worthwhile. Further investigating norms of sustainability and their activation is a promising approach to promote sustainability of livestock farming in semi-arid rangelands.

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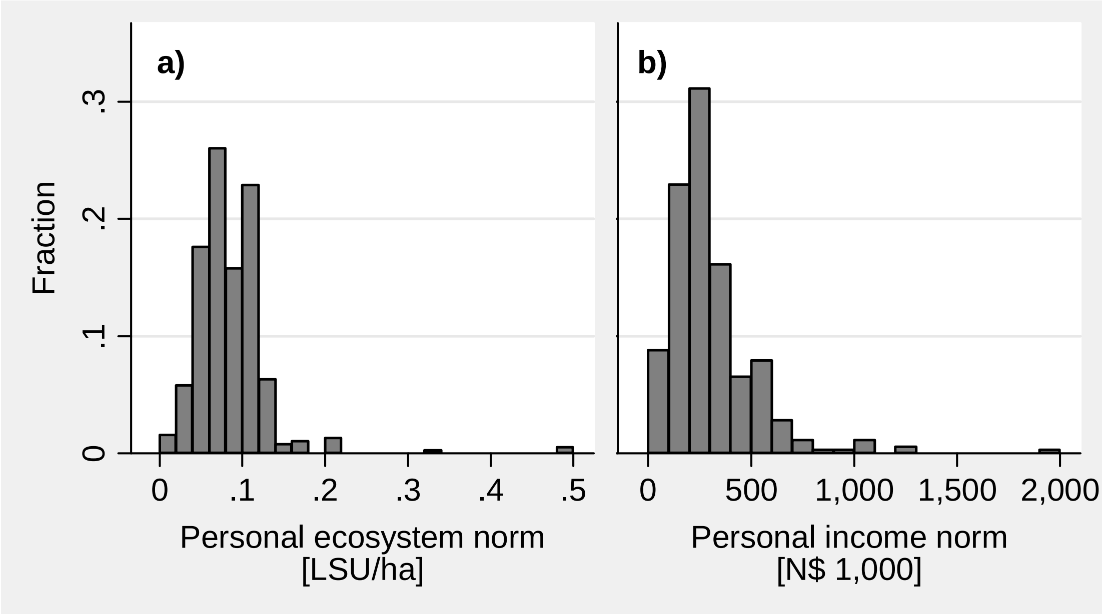

Figure 1: a) Personal ecosystem norm, measured in Large Stock Units per hectare [LSU/ha], N=380. b) Personal income norm, measured in 1,000 Namibian Dollar [N$1,000], N=353.

Table 1: Summary statistics. Mean, standard deviation, minimum and maximum for all those farmers who do not display missing values for any variable used in the estimation of management strategies (c.f. Equation 5, Table 4). N=260.

Variable	Definition	Mean	Std. dev.	Min	Max
Personal norms					
Ecosystem norm	Minimum threshold at or above which grazing capacity should be sustained, in Large Stock Unit per hectare	0.08	0.03	0.01	0.33
Income norm	Minimum threshold at or above which annual net income from cattle farming should be sustained, in N$	275,107	206,991	4,000	2,000,000
Socio-demographic characteristics					
Income	Net annual income from cattle farming; calculated as mid-points of six intervals of total annual income, corrected for fraction derived from cattle farming, in N$	114,019	96,820	0	360,000
Female	Female	0.03	0.16	0.0	1.0
Age	Age in years	54.0	11.6	27.0	90.0
Farm experience	Experience in farming in years	24.6	12.8	1.5	70.0
Afrikaans	Afrikaans	0.5	0.5	0.0	1.0
Low education	No college or apprenticeship education	0.2	0.4	0.0	1.0
Household size	Number of household members	3.3	1.6	0.0	8.0
Single ownership	Farm operated under single owner	0.7	0.5	0.0	1.0
Living off farm	Farmer lives off farm during week, proxy for part-time farming	0.2	0.4	0.0	1.0
NAU member	Member of the Namibia Agricultural Union	0.83	0.37	0.0	1.0
Rangeland area	Area of rangeland in hectares	8,212	5,460	0	44,244
Rented rangeland area	Area of net rented (i.e. rented minus rented out) rangeland in hectares	1,314	2,905	-5,000	13,000
Cattle quantity	Number of cattle in April 2008	478	393	0	3,200
Environmental characteristics					
Optimal-actual bush cover deviation	Deviation of actual from optimal bush cover on farm, in percent	-15.8	20.8	-80.0	30.0
Ecosystem condition	Ecosystem condition measured as Large Stock Unit per hectare	0.08	0.03	0.02	0.33
Erongo	Farm located in Erongo	0.06	0.23	0.00	1.00
Hardap/Karas	Farm located in Hardap or Karas	0.04	0.20	0.00	1.00
Khomas	Farm located in Khomas	0.20	0.40	0.00	1.00

Variable	Definition	Mean	Std. dev.	Min	Max
Kunene	Farm located in Kunene	0.09	0.29	0.00	1.00
Omaheke	Farm located in Omaheke	0.23	0.42	0.00	1.00
Oshikoto	Farm located in Oshikoto	0.02	0.14	0.00	1.00
Otjozondjupa	Farm located in Otjozondjupa	0.36	0.48	0.00	1.00
Management strategies [1=not at all important, 6=very important]					
Rangeland size increase	Purchase/lease of extra rangeland for scale effects	3.3	1.6	1.0	6.0
Spatial diversification	Purchase/lease of extra rangeland in areas with different rainfall patterns	3.2	1.7	1.0	6.0
Resting rangeland	Resting part of rangeland in good rainy seasons as buffer for bad seasons	4.6	1.6	1.0	6.0
Additional feed	Purchase of supplementary feed	4.6	1.6	1.0	6.0
Breed adaptation	Choice of breed adapted to high variability in grass production	4.5	1.5	1.0	6.0
Production system adaptation	Choice of cattle production system	4.4	1.4	1.0	6.0

