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Agricultural adaptation, local knowledge and livelihoods diversification in North-Central Namibia

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Executive Summary

This report looks at adaptation to climate change amongst smallholder farmers in the Omusati region of North-Central Namibia. Supplementing primary research with literature on a number of highly prevalent themes in Namibia, it has three main aims. **First**, it surveys available information on projected or potential climate change impacts on farming in Namibia and considers the implications for policy decision-making processes of the uncertainties inherent in these projections. **Second**, it focuses attention on another rich but under-utilised source of information for adaptation decision-making in smallholder farming: namely, local agro-ecological knowledge found across North-Central Namibia. **Third**, it takes stock of the implications for adaptation policy of a central phenomenon occurring across the country: livelihoods diversification away from farm-based activities. The report is relevant to researchers, policymakers and practitioners interested in agricultural development, climate change and adaptation

Principal findings and headline messages

The value of agro-ecological knowledge for adaptation policy

- Agro-ecological knowledge in North-Central Namibia has served farmers as a source of adaptive capacity to considerable climate variability historically, permitting settled agriculture in areas prone to recurring episodes of drought and flood. It may also strengthen resilience to future climate change impacts. Especially promising are instances of 'knowledge co-production' that occur through interactions between this body of knowledge and the science that informs agricultural extension policy and practice.
- However, agro-ecological knowledge does not appear to inform agricultural extension in any systematic way, sometimes leading to unpredictable and/or undesired outcomes. Further, the conditions that facilitate the kinds of 'knowledge co-production' which increase resilience to climate change impacts are not well-understood.
- It is important to value but not to romanticise agro-ecological knowledge, given concerns about contemporary farming practices as a driver of land degradation. Yet until we understand better the causes of land degradation in North Central Namibia, it will be hard to assess how potent a cause farming is. Understanding that better will help us assess more precisely the contribution local agro-ecological knowledge can make to climate change adaptation.

Adaptation and livelihoods diversification

- As a long-term adaptation strategy, attempts to strengthen the resilience of farming to climate change impacts may be less advisable, given the decreasing likelihood of avoiding global average temperature increases of 4ºC or above by the middle of the century.
- In Omusati – and to a greater extent in Namibia as a whole – there is growing evidence of livelihoods diversification into off-farm activities. Such diversification may be a more plausible long-term adaptation (and national development) strategy. However, diversification is a double-edged sword and may lead to inscribing poor people into different forms of entrenched poverty.

- Perhaps because of the potential pitfalls of livelihoods diversification away from farming as a (low carbon?) development strategy, the process of knowledge co-production is even more significant. Starting with what people already know, and not just with the kinds of knowledge that are transferred as a result of development intervention (i.e. through agricultural extension work), can lead to more legitimate, inclusive forms of development.

Priorities for action and research:

- It is necessary to develop a fuller understanding of the conditions for knowledge co-production which strengthens resilience, in order to see more clearly how to incorporate agro-ecological knowledge into adaptation policy. In this regard, there is some interesting work in Botswana on producing 'hybrid knowledge' for sustainable farming.
- It would be useful to conduct historical research which explored changes to farming practice over time, in order to ascertain what has changed and whether this made farming practice more or less sustainable over time. This would contribute to our understandings of land degradation in Northern Namibia.
- If livelihoods diversification is accepted as a long term adaptation strategy to reduce vulnerability to climate change impacts, adaptation policy needs to focus on developing tools and policy instruments to facilitate diversification into higher value activities and low-carbon development simultaneously.

1. Introduction

Recently, the potential implications of climate change have started to receive more attention in Namibia. In a country whose water demand is already projected to exceed its extraction capacity by 2015, and bearing in mind its location in Africa, the continent regularly pronounced most vulnerable to the effects of climate change, this is hardly surprising. Amongst the most pressing concerns that have come to the forefront are the potential impacts of climate change on the agricultural sector. Smallholder farming is an important, if not the only, source of livelihood for the majority of Namibia's rural dwellers.

One of the biggest difficulties for Namibian farmers and policy-makers alike is the uncertainty surrounding the posited impacts of climate change for Namibia. There have been attempts to produce downscaled climate models for the country. Aside, though, from the habitual risks that downscaling will amplify the errors in lower-resolution models, Namibia's high levels of climate variability and a lack of reliable data mean that the predictive capacity of such models is further restricted. Indeed, these limitations led the authors of the most recent national assessment of climate change vulnerability and adaptation in Namibia to conclude that it remained unclear *what* Namibians would have to adapt to (Dirkx et al 2008).

Notwithstanding this continuing uncertainty, efforts are being made to identify what climate change impacts may have to be adapted to, and how people involved in agricultural production could go about it. In this regard, local agro-ecological knowledge widely underpinning farming practice in North Central Namibia is worth exploring. A fascinating literature documents the sophistication and widespread use of what has come to be known as the 'indigenous land unit system'; that is, the body of knowledge North Central farmers use to understand, classify and utilise the environment for agricultural purposes (cf. Verlinden & Dayot 2000). To date, however, the potential of the land unit system as adaptive capacity, both in relation to current and historical climate variability, and also as adaptive capacity to future climate change, has not been evaluated.

On the basis of the findings from research conducted in North Central Namibia in July and August 2008, this report seeks, then, to outline the implications for climate change adaptation policy and practice in North Central Namibia of:

1. What is currently known about the potential impacts of climate change upon Namibian agriculture
2. current smallholder agricultural practice, as informed by local agro-ecological knowledge
3. diversification away from farming within the rural economy

Sections 2-5 of this report are organised around exploring these themes. Section 2 sketches the national context for impacts of and vulnerability to climate change, detailing what uncertainties in the projections relate to, but also considering areas where it is possible to make predictions with more certainty, i.e. increases in temperature. The potential implications of these for farmers in the Omusati region are also discussed.

Section 3 moves from the national to the specific context of the two fieldsite villages, Omufitugwanauyala and Oshikulufitu, within the Anamulenge Constituency of the Omusati region. It explores current agricultural practice and adaptation both in relation to the stresses and opportunities of current climate variability and in light of the potential ramifications of future climate change. In short, a sophisticated, widespread and long-established body of knowledge has been developed and is deployed across much of Northern Namibia to allow people to live with considerable climate variability, especially in terms of erratic rates of precipitation and temporal distributions. To a considerable extent it may also be taken as a proxy for adaptive capacity to future climate change. Yet if the way in which people use and interact with the environment through agricultural practice is not taken into account, adaptation policy and intervention may give rise to a variety of unintended consequences. Given, however, that local agricultural practice is commonly held in Namibia to be implicated in land degradation processes, it is important at the same time not to romanticise the attributes of such knowledge, nor to view it as a static, unchanging entity. It is argued here that a better understanding of landscape change over time in the North Central region is necessary for disentangling the impact of farming practice on the landscape from abiotic factors (i.e. rainfall variability).

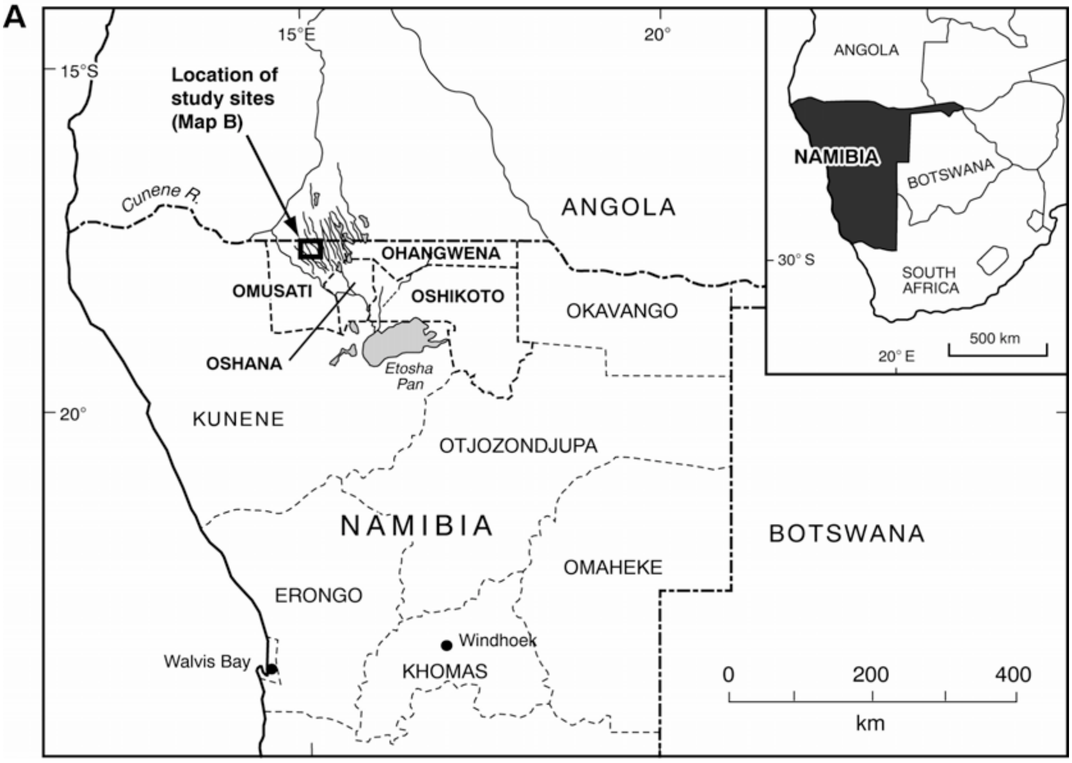
Section 4 focuses on livelihoods diversification away from agriculture in North-Central Namibia and nationally, which in itself could be seen as an adaptation strategy with the potential to reduce vulnerability to climate change impacts by reducing livelihood dependence upon subsistence farming. Fieldwork tended to confirm results from other studies, both Namibian and in other parts of Africa, which suggest that such diversification of livelihood activity away from farming is at least in some measure taking place in Omusati, as it has already done to a greater extent in other parts of Namibia.

Yet livelihoods diversification in itself can be highly problematic. In broader debates around rural development, a growing number of scholars have raised doubts about the extent to which diversification away from agriculture correlates positively with poverty reduction. The statistics on the national and regional distribution of income alone are sufficient to make clear that these concerns are highly pertinent in the Namibian context.

Section 5 brings together these themes, considers their implications and offers recommendations for adaptation policy and avenues for further research. In relation to the role of agro-ecological knowledge in agricultural adaptation policy, it concludes that whilst this knowledge is sometimes overlooked, there have also been fruitful instances of 'knowledge co-production' between local knowledge and agricultural science. These have in some cases strengthened resilience to climate variability, but the conditions for these types of knowledge 'co-production' are not well-understood and could usefully involve further research. In this regard, the work of Harry Collins on different types of expertise (2002, 2004) could prove a useful guide. Moreover, work in Botswana (i.e. Reed *et al* 2008) on producing 'hybrid' knowledge that draws on agricultural science and local knowledge to produce more sustainable farming could yield important lessons in the Namibian context.

Section 5 also considers the question of whether to concentrate on strengthening agricultural resilience to climate change impacts or whether diversification is a better adaptation option – without discarding the possibility of combining both, at least in the short-to-medium term.

