Revised version (July 2013) of Working Paper Series in Economics No. 248, University of Lüneburg

Characterizing commercial cattle farms in Namibia: risk, management and sustainability

Roland Olbrich[a*], Martin F. Quaas[b] and Stefan Baumgärtner[a]

[a] Department of Sustainability Sciences and Department of Economics, Leuphana University of Lüneburg, Germany

[b] Department of Economics, University of Kiel, Germany

Abstract

Commercial cattle farming in semi-arid regions is subject to high rainfall risk. At the same time it is prone to rangeland degradation, and theoretical works suggests that this may be due to inadequate management of the rainfall risk. In this paper, we provide a comprehensive empirical characterization of Namibian commercial cattle farming with respect to rainfall risk, risk management, and sustainability. Our data comes from a questionnaire among 2,119 farmers. With this data, we examine the critical link between risk, management and sustainability by exploring structural farm patterns with a cluster analysis. Our results show that the most distinct of the three identified clusters is characterized by high grazing capacity (indicating high sustainability) and low financial risk management, but not by high or low income. These results conform to the hypothesis that (financial) risk management may achieve income risk reduction at the cost of a decrease in the system's sustainability.

Keywords: cattle farming, semi-arid rangelands, Namibia, empirical questionnaire, rainfall risk, risk management, sustainability

---

[*] Address for correspondence: Sustainability Economics Group, Leuphana University of Lüneburg, P.O. Box 2440, D-21314 Lüneburg, Germany. Phone: +49.176.2320-7168, fax: +49.4131.677-1381, email: olbrich@uni.leuphana.de.

All authors have materially participated in the research and have approved of the final article. Roland Olbrich: design and conduction of data collection, conduction of statistical analyses, writing of article; Martin F. Quaas: development of conceptual background, design of data collection, writing of article; Stefan Baumgärtner: design of study, development of conceptual background, design of data collection, writing of article.

The work described in this article is in accordance with *The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans, the EU Directive 2010/63/EU for animal experiments* and *the Uniform Requirements for manuscripts submitted to Biomedical journals.*

This work was funded by the German Federal Ministry of Education and Research (BMBF) under grant No. 01UN0607. The Ministry was not involved in the study design, in the collection, analysis and interpretation of data, in the writing of the report or in the decision to submit the article for publication.

1. Introduction

A defining characteristic of semi-arid areas is low and highly variable rainfall. Roughly 50% of the land in these areas is used as rangeland for livestock farming (MEA, 2005), as this type of extensive land use offers sufficient flexibility to adapt to the prevailing rainfall conditions. However, even though livestock farming is intended to deal with the variable rainfall conditions, it is frequently unsustainable with at least 10–20% of semi-arid areas being degraded (MEA, 2005: 637, 640). One reason is that livestock farming is often practiced as *communal* open-access farming where it may be rational for farmers to "produce outcomes that are not in anyone's long-term interest" (Ostrom, 1999: 279).

However, degradation is also observed in *commercial* farming systems where property-owning farmers exclusively manage rangeland and may do so for decades (de Klerk, 2004). One reason for degradation in commercial systems is the use of inadequate management strategies (e.g. Fynn and O'Connor, 2000; de Klerk, 2004; Wiegand, 2010). More specifically, theoretical papers (Quaas and Baumgärtner, 2008; Baumgärtner and Quaas, 2009a; Müller et al., 2011) suggest that some strategies trade-off the reduction of risk, and thus the stabilization of income, against the system's sustainability. The precise link between risk, management and sustainability in commercial farming systems is, however, poorly understood, not least of all because comprehensive empirical data is lacking.

In this paper, we empirically characterize risk, management and sustainability and examine their links for commercial livestock farming in semi-arid rangelands. Our case study is commercial cattle farming in Namibia where it constitutes an economically important sector that contributes directly at least 1–2% to GDP (MAWF, 2009). Like other semi-arid areas, Namibian rangelands are subject to high rainfall risk (Sweet, 1998) as well as to degradation in the form of bush encroachment (de Klerk, 2004).

In August 2008, we conducted a large-scale questionnaire among 2,119 commercial cattle farmers through a mail-in questionnaire (Olbrich et al., 2012). We collected information on 1) perceived rainfall risk, 2) risk management strategies, 3) the farm's sustainability, 4) individual risk and time preferences and normative views of sustainability, and 5) personal and farm features. Here, we analyse these data by providing descriptive statistics and by exploring structural farm patterns through the use of a cluster analysis.

The descriptive statistics show that cattle farms are highly heterogeneous in a wide range of characteristics. Furthermore, results from the cluster analysis show that cattle farms are classified mainly by their sustainability and the farmer's financial risk management, but not by the farmer's income: the most distinct of the three identified clusters is characterized by high grazing capacity (a proxy for high sustainability) and low financial risk management, but not by high or low income. These results conform to the above mentioned theoretical work (Quaas and Baumgärtner, 2008; Müller et al., 2011).

The paper is organized as follows: Section 2 gives a brief description of commercial cattle farming in Namibia. Section 3 describes the data collection and the analytical procedures. Section 4 presents the descriptive statistics and the results for the cluster analysis. Finally, Section 5 discusses and concludes.