Table 2: Determinants of personal norms of sustainability. OLS regression, coefficients with standard errors in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Dependent variables:	**Ecosystem norm**	**Income norm**
Income	–2.4e–09	6.9e–01***
	(2.36e–08)	(1.33e–01)
Female	–1.5e–02	1.0e+04
	(1.13e–02)	(6.95e+04)
Age	8.1e–04***	1.2e+03
	(2.51e–04)	(1.40e+03)
Farm experience	–8.3e–04***	–3.4e+03***
	(2.20e–04)	(1.23e+03)
Afrikaans	–2.2e–03	2.2e+04
	(4.40e–03)	(2.43e+04)
Low education	8.3e–03	1.5e+04
	(5.20e–03)	(2.88e+04)
Household size	2.6e–03*	–4.3e+03
	(1.36e–03)	(7.52e+03)
Single ownership	2.1e–03	–4.6e+03
	(4.56e–03)	(2.56e+04)
Living off farm	–3.4e–03	–2.2e+03
	(5.31e–03)	(2.96e+04)
NAU member	3.2e–03	2.0e+04
	(5.67e–03)	(3.18e+04)
Rangeland area	–1.4e–06**	6.8e+00*
	(6.34e–07)	(3.49e+00)
Rented rangeland area	7.7e–08	–4.0e+00
	(7.83e–07)	(4.33e+00)
Cattle quantity	1.3e–05	–6.6e+00
	(8.92e–06)	(4.89e+01)
Optimal–actual bush	–9.7e–05	–4.7e+02
cover deviation	(1.11e–04)	(6.09e+02)
Ecosystem condition	6.0e–01***	9.1e+04
	(7.14e–02)	(3.97e+05)
Erongo	–2.3e–02**	1.8e+04
	(9.51e–03)	(5.36e+04)
Hardap/Karas	–1.8e–02	1.8e+05***
	(1.21e–02)	(6.62e+04)
Khomas	–9.9e–03*	4.5e+03
	(5.74e–03)	(3.23e+04)
Kunene	–5.3e–03	–4.7e+04
	(7.58e–03)	(4.22e+04)
Omaheke	–4.4e–03	1.0e+04
	(5.63e–03)	(3.09e+04)
Oshikoto	–1.3e–02	–7.8e+04
	(1.61e–02)	(8.80e+04)
Constant	6.9e–03	1.3e+05
	(1.66e–02)	(9.06e+04)
Adjusted R^2	0.303	0.165
F–statistic	7.120	3.679
Model significance	0.000	0.000
Observations	297	286

Table 3: Impact of personal norms on management, without covariates. OLS regressions, coefficients with standard errors in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Dependent variables:	**Rangeland size increase**	**Spatial diversification**	**Resting rangeland**	**Additional feed**	**Breed adaptation**	**Production system adaptation**
Ecosystem norm	–5.180	1.196	2.048	2.084	2.511	1.729
	(4.848)	(4.808)	(2.926)	(2.906)	(2.578)	(2.660)
Income norm	7.8e–07	1.2e–07	–3.0e–08	3.8e–07	7.5e–08	4.2e–07
	(5.2e–07)	(5.2e–07)	(4.8e–07)	(4.7e–07)	(4.2e–07)	(4.3e–07)
Constant	3.220***	3.181***	4.601***	4.557***	4.491***	4.346***
	(0.137)	(0.137)	(0.121)	(0.120)	(0.106)	(0.109)
Adjusted R^2	0.004	–0.006	–0.005	–0.002	–0.003	–0.002
F–statistic	1.612	0.063	0.245	0.615	0.502	0.717
Model significance	0.201	0.939	0.783	0.541	0.606	0.489
Observations	299	318	326	327	325	326