Figure 1: Map of fieldsites in North-Central Namibia



2. Impacts and Vulnerability in Namibian agriculture

Climate in Namibia

Most of Namibia's climate is characterised by semi-arid to hyper-arid conditions and highly variable rainfall; though small stretches of the country (about 8%) are classified as semi-humid or sub-tropical (MAWRD, 1995) These features arise in large part from Namibia's location, between 17º and 29º south of the equator (approximately). As a result, the climate is subject to the air movements driven by three major climate belts: the Intertropical Convergence Zone, the Subtropical High Pressure Zone and the Temperate Zone. Whilst in its southernmost position, the Inter-tropical Convergence Zone brings moist air, especially to the country's northern and eastern extremes, resulting in the rainy season which lasts from October to April each year. However, the more dominant system is the Subtropical High Pressure Zone, prevalent especially in the winter months. Namibia's dry climate is a consequence of this dominance. Two high pressure cells drive the dry climate. The Botswana Anticyclone blows dry air over the country, tending to block the southward movement of moist air; whilst the South Atlantic Anticyclone blows cool air from the south-west toward the coast. Another contributory factor is the Benguela current, which brings cold waters from the South Atlantic. Although winds blowing inland across the sea pick up moisture, the Benguela current cools them to the point where they cannot rise sufficiently high to form rainclouds. The moisture can, though, be seen along the length of Namibia's Atlantic coast as fog and due, which in turn support a surprisingly diverse range of biota and plant species in the Namib Desert ecosystem. But as they blow further inland, they become warmer and drier (Mendelsohn et al. 2002).

The relative influence of these pressure systems explains the varied distribution of rainfall across the country, which varies from an average of <25mm per year in parts of the Namib Desert to 700mm in some parts of the Caprivi Strip, in the north east. In addition to this inter-regional variation in rainfall, intra-regional rainfall variability is significant, with the interannual co-efficient of rainfall ranging from 25% in the north east to >80% in the southwest (although, as this region tends to receive less than 50mm per year of rainfall, this interannual variability is less significant than it might at first seem) (GRN 2002).

Observed changes and future projections for the Namibian climate

In 2008, the 'Climate Change Vulnerability and Adaptation Assessment Namibia' (Dirkx et al. 2008) was published. the Vulnerability and Adaptation Assessment provides empirically downscaled projections of future climate change for the country, as well as data on observed climate trends. At present, these are the most comprehensive available projections for Namibia. The document was commissioned by the government as one of the core documents to underpin Namibia's Second Communication to the UNFCCC, and is therefore a crucial reference point for policy makers. For this reason, the uncertainties inherent in the projections are very significant, as they have implications for the extent to which the projections can be used to guide policy. A summary of observed historical trends and future projections for Namibia is offered below.

Although historical climate trends in Namibia, as elsewhere in Southern Africa, remain comparatively under-studied (Midgley et al. 2005), the Assessment tentatively identifies trends in air temperature and air circulation over the course of the twentieth century, as well as significant changes to precipitation. The authors note an overall increase in mean air temperature over the second half of the twentieth century, in the order of 1-1.2ºC, as compared with the beginning of the century, and observe this rise to be greater than those in global air temperature trends over the same period. In seven climate stations across Namibia which had consistent data for 25 years or more, increases in both the maximum temperatures of hot days and the frequency of hot days were recorded from the 1960s onwards.

Citing Hewitson and Crane's (2006) study, which observes higher pressure on a daily frequency during the December-February period between 1979 and 2001 across the African continent, Dirkx *et al* correlate higher pressure with a reduction in the frequency of rainy days over this period. Following Tadross *et al* (2007), they note that these changes have occurred in Zambia, Zimbabwe and Malawi. They further note that whilst evidence for similar changes across broad spatial scales in Namibia was inconsistent, they were nonetheless observed at the Namibian climate stations used in this part of their assessment.

The Vulnerability and Adaptation Assessment found it more difficult still to establish trends in rainfall when measured in four-year intervals over the course of the twentieth century, largely due to Namibia's considerable climate variability. However, from the 1960s onwards, the authors suggest, a decrease in the length of the rainy season was apparent, with rains falling later – and in some areas with greater intensity – and finishing earlier in the year than had previously been the case.

The assessment also provided projections for rainfall, air temperature and surface wind over the period 2045-2065. These were generated through the empirical downscaling of six general circulation models (GCMs), the results of which were set against two regional circulation models (MM5 and PRECIS) that had been forced within one general circulation model (HadAM3P, A2 emissions scenario). This was done on the basis that the regional circulation models would capture potential land-atmosphere interactions that downscaling exercises could not, and were applied to smaller areas and at a higher resolution than their GCM counterparts.

Temperature increases were projected to be greater further away from the coast, ranging from between a minimum expected increase of 1-2ºC and a maximum of 2-3.5ºC. During winter, maximum projected temperatures were in the order of 2.5-4ºC, with minimum projected increases roughly equivalent to those anticipated for the austral summer. These are broadly consistent with IPCC regional projections for Africa (Christensen et al. 2007: 767).

However, the results from empirical downscaling for rainfall differed from both historically observed trends and from IPCC projections based on general circulation models. The GCMs tend to suggest a general decrease in precipitation over the course of the twenty-first century (ibid: 859). In the downscaled modelling exercises, in contrast, the most consistent projected change was for an increase in late (austral) summer rainfall over some of the country, whilst for the south and west a decrease in winter rainfall was posited. The indications were that north-eastern regions would experience an increase in rainfall between January and April, whilst the signals for the Cuvelai drainage basin – in which both Omufitugwanauyala and Oshikulufitu are situated –were inconclusive. Aware of these discrepancies, Dirkx *et al* suggest that they may be indicative of "increased uncertainty in projections" (2008:21), but do not view them as inherently irreconcilable. Rather, they maintain that the considerable variability inherent in Namibia's climate may change the outlook considerably at any given point, even in the context of an average drying trend, and that such variability is likely to remain an elemental characteristic of the Namibian climate.

Whilst, then, the GCM and empirically downscaled results are not necessarily contradictory, and whilst more modelling of inter-annual variability may provide a clearer picture, the difference between these results does serve to demonstrate that considerable uncertainty remains in Namibian future climate projections. It may be that there will be an overall drying trend with precipitation increases in certain periods, i.e. the 2046-2065 period used in the Vulnerability and Adaptation Assessment. Nonetheless, current information does not permit an understanding – beyond an educated guess – of why the empirical downscaling produced results for precipitation levels which were so significantly different from those both for observed trends and for the general. Therefore, the question of whether precipitation will increase or decrease remains at present unresolved. Consequently, the extent to which current climate data serves as a guide for decision-making in the context of adaptation – be it national or local in character – is correspondingly unclear. For this reason, the Assessment's executive summary is at pains to emphasise that ultimately, in the formulation of adaptation policy, one of the most crucial points to grasp currently is that precisely *what* is to be adapted to remains indeterminate.

Potential impacts on and vulnerability within Namibian agriculture

Uncertainties in climate modelling outcomes, coupled with a lack of reliable data, circumscribed attempts to model the potential impacts of climate change on agricultural production. For the crop modelling exercises undertaken, the Vulnerability and Adaptation Assessment ran BUDGET (V6.2, 2005), with input data based on four downscaled GCMs, namely MRI, Miroc, HADCM and CSIRO). Most pertinent to the purposes of this paper, the Vulnerability and Adaptation Assessment was unable to conduct any crop modelling in the North Central region, owing to an insufficiency of climate data (Dirkx *et al* 2008:96). Moreover, even in areas where data were more readily available, results from modelling of maize and pearl millet production, two staple crops for farmers across Northern Namibia, proved inconclusive (ibid:98-100). In the case of livestock production, no modelling was attempted owing to a lack of capacity. And yet, in spite of these gaps and limitations, it is possible to present a sketch of some of the potential impacts climate change could have upon Namibian agriculture, and to identify its key vulnerabilities. In this regard, it is useful to make recourse to work done by Reilly and Schimmelpfennig on vulnerability to climate change specifically within the context of agricultural production (1999:774-777). One central form of vulnerability that Reilly and Schimmelpfennig identify is yield vulnerability: the extent to which the quantity and quality of a yield are susceptible to adverse effects as a result of climate change. As Reilly and Schimmelpfennig employ it, the term appears to refer to crop production, but it is also applicable to livestock production.

Yield vulnerability in crop production

Notwithstanding the lack of certainty inherent in current assessments of climate change impacts, four important points can be drawn from what is known, which give us useful indications of current and potential yield vulnerabilities in Namibian crop production. First, substantially more model agreement (both within and between the GCM and downscaled outcomes) was reported on increases both in average temperatures and also in the intensity and frequency of hot days. Using the data from one of the downscaled models, CSIRO, for crop modelling in Rundu, Dirkx *et al* report that in the six hottest months in the year, between 2046-2065, the number of days exceeding 34ºC per year was projected to increase from 67 to 118 (ibid:107-108). Should this projection prove accurate, the implications for crop production would be a cause for concern. Even a crop such as pearl millet, selected especially by farmers in the North-Central region for its hardiness in the face of prolonged heat stress, as well as its ability to recover by night even when it wilts by day, might struggle to withstand such a consistently hotter growing season.

Second, the legitimacy of such concerns is bolstered by evidence from the Southern African region. Stige *et al* (2006) look at the impacts of El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation on agricultural production in Africa, noting that climate models predict global climate change conditions which are more Niño-like in character. Observing the strong association between ENSO trends and Southern Africa, they contend that productivity could be expected to drop by 20-50% (ibid: 3050). In their analysis, maize, another staple crop in North-Central Namibia (as it is across Southern Africa), fares worst in high El Niño conditions, with crop production calculated to drop by 1,741,000 metric tonnes, relative to a crop of 14,893,000 metric tonnes in a 'normal' year, a reduction of approximately 11.7% (ibid:3051). They do, though, qualify that the response for sorghum, millet and groundnut – three particularly popular staple crops in North Central Namibia – is non-linear, as the ENSO effect manifests itself only when certain thresholds are passed. Nonetheless, they record significant reductions in the yield of all of these crops in high ENSO years. Other studies paint an even gloomier picture: work by Benhin on South African agricultural impacts posits a 90% reduction in crop revenues by 2100 (assuming no adaptive measures are taken), with smallholder farmers left worst off (2006).

Third, observed trends in Namibian climate suggest, over the course of the second half of the twentieth century, a shorter growing season characterised by a later arrival of rainfall, an earlier cessation of rainfall, greater intervals between rainy days and an increase in the intensity of rainfall when it does occur (Dirkx *et al* 2008:10). Were these trends to continue, the combination of a shorter rainy season with higher temperatures might impact adversely on crop harvests. Later onset of the rains, the interruption of rains within the growing season and the adverse effects of drought upon soil conditions are all factors which could render crop failure a likelier occurrence (University of Namibia 2008), especially given that the majority of smallholder farmers in the North Central (and other regions) rely largely on rainfall for their staple crops.

Fourth, the devastating effects of sudden increases in rainfall intensity were demonstrated two years running, in 2008 and 2009. In early 2008, abnormally high rainfall levels in Northern Namibia and Southern Angola throughout January to March led to flooding across much of Northern Namibia on a level unseen for four decades (Weidlich 2008; Ellis & Matjila 2008). Aside from killing 42 people, the floods displaced thousands into makeshift camps which played host to cholera outbreaks. In total, the flooding adversely affected, according to one government estimate, 65, 000 people (GRN 2008a). By March 2008 the government was expressing concern that the impacts would be felt most keenly by subsistence farmers, and indicated that the floods had caused up to a 50% reduction in the area under cultivation (GRN 2008). Food aid was provided in the wake of the floods, but continued also throughout the year. By August 2008, many of those affected by the floods had depleted grain stores from whatever minimal harvest they had managed to rescue, and had to purchase food or procure government food aid in the form of maize (The Namibian 2009).