2. Background: commercial cattle farming in Namibia

The commercial cattle farming area in Namibia covers approximately 14.5 million hectares (ha) (Mendelsohn, 2006: 42) and is located in the northern half of Namibia (Figure 1). It is confined to the south and west by areas too dry for farming and in the north and east by communal lands. On average, the commercial farming area receives an annual rainfall of 374 mm, with 95% (352 mm) of rainfall falling during the rainy season from November to April (NMS, unpublished).[1] Rainfall is highly variable from one rainy season to the next: the coefficient of variation of total rainy season rainfall amounts to 0.35 (NMS, unpublished).[2] The ecosystem is widely degraded by bush encroachment und thus in an unsustainable state, with the capacity of farm land to support grazing cattle ("grazing capacity") (see Table 1) being nowadays much worse than the historic value of > 0.1 Large Stock Unit per hectare (LSU/ha) (< 10 ha/LSU)[3] 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).[4] An estimated 2,250 commercial cattle farmers (Olbrich et al., 2012) 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%) are sold as live cattle

---

[1] 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.

[2] The coefficient of variation for total annual rainfall is with a value of 0.35 very similar. For comparison: the corresponding coefficient of variation is between 0.1 and 0.2 for countries in central and northern Europe (Chapman, 2010: Map 2).

[3] Throughout this paper, we report grazing capacity in the unit LSU/ha which is 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.

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

(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 small fraction consumed domestically (15%) (MAWF, 2009: 14, 15).

Politically, the majority of commercial cattle farmers is organized in the Namibia Agricultural Union (NAU), which is the main interest group of commercial farmers. A small part of farmers is organized in the Emerging Commercial Farmers' Support Programme, which specifically represents indigenous commercial farmers (which are typically referred to as "emerging commercial farmers").

2.2 Risk, management and sustainability in cattle farming

Risk, management and sustainability are closely linked in the production process in cattle farming. Farmers derive income from cattle production, selling either weaners (at age 9 months) or oxen (at age 18–24 months). Given that farming in Namibia is extensive farming, the main input for cattle farming is pasture.

Pasture production is positively dependent on the condition of the ecosystem and on rainfall. Ecosystem condition in Namibian rangelands is essentially characterized by the level of bush encroachment. It can be measured as grazing capacity in the unit LSU/ha.[5] Accordingly, a high grazing capacity denotes few bush encroachment and thus a sustainable ecosystem condition. Bush encroachment changes only little in the short run (i.e. from year to year), but may change considerably over the long run.

Due to the dependency of pasture production on rainfall, farmers' income is highly risky since the high rainfall risk translates (through the production process) into the income risk. Income may thus change dramatically from year to year if no risk management is conducted. A farmer may manage the risk through a number of risk management strategies. These strategies either adjust the organization or production processes of the farm ("on-farm strategies") or makes use of financial products or off-farm assets ("financial strategies").

The main on-farm strategies are:

- increasing the rangeland size ("rangeland size increase"),
- resting part of the rangeland to provide feed throughout the year ("resting rangeland"),

[5] Bush encroachment is not simply reflected in the bush cover, since not all bush species are considered to be detrimental to ecosystem condition (de Klerk, 2004). Thus, grazing capacity, and not bush cover, is the more adequate measure for ecosystem condition (we do, however, include bush cover as one of several important personal and farm characteristic in our later analysis).

- providing cattle with purchased hay and licks (“additional feed”),
- choosing cattle breeds adapted to local environmental conditions (“breed adaptation”),
- choosing a production system, such as weaner or ox production, that is adapted to local environmental conditions (“production system adaptation”).

The main financial strategies are

- agreeing on advances on livestock sales (“advances on livestock sales”),
- keeping a checking account as a financial buffer (“checking account as buffer”),
- taking up loans for covering operating losses (“loans for covering operating losses”),
- obtaining income from off-farm sources (“off-farm income”), and
- investing into agricultural derivatives (“investment into agricultural derivatives”).

All these strategies are in principle substitutes with respect to risk management. However, beyond managing risk some strategies may simultaneously and adversely affect the sustainability of the system (i.e. increase bush encroachment and thus lower grazing capacity). More specifically, Quaas and Baumgärtner (2008), Baumgärtner and Quaas (2009a) and Müller et al. (2011) showed for Namibian rangelands in a series of theoretical papers that on-farm and financial strategies may indeed be substitutes with regards to risk management, but that the use of financial strategies may decrease the system’s sustainability.

3. Data and methods

3.1 Data sources

In this section, we briefly describe the process and the questionnaire that we used for the data collection. A detailed description of the data collection can be found in Olbrich et al. (2012) and a copy of the questionnaire is included in Olbrich et al. (2009).

Description of data collection

In August 2008, we send out mail-in questionnaires to commercial cattle farmers in Namibia in order to elicit 1) perceived rainfall risks, 2) risk management strategies, 3) the farm’s sustainability, 4) individual risk and time preferences and normative views of sustainability, and 5) personal and farm features. Questionnaires were sent to a group of 2,119 farmers which consisted of members of the NAU and of farmers that deliver cattle to MeatCo, the largest slaughterhouse in Namibia. This group essentially is the whole population of commercial cattle farmers in Namibia (Olbrich et al., 2012; see also Section 2). 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.

398 questionnaires were returned, equaling a return rate of 19%. 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 299 (75.1%) of questionnaire participants.

Elicitation of rainfall risk, management and sustainability

We elicited rainfall risk by asking farmer to rate this risk on a six-item Likert-scale ranging from "no risk at all" to "very high risk".