Table 4: Impact of personal norms on management, with covariates. OLS regressions, coefficients with standard errors in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Dependent variables:	**Rangeland size increase**	**Spatial diversification**	**Resting rangeland**	**Additional feed**	**Breed adaptation**	**Production system adaptation**
Ecosystem norm	–1.943	5.884	3.540	–0.036	2.714	4.018
	(5.731)	(5.642)	(3.153)	(3.081)	(2.865)	(2.915)
Income norm	4.7e–07	–5.1e–08	3.9e–07	2.6e–08	1.6e–07	4.2e–07
	(5.8e–07)	(5.8e–07)	(5.2e–07)	(5.1e–07)	(4.7e–07)	(4.8e–07)
Female	0.192	–0.031	1.135**	0.379	1.104**	0.436
	(0.645)	(0.625)	(0.562)	(0.549)	(0.511)	(0.519)
Age	–0.006	0.001	–0.001	0.012	0.014	0.009
	(0.013)	(0.013)	(0.012)	(0.011)	(0.011)	(0.011)
Farm experience	–0.016	–0.006	0.013	–0.019*	–0.008	0.006
	(0.012)	(0.012)	(0.010)	(0.010)	(0.009)	(0.010)
Afrikaans	0.367	0.077	0.486**	0.141	0.011	0.174
	(0.224)	(0.221)	(0.197)	(0.193)	(0.179)	(0.182)
Low education	0.109	0.222	0.111	0.344	0.077	–0.133
	(0.278)	(0.268)	(0.237)	(0.231)	(0.216)	(0.219)
Household size	0.042	0.035	0.046	0.036	0.076	–0.008
	(0.068)	(0.069)	(0.061)	(0.060)	(0.056)	(0.057)
Single ownership	–0.090	0.092	0.332	–0.053	–0.086	–0.284
	(0.232)	(0.231)	(0.207)	(0.202)	(0.188)	(0.191)
Living off farm	0.190	0.480*	0.322	0.475**	0.138	–0.069
	(0.266)	(0.269)	(0.239)	(0.233)	(0.217)	(0.220)
NAU member	–0.135	–0.293	–0.128	0.218	–0.115	0.241
	(0.285)	(0.285)	(0.256)	(0.250)	(0.233)	(0.237)
Rangeland area	6.5e–06	7.2e–05**	4.0e–05	1.3e–05	2.2e–05	7.5e–05***
	(3.0e–05)	(3.1e–05)	(2.8e–05)	(2.7e–05)	(2.5e–05)	(2.5e–05)
Rented rangeland area	7.5e–05*	9.7e–05**	–4.5e–05	–3.0e–05	–8.7e–06	–5.5e–05*
	(3.9e–05)	(3.9e–05)	(3.5e–05)	(3.5e–05)	(3.2e–05)	(3.3e–05)
Cattle quantity	1.9e–04	–1.0e–03**	–8.9e–04**	1.6e–04	–1.6e–05	–4.9e–04
	(4.1e–04)	(4.2e–04)	(3.8e–04)	(3.7e–04)	(3.4e–04)	(3.5e–04)
Optimal–actual bush cover deviation	–0.004	–0.003	0.001	0.002	–0.003	–0.003
	(0.006)	(0.006)	(0.005)	(0.005)	(0.004)	(0.005)
Erongo	0.387	–0.502	0.189	–1.430***	0.280	0.324
	(0.473)	(0.485)	(0.435)	(0.425)	(0.404)	(0.401)
Hardap/Karas	–0.784	–0.592	–0.751	–0.482	–0.770	–0.649
	(0.590)	(0.606)	(0.544)	(0.532)	(0.494)	(0.503)
Khomas	–0.029	–0.010	0.023	–0.291	0.011	0.232
	(0.300)	(0.300)	(0.265)	(0.259)	(0.240)	(0.246)
Kunene	0.170	0.414	–0.029	–0.336	0.328	0.403
	(0.383)	(0.377)	(0.338)	(0.330)	(0.306)	(0.312)
Omaheke	–0.347	–0.261	–0.154	0.652***	0.094	–0.056
	(0.284)	(0.283)	(0.251)	(0.245)	(0.228)	(0.232)
Oshikoto	–0.642	–0.838	0.530	0.419	0.113	0.409
	(0.761)	(0.786)	(0.706)	(0.690)	(0.641)	(0.652)
Constant	3.525***	2.986***	3.807***	3.836***	3.483***	3.209***
	(0.752)	(0.761)	(0.675)	(0.660)	(0.614)	(0.625)
Adjusted R^2	0.027	0.028	0.039	0.090	–0.006	0.023
F–statistic	1.346	1.385	1.553	2.333	0.918	1.317
Model significance	0.147	0.125	0.061	0.001	0.568	0.163
Observations	261	278	284	284	283	283

Appendix A: Proofs

A.1 Calculation of first order condition

Assume $\overline{g} - g(a) > 0$ and that $\overline{y} - y(a) > 0$. Then, differentiating Equation (2) with respect to a and specifying the involved functions as detailed in Section 2.4 yields the first order condition:

$$\begin{aligned}\frac{dU(a)}{da} &= u'(y(a)) \cdot y'(a) + \gamma \cdot (\overline{g} - g(a)) \cdot g'(a) + \upsilon \cdot (\overline{y} - y(a)) \cdot y'(a) \\ &= (\alpha - \beta \cdot \varphi \cdot a) \cdot \varphi + \gamma \cdot (\overline{g} - a) + \upsilon \cdot (\overline{y} - \varphi \cdot a) \cdot \varphi = 0\end{aligned} \tag{2a}$$

Rearranging the equation yields

$$(\upsilon \cdot \varphi^2 + \gamma + \beta \cdot \varphi^2) \cdot a = \alpha \cdot \varphi + \gamma \cdot \overline{g} + \upsilon \cdot \varphi \cdot \overline{y}$$

and finally

$$a^* = \psi_1 + \gamma \cdot \psi_2 \cdot \overline{g} + \upsilon \cdot \psi_3 \cdot \overline{y} \tag{3}$$

with

$$\psi_1 = \frac{\alpha \cdot \varphi}{(\upsilon \cdot \varphi^2 + \gamma + \beta \cdot \varphi^2)} > 0, \psi_2 = \frac{1}{(\upsilon \cdot \varphi^2 + \gamma + \beta \cdot \varphi^2)} > 0,\ \psi_3 = \frac{\varphi}{(\upsilon \cdot \varphi^2 + \gamma + \beta \cdot \varphi^2)} > 0$$

The change in optimal management is thus characterized by the following result:

Proposition 1: *A change in optimal management choice* a* *for a change in the norm* $\overline{g}$ *is zero if and only if* γ *equals zero.*

Proposition 2: *A change in optimal management choice* a* *for a change in the norm* $\overline{y}$ *is zero if and only if* υ *equals zero.*

A.2 Reduced form of the piecewise regression

The full form for the piecewise regression of Equation (5) is

$$S_{ji} = \nu_0 + \nu_{\bar{g}n} G_n[\bar{g}_i] + \nu_{\bar{g}c} G_c[\bar{g}_i] + \nu_{\bar{y}n} Y_n[\bar{y}_i] + \nu_{\bar{y}c} Y_c[\bar{y}_i] + \beta_x X_i + \chi_i \tag{5a}$$

with

$$G_n[\bar{g}_i] = \begin{cases} \bar{g}_i - g_i & \text{for } \bar{g}_i > g_i \\ 0 & \text{otherwise} \end{cases}, \qquad G_c[\bar{g}_i] = \begin{cases} g_i - \bar{g}_i & \text{for } \bar{g}_i \le g_i \\ 0 & \text{otherwise} \end{cases}$$

and

$$Y_n[\bar{y}_i] = \begin{cases} \bar{y}_i - y_i & \text{for } \bar{y}_i > y_i \\ 0 & \text{otherwise} \end{cases}, \qquad Y_c[\bar{y}_i] = \begin{cases} y_i - \bar{y}_i & \text{for } \bar{y}_i \le y_i \\ 0 & \text{otherwise} \end{cases}$$

Rescaling the norms $\bar{g}$ and $\bar{y}$ by subtracting the actual values g and y ensures that the pieces are joined together at the respective breakpoints.

