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Roland Olbrich, Martin F. Quaas
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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 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 rangeland 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 highly 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 or 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

* Address for correspondence: Sustainability Economics Group, Leuphana University of Lüneburg, P.O. Box 2440, D-21314 Lüneburg, Germany. Phone: +49.4131.677-2530, fax: +49.4131.677-1381, email: olbrich@uni.leuphana.de.

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, 2005: 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 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, 2005: 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, 2005: 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 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 (2012), pp. 17–52, 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 2,119 commercial cattle farmers in Namibia in August/September 2008 (Olbrich et al., in press). 398 questionnaires were returned, equaling a return rate of 19%. 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 highly 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 or 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. Figures and tables are relegated 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 in Namibia is beyond the scope of this paper, but is given by Olbrich (2012, pp. 17–52). 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 too 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 from November to April (NMS, unpublished).[1] Precipitation is highly variable from one rainy season to the next: the coefficient of variation of total rainy season

[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.

precipitation amounts to 0.35 (NMS, unpublished).[2] The land 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)[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 2,500 commercial cattle farmers[5] 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

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[2] 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).

[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.

[5] 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 can be found in Olbrich et al. (in press) and a copy of the questionnaire is included in Olbrich et al. (2009).

We sent out questionnaires 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., in press). 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.

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 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 at 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.[6]

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

[6] 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.

owner (another open question) which is expected to be a family member (68.2%), an 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 Section 4.2 below) 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).[7] 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

[7] 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.

or hobby, while earning their livelihood primarily in a field that requires post-secondary education (Table 13).[8]

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 in 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

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

of charge by a third of land-owning farmers (32.5%)[9], resulting in *operated* farmland (i.e. *owned* farmland plus net *rented / used free of charge* farmland) averaging 8,401 ha.[10] Finally, 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.[11] 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

[9] 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.

[10] 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 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) must not be rented out.

[11] 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%.

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.

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 of 377 cattle is 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 than in April 2008, 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, 2012: 17–52).

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).[12] In terms of income diversification we find that most farmers only partly rely on 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 with the EU (Meyn, 2007), volatile petroleum 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).

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

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.[13]

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 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.

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

[13] 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).

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 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. (2011b) calculate for the average farmer a point estimate for the coefficient of relative risk aversion (CRRA) of 0.78.[14] 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%

[14] 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.

(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-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 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[15] 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.

[15] Alternative terms exist for what we labeled "normative views" in the questionnaire. For example, common in the psychological literature is the term "personal norms" which was coined by Schwartz (1973, 1977) and which we use in Olbrich et al. (2011a).

We find that farmers consider on average that grazing capacity should be sustained at or above a threshold of 0.082 LSU/ha[16] and annual net income at or above a threshold of N$ 275,791. 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.[17] 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.

Finally, we note that the normative view pertaining to acceptable income risk is uncorrelated to risk preference (Pearson correlation: r=-0.01, p=0.89, N=359) and that the normative view pertaining to time horizon for sustaining grazing capacity and income is uncorrelated to time preference (Pearson correlation: r=-0.04, p=0.51, N=346). We have not elicited preferences over income, grazing capacity or grazing capacity risk and may thus not conduct likewise correlation analyses that involve these preferences and the respective normative views.

[16] 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.

[17] 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.

Nonetheless, we conclude that we find no evidence that normative views are dependent on preferences.

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.[18]

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,

[18] 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.

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

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.

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.[19] 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.[20] In regards to the time horizon characteristic we set all values greater than ten generations, such as

[19] 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.

[20] 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.

“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 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.[21]

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).[22] We report the most important omitted characteristics in the table that displays the results alongside the included

[21] 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.

[22] 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.

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.

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 patient (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 or 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 highly 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., 2011a). 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., 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.