The floods in 2009, which badly affected Angola, Botswana, Mozambique and Zambia, were reported as "the worst floods in years" (AFP 2009). The most adversely impacted regions in Namibia were Omusati, Ohangwena, Oshana, Oshikoto, Caprivi, Kavango and Kunene (Relief Web 2009). In March 2009 the Red Cross estimated that up to 276,000 people were displaced in the flooding in Namibia alone. Confusingly, an FAO report released in July 2009 claimed that the numbers of displaced families ran only into the hundreds (Rukandema et al. 2009:4). Press coverage offered similarly conflicting mortality figures but the Namibian government's flood coordinator, Erastus Negonga, was reported (on a date before the end of the floods) as giving a death toll rate of 112 (AFP 2009). Surprisingly, however, despite the widespread view that the 2009 floods were more extensive than those of 2008, the FAO reported that overall production of millet, sorghum and maize for the 2008/2009 season increased by 31% from 2007/2008 (Rukandema et al 2009:5).

Yield vulnerability in livestock production

As noted, no livestock modelling was conducted by the Vulnerability and Adaptation Assessment. Nor was this gap filled by another report also commissioned as a contribution to the Namibia Second National Communication to the UNFCCC, entitled 'Research on Farming Systems Change to Enable Adaptation to Climate Change' (UNAM 2008). The authors of this report recommended that a Ricardian analysis (cf: Mendelsohn et al. 1994) be undertaken specifically for Namibia, with a view to shedding light on current modes of adaptation to climate change at the farm level. Such an analysis has, though, been undertaken for Africa as a whole by Seo and Mendelsohn (2006), with differentiated effects for small and large livestock farms. In this very broad aggregate, they estimate that if average temperatures were to increase by 2.5ºC, conditions for stock expansion would be more favourable, and income from small livestock farming might rise by as much as 26%, or US$1.4 billion. A 5ºC rise might entail a concomitant increase in revenues by up to 58%, or US$3.2 billion. Under the same projections, however, large livestock farms were to experience a 22%, or US$13 billion, reduction in revenue at 2.5ºC and a 35%, or US$20 billion, reduction at 5ºC, assuming declines both in stock numbers and net revenue per animal. In view of these remarkable figures, it is as well to consider the cautionary note sounded by Roy Darwin. He argues that Ricardian analysis serves only poorly as a quantitative measure of farmer welfare in a changed climate, because of its systematic tendency to inflate both benefits and losses, to a larger to a lesser extent respectively (1999:374-375).

Notwithstanding the lack of Namibia-specific modelling, it is possible to identify some of the factors and processes that have the potential to affect yield vulnerability in livestock production. One important factor relates to projected changes in the structure and function of vegetation in Namibia. Midgley *et al* (2005) project that grassy savannah will be overtaken by desert and arid shrubland as Namibia's most common vegetation by 2080. This, they maintain, will have important (adverse) implications for agricultural production (2005:3), principally in the form of bush encroachment. Introducing higher levels of carbon dioxide (CO_2) into the projections creates uncertainty in results across much of the country. However, projections both with and without a carbon dioxide increase suggest a retreat in C4 grass cover in a north-easterly direction. The reduction in grass cover is more dramatic in the increased carbon dioxide scenario, owing to the extent to which carbon dioxide fertilisation stimulates the production of woody shrubs at the expense of grasslands (where moisture and ecosystem feedback conditions are conducive). One worrying outcome of these projections would be increased difficulty in the provision of sufficient grazing.

However, there is not full agreement in the expanding literature on the effects upon plants of carbon dioxide fertilisation. Ward *et al* tested the comparative responses of C3 and C4 plants to drought in conditions of low and elevated CO_2, concluding that C4 species may even have an advantage over C3 counterparts in conditions of elevated CO_2 (Ward et al. 1999). In their simulation of vegetation processes along the Kalahari transect between 1970-1994, Woodward and Lomas found a decline in natural primary production "even with a continued increase in atmospheric CO_2 concentration" (Woodward & Lomas 2004:390). This is significant because, given both modelled and observed increases in atmospheric CO_2 concentration from the 1960s onwards, one might have expected to see an increase in natural primary production as a result of CO_2 fertilisation. Similarly, in Free-Air CO_2 Enrichment experiments with arid shrubs in the Nevada Desert, Jasoni *et al* (2005) registered a 30% decline in net ecosystem production and a decline in cover under conditions of elevated CO_2. Again, if one assumes that CO_2 fertilisation increases natural primary production and favours C3 plants, these results may be difficult to explain. As Ward et al postulate, it may be the interactive effects of CO_2 and water availability that explains the relative performance of C3 and C4 plants; measuring the effects of CO_2 in isolation therefore may be misleading. Given, moreover, the uncertainty characterising rainfall projections for Namibia, it may therefore be precipitate to argue that CO_2 fertilisation will likely contribute to a shift in Namibia's dominant vegetation structure.

Heat stress is another potential factor, principally due to the extent to which it can affect feeding and reproduction rates in livestock. Higher average temperatures reduce conception rates in cattle, in part because of the positive correlation between high rectal temperatures and lower fertility rates, and partly as a consequence of the appetite-suppressing tendencies of heat stress (Swanepoel and Setshwaelo 1995, cited in Dirkx *et al* 2008). In this regard, Dirkx *et al* note with concern the data, as mentioned above, suggesting in the Namibian context a dramatic increase in the quantity of days in summer exceeding 34ºC (2008:108). This temperature which has been identified as a threshold for conception rates in some of the European breeds of cattle that can also be found in Namibia. Notwithstanding the limitations of European cattle in an environment to which they are ill-accustomed, the Nguni cattle, which have been used across the North Central region for centuries, are much better adapted to conditions (Bester et al. 2001). As medium-frame animals with selective grazing and browsing capacity, higher tick and disease tolerance, it is thought that they can extract more nutrients from available vegetation and cover greater distances in search of forage and water. However, agricultural policy to support the adoption amongst smallholder farmers of European breeds over and above Nguni cattle, on account of their higher market value, is attractive to some farmers (UNAM 2008). Similar heat stress effects have also been found in sheep and goats, which are farmed predominantly in the middle and southern parts of the country (Parsons et al. 2001).

Water availability also constrains livestock production. Howden and Turnpenny (Howden & Turnpenny 1998) note that if distances are great between water sources, reproduction rates may be lowered if metabolic rates and food intake are reduced. Moreover, in hotter temperatures such as those Namibia is very likely to experience, it becomes harder to move cattle between water sources, putting additional pressure on the grazing around the water sources at which they remain (ibid).

Finally, climate change could have impacts related to disease and parasites. These may be manifest in changes in the development of pathogens (Harvell et al. 2002), on the susceptibility of hosts to infection (Eisler et al. 2003), or in the vector dispersal (Kock et al. 1999, cited in Dirkx et al 2008)

These considerations would tend to suggest that livestock farming in Namibia may face significant challenges. Moreover, it is against this background that potential yield vulnerabilities in crop production must be set. Jones and Thornton suggest that, although the climate change impacts are likely to be heterogeneous across the continent, in semi-arid regions characterised by rainfed mixed crop and livestock systems – such as those commonly found in North Central Namibia – livestock is likely to gain in importance as crop production becomes, according to their projections, ever more marginal (Jones & Thornton 2009). Nonetheless, given the uncertainties surrounding climate projections in Namibia, it is more appropriate at this stage simply to highlight this potential scenario, especially when the outcome of empirically downscaled modelling on rainfall and crop production offers such different results from those extrapolated from general circulation models.

3. Agro-ecological knowledge as adaptive capacity in North Central Namibia

Introduction to North Central Namibia

The research was conducted across three sites in the Omusati Region, North-Central Namibia. It is important to understand from the outset that the North-Central regions differ significantly from other Namibian regions in a number of important respects. One factor in its development which accounts for many of these differences relates to the relatively limited reach of the colonial state, under both German and

South African rule (Werner 1998; Katjavivi 1988). In contrast to the majority of settler colonies throughout Southern Africa, a monopoly over all of the territory's best agricultural land was not fully established for German settlers. This was largely because the German military presence was too slight to dislodge the well-organised and well-armed Ovambo people who lived – and continue to live – in the north. Instead, a Police Zone was established, in which the German administration guaranteed the safety of its settlers, but which gave out at the southern edges of the area known then (and still frequently referred to) as Ovambo (Katjavivi 1988).

South African rule gave rise to high levels of eviction, displacement and resettlement amongst ethnic groups inhabiting lands further south, such as the Herero, Nama and Damara. Clearly, the establishment of the international border between South West Africa and Angola, which bisected the Ovambo kingdoms, affected mobility. However, neither under German nor South African rule were the Ovambo societies subject, by and large, to the same level of social, economic and political dislocation as other ethnic groups (Dobell 1998; Werner & Kruger 2007).

Ovambo became 'Ovamboland' following the establishment of homelands in South West Africa in 1964. It was subsequently split into the four North-Central regions – Ohangwena, Omusati, Oshana and Oshikoto – that are part and parcel of Namibia's post-independence geography. As a result, although Ovambo institutions, traditions and customs were affected by colonial intervention, they were not reconstituted – or indeed invented – to the same extent as those of, for instance, the Damara or the Herero (see Gewald 1998). It has been argued that 'traditional'[1] ecological knowledge results from continuity over time in resource use practice (cf. Williams & Baines 1993). The continuity in Owambo throughout much of the twentieth century may therefore go some way to explaining the still-widespread existence of the sorts of agro-ecological knowledge that underpin farming practice in North-Central Namibia.

All four of the North-Central regions are located within the Ovambo basin which, over the course of the last seventy million years, has become a broadly flat landscape. This is the result of looping cycles of water- and wind-borne deposition of sediments moved from the higher ground surrounding the basin (Miller 1997). Six variations within this broad landscape are commonly distinguished, the most iconic of which are the Cuvelai and the salt pans (ibid). The best-known example of the latter is the vast Etosha Pan, which dominates the Etosha National Park. A large proportion of the former, the Cuvelai, is found in the Omusati Region (which is also made up of Western Kalahari woodland, mopane shrub, pockets of karstveld and smaller salt pans). The Cuvelai consists of a series of southward-flowing, seasonal watercourses that, on their way downstream, carve the gentle undulations characterising this landscape, often draining into the Etosha Pan. In the rainy season, pools of water, known in Namibia as *iishana* (*oshana* in the singular), form across the Cuvelai. In addition to the fish that can be found in them, *iishana* support various forms of tree and plant life that can be eaten or used for house-building, basketry or medicinal purposes,. Fruit trees – especially *Berchemia Discolor* and Marula – provide wild fruit resources to supplement agricultural produce. For those less equipped to cultivate, such as the elderly, these resources are especially important sources of food, but they are more widely significant part of the diet, helping to reduce instances of disease such as pellagra (Marsh & Seely 1992). There are longstanding concerns about

[1] 'Longstanding' may be the better adjective than 'traditional', given how contentious, loaded and sometimes misleading this latter term has become.

deforestation in North-Central Namibia (i.e. Brown 1992; Erkkila 2001). However, a recent study concurred only partially with this appraisal, concluding that whilst some indigenous practices caused deforestation, others had encouraged the dispersal and establishment of multipurpose trees with cultural as well as economic values (Verlinden *et al* 2006). Contrary to previous assessments, matched photography suggested that settlement patterns across the Cuvelai had led to an increase, not a reduction, in the prevalence of fruit trees in the landscape (ibid).Partly because of these resources, but also due to the presence of clay soils that are suitable for cultivation, the Cuvelai is a favoured area for settlement (Marsh & Seely 1992).

The climate in Omusati, as across North-Central Namibia, is in broad terms semi-arid. Rainfall is seasonal, falling mostly between the months of November to April, with January to March statistically the wettest period of the year (Mendelsohn *et al* 2000:9). As well as being seasonal, rainfall is also highly variable, both in quantity and timing of rainfall within the rainy season. Across Omusati, average rainfall varies from 250mm in the south west to 550mm in the north east (ibid).