The behavioral model in Equation (2) states that personal norms do not influence utility if farmers comply with the norms, i.e. if actual values exceed the respective norms. For the regression equation this implies that the coefficients $\nu_{\bar{g}c}$ and $\nu_{\bar{y}c}$ are zero for the terms G_c[.] and Y_c[.], respectively, which describe the pieces where norms are complied with.

Thus, equation (5a) can be reduced to

$$S_{ki} = \nu_0 + \nu_{\bar{g}} G[\bar{g}_i] + \nu_{\bar{y}} Y[\bar{y}_i] + \nu_x X_i + \chi_i \tag{5}$$

where $\nu_{\bar{g}}$, $\nu_{\bar{y}}$, G[.] and Y[.] correspond to $\nu_{\bar{g}n}$, $\nu_{\bar{y}n}$, G_n[.] and Y_n[.], respectively.

Appendix B: Robustness checks

We perform several robustness checks for Research Question 2 (determinants of personal norms) and Research Question 3 (impact of personal norms on management). If indicated, we have provided estimation results of the checks in tables at the end of this appendix. Tables with estimation results for the other checks are available upon request.

B.1 Robustness check for analysis of Research Question 2 (determinants of personal norms)

Other personal norm as covariate

As previously noted, N_j, that is one of the j = 1, 2 elicited personal norms, may also depend on the respective other norm, but including the other norm may create an endogeneity problem. We cannot adequately address this problem in a simultaneous equation model as we do not have suitable instrument variables. Instead, we here augment Equation (4) by also including the other norm as a covariate and estimate

$$N_{ji} = \tau_0 + \tau_{ON} ON_i + \tau_Z Z + \theta_i \quad (4a)$$

where ON_i the respective other elicited norm and θ_i is the error term. All other variables are defined as in Equation (4). Results show that almost all coefficients significant (insignificant) in Equation (4) remain significant (insignificant) in Equation (4a) (Table 5). The exception are the dummy variables for farm location in the region Khomas, which is no longer significant in the robustness check, and for farm location in Hardap/Karas, which is significant in the robustness check. Furthermore, all coefficients that are significant in Equation (4) retain sign and order of magnitude in Equation (4a), and vice versa. We thus conclude that we can exclude the respective other norms without incurring an omitted variable bias for almost any variable.

B.2 Robustness checks for analysis of Research Question 3 (impact of personal norms on management)

Other management strategies as covariate

We expect that S_k, i.e. the self-reported extent of management strategy k = 1, …, 6, also depends on the extent of the respective five other management strategies, but, similar to above, we cannot adequately address the ensuing endogeneity problem. Instead, we here augment Equation (5) by including the respective five other strategies as covariates and estimate

$$S_{ki} = \delta_0 + \delta_{\bar{g}} G[\bar{g}_i] + \delta_{\bar{y}} Y[\bar{y}_i] + \delta_{OS} OS_i + \delta_x X_i + o_i \quad (5a)$$

where OS_i a vector of the respective five other management strategies and o_i is the error term. All other variables are defined as in Equation (5). Estimation results of Equation (5a) show that the coefficients of personal norms remain insignificant (Table 6). We thus conclude that we do not incur an omitted variable bias for the coefficient of primary interest, i.e. the personal norm coefficients, by excluding these other strategies.

Alternative income definitions

We perform three robustness checks in which we employ alternative specification of the income variable to estimate Equation (5). In the first, we substitute both the personal income norm and actual income by their respective logarithms. In the second and third check we address the fact that we did not elicit the precise level for actual income but rather income intervals. Previously, we use interval mid-points as an approximation to precise actual income. We now instead use the lower bound of the income interval in the second robustness check, and the upper bound of the income interval in the third check. Estimate results for all checks confirm our previous results in that we do not find evidence that personal norms impact on management.

Alternative regression models

We perform three robustness checks in which we employ alternative regression models to estimate Equation (5). In the first two checks, we defined S_k, the self-reported extent of management strategy k = 1, …, 6, as an ordinal variable whereas we previously had defined it as a continuous variable. We then estimate Equation (5) as an ordered probit model (first check) and as an ordered logit model (second check). For the third check, we estimate the previously separate equations for the six management strategies jointly in a seemingly unrelated regression system (Zellner, 1962). We thereby allow for correlation of the error terms across equations, essentially assuming that unspecified factors impact equally on all six strategies. Again, estimate results for all checks confirm our previous results in that we do not find evidence that personal norms impact on management.

Influence of other farmers' personal norms and management

Previously, we assumed that compliance with the personal norms is independent of what other farmers are doing. Here, we conduct two robustness checks of this assumption for Equation (5) which we expand by additionally allowing for social interactions to influence compliance. Ideally we would require information on exactly what other farmers a given farmer interacts, but we do not have this information. Instead, we make use of various other information: firstly, the NAU provides a variety of platforms for meetings and knowledge exchange between their members; secondly, NAU members within a region are more likely to interact than NAU members between regions as the NAU provides many of its platforms at the major regional cities; and thirdly, only full-time farmers regularly interact on these platforms since part-time farmers typically do not have the time to attend these platforms (many part-time farmers do not live in their farms' region and can attend these platforms only rarely). Thus, we focus on farmer who are NAU members and live on farm, and group farmers by regions.