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Appendix A: Descriptive statistics, figures

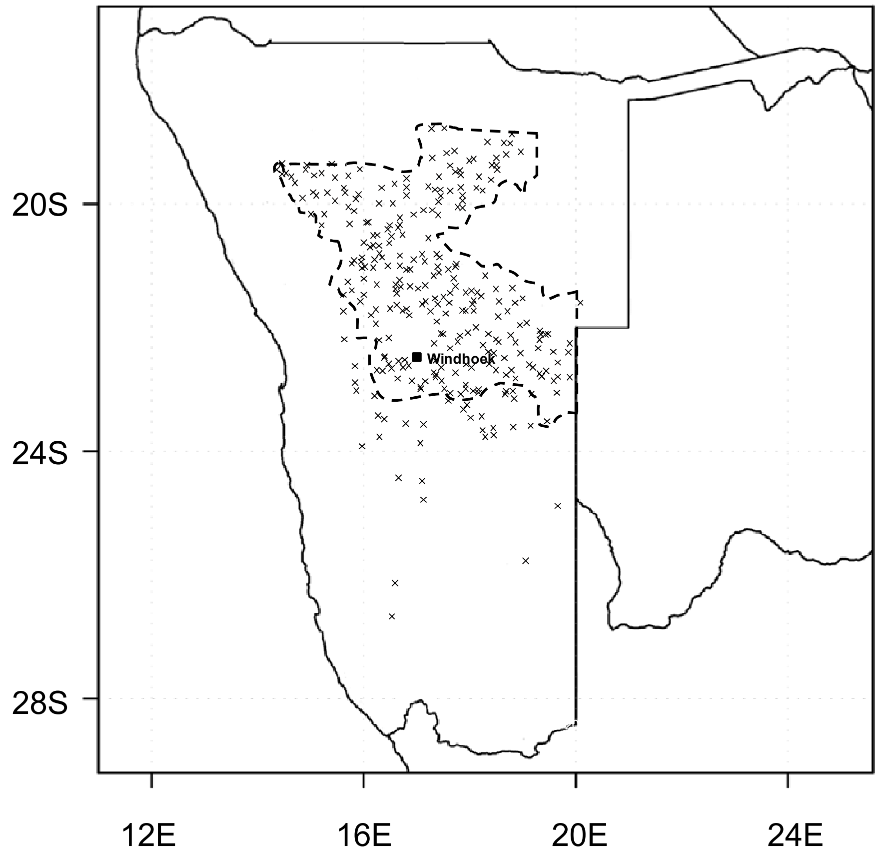

Figure 1: Commercial cattle farms in Namibia. Dashed line denotes what is considered the commercial cattle farming area (Mendelsohn, 2006). Crosses denote position of all 299 farms which were identified in our mail-in questionnaire.