We elicited risk management by asking farmers for each on-farm risk management strategy (i.e. *rangeland size increase*, *resting rangeland*, *additional feed*, *breed adaptation* and *production system adaptation*) and financial risk management strategy (i.e. *advances on livestock sales*, *checking account as buffer*, *loans for covering operating losses*, *off-farm income* and *investment into agricultural derivatives*) to self-report the importance they ascribe to each strategy. Importance was recorded on a six-item Likert-scale ranging from "not at all important" to "very important".

We measured sustainability by the grazing capacity in the unit LSU/ha, in line with our depiction of the rangeland system that we provided in Section 2.2.

Elicitation of risk and time preferences and of normative views of sustainability

We elicited risk and time preferences by hypothetical choice experiments in the questionnaire using a multiple-price-list format (see Olbrich et al., 2012). Based on this elicitation, we construct indices for risk and time preference out of the raw responses in the experiments. The *risk* preference index hereby is a discrete variable with values in {1, 2, …, 7} where low values denote high risk aversion and high vales denote risk attraction. For the *time* preference index we construct a discrete variable with values in {1, 2, …, 6} where low values denotes patience and high values denote impatience.[6]

The normative views of sustainability that we elicited are conceptually based on the notion of strong sustainability: critical natural and economic components of a given system have to be conserved at or above specified thresholds, and have to be conserved independently of each

[6] As Olbrich et al. (2011b) 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.

other (Pearce et al., 1989; Ekins et al., 2003). We expand this notion by also requiring the specification of the acceptable risk that the components' conservation fails due to stochastic system dynamics and of the time horizon over which the components should be conserved (Baumgärtner and Quaas, 2009b). In accordance with our system description in Section 2.2, we pre-selected ecosystem condition of the rangeland, measured as grazing capacity in the unit LSU/ha, as one critical component for conservation. In addition, we selected income, measured as net annual income in the unit N$, as an additional critical component. We then elicited 1) the threshold level at or above which ecosystem condition (income) should be conserved, 2) the acceptable risk that the conservation of ecosystem condition (income) fails in a given year, measured as a probability,[7] and 3) the time horizon for conservation of ecosystem condition and income, measured in the unit generations.[8]

Elicitation of personal and farm features

In addition to the aforementioned variables, we elicited a variety of personal and farm features. A list of all elicited variables along with their summary statistics is given in Table 1.

3.2 Statistics analysis

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. We then analyze characteristics jointly through a cluster analysis to explore whether we may classify farms into similar groups.

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

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

---

[7] In the questionnaire we elicited acceptable grazing capacity risk (acceptable income risk) by asking for how many years out of ten years it is manageable that grazing capacity (income) falls *below* the specified grazing capacity (income) threshold. We make two adjustments here: firstly, we invert the corresponding variables and thus report the still acceptable risk that grazing capacity (income) is *above* the threshold. Secondly, we express values as probabilities. Thus, 'one out of ten years' is expressed as a probability value of 0.1 that grazing capacity (income) is above the threshold in a given year, 'two out of ten years' as a probability value of 0.2, and so forth.

[8] Altogether, more demanding views of sustainability are thus reflected in *higher* values for the threshold level of ecosystem condition (income) and for the time horizon, and in *lower* values for the acceptable risk that conservation of ecosystem condition (income) fails.

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,

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

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

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). However, none of the 528 unique characteristics pairs (based on 33 characteristics over which we conduct the cluster analysis) display a correlation coefficient above 0.6 and only 11 a correlation coefficient above 0.4 .

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.

4. Results

4.1 Descriptive statistics

A comprehensive overview of descriptive statistics is given in Table 1. In this section we will briefly discuss these statistics, beginning with rainfall risk, risk management and sustainability, and closing with farmers' preferences, normative views and personal and farm features.

Rainfall risk

The rainfall risk is rated above average with a value of 4.6 (out of 6.0) on the Likert scale. Heterogeneity among farmers is with a standard deviation of 1.2 moderately high

Risk management strategies

In terms of risk management, 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 rangeland* (4.7 on a six-item Likert-scale), *additional feed* (4.7), *breed adaptation* (4.5) and *production system adaptation* (4.4). In contrast, the remaining on-farm strategy, *rangeland size increase* is rated considerably lower (3.3). We cannot conclusively explain this latter finding.

Financial risk management strategies are of less importance. *Checking accounts as buffer* (4.7) and *off-farm income* (4.0) are rated relatively high, which is unsurprising since farmers generally have a checking account and earn at least some off-farm income. In contrast, farmers seem to be sceptical 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.

Heterogeneity in ratings across farmers is considerable for most risk management strategies (standard deviations of 1.6 to 1.8). This finding is in accordance with our aforementioned statement that strategies may (in part) be substitutes with respect to risk management, which allows for considerable leeway in whether to apply a specific strategy or not.

Sustainability

Average grazing capacity is 0.080 LSU/ha (14.8 ha/LSU) and is lower than the historic 0.1 LSU/ha (10 ha/LSU) that were found on average prior to the mid 1960s (de Klerk, 2004: 21). The rangeland is thus (on average) not managed sustainably. However, grazing capacity is spatially variable across farms with a standard deviation of 0.040 LSU/ha, suggesting large differences in sustainability of individual farms.