We firstly examine whether other farmers' management influence compliance with personal norms. To this end, we assume that farmers discuss their farm management at the NAU platforms and that based on these discussions each farmer can deduce the average level of extent for each strategy in his region. Thus, we calculate regional averages for the extent of each management strategy and interact them with farmers' individual ecosystem and income norms, respectively, estimating the equation

$$\begin{aligned} S_{ki} = \eta_0 + \eta_{\bar{g}} G[\bar{g}_i] + \eta_{\bar{y}} Y[\bar{y}_i] + \eta_{S_k R} S_{ki}^R \\ + \eta_{\bar{g} \times S_k R} G[\bar{g}_i] \times S_{ki}^R + \eta_{\bar{y} \times S_k R} Y[\bar{y}_i] \times S_{ki}^R + \eta_x X_i + \mu_i \end{aligned} \quad (5b)$$

where S_{ki}^R is the regional averaged extent of management Strategy *k*, $G[\bar{g}_i] \times S_{ki}^R$ and $Y[\bar{y}_i] \times S_{ki}^R$ are interaction effects between the regional averaged extent of this strategy and the ecosystem norm and income norm, respectively, and μ_i is the error term. All other variables are defined as in Equation (5). We run two specifications, one without X_i (for which we provide no table) and one with X_i (Table 7). Estimation results confirm our previous findings as neither the main effect of the personal norms nor their interaction effects impact on management. Thus, we find no evidence that other farmers' management, as averaged per region, influences compliance with the norms.

Secondly, we examine whether other farmers' personal norms influence compliance with personal norms. Again, we assume that farmers know the regional averaged level for each personal norm based on exchange at NAU platforms. We calculate regional averages for the personal ecosystem and income norm and interact them with farmers' individual ecosystem and income norms, respectively, estimating the equation

$$\begin{aligned} S_{ki} = \kappa_0 + \kappa_{\bar{g}} G[\bar{g}_i] + \kappa_{\bar{y}} Y[\bar{y}_i] + \kappa_{\bar{g}R} \bar{g}_i^R + \kappa_{\bar{y}R} \bar{y}_i^R \\ + \kappa_{\bar{g} \times \bar{g}R} G[\bar{g}_i] \times \bar{g}_i^R + \kappa_{\bar{y} \times \bar{y}R} Y[\bar{y}_i] \times \bar{y}_i^R + \kappa_x X_i + \varsigma_i \end{aligned} \quad (5c)$$

where $\bar{g}_i^R$ and $\bar{y}_i^R$ are regional averaged levels for the personal ecosystem and income norm, respectively, $G[\bar{g}_i] \times \bar{g}_i^R$ and $Y[\bar{y}_i] \times \bar{y}_i^R$ are interaction effects between an individual farmer's ecosystem norm and the regional averaged ecosystem norm, and between and individual farmers' income norm and the regional averaged income norm, respectively. ζ_i is the error term. All other variables are defined as in Equation (5). We run two specifications, one without X_i (for which we provide no table) and one with X_i (Table 8). Again, we find that neither the main effect of personal norms nor their interaction effects are significant in either the model with or without covariates. Thus, we find no evidence that other farmers' personal norms, as averaged per region, influence compliance with the norms.

Table 5: Determinants of personal norms of sustainability with the respective other personal norm included. OLS regressions, coefficients with standard errors in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Dependent variables:	**Ecosystem norm**	**Income norm**
Ecosystem norm		3.3e+05
		(3.33e+05)
Income norm	1.1e–08	
	(1.15e–08)	
Income	–1.2e–08	6.9e–01***
	(2.61e–08)	(1.34e–01)
Female	–1.0e–02	1.3e+04
	(1.29e–02)	(6.97e+04)
Age	8.6e–04***	1.0e+03
	(2.62e–04)	(1.44e+03)
Farm experience	–8.6e–04***	–3.2e+03**
	(2.34e–04)	(1.28e+03)
Afrikaans	–2.1e–03	2.3e+04
	(4.53e–03)	(2.44e+04)
Low education	8.7e–03	1.6e+04
	(5.41e–03)	(2.93e+04)
Household size	2.8e–03**	–5.6e+03
	(1.40e–03)	(7.61e+03)
Single ownership	2.0e–03	–4.0e+03
	(4.77e–03)	(2.57e+04)
Living off farm	–3.6e–03	–2.3e+03
	(5.51e–03)	(2.97e+04)
NAU member	1.9e–03	1.9e+04
	(5.91e–03)	(3.18e+04)
Rangeland area	–1.5e–06**	7.3e+00**
	(6.54e–07)	(3.53e+00)
Rented rangeland area	1.4e–07	–3.9e+00
	(8.18e–07)	(4.40e+00)
Cattle quantity	1.3e–05	–1.1e+01
	(9.10e–06)	(4.92e+01)
Optimal–actual bush	–1.1e–04	–5.2e+02
cover deviation	(1.16e–04)	(6.26e+02)
Ecosystem condition	6.0e–01***	–9.5e+04
	(7.38e–02)	(4.45e+05)
Erongo	–2.4e–02**	2.7e+04
	(9.97e–03)	(5.43e+04)
Hardap/Karas	–2.1e–02*	1.9e+05***
	(1.25e–02)	(6.68e+04)
Khomas	–7.7e–03	9.4e+03
	(6.11e–03)	(3.30e+04)
Kunene	–5.0e–03	–4.4e+04
	(7.87e–03)	(4.23e+04)
Omaheke	–4.8e–03	1.5e+04
	(5.78e–03)	(3.12e+04)
Oshikoto	–1.3e–02	–7.3e+04
	(1.64e–02)	(8.83e+04)
Constant	4.7e–03	1.3e+05
	(1.70e–02)	(9.13e+04)
Adjusted R^2	0.300	0.167
F–statistic	6.525	3.571
Model significance	0.000	0.000
Observations	284	284