Demographically, North-Central Namibia is significant because it is the most populated area of the country. In 2006, an estimated 152,000 households (960,000 people) lived across the North-Central regions and the Caprivi Strip; of which 118,000 households were located in the North-Central region (Mendelsohn et al. 2006:33). In Omusati in particular, average population density stands at twelve people per km², but is significantly higher in the areas surrounding the regional capital, Outapi, reaching 100-300 people per km² (Mendelsohn et al. 2000:39).

In Omusati, as in other North-Central regions, land use is characterised by an agro-silvi-pastoral system (Marsh & Seely 1992:23), combining livestock herding and small-scale cereal production, supplemented by a range of timber- and non-timber resources. The favoured livestock breed by some margin is cattle, mostly of the Sanga variety (Marsh & Seely 1992). Donkeys are the only other form of large livestock kept, but smaller livestock, including goats, pigs and chickens, are common and of special importance for those households that do not own cattle. Indeed, fewer than half of farmers in the North Central regions own cattle, whereas most own some small livestock, principally goats and pigs. Livestock, and especially cattle, are a more critical asset than land, chiefly because unlike land, they can be inherited (Williams 1994). Williams lists the six purposes that they have historically served: breeding; sacrifice; inheritance; bride-wealth; refund or ransom; and barter (ibid:42). We might add, in the context of a monetarized economy, that cattle also substitute for pensions and savings, and can be converted as required into cash, to buy food, to pay for education, health and other services, or to service debts.

Crop production across North-Central Namibia is predominantly rain-fed, especially with pearl millet (or *mahangu* in Oshivambo), as well as maize and sorghum in much smaller quantities, long established as the most frequently-grown crops (Mendelsohn et al 2006). These cereals are supplemented by vegetables and legumes, most commonly beans, cowpeas, bambara nuts, groundnuts, pumpkins and melons, and more rarely spinach, cabbages and tomatoes. Farm holdings vary from region to region. For the Omusati region, the average holding is 3.2 hectares, but this average masks significant variety, with wealthier farmers holding up to ten hectares and poorer ones less than one (ibid).

Agro-ecological knowledge in Northern Namibia: an introduction

A modest yet exciting body of work has, since the 1990s, been delineating the contours of agro-ecological knowledge in Northern Namibia (Verlinden & Dayot

2000; Shitundeni & Marsh 1999), principally in terms of the important livelihood activities of crop and livestock farming but also in terms of fruit tree management (Hillyer, McDonagh & Verlinden 2006). Resonating with the 'farmer first' approach to the use of farmers' knowledge in agricultural development (Bunch 1985; Richards 1985) and more broadly with debates around what has variously been called 'traditional', 'indigenous', 'local' and 'endogenous' knowledge[2], researchers such as John McDonagh and Alex Verlinden have sought to document the classification system which farmers in Northern Namibia employ as the basis for making decisions about cropping and livestocking strategies (Hillyer et al. 2006; Verlinden & Kruger 2007). When deciding where to graze animals or grow crops, farmers draw upon a sophisticated understanding of the productive potential of their environment, which includes (but is not limited to) considerations of topography, elevation, soil properties, depth of hardpan, soil-water dynamics and availability of annual and perennial grasses. Hillyer *et al* refer to this as an 'indigenous land unit management classification system' (2006), highlighting not just its taxonomical interest *per se* but also its utility and widespread application. Verlinden and Dayot (2000) are keen, moreover, to stress that indigenous land units (ILUs) are sold short if construed as a simple exercise in soil classification. As well as serving to aid decisions about what to plant and where, or about the management of a rangeland, they also serve as a central factor in determining settlement patterns. Indeed, such is the utility of the land unit system that length of settlement can even be inferred from the number of land units on any given individual farm, with those having arrived first choosing the spots with the greatest variety and those arriving later finding plots with much less variety (cf. Verlinden, Seely & Hillyer 2006) In a comparison of the land unit system used in Northern Namibia with a conventional vegetation analysis, Verlinden and Dayot (Verlinden & Dayot 2005) note that a number of different criteria are used to identify land units and, by extension, land uses. Following Weinstock ((1984), Verlinden and Dayot characterise these indicators as 'physical' and 'perceptual' (2005:144). 'Physical' criteria may refer to soil colour and texture, or to landscape characteristics such as elevation, vegetation structure or abundance of termitaria (the presence of the latter being associated with soil fertility). 'Perceptual' criteria, not always identifiable through the senses, refer to soil–water relationships, the ease or difficulty of working the soil, the suitability of the land for cultivation, grazing or non-agricultural purposes, such as for use in building and pottery material.

A striking feature of this study is the convergence found between the conventional scientific classification system and that underpinning those land units which are based on vegetation criteria. When applying a detrended correspondence analysis, the results demonstrate that such land units do not, by and large, overlap (as opposed to those principally classified according to landform features). Put differently, the ILUs based on vegetation structure form consistent classification categories which capture what in scientific terms would be seen as key ecological characteristics, in terms of vegetation species and structure, of the environment which they describe. In another study on

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[2] Given the plurality of adjectives used to denote and specify types of knowledge held by particular people in particular places, the reader may legitimately wonder why this article introduces another, in the form of agro-ecological knowledge. At the risk of amplifying confusion, the qualifier 'agro-ecological' is deployed here because it avoids giving the erroneous impression that such knowledge is wholly local in origin, and sidesteps the debates, critiques and counter-critiques which have rendered 'indigenous' an almost unusable term. Moreover, 'agro-ecological' is more specific than 'endogenous' or 'hybrid', referring to what people know about how their farming systems are shaped by environmental factors and vice versa. It is, finally, a term already in usage, not one specifically coined for the purposes of this work.

land units favoured for cattle grazing, Verlinden and Kruger compared the land unit system with the results of canonical correspondence analysis and concluded it was "consistent with the ordination diagram of a CCA and most species indicators were reliable and in agreement with published data" (2007:193).

It might thereby be inferred that the land unit system has at least some of the rigour and robustness of a scientific classificatory system. There is, of course, no reason to suppose that that this should not be the case, nor to privilege *a prirori* scientific knowledge over ostensibly 'non scientific' knowledge (cf: Thomas & Twyman 2004; Barnes & Bloor 1982). Yet it a is point worth emphasising. The significance of this robustness is that the system has contributions to make to the formulation of appropriate and effective adaptation policy and it is important, therefore, to bring it more fully to the attention of policy makers.

Agro-ecological knowledge in North-Central Namibia as adaptive capacity to historical and current climate variability

Clearly, then, local agro-ecological knowledge in North-Central Namibia constitutes a sophisticated understanding of the environment in which farmers live, as well as a guide to its utility in agricultural terms. As yet, however, little or no attention has been paid to the extent to which such knowledge also constitutes adaptive capacity to climate change. This research starts to fill the gap, arguing that the indigenous land unit system already provides a fundamentally important source of adaptive capacity to climate variability, particularly in terms of rainfall. Moreover, to the extent that agriculture continues to be an important livelihood activity into the twenty-first century, this type of agro-ecological knowledge is likely to be a source of adaptive capacity to future climate change. A certain level of historical resilience in the face of considerable climate variability, including shocks such as recurring droughts and occasional floods, may be inferred from the continued presence of agro-pastoral activity in North Central Namibia over the last 400 years (cf. Williams 1994). Moreover, agricultural practice has adapted considerably, over the course of the twentieth century, to take advantage of the introduction of technological innovations, partly in response to periods when farming conditions have become more difficult, such as the drying trend across Southern Africa since the 1980s.

Evidently, it cannot be assumed that current (or historical) adaptive capacity will continue to be adaptive capacity in the face of future climate change, not least in view of the aforementioned uncertainties surrounding the crucial variable of rainfall projections. These concerns were central to the research conducted in the Omusati region, the results of which are presented in the following sections. Yet from what has already been written, it is possible to demonstrate the extent to which agro-ecological knowledge in North-Central Namibia has served as a rich source of adaptive capacity to historical and current forms of climate variability.

The indigenous land unit system could well be described as an attempt to ensure the possibility of ongoing, settled agriculture in conditions of considerable climate-related uncertainty. An understanding of the environment through the lens of indigenous land units helps a farmer to decide what type of crop to plant and where, according to the weather conditions expected for the growing season. Verlinden and Dayot (2005:152-153) distinguish between three broad classes of indicators employed in the identification of indigenous land units: soil, vegetation and landform. Each of these indicator classes is comprised of sub-indicators, such as texture or hardpan depth for soil, species and structure for vegetation, and elevation or depression for landform. On this basis, particular land units have come to be associated with particular crops under particular conditions. For instance, that *ehenge*, a land unit found in (and characterised by) depressions in the landscape, is a desirable location for planting pearl millet in drier growing seasons. In wetter growing seasons, however, farmers often prefer to plant pearl millet in *omutunda*, a land unit characterised primarily by elevation, and which is held also to be more fertile. In contrast, other land units such as the sandy, dry and well-drained *omufitu* tend to be reserved for legumes such as bambara groundnuts, where farmers would expect little from a pearl millet crop (see Hillyer *et al* 2006 for a broader matching of crops to ILUs). Critically, then, the stability of crop production is enhanced when farms are comprised of a mixture of two or more land units, precisely because it allows farmers to adapt their cropping strategies across a variety of growing season conditions ranging from dry to wet. It is for this reason that the indigenous land unit system is an important determinant in settlement patterns, as people settle, ideally, in places in which they can gain access to more than one of the land units most prized for agricultural purposes. Hillyer *et al* have captured this process visually, using landsat imagery and aerial photography to produce a map of one of the villages in their study area (2006:257). The map superimposes farm boundaries on top of a delineation of each of the land units in that area, demonstrating that farms are more often than not composed of a number of land units, as opposed to being on the one land unit perceived to be most fertile, even where this would have been a perfectly feasible settlement option.

The categories of the land unit system also identify those features of the landscape which are most conducive to cattle grazing. In their study in the Oshikoto region, Verlinden and Kruger (2007) documented the ten land units most used for grazing purposes, finding a preference amongst farmers for *Omutunda*, *Omutuntu* and *Omuthitu*. *Omutunda* was highly rated for grazing purposes but, as noted above, is also a popular land unit for cultivation. Farmers seeking it out for one or the other of these two land uses can, therefore, find themselves in competition (2007:184). *Omutuntu* is valued for its low tree cover and higher nutrient content, whilst *omuthitu* was viewed as an important grazing resource especially in the dry season (ibid). The other land units were all known for offering grazing opportunities of differing quality depending upon the time of year and quantity of rains received. As with the range of land units selected for cultivation purposes, the range of land units people in the Oshikoto region were aware of gave them a flexibility to graze cattle in the face of a range of dynamic environmental states linked to climate variability. For this reason, as Verlinden and Kruger point out, the search for land units best suited for grazing purposes was another factor influencing settlement decisions. The centrality of the land unit system to Ovambo social and economic organisation is difficult, therefore, to overstate.

Fieldsites, research methods & rationale

Fieldwork took place at Omufitugwanauyala and Oshikulufitu, two villages within the Anamulenge constituency of the Omusati region. In most important respects they correspond to the North Central profile described above. Located within the Cuvelai landscape, close to Outapi, the regional capital, both are inhabited predominantly by Oshivambo-speaking people who combine rain-fed cultivation and livestock farming, supplemented by resources available from the *oshanas* and a variety of fruit trees, including *Berchemia Discolour* and Marula. The research methods selected for use were focus group exercises, semi-structured interview schedules with farmers, agricultural extension staff and policy makers, farm visits, as well as policy document analysis.