Risk and time preferences

Farmers are on average risk averse, as indicated by a value of 4.8 (out of 7.0) for the risk preference index. In another study, Olbrich et al. (2011b) calculate for the average farmer a point estimate for the coefficient of relative risk aversion (CRRA) of 0.78.[9] 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).

Farmers are of intermediate impatience as exemplified by a value of 3.2 (out of 6.0) for the time preference index. Calculating point estimates of discount rates – to mirror the aforementioned point estimates of risk aversion – has not yet been done by the authors in a separate publication, and is beyond the scope of this publication.

Normative views of sustainability

Farmers believe that ecosystem condition should be sustained at or above a threshold of 0.082 LSU/ha and annual net income at or above a threshold of N$ 275,791.[10] Heterogeneity for both the normative view on ecosystem condition 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 ecosystem condition 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. On average, farmers indicated that ecosystem condition and income ought to be sustained for the 3.3 generations following their own generation, i.e. for the generations of their children, grandchildren, and great-grandchildren. This is the timeframe that most farmers are be expected to experience in their lifetime.[11]

[9] In Olbrich et al. (2011b), 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.
[10] For comparison: median annual income for the Namibian population was N$ 29,361 in 2003–2004. See also Footnote 12.
[11] Namibian farmers typically have their children at a young age (personal observation), and life expectancy is high (see for comparison our findings on farmers' age in below in this section).

Acceptable ecosystem condition risk and acceptable income risk are both centred at an intermediate probability value of 0.6, i.e. a probability of 60% that grazing capacity (income) falls below the specified threshold is still acceptable. 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.

Personal and farm features

Farmers are very heterogeneous in age and the distribution is centred within the advanced age: average age of farmers is 55.4 years with a standard deviation of 11.9 years. The majority of farmers (50.4%) are of Afrikaans decent, with the remaining farmers being predominantly of German descent. Education is of high importance among farmers with a median of 4.0, indicating that half of the farmers have an university degree (bachelor, master or doctorate). Household size is on average 3.3 members.

Farms are typically large with an average area of rangeland of 7,949 ha, but individual farms are very heterogeneous in size as indicated by a standard variation of 6,765 ha. On average, farmers rent 1,149 ha of farmland in addition to the land they own. Farms are typically operated by a single owner (70.7%) as opposed to forms of joint ownership (e.g. corporations, partnerships or cooperatives). The most common production system is oxen production (pursued by 47.7% of farmers), while other production systems such as weaner production or speculation production are of less importance. Farmers earn a considerable higher income than other Namibians: median income among farmers is N$ 150,001 to N$ 250,000 which is much greater than the 2003/2004 Namibian median income of N$ 29,361.[12] Not all farmers earn this income primarily from their farm: 20% of farmers are weekend farmer that operate the farm only on the weekend (as a hobby or secondary occupation) while earning their livelihood primarily in a different occupation.

Farmers assess the previous five rainy seasons as above average as indicated by a value of 4.0 (out of 6.0). Land quality (e.g. soil conditions) is likewise assessed to be above average with a value of 4.3 (out of 6.0). Almost half of the farms (48.2%) have actual bush cover that is intermediate or higher (i.e. 41% or more of the farm covered by bushes). Finally, the bush

[12] The latest available national income data was elicited in 2004 by the Namibian statistical office (CBS Namibia, 2006: 38). In order to properly compare our 2008 farm data to the 2004 national data, we have to adjust for inflation which amounted to 17% in Namibia in the period 2004–2008 (CIA, 2011). Adjusted median farmer income is then N$ 124,500 to N$ 207,500 in 2004 prices, and is thus still considerably higher than the N$ 29,361 median national income.

cover that farmers consider optimal on their farms is a low to medium cover (an average of 25% of the farm being covered by bush) and thus lower than actual bush cover.

4.2 Cluster analysis

In reporting results, we make three terminological simplifications for convenience sake: firstly, we say “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 2, Table 2). 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.

Finally, since we excluded in the cluster analysis all observations which had a missing entry in any of the analyze characteristics, only 108 observations (out of 398) were used in the cluster analysis.

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 (Table 3). It differs significantly from each of the two other clusters in 10 out of the 33 analyzed characteristics. It is best described by high sustainability and low financial risk management (“EnFiMa”).

The cluster has the highest grazing capacity (0.089 LSU/ha; $p<0.05$). 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 for all on-farm strategies, but only for three of these strategies: for *rangeland size increase* (2.7; $p<0.1$), albeit at only the 10% significance level; and for *production system adaptation* and *breed adaptation* (both 3.9; $p<0.05$), albeit differing in both strategies only from one other cluster. Finally, it also has 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. Thus, of the aforementioned characteristics it is grazing capacity (the proxy for sustainability) and financial risk management strategies that make this cluster distinct.

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 sustainability and management: it has the lowest number of household members (2.7 members; $p<0.1$) and it is the most patient (2.6 out of 6.0, $p<0.1$), albeit it is again significantly distinct in the latter characteristics from only one other cluster.

The cluster does not differ significantly in any other personal and farm features or in risk preferences. We especially note that it does not differ in income, and that it also does not differ in weekend farming (a criterion which, in Namibian everyday use, is typically employed to characterize farmers).