Table 6: Impact of personal norms on management with respective other management strategies included. OLS regressions, coefficients with standard errors in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Dependent variables:	**Rangeland size increase**	**Spatial diversification**	**Resting rangeland**	**Additional feed**	**Breed adaptation**	**Production system adaptation**
Ecosystem norm	–5.064	5.602	0.712	–0.672	1.664	1.359
	(4.527)	(4.545)	(5.366)	(5.180)	(4.620)	(4.691)
Income norm	5.9e–07	–5.1e–07	1.4e–07	9.1e–08	–3.3e–09	4.0e–07
	(4.6e–07)	(4.6e–07)	(5.4e–07)	(5.2e–07)	(4.7e–07)	(4.7e–07)
Female	0.075	–0.223	0.865	0.104	0.919*	–0.006
	(0.516)	(0.519)	(0.608)	(0.589)	(0.522)	(0.534)
Age	–0.003	–0.003	–0.001	0.008	0.005	0.003
	(0.011)	(0.011)	(0.012)	(0.012)	(0.011)	(0.011)
Farm experience	–0.012	0.003	0.015	–0.011	–0.005	0.013
	(0.010)	(0.010)	(0.011)	(0.011)	(0.010)	(0.010)
Afrikaans	0.213	–0.097	0.538**	0.110	–0.009	0.163
	(0.180)	(0.182)	(0.211)	(0.206)	(0.184)	(0.187)
Low education	0.008	0.138	0.020	0.215	–0.070	–0.248
	(0.222)	(0.223)	(0.263)	(0.253)	(0.226)	(0.229)
Household size	0.020	0.007	–0.002	0.026	0.082	–0.054
	(0.054)	(0.054)	(0.064)	(0.062)	(0.055)	(0.056)
Single ownership	–0.166	0.214	0.363*	–0.052	–0.071	–0.240
	(0.185)	(0.186)	(0.218)	(0.211)	(0.189)	(0.191)
Living off farm	–0.113	0.232	0.335	0.342	0.058	–0.026
	(0.213)	(0.214)	(0.251)	(0.242)	(0.217)	(0.220)
NAU member	0.026	–0.245	–0.009	0.236	–0.185	0.377
	(0.227)	(0.228)	(0.268)	(0.259)	(0.231)	(0.233)
Rangeland area	–3.5e–05	5.0e–05**	3.9e–05	–7.3e–06	–9.6e–06	6.5e–05**
	(2.5e–05)	(2.5e–05)	(2.9e–05)	(2.8e–05)	(2.5e–05)	(2.5e–05)
Rented rangeland area	2.2e–05	6.0e–05*	–5.8e–05	–4.0e–05	1.4e–05	–6.5e–05**
	(3.1e–05)	(3.1e–05)	(3.7e–05)	(3.6e–05)	(3.2e–05)	(3.2e–05)
Cattle quantity	7.3e–04**	–9.4e–04***	–8.9e–04**	3.7e–04	2.4e–04	–4.2e–04
	(3.3e–04)	(3.3e–04)	(3.9e–04)	(3.8e–04)	(3.4e–04)	(3.5e–04)
Optimal–actual bush cover deviation	–0.002	–0.002	0.001	0.003	–3.1e–04	–0.001
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Erongo	0.697*	–0.409	0.145	–1.223***	0.287	0.219
	(0.389)	(0.393)	(0.463)	(0.440)	(0.398)	(0.405)
Hardap/Karas	–0.445	0.150	–0.573	–0.271	–0.450	–0.339
	(0.469)	(0.472)	(0.555)	(0.536)	(0.478)	(0.486)
Khomas	–0.036	0.057	–0.021	–0.288	–0.117	0.340
	(0.238)	(0.239)	(0.282)	(0.271)	(0.242)	(0.245)
Kunene	–0.053	0.327	–0.151	–0.543	0.212	0.192
	(0.305)	(0.306)	(0.361)	(0.346)	(0.310)	(0.315)
Omaheke	–0.183	–0.194	–0.270	0.804***	0.064	–0.070
	(0.229)	(0.230)	(0.271)	(0.257)	(0.234)	(0.237)
Oshikoto	–0.267	–0.453	0.578	0.606	–0.011	0.498
	(0.604)	(0.606)	(0.713)	(0.688)	(0.615)	(0.623)
Rangeland size increase		0.596***	0.033	0.043	0.042	–0.020
		(0.053)	(0.077)	(0.075)	(0.067)	(0.068)
Spatial diversification	0.591***		0.067	0.206***	0.004	0.142**
	(0.052)		(0.077)	(0.073)	(0.066)	(0.067)
Resting rangeland	0.023	0.048		2.6e–04	0.133**	–0.051
	(0.055)	(0.056)		(0.063)	(0.056)	(0.057)
Additional feed	0.033	0.160***	2.8e–04		0.054	–0.033
	(0.057)	(0.057)	(0.068)		(0.058)	(0.059)
Breed adaptation	0.041	0.004	0.180**	0.068		0.326***
	(0.064)	(0.065)	(0.075)	(0.073)		(0.063)
Production system adaptation	–0.019	0.134**	–0.067	–0.040	0.316***	
	(0.063)	(0.063)	(0.075)	(0.072)	(0.061)	