Figure 2 - satellite image of fieldsites and surrounds

The fieldsites were identified in conjunction with Alex Verlinden of the National Planning Commission (NPC), one of the foremost (non-Ovambo) experts on agro-ecological knowledge in North-Central Namibia. Using NPC satellite imagery accessed through ArcView GIS software, on top of which was super-imposed a map of all settlements across the Omusati Region, the two villages were chosen on the basis of their location in terrain characterised by subtle but significant topographical variations, such as elevation, soil colour and the positioning of the villages in relation to water drainage channels. Of the variations that can be detected from satellite imagery, these are the principal ones which characterise different indigenous land units. From the presence of such variety, therefore, it was inferred that local agro-ecological knowledge would also be present; and indeed employed in settlement decisions and subsequent farming strategies. This inference was later tested in focus group exercises and farm visits, by identifying with farmers a) the indigenous land units present in and around their village and b) the ILUs present on their farm and the crops cultivated on them.

Table 1 lists these land units, specifying the crops grown on them and in which village the land units were found. It should be noted that the table focuses more on indicating which crops were grown on any given land unit, than on what the farmers thought were, ideally, the best land units to use for which crops. From an adaptation perspective, this focus is important because it emphasises that not all farmers had access to all of the land units they might have wanted to include on their farmstead. Some farmers, and especially 'latecomers' – for instance, people who had spent time in exile in Angola during Namibia's liberation struggle – found that the preferred land had been settled prior to their arrival. Having a farm with only one land unit is, all other factors held equal, likely to make farmers more vulnerable to climate change impacts, precisely because they are not in a position to exploit the flexibility in growing strategies that access to a combination permits. Therefore, there is an extra dimension to consider when attempting to identify vulnerability to climate impacts which relates at least as much to the dynamics of land distribution and access as it does to the biophysical properties and propensities of the land units themselves. In the sample of people in the focus group exercises and farm visits, it was found that more than half had farms comprised of two or more land units (the greatest number being five land units on one farm), whereas a quarter had only one. It is not straightforward to establish a direct correlation between farms comprising one land unit and increased household vulnerability to the impacts of climate change; not least because households increasingly have access to climate-insensitive forms of income generation (explored further in the following section). Nonetheless, establishing a farm with fewer than two land units, and in particular on land which has been passed over in preference for land units which confer fertility and other advantages, cannot but reduce capacity to respond to the range of climate variation experienced historically in this area.

Following the identification of villages in terrain manifesting the sorts of variation registered by the indigenous land unit system, a further selection criterion was added. In conjunction with Ministry of Agriculture, Water and Forestry staff, Omufitugwanauyala and Oshikulufitu were selected as two villages close to each other and with comparable demographic and livelihood profiles. Yet they differed in one essential respect, In Oshikulufitu, a regular work programme of agricultural extension was established, whereas in Omufitugwanauyala there was as yet no such regular contact or opportunities for training in new agricultural techniques. Since independence in 1990, much greater government investment has been made in providing all Namibian farmers with agricultural extension assistance, which had hitherto been limited to a (white) minority of farmers practising farming on a commercial, rather than a subsistence, basis. The expansion of this service has in some measure changed farming knowledge and practice in North-Central Namibia, and for this reason it was useful to select one site exposed and the other not exposed to such services, in order to understand better the impact on farming practice of such services.

Table 1 – Land units and crops grown in Omufitugwanauyala and Oshikulufitu

Land Unit	Crop grown	Found in
Omutunda	Pearl millet (mahangu)	Oshikulufitu
Omuhenye	Pearl millet, beans, watermelon, squash	Oshikulufitu and Omufitugwanauyala
Ehenge	Nuts, mahangu, beans	Oshikulufitu and Omufitugwanauyala
Oshindabo	sorghum, watermelon and maize	Oshikulufitu
Ehenene	sorghum, maize, watermelon, matanga, beans	Oshikulufitu and Omufitugwanauyala
Ombode	Mahangu, sorghum, melon	Oshikulufitu and Omufitugwanauyala
Omufitu	mahangu, beans, maize, nuts, pumpkin, watermelon	Oshikulufitu and Omufitugwanauyala

Access to both villages was secured with the assistance of the Ministry of Agriculture, Water and Forestry officers at the Outapi office, who facilitated contact with the councillor for Anamulenge Constituency. The councillor in turn set up contact with the village headman to gain consent for the research to take place. The councillor then made radio announcements to call for village meetings, which were to serve two central purposes. First, the meetings were to provide an opportunity for residents to learn about climate change and its potential implications for their farming activity. Second, volunteers for the focus group exercises were enlisted, with a view to securing a varied sample primarily in terms of gender and age. The focus groups then provided the opportunity to select participants for individual semi-structured interviews and farm visits.

The principal thrust of the field research was three-pronged. First, it explored the extent to which local agro-ecological knowledge could be considered adaptive capacity to future climate change as well as current and historical climate variability. Second, the research sought also to explore how strong disturbances such as drought and flood had been experienced by village residents, and the extent to which extreme instances of either drought or flood marked thresholds beyond which coping capacity was exceeded. Third, and by way of locating these climate stressors within a broader context of multiple stressors, the research examined other changes within people's livelihood strategies, by way of giving a fuller account of the breadth and depth of adaptations that are occurring beyond those relating to climate. For all three research objectives, a number of focus group exercises were conducted, which included timelines exploring memories of and responses to drought and flood, ranking exercises on the relative importance of different livelihood activities, in addition to semi-structured and, where appropriate, unstructured discussions which allowed space for information that would not otherwise have been captured by the format of the exercises.

Agro-ecological knowledge as adaptive capacity to future climate change in the fieldsites

Given the considerable uncertainty surrounding the future impacts of climate change in North-Central Namibia, adaptive capacity is not, of course, a value amenable to precise calculation. In such circumstances, from a resilience perspective, capacity to predict future climate (and other) change accurately and plan accordingly may, ultimately, be less important than flexibility in response to surprise and disturbance, of the sort that the indigenous land unit system appears historically to have offered. As Lugo argues, the management of available natural resources "does not require a precise capacity to predict the future; but only a qualitative capacity to devise systems that can absorb and accommodate future events" (1995:959). For this reason, the research sought instead to capture change in agro-ecological knowledge and concomitant changes in agricultural practice over time. This approach permitted an understanding of the ways in which such changes had enhanced or detracted from the resilience of the farming system in the face of the climate variability experienced, and, hence, its flexibility in responding to climate-related surprise and disturbance. It also revealed the extent to which such changes were incremental in character or constituted a transformation to the system (Nelson et al. 2007).

The focus group discussions, and in particular the timeline exercises documenting changes made to farming practice, drew attention to a number of important adjustments and innovations over the last 50-60 years, the time period defined by group participants. This section highlights fundamental changes to agro-ecological knowledge and practice over time: the introduction of early-maturing crop varieties; the use of draft animal power for preparing plots for cultivation; and the tendency to keep cattle at cattle posts all year round, instead of a more rotational grazing system. The first two of these changes have, on balance, served to increase the resilience to climate and other stressors of this farming system; however, the third may have served, in combination with other fundamental changes in society, to undermine the resilience of the system to the point where its viability has since been subjected to considerable scrutiny.

Early-maturing crop varieties

One of the most evident and effective changes has been the introduction of early-maturing crop varieties across a number of the crops that farmers cultivated. Of these, far and away the most popular are the Okashana 1 and 2 varieties of pearl millet, the most widely-grown crop across North-Central Namibia. Although named for the Okashana Agricultural Research station, in Tsumeb, these varieties were in origin Zimbabwean and were first tested in Namibia in the late 1980s (Uno 2005:107). They have two principle advantages over other pearl millet varieties. First, the length of time between seeding and harvesting is cut, and second, they required less water to mature, and were therefore hardier in times of lower than average rainfall and drought[3]. The use of these types of cultivar are essentially an adaptation to the drier conditions that characterised the rainy seasons throughout the 1980s and the 1990s in Namibia and across Southern Africa. There were disadvantages: some (but by no means all) farmers thought that the taste of these varieties was inferior to the seed that had conventionally been grown; they produced shorter, smaller plants than their longer-maturing counterparts; and they cannot be not stored for as long as traditional varieties. However, they were much likelier to produce a harvest in the rainy seasons that farmers were often exposed to, which were starting later, ending earlier and during which less rain was falling.

Given that agricultural extension services had been available in Oshikulufitu since 1992, it was not surprising to find that all of the participants in that village were using the Okashana varieties of pearl millet. Indeed, for many of the farmers it was the contact with extension officers that had introduced them to this new option. Significantly, though, uptake of the Okashana varieties was almost equally high amongst focus group participants in Omufitugwanauyala despite its lack of exposure to agricultural extension services, indicating that this change in cropping practice was as likely to be brought about through social networks as through formal intervention; at least in the case of a change whose benefits were so widely recognised and valued as they were with these seeds.

Introduction of the donkey for field preparation

Another important change in farming practice flagged by the timeline exercises relates to the introduction of the donkey to plough the fields, which previously had been carried out by hand. Farmers in Oshikulufitu traced the arrival of the donkey back to the 1950s, attributing the change to the influence of exposure to different farming methods arising from migrant labour patterns under South African rule. Ovambo farmers were induced in various ways to provide labour on the commercial farms owned and run by white settlers (Werner et al. 1990). Once on such farms, they

[3] See Ipinge (1998) for the results of crops trials comparing Okashana 1, 2 and Kangara varieties.

came into contact with the practice of employing draft animal power for ploughing and, thereinafter, became desirous of introducing the donkey on their own farms back home, sometimes accepting a donkey as payment for a season's work.

An important corollary of this innovation, aside from the labour-saving attractions, is that it permits greater quantities of land to be prepared for cultivation given the same labour constraints. The extent to which more amounts of land did therefore fall under the plough was also subject to the availability of and access to land suitable for the type of cultivation required, itself dependent upon population dynamics; which, in the case of North Central Namibia over the twentieth century, have been fluid. Nonetheless, as an important response to unforeseen disturbances such as drought, or as a means of better exploiting the increased opportunities of a good rainy season, this extra capacity can give greater flexibility. Increasingly, moreover, the uses to which draft animal power is put have been extended. In Oshikulufitu, almost a third of farmers had experience of using donkeys for weeding as well as ploughing purposes. Mendelsohn reports that in Northern Namibia, weeding one hectare by hand takes on average 13 days, a figure which drops to 4 days with draft animal power, and 8 hours with a tractor (2006: 36). The efficiency gains help explain the popularity of this more recent introduction. None had started to weed using donkeys in Omufitugwanauyala, reflecting the fact that this particular technique had been brought by agricultural extension workers in Oshikulufitu.

Increased use of the donkey is not, however, devoid of risk. Farmers in both villages highlighted the difficulties faced in maintaining the efficacy of draft animal power in lean periods following droughts or floods. Although donkeys are often thought to be hardy performers in times of drought, focus group participants viewed them as more vulnerable to the effects of drought than cattle. This is chiefly because donkeys, as a recent introduction to the North-Central environment, are not well-adapted to the range of potential sources of food. When grazing is unavailable, the local Nguni cattle can browse on a variety of different shrubs; one farmer even recounted an instance he had heard of in which cattle had been fed on discarded cardboard on the edge of an urban area. Donkeys, conversely, cannot make this switch and therefore struggle to find sufficient food once the grass gives way. There are knock-on effects for cultivation strategies when donkeys are not strong enough to provide ploughing services. Greater difficulties for farmers to prepare the ground are especially unwelcome in periods when they are already facing more challenging climate stressors. Moreover, the more central to cultivation strategies donkeys become, the harder it is to sell them; unlike cattle, which may lose value, but can still generate household income without further reducing the likelihood of producing a harvestable crop.