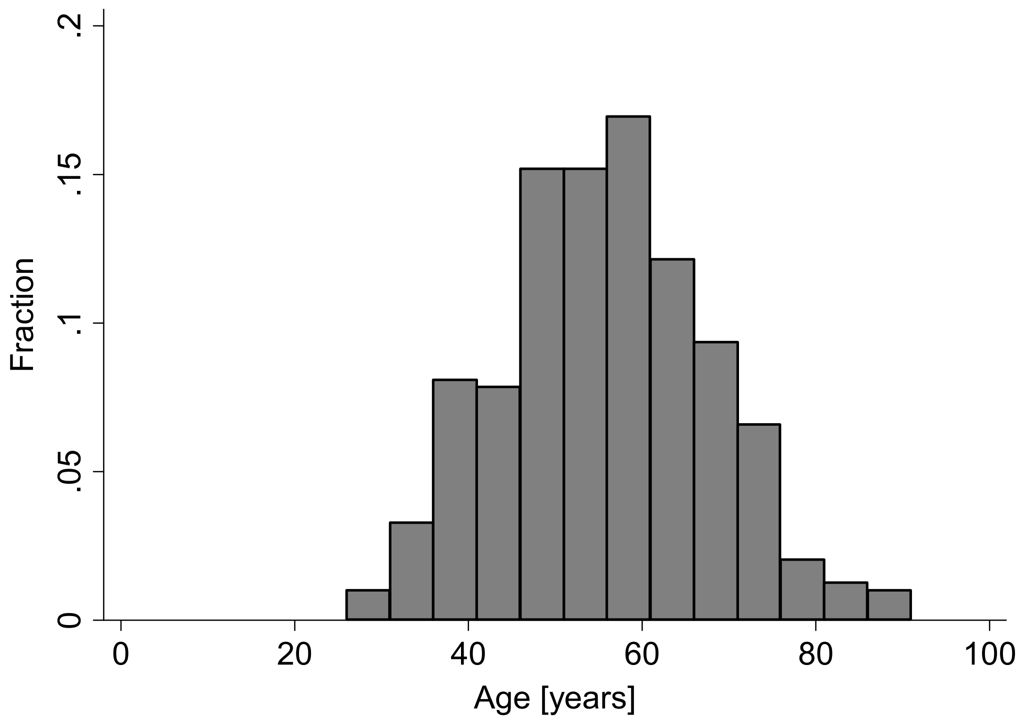

Figure 2: Distribution of age. N = 395.

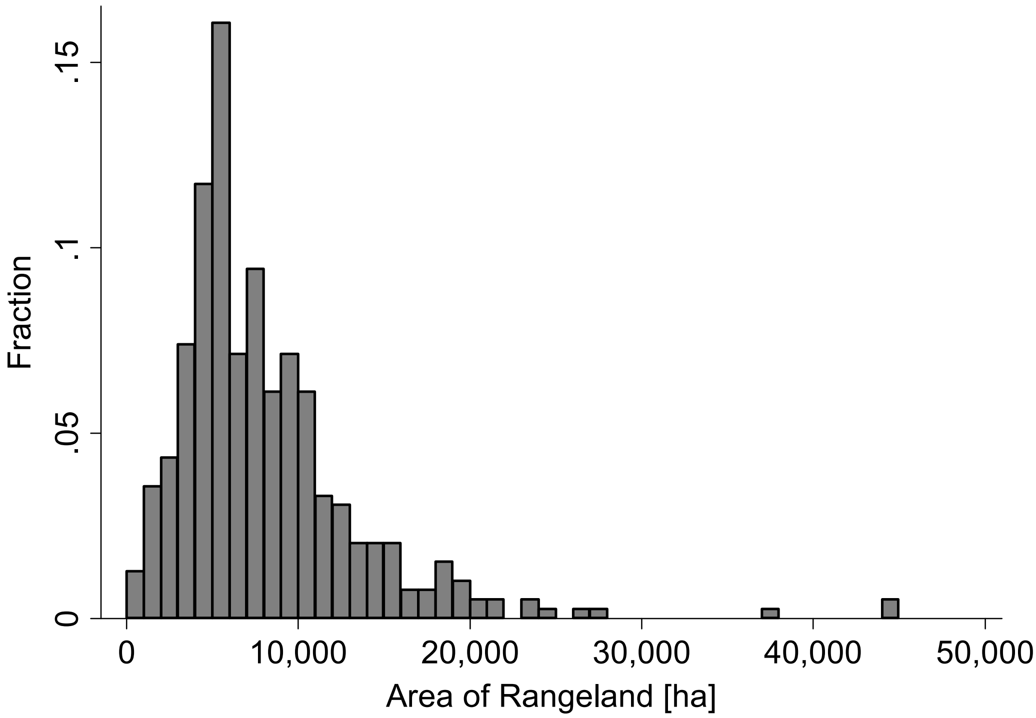

Figure 3: Distribution of area of rangeland. N = 392.