Cluster MultOwn

Based on the distinct characteristics of cluster EnFiMa, the remaining two clusters are accordingly characterized by low sustainability and high financial risk management. Beyond this distinction, however, they also have their own distinct characteristics.

The next larger cluster with 36 farms is significantly distinct in five such characteristics and best characterized by multiple ownership ("MultOwn") as it has the highest proportion of multiple ownership (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 in the latter variable 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 rangeland* (4.1; p<0.05) and the youngest farmers (46.9 years; p<0.01), albeit it significantly differs in latter two characteristics from only one other 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).

Altogether, we thus also observe heterogeneity of cattle farms when classifying them, albeit only one cluster of farms is very distinct. In accordance with the key distinct characteristics of this cluster, classification is predominantly driven by sustainability and financial risk management. To a lesser extent, classification is driven by organizational structure or ethnicity, the defining characteristics of the remaining two clusters. Rainfall risk, risk and time preferences as well as normative views play only a marginal role for classification. Finally, we especially note that income does not drive classification at all.

5. Discussion and conclusion

We characterize commercial cattle farms in Namibia, a prime case of livestock farming in semi-arid rangelands, according to 1) perceived rainfall risk, 2) risk management, 3) the farm's sustainability, 4) risk and time preferences and normative views of sustainability, and 5) personal and farm features. We find that cattle farms are highly heterogeneous in a wide range of characteristics. When classifying farms in a cluster analysis, we also find heterogeneity as exemplified by the identification of three separate clusters. Classification is driven predominantly by the farm's sustainability and the farmer's financial risk management, and to a lesser extent by organizational structure of farms and ethnicity.

Classification is not driven by farmer's income. This is curious in the light of the observed differences in the farm's sustainability (measured by the proxy grazing capacity) and in financial risk management. One possible explanation, that we have already mentioned in

Section 2.2, is that financial risk management stabilizes income but simultaneously impacts negatively on grazing capacity and thus leads to a degradation of the system (Quaas and Baumgärtner, 2008; Baumgärtner and Quaas, 2009a; Müller et al., 2011).

It is also interesting to note other characteristics that are *not* driving farm classification. Firstly, risk and time preferences as well as normative views of sustainability are only marginally important for classification. Based on the observed differences in management, one might hypothesize that preferences and normative views, which are key behavioural determinants, are not related to management behaviour in Namibian cattle farming. Regarding preferences, this is controversial and we do not expect that such a hypothesis will be upheld under more in-depth scrutiny than can be achieved through a cluster analysis. Regarding normative views, however, we indeed find no evidence that they impact on farm management in an in-depth analysis (Olbrich et al., 2011a). Secondly, weekend farming, a characteristic typically employed by local farmers and decision makers for characterization of farms, also does not drive our classification. It thus seems that it is only of minor importance for characterization in comparison to other characteristics.

Having provided these observations, 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. Most importantly, we cannot clarify the exact relationship between sustainability, financial risk management and income without further analysis, as we have for example done in respect to normative views (Olbrich et al., 2011a).

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 questionnaire, 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 Federal Ministry of Education and Research (BMBF) for financial support under grant 01UN0607.

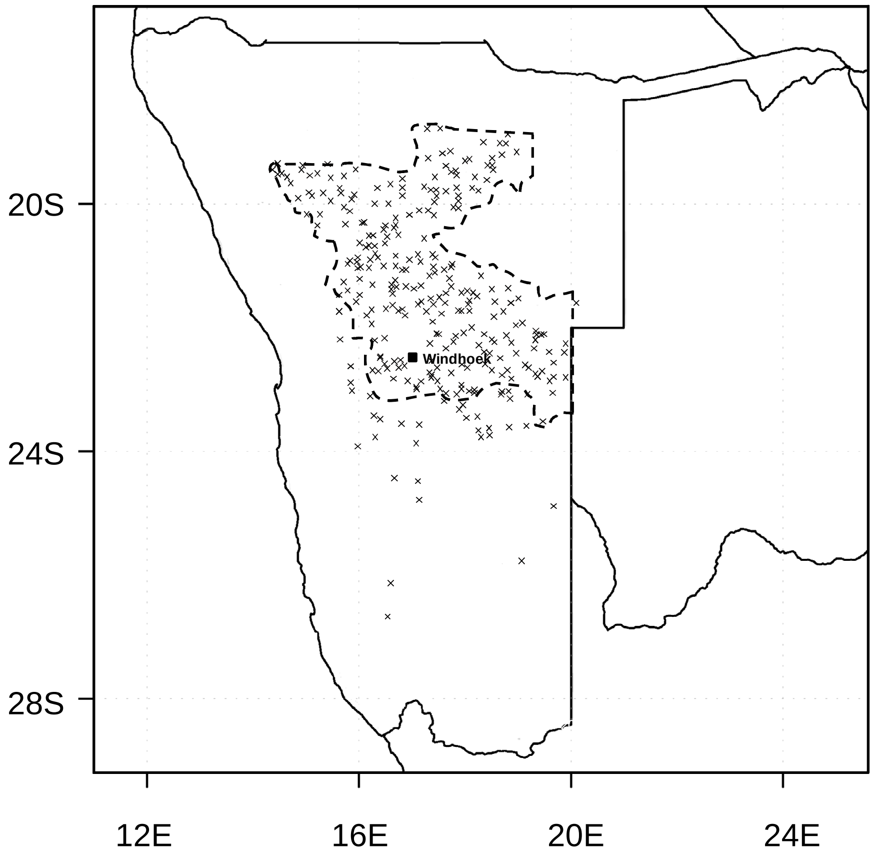

Figure 1: Commercial cattle farms in Namibia. The dashed line delimits what is considered the commercial cattle farming area (Mendelsohn, 2006). Crosses denote the position of all 299 farms which were identified in our mail-in questionnaire.