Implications of interactions between local knowledge & agricultural science

Three inter-related points can be made, then, about these changes to farming practice. The first is that the agro-ecological knowledge people use to make decisions about farming is not static and is clearly not closed to innovation, especially in the form of new agricultural technologies. However, what is also clear is that all of the technologies that have been adopted are modifications of existing practice which are compatible with, and make sense within, the land unit system. Therefore, agricultural extension work which has added to existing repertoires, rather than attempting wholly to revamp them, has enhanced adaptive capacity to currently experienced forms of climate variability (extreme events aside). This is another important point to be taken on board in the context of formulating climate adaptation policy, especially in the context of debates around the character of agricultural reform (see discussion and conclusion for more on this topic).

Second, there is still more to learn about the transfer and acquisition of knowledge used for farming practice. Nevertheless, the ways in which techniques from agricultural science have been incorporated into local agro-ecological knowledge may be seen as an exercise in knowledge 'co-production' between farmers and extensionists, the results of which have been put into practice. This is another important point to grasp. In any kind of development intervention, be it agricultural or otherwise, the legitimacy of the process – is it imposed or embraced? – hinges on questions of how knowledge is transferred and who's knowledge, ultimately, counts, in defining what development will happen. Knowledge 'co-production' between 'agents' of development, such as extension workers, and the people who want – or at least are thought to want – to become 'developed', can be an inclusive activity, legitimated by the support of all those involved in the process.

Third, there is more to learn about knowledge transfer and acquisition in North Central Namibia. it is worth mentioning in this regard the PhD research of Lukas Nantanga, formerly Senior Agricultural Extension Officer for Outapi, on what he terms the 'cultural logic' of knowledge transfer and acquisition in Ovambo societies (Nantanga, unpublished material and pers. comm.). He understands acquiring and using new knowledge in Ovambo culture in three basic ways: add, substitute and graft. Adding a new technique does not always lead to the abandonment of previous techniques, i.e. the addition of donkeys has not led the hoe to become completely redundant. Substitution likewise does not always imply a permanent replacement, i.e. when it seems like the rains will be good, some people will revert to the traditional mahangu variety as opposed to newer varieties. Grafting is taken to mean joining different practices together to create a new practice, in much the same way one would, in the botanical sense, join different plants together to form a new one. This work was in 2009 still in progress, but is likely to have implications for the co-production of knowledge for adaptation and development.

Changes in livestock farming: transhumance or migration? Implications for ecological thresholds

In the literature on resilience, thresholds are expressed as boundary points, beyond which a social-ecological system undergoes a transition from one state to another (Berkes et al. 2003; Nelson et al. 2007). From the point of view of people living within a social-ecological system, states may be desirable or undesirable. For this reason it is critical to realise that if there is a change from one state to another, it can be difficult or impossible to return to the initial state (cf. Walker et al. 2004). In this light, the high levels of concern about changes in the farming system in North-Central Namibia are more readily understandable.

Perhaps the greatest change in farming practice that has occurred relates to livestock; one so profound that it raises the question of whether an ecological threshold may already have been reached. When focus group participants in both villages were asked how livestock farming had changed within their lifetimes, the most significant change was to the practice of cattle rotation. One participant in Oshikulufitu estimated that since the 1980s, it had become increasingly common practice to leave cattle all year round at the *Ohambo* (cattle post). The reason given for the change was that grazing around the village was no longer sufficient to maintain the cattle, largely as a result of increased (human) population density in the area, leading to competition over land use between settlement and cropping on the one hand, and grazing on the other. Focus group participants also lamented that the distance between cattle posts and their village was increasing, as cattle were moved from nearer posts once grasses had been exhausted to posts further away. When asked to comment on how long this practice of moving from one cattle post to the next could be sustained, participants displayed concerns about its durability. One farmer worried that grazing for cattle might run out even within five years.

This change to livestock herding is consistent with broader trends which have been documented in other parts of North-Central Namibia. It has long been maintained that livestock farming was practiced on a transhumance basis (Marsh & Seely 1992; Tapscot & Hangula 1994; Williams 1994). Much as was previously the case in Oshikulufitu and Omufitugwanauyala, cattle would be kept close to the village during the rainy season (October to May), when sufficient grazing was available and when the cattle could feed on stalks in pearl millet fields after harvest (Williams 1994). With the arrival of the dry season, they would be taken off to the *ohambo* (cattle post) where grazing was more reliable. More recently, Verlinden and Kruger have suggested that transhumance has over time become a pattern of migration; or even that what is taken for transhumance may always have been migration (2007:194). As grazing around the homestead becomes less sufficient to support the larger of the herd sizes, it is increasingly common for cattle to be left at the post, which in turn encourages human settlement at the site of the cattle post. As the grazing resources become more depleted due to cultivation activities which reduce available grazing land, new cattle posts are established, and the cycle begins again. The significant expansion in the availability of water from boreholes and pipes (cf. Nangula & Oba 2004) has permitted the expansion of herds into areas that previously would have remained ungrazed. Verlinden and Kruger reported from a study in the Oshikoto region that 77% of the pastures in the study sample areas were in poor condition (2007:187). Further, they postulate that whilst this form of migration was viable whilst land was still available for further expansion, it has since reached its limit. Migration has extended to the easternmost reaches of Oshikoto, on the border with the Kavango region, leading to increased competition over the same land between herders and cultivators (2007:194).

Compounding the difficulties of finding sufficient grazing are two other factors. One of these is bush encroachment, which is widely thought to be on the increase across much of North-Central Namibia, and which may be linked to this pattern of migration; if it is indeed a migration pattern. In Verlinden and Kruger's Oshikoto study, almost half of the woody vegetation samples they analysed were reported to feature some level of bush encroachment (2007:191). The second is the increase in instances of fencing off by individual households of communal rangeland, with a view to gaining exclusive access to emergency grazing resources (Kerven 1997; Marsh & Seely 1992; Mendelsohn et al. 2000; Mendelsohn et al. 2006). Verlinden and Kruger found that in their study area in the Oshikoto region, 40% of the total area was enclosed by fencing. Of this total, only 10% had been enclosed by smallholder farmers, whilst larger farms, accounted for 17% of all enclosed areas even though there were fewer of them (2007:191). Neither in Omufitugwanauyala nor in Oshikulufitu was increased fencing cited as a reason for decreased availability of grazing for cattle. However, the question of fencing off pastures in communal land, in which farmers have, ostensibly, equal right of access to available pastures, may not be one that is easily dealt with in public situations such as focus groups. The silence on this important factor may therefore be explained by this consideration.

Livestock farming and broader patterns of land degradation in North Central Namibia

Verlinden and Kruger reveal, then, the sophistication of the land unit system, presenting a plausible hypothesis on how the search for those land units with preferred grasses drove migration patterns. Yet their argument accords with the general proposition, widely accepted within Namibia, that land degradation is widespread, both in the North-Central regions (and across the rest of the country). This line of argument is embodied by the Integrated State of the Environment Report. It concludes that "Large areas of land in northern Namibia are severely degraded due to deforestation, overgrazing, overstocking, high population pressure, unsustainable farming practices, and the clearing of large tracts of land for crop farming" (Nangolo et al. 2006:viii). It ranks land degradation – mentioned often in the same breath as desertification – as the most urgent environmental priority for the country to address.

These concerns about the scale of degradation pose the question of whether current farming practice in North-Central Namibia may be pushing its ecosystems to the brink of, or even beyond, ecological thresholds. Ultimately, however, there may not be sufficient evidence to arrive at a firm conclusion. The extent of assumed land degradation has been challenged in other parts of the country by scholars seeking to apply insights from resilience science. Notably, the work of Sian Sullivan (1999; 2000) concluded that the proposition that degradation was widespread in Northwest Namibia was not supported by ecological evidence. In her own study she found the predicted patterns of degradation only in smaller areas of settlement, but not at larger scales. Moreover, she argues that the interpretation of available ecological evidence in initiatives such as Namibia's Programme to Combat Desertification did not take into account the implications of spatial and temporal scale. There was a tendency to attribute perceived degradation to the presence and impacts of people and livestock, without exploring "the fundamental relationship between variable abiotic factors and primary productivity" (1999:272). The work of other authors (i.e. Rohde 1997) make a similar case to that made by Sullivan; although, like Sullivan, only in the context of Northwest Namibia, to which all of these authors are careful to confine their conclusions. Indeed, in earlier research conducted in North-Central Namibia, Sullivan *et al* reported that the effects of livestock grazing on vegetable ivory palm (*Hyphaene petersiana*), a resource highly valued both for basket weaving and for its fruit, were so adverse that the long-term viability of the vegetable ivory palm populations in the study areas was in doubt (Sullivan et al. 1995:357). Even if assertions of degradation are problematic in the Northwest, they are likely to be more applicable in the North Central regions, because of the much greater population densities of humans and livestock alike.

Nevertheless, reading the (2006) State of the Environment Report in the light of the findings in the Northwest raises concerns. Although it does mention natural variability as one potential factor affecting the availability of resources such as grazing, none of its five indicators of degradation seeks to measure the influence of abiotic factors. Instead, all measure human-derived impacts, and all attribute therefore any evidence of degradation solely to such factors. The report also uses the concept of carrying capacity without reference to the large body of work from non-equilibrium perspectives which have rendered this notion so problematic. Perhaps there is a case for maintaining this concept; but it seems unwise to do so without contemplating the array of critiques to which it has been subjected. Perhaps most problematically of all, the report concedes that it was not possible to present the Desertification Index – the national measure of degradation and desertification – "due to a lack of regular data".

Given the vast literature on debates around the difficulties and dangers of inferring widespread degradation without sufficient evidence (i.e. Thomas & Middleton 1994; Thomas 1997; Swift 1996; Robbins 2008), it is surprising and perhaps unhelpful that such claims are made so boldly.

In the North Central regions, much less work has been done on degradation from a standpoint which attempts to measure abiotic as well as human-induced factors. The Midgley *et al* paper (2005) mentioned in section 2 is one instance, with its consideration of the implications of carbon dioxide fertilisation of woody shrubs for vegetation structure. Another is a study by Nangula and Oba (2004) on the impacts of the introduction of water points on the oshana ecosystem and the increased grazing that water points permitted. It examined the proposition that the radial distance and age of water points correlated with the loss of perennial grass species, an increase in annuals, and general loss of herbaceous species richness, herbaceous biomass and grass cover. Comparing the oshana landscape with a mopane landscape, it concluded that the latter was more vulnerable to degradation induced by the presence of waterpoints than was the former. Variations in perennial:annual grass ratios in particular could not be explained by radial grazing distance, but were instead attributed to differences between the landscape types. One study does not permit generalisations, but it is sufficient to recommend the use of caution in assessing the extent and severity of degradation in the North Central regions and hence any proclamations about the likelihood of crossing an ecological threshold. Nevertheless, there is a concurrence between local perceptions in Omusati (captured in this research) regarding the availability of grazing, the results of Verlinden and Kruger's Oshikoto study and the broader concerns about degradation. Therefore it is at least legitimate to 'raise the spectre' of an ecological threshold and to call for further research into degradation which incorporates contributions from a resilience perspective. If a transhumance pattern has become one of migration, driven by increases in population density and an informal part-privatisation of the rangeland, the implications for the resilience of the farming system may be ominous – even in isolation from potential climate change impacts.