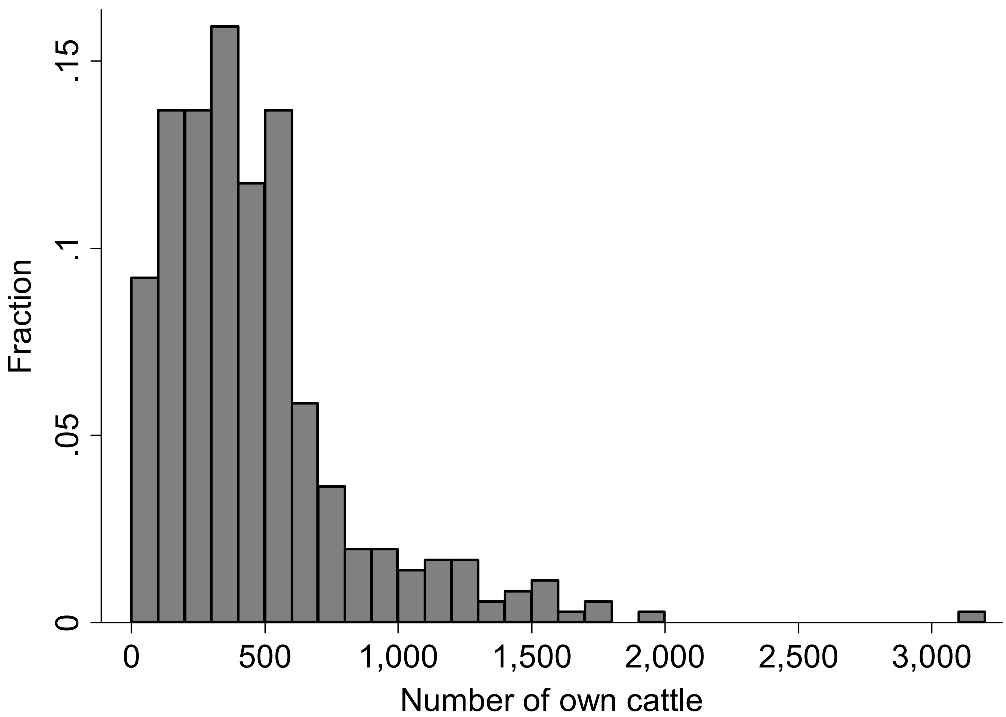

Figure 4: Distribution of own cattle on farm in April 2008. N = 358.

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[23] 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

[23] 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. (2011b). 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

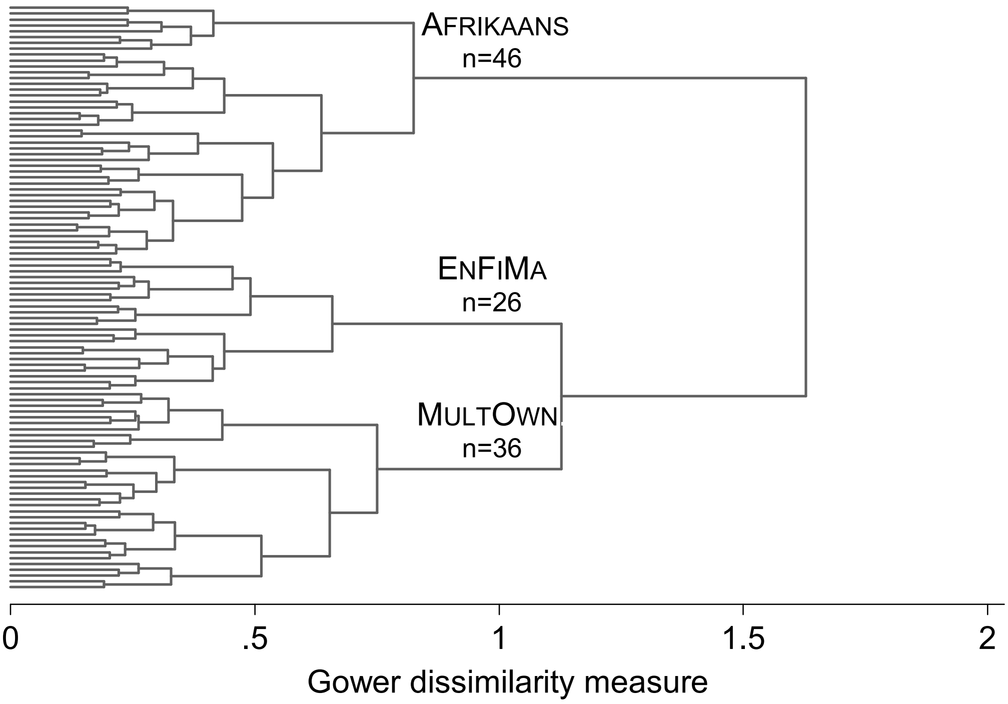

Figure 5: Dendrogram for three cluster solution. Cluster labels and observations per cluster are indicated above the respective branch. Clusters are MULTOWN (multiple owners), ENFIMA (favorable environment / low financial risk management) and AFRIKAANS (Afrikaans farmers). N=108.

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	

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Postfach 2440
D-21314 Lüneburg
Tel.: ++49 4131 677 2321
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