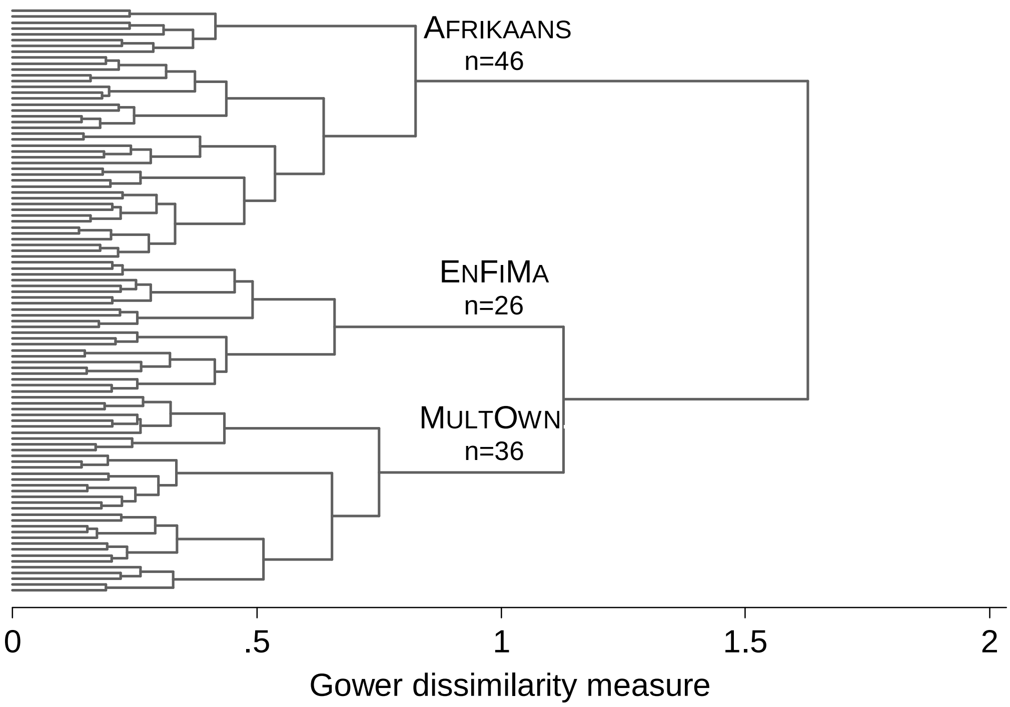

Figure 2: Dendrogram for three cluster solution. Cluster labels and observations per cluster are indicated above the respective branch. Clusters are MULTOWN (multiple owners), ENFIMA (favorable environment / low financial risk management) and AFRIKAANS (Afrikaans farmers). N=108.

Table 1: Summary statistics for 1) rainfall risk, 2) risks management strategies, 3) the farm's sustainability, 4) risk and time preferences and normative views of sustainability, and 5) personal and farm features. 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) Rainfall risk					
Rainfall *[1=no risk, 6=very high risk]*	4.6	5.0	1.2	1.0	6.0
2) Risk management strategies *[1=not at all important, 6=very important]*					
On-farm management strategies					
Additional feed	4.7	5.0	1.5	1.0	6.0
Production system adaptation	4.4	5.0	1.4	1.0	6.0
Breed adaptation	4.5	5.0	1.3	1.0	6.0
Resting rangeland	4.7	5.0	1.5	1.0	6.0
Rangeland size increase	3.3	3.0	1.7	1.0	6.0
Financial management strategies					
Advances on livestock sales	3.1	3.0	1.8	1.0	6.0
Checking account as 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
Off-farm income	4.0	4.0	1.7	1.0	6.0
Investment into agricultural derivatives	2.4	2.0	1.6	1.0	6.0
3) Sustainability indicators					
Grazing capacity *[LSU/ha]*	0.080	0.077	0.040	0.012	0.500
4) Preferences and normative views					
Risk preference index *[1=very risk averse, 5=risk neutrality, 7=very risk attracted]*	4.8	5.0	1.1	1.0	7.0
Time preference index *[1=very patient, 6=very impatient]*	3.2	3.0	1.1	1.0	6.0
Sustainable annual net income *[N$]*	275,791	240,000	206,896	4,000	2,000,000
Sustainable ecosystem condition *[LSU/ha]*	0.082	0.077	0.045	0.013	0.05
Acceptable income risk *[probability]*	0.6	0.6	0.2	0.0	1.0
Acceptable ecosystem condition risk *[probability]*	0.6	0.6	0.2	0.0	1.0
Time horizon *[generations]*	3.3	2.0	3.2	0	10