Limits to coping capacity to deal with droughts and floods

As noted, local agro-ecological knowledge allows farmers to respond to a range of conditions in the growing season. Yet an absence or abundance of water, especially combined with soaring temperatures, can exceed the physiological limits of any of the crops, land or animals available to the farmer. Another means of gaining some perspective on the potential impacts of climate change, in the face of uncertainty in the modelling projections, is to identify the more immediate thresholds of drought and flood beyond which the functioning of the farming system breaks down, namely droughts and floods. The research sought thereby to identify local perceptions of what constituted drought and flood, by asking focus group participants to recall their experiences of either, along with the year in which they experienced them. These recollections were then compared against rainfall data available for Outapi between 1930 and 2001, supplied by the Namibian Meteorological Services. Whilst helpful to have a different source against which to make this comparison, the dataset had to be used with some caution, given that the data was not specific to either of the two villages. Even though they are both within 30km of Outapi, the spatial distribution of rainfall across the region is so varied that even locations that are very close to each other can experience the same rainy season in markedly different ways. As one participant said of 1992, a notoriously drought-stricken year across Namibia, people in Ogongo (at a distance of perhaps 40km from Outapi) had suffered whilst in Omufitugwanauyala they had not.

Despite these limitations, the dataset does capture the range of rainfall variation over the greater part of the twentieth century in this area. More significantly, as shown in Table 2, there was broad agreement between the recollections of extreme events and the rainfall record, in that the years identified as drought or flood by focus group participants featured in the dataset with almost complete consistency as years of very low or very high rainfall (relative to that area). Even for 1940, the year in which villagers' recollections in Omufitugwanauyala were of drought, but for which the rainfall record suggested average-to-good rainfall, both 1939 and 1941 are recorded as dryer-than-average years. The discrepancy might therefore be attributed to a confusion over the precise year.

Table 2– Comparison of droughts and floods identified in Omufitugwanauyala and Oshikulufitu

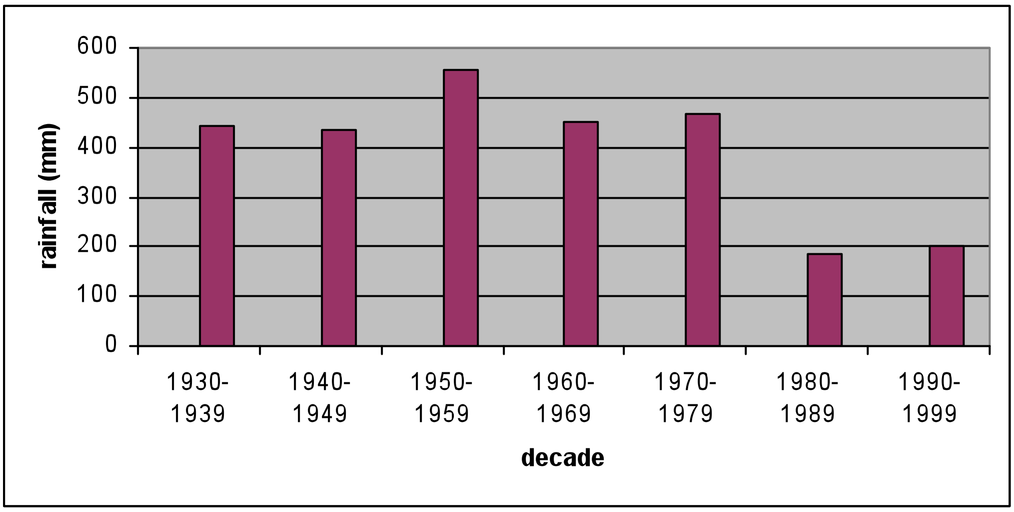
Year identified	Hazard type identified in focus group	Village	rainfall (mm per annum)
1940	Drought	Omufitugwanauyala	434.1*
1946	Drought	Omufitugwanauyala	224.8
1950	Flood	Omufitugwanauyala /Oshikulufitu	1022.4
1959	Drought	Omufitugwanauyala	242.1
1981	Drought	Oshikulufitu	146.3
1983	Drought	Oshikulufitu	204.3
1988	Drought	Oshikulufitu	131.3
1992	Drought	Omufitugwanauyala	104.9
1995	Drought	Oshikulufitu	92.0
2008	Flood	Omufitugwanauyala /Oshikulufitu	541.5*

†In discussions with Namibia Meteorological Service staff, it was posited that for this Namibian region, annual rainfall totals below 300mm or above 700mm correlated positively with drought or flood conditions respectively.

*These totals were likely higher, with rainfall data missing for some rainy (and dry) season months

The accuracy of local memories of previous rainfall patterns and events was also manifest in responses to questions about what had happened to rainfall over time. There was a strong perception in both focus groups that the weather had become significantly drier over the course of the twentieth century. The decades which were singled out as characterised by good rainfall – the 1930s, 1950s, 1960s and 1970s – match well with the rainfall record for Outapi, which shows that average annual rainfall between 1930 and 1979 was significantly higher than from 1980 to 2001, as Figure 1 (below) illustrates. This collective memory is a resource to draw upon, which fosters capacity for coping with the consequences of inter-annual rainfall variation, including the extreme instances. It provides a range of experience to fall back on when attempting to cope with the next drought or flood, which is especially important given that the timing, duration and magnitude of such events remains largely unknown to these farmers even in the twenty-first century. It seems probable that the precision shown in recollecting previous climatic conditions is born of necessity, especially given that state assistance in times of drought and flood was less forthcoming prior to independence. It is also likely that observing the frequency of extreme events over time, and developing such a keen awareness of thresholds in coping strategies, has given farmers a better idea of how much grain to store in the good years when it is possible to produce a surplus.

Figure 3 - Decadal rainfall for Outapi 1930s-1990s (produced with time series data provided by the Namibian Meteorological Service)



When droughts or floods cause harvest failure and/or drastically reduce available grazing resources, the responses farmers have in their attempts to cope are subsequently more limited, not least because the supplementary resources people obtain from the oshanas are likewise depleted. Yet a number of options were listed by focus group participants when asked how they, their parents or grandparents had responded to the droughts and floods that they had identified. Most of these responses were common to droughts and floods because both phenomena were viewed by participants as having essentially the same consequences for crop and livestock farming alike. The most common responses for both villages are listed below:

- sharing food with family and neighbours
- Selling cattle
- Hunting wild animals
- Increasing consumption of hardier wild resources such as leaves
- Digging wells for water
- Government assistance (post independence)
- Purchasing food to compensate for a shortfall

It should be noted that whilst many of these responses are of use for floods as well as droughts, there is less adaptive capacity in relation to the former than to the latter. This is partly because, despite the preference for settlement in a flood plain and, hence, an awareness of the potential consequences, there are few defences against floods. Furrows in fields will often be ploughed so as to point toward an *oshana*. Principally, however, it is because floods – at least of a level to endanger harvests or immovable property – are experienced less frequently than drought, as the Outapi rainfall dataset demonstrates.

Many of these responses have changed over time. Game is no longer available as an alternative protein resource when livestock is heavily depleted. Digging wells in a search for drinking water has become less necessary because of extensions in the provisions of water from boreholes. A number of participants in both villages commented that the element of reciprocity in food sharing had become ever rarer over time. It had become increasingly common to charge for any food requested. This change may be linked to the increased presence of state assistance in times of drought or flood, primarily in the provision of food. Participants in both villages felt that there was an increased dependency on the state, which had lowered both the capacity and willingness of people to assist each other.

Nevertheless, in relation to coping with drought or flooding, the most important factor which determines whether the farming system is taken beyond a threshold is the frequency of reoccurrence. Farming in North-Central Namibia is in many ways premised on the possibility of preparation for and recovery from the toughest years. It is perhaps for this reason more than any other that even when surplus harvests are grown, the produce does not tend to be taken to market. In years of good harvests, the surplus is stored in the *eshisha* (grain storage baskets), in order to compensate for poor harvests. The same logic influences the tendency to keep livestock herds and sell them more at times of distress, for instance when farmers worry that they will not survive the dry season. There are other reasons which explain the low levels of cattle sales in North-Central Namibia, but focus group participants in Omufitugwanauyala and Oshikulufitu clearly appreciated the benefit of the buffer provided by a larger herd in lean times.

In view of the adverse and uncertain conditions currently characterising the global economy, another advantage of farming for subsistence and storage, as opposed to farming for sale – especially in international markets – is that the risk of 'double exposure' is reduced. A growing body of literature has documented the extent to which some farmers are simultaneously vulnerable to the impacts of globalisation as well as climate change (see Leichenko & O'Brien 2008 for an overview). Studies such as those by Eakin (2005) and O'Brien *et al* (2004) have demonstrated that policies related to structural adjustment and trade liberalisation have, in countries such as México and India, exposed farmers to cheap agricultural imports from other countries whilst removing state support for agricultural production. They have also argued compellingly that, in attempting to push farmers in the direction of more commercial production for the international market, farmers have found themselves a) at the mercy unstable and frequently unprofitable prices for their produce, and b) choosing to grow crops which are less well adapted to climatic variation than those they had previously grown. The net result can therefore be greater vulnerability to both globalisation and climate change. This literature provides, therefore, a cautionary tale for proponents in the Namibian context of a switch from subsistence agriculture to more commercially viable crops; such as advocates within the Ministry of Agriculture, Water & Forestry of a switch from pearl millet to cotton in North-Central Namibia.

Ultimately, though, the limits of these strategies could be tested or exceeded if the frequency of extreme weather events were to increase in ways consonant, for instance, with the increase in ENSO-related phenomena projected under climate change scenarios (Stige *et al* 2006). Focus group participants in both villages were asked how many good (i.e. surplus-producing) harvests they might expect to receive over a ten year period. The answer varied between participants, but responses ranged from three to five years. Farmers in both focus groups perceived these conditions to be more difficult than they had previously been in the 1960s and 1970s, and worried that any increase in the frequency of dry years could make crop farming impossible.

Likewise, farmers felt that they would require a period of at least five years to recover from the adverse effects of flooding at the scale of 2008; a finding which makes the 2009 reoccurrence of floods across North Central Namibia all the more disconcerting.

Consonant with the perception that the limits of farming strategies under changed climate conditions – in conjunction with other pressures i.e. bush encroachment, population density increase – were being reached, farmers expressed decreasing confidence in their early warning indicators for wet or dry rainy seasons. Individual interviews identified a variety of indicators (see Table 3 below), but when asked how reliable these indicators were over time, a majority thought that they had become less reliable. This was, then, one indication that farmers felt less certain that they could deal with some of the variations in climate that they were currently facing.

Table 3 – Early warning indicators used by farmers in Omufitugwanauyala and Oshikulufitu

Indicator type	Indicator	Indicates
Plant	· *Uumpishi/uutwishi*, or mopane sugar, secretion on mopane leaf · *Omhuzi* tree produces fruits before start of rainy season · Trees & plants i.e. mopane lose leaves slowly	Good rainy season Good rainy season Poor rainy season
Animal	· *Oimote* birds seen walking on the ground · Appearance of small white butterflies · Goats give birth in April	Poor rainy season Army worm pest next growing season Early onset of rains
Climate	· *edhiva* (mini oshana) holds first rain water for two weeks · continuous or east-west winds in summer	Poor rainy season Good rainy season

It is as well to qualify these comments about the reliability of early warning indicators. A survey on weather forecast and early warning information available to Omusati farmers found that 76% of respondents found local forms of such information useful for making farming decisions (IECN 2008:5). This was in spite of the widespread availability on radio and television of weather forecasts from the Namibian Meteorological Offices, which were often deemed too general to be of use in decision-making processes (ibid).