Dependent variables:	**Rangeland size increase**	**Spatial diversification**	**Resting rangeland**	**Additional feed**	**Breed adaptation**	**Production system adaptation**
Constant	1.306* (0.701)	–0.235 (0.710)	3.102*** (0.810)	3.065*** (0.781)	1.718** (0.711)	2.035*** (0.718)
Adjusted R^2	0.394	0.424	0.058	0.126	0.104	0.136
F–statistic	7.468	8.343	1.615	2.435	2.162	2.563
Model significance	0.000	0.000	0.034	0.000	0.001	0.000
Observations	260	260	260	260	260	260

Table 7: Impact of personal norms on management with regional averages (reg. avr.) of management and interaction effects. For brevity sake, abbreviations of management strategies, as indicated in the table header, are used. OLS regressions, coefficients with standard errors in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Dependent variables:	**Rangeland size increase [RSI]**	**Spatial diversification [SD]**	**Resting rangeland [RR]**	**Additional feed [AF]**	**Breed adaptation [BA]**	**Production system adaptation [PSA]**
Ecosystem norm	226.917	162.589	54.092	52.695	–23.475	116.911
	(138.691)	(165.166)	(326.528)	(36.105)	(119.537)	(287.491)
Income norm	–1.3e–05	–1.9e–05	–2.6e–05	–2.8e–07	2.2e–05	4.7e–06
	(1.3e–05)	(1.2e–05)	(5.0e–05)	(5.5e–06)	(2.0e–05)	(1.3e–05)
Reg. avr. RSI	–2.269					
	(1.581)					
Ecosystem norm x Reg. avr. RSI	–69.299					
	(42.128)					
Income norm x Reg. avr. RSI	4.1e–06					
	(4.0e–06)					
Reg. avr. SD		–3.371*				
		(1.801)				
Ecosystem norm x Reg. avr. SD		–47.971				
		(51.492)				
Income norm x Reg. avr. SD		5.9e–06				
		(3.6e–06)				
Reg. avr. RR			0.285			
			(2.229)			
Ecosystem norm x Reg. avr. RR			–10.803			
			(70.410)			
Income norm x Reg. avr. RR			5.6e–06			
			(1.1e–05)			
Reg. avr. AF				–0.379		
				(23.166)		
Ecosystem norm x Reg. avr. AF				–10.063		
				(6.921)		
Income norm x Reg. avr. AF				1.1e–07		
				(1.2e–06)		
Reg. avr. BA					–0.170	
					(2.512)	
Ecosystem norm x Reg. avr. BA					5.838	
					(26.597)	
Income norm x Reg. avr. BA					–5.1e–06	
					(4.5e–06)	
Reg. avr. PSA						0.602
						(1.551)
Ecosystem norm x Reg. avr. PSA						–25.070
						(64.083)
Income norm x Reg. avr. PSA						–9.4e–07
						(3.0e–06)
Female	–0.377	–0.748	1.366*	–0.121	1.156*	0.606
	(0.747)	(0.762)	(0.714)	(0.715)	(0.620)	(0.655)
Age	–0.006	0.017	0.005	0.018	0.010	0.013
	(0.018)	(0.017)	(0.015)	(0.015)	(0.013)	(0.014)
Farm experience	–0.021	–0.016	0.021	–0.018	–0.008	0.005
	(0.015)	(0.014)	(0.013)	(0.013)	(0.011)	(0.012)
Afrikaans	0.552**	0.138	0.519**	0.157	0.161	0.179
	(0.271)	(0.263)	(0.245)	(0.244)	(0.213)	(0.226)
Low education	0.203	0.433	0.466	0.518*	0.368	–0.034
	(0.341)	(0.318)	(0.289)	(0.290)	(0.253)	(0.268)
Household size	0.018	0.023	0.137*	0.048	0.088	–0.004
	(0.087)	(0.088)	(0.081)	(0.082)	(0.070)	(0.074)

Dependent variables:	**Rangeland size increase [RSI]**	**Spatial diversification [SD]**	**Resting rangeland [RR]**	**Additional feed [AF]**	**Breed adaptation [BA]**	**Production system adaptation [PSA]**
Single ownership	–0.025	0.122	0.215	0.095	–0.266	–0.270
	(0.290)	(0.287)	(0.265)	(0.264)	(0.231)	(0.246)
Rangeland area	4.7e–05	1.4e–04***	1.0e–04***	6.6e–06	7.5e–05**	6.7e–05*
	(4.3e–05)	(4.3e–05)	(4.0e–05)	(4.0e–05)	(3.4e–05)	(3.7e–05)
Rented rangeland area	3.6e–05	8.4e–05*	–3.5e–05	–2.7e–05	–2.2e–05	–1.9e–05
	(4.6e–05)	(4.7e–05)	(4.3e–05)	(4.3e–05)	(3.8e–05)	(4.0e–05)
Cattle quantity	3.8e–04	–1.3e–03**	–1.8e–03***	4.1e–04	–4.6e–04	–2.1e–04
	(5.3e–04)	(5.3e–04)	(4.9e–04)	(4.9e–04)	(4.3e–04)	(4.6e–04)
Optimal-actual bush cover deviation	–0.007	–0.006	0.005	0.004	–0.001	–0.002
	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)
Erongo	0.467	–1.246	–0.900	–2.199	–0.332	0.134
	(0.614)	(0.767)	(0.580)	(26.852)	(0.528)	(0.670)
Hardap/Karas	0.805	1.318	–0.180	–1.333	–0.738	–0.065
	(1.109)	(1.298)	(0.858)	(32.867)	(1.264)	(1.635)
Khomas	–0.831	–0.863	0.069	–0.181	–0.422	0.095
	(0.805)	(0.726)	(0.342)	(6.106)	(0.768)	(0.438)
Kunene	–0.595	0.118	–0.652	–0.710	0.268	0.275
	(0.657)	(0.487)	(0.434)	(7.751)	(0.525)	(0.416)
Omaheke	–0.361	–1.177*	–0.403	1.249	–0.376	–0.034
	(0.351)	(0.665)	(0.372)	(20.411)	(0.497)	(0.284)
Constant	10.770**	12.690**	1.780	5.089	4.480	0.434
	(5.218)	(5.763)	(10.098)	(106.801)	(11.414)	(6.850)
Adjusted R^2	0.066	0.051	0.074	0.106	–0.012	–0.035
F–statistic	1.594	1.483	1.731	2.084	0.895	0.694
Model significance	0.057	0.089	0.030	0.005	0.598	0.836
Observations	177	190	194	194	193	193