Characteristics	Mean	Median	Std. dev.	Min	Max
5) Personal and farm features					
Household size *[number of members]*	3.3	3.0	1.8	1.0	14.0
Land quality *[1=very poor quality, 6=very good quality]*	4.3	4.0	1.0	1.0	6.0
Age *[years]*	55.4	55.0	11.9	27.0	90.0
Afrikaans *[%]*	50.4	100.0	50.1	0	100.0
Education level *[1=no high school graduation, 6=Doctorate]*	3.4	4.0	1.2	1	6
Weekend farmer *[%]*	20.0	0.0	40.0	0.0	100.0
Average rainy season assessment (2004–2008) *[1=very poor, 6=very good]*	4.0	4.0	0.7	1.0	6.0
Single owners *[%]*	70.7	100.0	46.0	0.0	100.0
Rangeland *[hectare]*	7,949	6,765	5,512	0	44,244
Land net rented [13] *[hectare]*	1,149	0	2,897	-5,017	14,000
Actual bush cover *[1=0%, 6=81 to 100%]*	3.5	3.0	1.1	1.0	6.0
Optimal bush cover *[%]*	25.1	20.0	16.0	0.0	81.0
Oxen production *[%]*	47.7	50.0	40.3	0.0	100.0
Annual net income *[1= <N$50,000, 5= >N$350,000]*	2.9	3.0	1.4	1.0	5.0

Table 2: 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

[13] We define ‘land net rented’ as land rented *from* others minus land rented *out to* others. Thus, positive values signify that a farmer has rented more land from others than he has rented out, while negative values signify the opposite.

Table 3: 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) Rainfall risk ***[1=no risk, 6=very high risk]***				
Rainfall	4.9	4.4*	5.0	0.067
2) Risk management strategies ***[1=not at all important, 6=very important]***				
On-farm management strategies				
Additional feed	4.3	4.8	4.5	0.371
Production system adaptation	4.9	3.9**	4.5	0.039
Breed adaptation	4.8	3.9**	4.6	0.032
Resting rangeland	4.1**	4.7	5.0	0.025
Rangeland size increase	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 buffer	4.8	4.3	4.8	0.327
Loans for covering operating losses	3.0	1.5***	3.4	0.000
Off-farm income	3.9	3.6	3.8	0.803
Investment into agricultural derivatives	2.4	1.9	2.0	0.392
3) Sustainability indicators				
Grazing capacity *[LSU/ha]*	0.071	0.089*	0.074	0.016
4) Preferences and normative views				
Risk preference index *[1=very risk averse, 5=risk neutrality, 7=very risk attracted]*	4.6	5.0	4.7	0.416
Time preference index *[1=very patient, 6=very impatient]*	3.1	2.6*	3.2	0.069
Sustainable annual net income *[N$]*	292,806	251,539	294,000	0.567
Sustainable ecosystem condition *[LSU/ha]*	0.074	0.086	0.076	0.217
Acceptable income risk *[probability]*	0.6	0.5	0.6	0.801
Acceptable ecosystem condition risk *[probability]*	0.6	0.7**	0.6	0.009
Time horizon *[generations]*	3.3	4.1	3.5	0.671

Characteristics (continued)	MULTOWN	ENFIMA	AFRIKAANS	p-value
5) Personal and farm features				
Household size *[number of members]*	3.6	2.7*	3.6	0.036
Land quality*[1=very poor quality, 6=very good quality]*	4.0	4.2	4.4	0.342
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 (2004–2008) *[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
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
Oxen production *[%]*	68.3	60.5	42.3***	0.008
Annual net income *[1= <N$50,000, 5= >N$350,000]*	2.9	3.4	3.2	0.358

References

Andersen, S., Harrison, G.W., Lau, M.I., Rutström, E.E., 2006. Elicitation using multiple price list formats. Experimental Economics 9, 383–405.

Backhaus, K., Erichson, B., Plinke, W., Weiber, R., 2006. Multivariate Analysemethoden: Eine anwendungsorientierte Einführung, 11th ed. Springer, Berlin, Germany.

Baumgärtner, S., Quaas, M.F., 2009a . Agro-biodiversity as natural insurance and the development of financial insurance markets, in: A. Kontoleon, U. Pascual and M. Smale (eds), Agrobiodiversity, Conservation and Economic Development. Routledge, London, pp. 293–317.

Baumgärtner, S., Quaas, M.F., 2009b. Ecological-economic viability as a criterion of strong sustainability under uncertainty. Ecological Economics 68, 2008–2020.

Burke, A., 1997. The impact of large herbivores on floral composition and vegetation structure in the Naukluft Mountains, Namibia. Biodiversity and Conservation 6, 1203–1217.

Calinski, T., Harabasz, J., 1974. A dendrite method for cluster analysis. Communications in Statistics 3, 1–27.

CBS Namibia, [Central Bureau of Statistics Namibia], 2006. Namibia Household Income and Expenditure Survey 2003/2004, Preliminary Report. Central Bureau of Statistics, Windhoek, Namibia.

CBS Namibia, [Central Bureau of Statistics Namibia], 2010. Namibia Consumer Price Index – October 2010. Central Bureau of Statistics, Windhoek, Namibia.

Chapman, G., 2010. Popular perception and climate change: Mapping the varying experience of rainfall. Centre for Advanced Study, Oslo, Norway. (Internet publication, http://www.cas.uio.no/publications_/transference.php).

CIA, [Central Intelligence Agency], 2011. The World Factbook 2011. https://www.cia.gov/library/publications/the-world-factbook/. Accessed 09th June 2011.

de Klerk, J., 2004. Bush Encroachment in Namibia. Report on Phase 1 of the Bush Encroachment Research, Monitoring and Management Project. Ministry of Environment and Tourism, Windhoek, Namibia.

Duda, R.O., Hart, P.E., 1973. Pattern classification and scene analysis. John Wiley and Sons, New York, United States.

EIA, [Energy Information Administration], 2011. Database of spot prices for WTI crude oil, Cushing, Oklahoma. http://www.eia.gov/. Accessed 07th October 2011.

Ekins, P., Simon, S., Deutsch, L., Folke, C., Groot, R., 2003. A framework for the practical application of the concepts of critical natural capital and strong sustainability. Ecological Economics 44, 165 –185.

Fynn, R., O'Connor, T., 2000. Effect of stocking rate and rainfall on rangeland dynamics and cattle performance in a semi-arid savanna, South Africa. Journal of Applied Ecology 37, 491–507.

Gower, J., 1971. A general coefficient of similarity and some of its properties. Biometrics 27, 857–871.

Harrison, G.W., Humphrey, S.J., Verschoor, A., 2010. Choice under uncertainty: Evidence from Ethiopia, India and Uganda. Economic Journal 120, 80–104.

Howarth, R.B., 2007. Towards an operational sustainability criterion. Ecological Economics 63, 656–663.

Isaacs, D., 2007. Tenth arrest for Khorixas stock theft. The Namibian, Windhoek, Namibia, 15th January 2007.

MAWF, [Ministry of Agriculture, Water and Forestry], 2009. Agricultural statistics bulletin (2000–2007). Ministry of Agriculture, Water and Forestry, Windhoek, Namibia.

MEA, [Millenium Ecosystem Assessment], 2005. Chapter 22: Dryland systems, in: Hassan, R., Scholes, R., Ash, N. (Eds.), Ecosystem and human well-being. Current state and trends, Volume 1. Island Press, Washington, D.C., United States.

Meat Board, [Meat Board of Namibia], unpublished. Monthly cattle prices 2008. Meat Board of Namibia, Windhoek, Namibia.

Mendelsohn, J., 2006. Farming systems in Namibia. Research and Information Services in Namibia, Windhoek, Namibia.

Meyn, M., 2007. The end of the current EU preferences for Namibia: Economic and social impacts. Overseas Development Institute, London, United Kingdom.

Müller, B., Quaas, M.F., Frank, K., Baumgärtner, S., 2011. Pitfalls and potential of institutional change: Rain-index insurance and the sustainability of rangeland management. Ecological Economics 70(11), 2137–2144.

NMS, [Namibia Meteorological Service], unpublished. Daily rainfall data for 160 weather stations for the period 1913–2008. Namibian Meteorological Service, Windhoek, Namibia.

Olbrich, R., 2012. Environmental risk and sustainability: The case of commercial livestock farming in semi-arid rangelands. Dissertation, Leuphana University Lüneburg, Germany.

Olbrich, R., Quaas, M.F., Baumgärtner, S., 2009. Sustainable use of ecosystem services under multiple risks – A survey of commercial cattle farmers in semi-arid rangelands in Namibia. Working Paper Series in Economics No. 137, Leuphana University Lüneburg, Germany.

Olbrich, R., Quaas, M.F., Baumgärtner, S., 2011a. Personal norms of sustainability and their impact on management – The case of rangeland management in semi-arid regions. Working Paper Series in Economics No. 209, Leuphana University Lüneburg, Germany.

Olbrich, R., Quaas, M.F., Baumgärtner, S., 2012. A survey of commercial cattle farmers in semi-arid rangelands of Namibia on risk, sustainability and management. Schmollers Jahrbuch / Journal of Applied Social Science Studies 132, 463–471.

Olbrich, R., Quaas, M.F., Haensler, A., Baumgärtner, S., 2011b. Risk preferences under heterogeneous environmental risk. Working Paper Series in Economics No. 208, Leuphana University Lüneburg, Germany.

Ostrom, E., 1999. Revisiting the commons: Local lessons, global challenges. Science 284, 278–282.

Pearce, D.W., Marandya, A., Barbier, E. B., 1989. Blueprint for a Green Economy. Earthscan, London.

Quaas, M.F., Baumgärtner, S., 2008. Natural vs. financial insurance in the management of public-good ecosystems. Ecological Economics 65, 397–406.

Schutz, W., 2010. Personal communication, interview conducted on 01st March 2010, Meat Board of Namibia, Windhoek, Namibia.

Schwartz, S.H., 1973. Normative explanations of helping behavior: A critique, proposal and empirical test. Journal of Experimental Social Psychology 9, 349–364.

Schwartz, S.H., 1977. Normative influences on altruism. Advances in Experimental Social Psychology 10, 221–279.

Shogren, J.F., Crocker, T.D., 1999. Risk and its consequences. Journal of Environmental Economics and Management 37, 44–51.

Sweet, J., 1998. Livestock – Coping with Drought: Namibia – A case study. Pasture Development Network, Overseas Development Institute, London, United Kingdom.

Unganai, L., 1996. Historic and future climatic change in Zimbabwe. Climate Research 6, 137–145.

Ward, J.H., 1963. Hierarchical grouping to optimize an objective function. Journal of the American Statistical Association 58, 236–244.

Wiegand, K., 2010. In the rhythm of the vegetation. German Research 32, 12–16.