Table 8: Impact of personal norms on management, with regional averages (reg. avr.) of personal norms and interaction effects. For brevity sake, abbreviations of personal norms are used for regional averages and in interaction effects, as indicated. OLS regressions, coefficients with standard errors in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Dependent variables	**Rangeland size increase**	**Spatial diversification**	**Resting rangeland**	**Additional feed**	**Breed adaptation**	**Production system adaptation**
Ecosystem norm [EN]	92.577	87.279	44.258	53.929	4.649	–20.460
	(71.531)	(69.955)	(36.567)	(36.646)	(31.905)	(33.857)
Income norm [IN]	1.1e–07	–5.7e–06	4.8e–07	2.6e–06	1.4e–06	1.6e–07
	(6.0e–06)	(6.2e–06)	(5.7e–06)	(5.8e–06)	(5.1e–06)	(5.3e–06)
Reg. avr. EN	34.910	41.764	–6.391	–21.343	15.853	–6.807
	(32.411)	(32.770)	(30.386)	(30.452)	(26.551)	(28.041)
Reg. avr. IN	–1.7e–06	–4.0e–06	–4.7e–06	1.8e–05***	–3.9e–06	–1.6e–06
	(6.9e–06)	(6.8e–06)	(6.2e–06)	(6.2e–06)	(5.4e–06)	(5.7e–06)
EN x Reg. avr. EN	–3.3e–04	–2.8e–04	–1.3e–04	–1.7e–04	–6.8e–06	7.9e–05
	(2.5e–04)	(2.5e–04)	(1.2e–04)	(1.2e–04)	(1.0e–04)	(1.1e–04)
IN x Reg. avr. IN	4.5e–06	6.3e–05	–9.8e–06	–2.8e–05	–2.3e–05	4.5e–06
	(7.2e–05)	(7.3e–05)	(6.8e–05)	(6.8e–05)	(6.0e–05)	(6.3e–05)
Female	–0.358	–0.770	1.460**	–0.101	1.140*	0.570
	(0.753)	(0.768)	(0.713)	(0.715)	(0.623)	(0.658)
Age	–0.009	0.007	0.005	0.018	0.011	0.012
	(0.018)	(0.017)	(0.015)	(0.015)	(0.013)	(0.014)
Farm experience	–0.016	–0.008	0.022*	–0.018	–0.008	0.006
	(0.015)	(0.014)	(0.013)	(0.013)	(0.011)	(0.012)
Afrikaans	0.567**	0.144	0.510**	0.163	0.140	0.172
	(0.273)	(0.264)	(0.245)	(0.245)	(0.213)	(0.226)
Low education	0.220	0.349	0.495*	0.520*	0.340	–0.055
	(0.343)	(0.319)	(0.289)	(0.289)	(0.253)	(0.266)
Household size	0.022	0.013	0.149*	0.052	0.094	–0.013
	(0.088)	(0.088)	(0.081)	(0.082)	(0.071)	(0.075)
Single ownership	–0.099	0.010	0.221	0.104	–0.268	–0.297
	(0.291)	(0.286)	(0.265)	(0.265)	(0.233)	(0.244)
Rangeland area	3.9e–05	1.2e–04***	1.1e–04***	9.6e–06	7.5e–05**	6.3e–05*
	(4.4e–05)	(4.3e–05)	(4.0e–05)	(4.0e–05)	(3.5e–05)	(3.7e–05)
Rented rangeland area	4.5e–05	9.2e–05*	–3.3e–05	–2.9e–05	–2.1e–05	–1.9e–05
	(4.7e–05)	(4.7e–05)	(4.3e–05)	(4.3e–05)	(3.8e–05)	(4.0e–05)
Cattle quantity	4.2e–04	–1.2e–03**	–1.8e–03***	4.0e–04	–4.8e–04	–2.0e–04
	(5.4e–04)	(5.3e–04)	(4.9e–04)	(4.9e–04)	(4.3e–04)	(4.6e–04)
Optimal–actual bush cover deviation	–0.007	–0.005	0.007	0.004	–0.002	–0.003
	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.006)
Erongo	1.423	1.025	–1.399	–2.039*	–0.043	–0.029
	(1.128)	(1.154)	(1.073)	(1.075)	(0.950)	(0.990)
Hardap/Karas	2.078	3.162*	–0.289	–2.710*	0.404	–0.530
	(1.606)	(1.636)	(1.514)	(1.517)	(1.320)	(1.397)
Khomas	0.305	0.325	–0.161	0.067	–0.150	–0.012
	(0.406)	(0.404)	(0.369)	(0.370)	(0.322)	(0.344)
Kunene	0.006	0.234	–0.881*	–0.144	0.106	0.284
	(0.577)	(0.556)	(0.513)	(0.514)	(0.448)	(0.474)
Constant	0.469	–0.454	4.863	–0.006	3.293	4.290
	(3.341)	(3.381)	(3.128)	(3.135)	(2.736)	(2.890)
Adjusted R^2	0.054	0.042	0.079	0.106	–0.018	–0.033
F–statistic	1.475	1.390	1.784	2.094	0.836	0.709
Model significance	0.094	0.129	0.023	0.005	0.672	0.820
Observations	177	190	194	194	193	193

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