4. Livelihoods diversification

Livelihoods diversification in Oshikulufitu and Omufitugwanauyala

One key insight provided by the literature on climate change and development is that the implications of climate change for development are best understood within a context of the multiple stressors faced by people in developing countries, to which they are also adapting, and which in some cases are already transforming the social-ecological systems within which their development trajectories are unfolding (Ziervogel et al. 2006; Ziervogel & Taylor 2008; Adger et al. 2005; Huq & Reid 2007). Against this background, evidence from the data relating to changes in livelihood strategies within Omufitugwanauyala and Oshikulufitu acquire greater significance. In essence, whilst farming remains the most important set of livelihood activities for people in both villages, other livelihood strategies – and especially those from which a monetary income is derived – have become increasingly central to how households make a living. Furthermore, the status of farming itself is being renegotiated from one generation to the next. Currently, it is not wholly clear whether these changes constitute adaptations within the existing system that permit its continuation, or whether they are evidence of a transformation into a "fundamentally new system" (Walker et al. 2004).

Table 4 – livelihood activities in Omufitugwanauyala and Oshikulufitu

Livelihood activity/income source	Male	Female
Livestock farming		
Cattle	✓	✗
Goat	✓	✗
Poultry	✗	✓
Pig	✗	✓
Crop farming		
Staple: mahangu, sorghum, maize	✓	✗
Other: groundnuts, bambara nuts, beans, melons	✗	✓
Services & goods made to sell		
Make hoes	✓	✗
Make bricks	✓	✗
Make thatch roofs for huts	✓	✗
Sell fruit from local fruit trees	✓	✗
Make clay pots	✗	✓
Make okapana (street or fast food)	✗	✓
Off-farm employment		
State (i.e. teacher, govt administration, agricultural extension)	✓	✓
Private (i.e. NGO, office, mechanic, taxi driver, work on commercial farms, cuca shop)	✓	✓
State subsidy		
Pension	✓	✓

Focus group participants in both villages were asked to identify all of the livelihood activities available to them, listed below in Table 5. Subsequently they were asked to rank these activities in order of importance to the subsistence and economic wellbeing of the household. As Table 5 demonstrates, farming was still considered to be the most important, but the contributions from off-farm employment or from pensions were considered "very important" in both Omufitugwanauyala and Oshikulufitu. In Omufitugwanauyala, seven out of eleven focus group participants lived in households in which at least one person contributed income derived from off-farm employment; in Oshikulufitu the corresponding figure was six out of eleven participants. Further, no participant in either village thought that returns from farming and pensions alone would be sufficient to meet household needs.

Table 5 - Livelihood options ranked according to their importance to household income

Importance	Omufitugwanauyala	Oshikulufitu
1	Farming (livestock & crop)	Farming (livestock & crop)
2	Formal sector employment	Pension
3	Pension	Formal sector employment
4	Services & goods made to sell	Services & goods made to sell

This ordering of priorities reflects the importance of off-farm activities to household strategies for making a living. Whilst farming remained the most important set of livelihood activities, off-farm employment and pensions are vital sources of income, far from being considered mere supplements of comparative insignificance. These results point, then, toward a significant degree of diversification in livelihood strategies. One might be tempted to overlook the importance of such diversity in the broader context of Omusati, given that the most recent Household Income & Expenditure Survey (NPC 2006) reported that 80.5% of Omusati residents named farming as their main source of income. Yet phrasing the question in terms of 'main' income may not capture the extent to which the economic wellbeing of a household is dependent upon a number of activities whose importance can vary across time. It certainly does not indicate the indispensability of off-farm activities for people in the fieldsite villages.

Focus group work in both villages revealed substantial inter-generational differences in attitudes towards the desirability of farming as the main source of livelihood. The older participants tended to think that all other activities should be organised around farming. In the words of one elderly woman, "Farming should come first. You can't go to work with an empty stomach". The younger participants (aged 16-25) tended to want to combine paid work in the formal economy with farming. As finding formal employment often required a move to an urban centre such as Windhoek (roughly 900km south of the villages), these participants suggested that they would pay for their farms to be worked during their absence and farm themselves at weekends or during holidays. There was, then, clearly a reluctance to sever relations completely with the farm, reflecting not least the sense of obligation felt by young people to contribute to household income even if they no longer resided within it. Yet there was also an implicit valuing of formal-sector employment above farming as a main source of livelihood. This is not wholly surprising in terms of the career aspirations expressed by younger participants, such as teaching, which effectively offer complete independence from subsistence farming.

Livelihoods diversification in historical perspective

Another reason to refrain from a characterisation of Omusati inhabitants chiefly in terms of farming is that livelihoods diversification is not a new phenomenon in this part of Namibia. Even a brief acquaintance with the history of the Owambo peoples reveals the centrality of trade and migration – fashioned by European trading, colonial expansion, inter-clan conflict, disease and famine – upon Ovambo society and its forms of making a living. Trade with the Hei //om[4] and Otjiherero-speaking societies developed partly as a buffer against food shortage in times of drought or flood (Siiskonen 1990; Mendelsohn et al. 2000). In this way, trade to some extent made a contribution to Owambo resilience in the face of more extreme instances of climate

[4] The Hei //om are thought to have inhabited present-day North-Central Namibia prior to the arrival of the Bantu speakers who would come to be known as the Ovambo.

variation associated with droughts and floods. Yet in respect of resilience to the vicissitudes of climate variation, the impact of trade was at best a double-edged sword. Trade was also spurred by the increased presence of European traders in the area, who brought firearms, alcohol, horses and ox-wagons (amongst other commodities) in exchange for ivory, cattle and labour; often in the form of slaves (Siiskonen, 1990). The influence of these types of trade upon wildlife populations is thought to be adverse (Hayes 1992); even greater were their effects on political stability between Owambo kingdoms. It has been argued that trade led to the development of more stratified and politically centralised power structures in those Eastern Ovambo societies most engaged in the new trading relations (Clarence-Smith & Moorsom 1975).

The desire to maintain these trading relations led Eastern Ovambo kings to levy ever greater taxes from their subjects, and also to sanction more raids upon Western Ovambo societies (ibid). These were less able to defend themselves as a result of their comparative lack of exposure to firearms trading. Raids captured people as well as cattle, and in so doing engendered a spiral of depleting human and farming resources, with dismal consequences for households' self-sufficiency (Gewald 2003; McKittrick 1998). As a result of the weakening of this capacity, when environmental hazards did occur, famine ensued – and in tragically spectacular fashion in the droughts of 1914/15, which came to be known as the 'famine that swept' (Gewald 2003). Populations that had lost the capacity to feed themselves trekked southward in desperation, in search of work on commercial farms or the mines that had started to be established following the discovery of diamonds from 1908 onwards (ibid). Gewald holds this particular episode of famine to be a tipping point in the history of Owambo migration southwards (ibid); and indeed the tradition of migration as a means with which to supplement farming activity continues to this day. This was evident in Omufitugwanauyala and Oshikulufitu but remains the case more broadly in North-Central Namibia (Mendelsohn *et al* 2000). Moreover, it may yet prove the catalyst for a significant transformation in the livelihood strategies of the Ovambo people, in which farming becomes gradually less important over time. It is vital, however, to keep in view that the kinds of employment gained from migration towards mines or commercial farms were not only borne of famine-induced desperation. Colonial administrations had a keen interest in sourcing labour supply for the farming and mining industries which formed the economic backbone of the settler colony, with all of its attendant injustice and exploitation. Those who sought migrant labour were subjected to notoriously harsh working conditions. Nor can commercial farming and mining be described as a source of economic prosperity for most workers over the course of the twentieth century. They are more accurately seen as principal elements in the inequitable character even of the modern Namibian economy.

Diversification, adaptation and inequity

Studies from across the developing world have made clear the extent to which diversification away from agriculture is a global phenomenon, albeit one which varies markedly according to local conditions (i.e. Francks et al. 1999; Eder 1999; for an overview see Rigg 2006). To be sure, changes in Omufitugwanauyala and Oshikulufitu to the importance of farming to household economic wellbeing may not exactly mirror at this point in time the sorts of transformations witnessed in, for instance, the East Laguna Village in the Philippines, so frequently studied by livelihoods diversification scholars (cf. Hayami & Kikuchi 2000). Yet the tendency – if it can be described as such – to turn away from agriculture is not solely to be found in Omufitugwanauyala and Oshikulufitu. Nationwide, the share of agriculture as a proportion of the national workforce has been declined in recent years. According to the Namibian Labour Force Surveys, in 1997 agriculture provided employment for 36.6% of the national workforce, but by 2000 this figure had fallen to 29.3% and by 2004 further still to 26.6%. In contrast, other sectors, such as Hotels and Restaurants (from 0.7% in 1997 to 3.4% in 2004) or Wholesale and Retail Trade (from 8.4% in 1997 to 14% in 2004) increased their share of the labour market markedly (IPPR 2001; 2002; 2006)[5].

From the standpoint of adaptation, any kind of livelihoods diversification might be seen as a promising development. One way to respond to the uncertainty surrounding the future impacts of climate change upon agricultural productive capacity is to place more emphasis on equipping people to engage in activities that are less susceptible to disruption from climate impacts. Furthermore, it is tempting to view livelihoods diversification away from agriculture as a means to reduce poverty. The broader literature on diversification has certainly put the spotlight on the extent to which diversification correlates positively with poverty reduction (i.e. Scoones 1998; Carney et al. 1999). Yet just as twentieth-century diversification into wage labour in the mining and commercial farming sectors seemingly did little to increase the overall wealth of the Ovambo (and other Namibian) peoples, one might ask the same question about current moves away from farming.

There is, though, another strand of analysis which suggests that changes to geographical mobility with respect to livelihood activity do not automatically lead to the kinds of social mobility associated with poverty reduction. For instance, Jonathan Rigg maintains that whilst diversification may have allowed poor households to maintain a rural existence in the face of an ever less viable rural economy, it may simultaneously have inscribed many into the production and reproduction of “new” forms of poverty, which require correspondingly new forms of development intervention (Rigg, 2006:194-195). In the African context, perhaps the best known set of studies on diversification are those comprising the DARE project (Bryceson 2002). As well as documenting the extent of diversification in six African countries, the studies sought also to challenge the posited link between livelihoods diversification and poverty reduction In her critique of the World Bank-led structural adjustment and market liberalisation programmes to which many African governments (often reluctantly) signed up in the 1980s and 1990s, Bryceson argues that small-scale agricultural producers were largely ‘abandoned…to the forces of the global market’ (2004:619). In other words, structural adjustment and liberalisation precipitated the declines in African agricultural production, thereby initiating a scramble into off-farm livelihoods diversification which had little to do with poverty reduction.

One may take issue with the magnitude of the claims made on the basis of the DARE research. One may further wish to question the extent to which structural adjustment and liberalisation were prime drivers of diversification in Africa with reference to the exceptions that can be found across the African continent; Namibia is indeed one such exception. The diversification found in Namibia cannot be explained with reference to these policy drives because the country did not implement structural adjustment or liberalisation policies in the way the other African countries, as it was

[5] Perhaps these figures should, though, be treated with caution, given that other fluctuations between the surveys raise the questions of whether the same sample was utilised for all three surveys, and how representative the sample was of the broader population. For instance, in 1997, 22% of all respondents classified by occupation were reported as working for the armed forces, but by 2000 this figure had dropped to 1.2%, and then to 0.8% by 2004.

never as dependent upon the World Bank for financial assistance. Nevertheless, the DARE case studies effectively problematise any positive or automatic correlation between livelihoods diversification and poverty reduction.

One telling but simple indicator that has been used to measure the relationship between off-farm livelihoods diversification and poverty is the distribution of national income (i.e. Hayami and Kikuchi, 2000). Namibia has a GINI co-efficient of 0.6, and is thereby ranked as one of the most inequitable countries in the world in terms of income disparity between the wealthiest and the poorest (NPC 2006). Though high, the GINI co-efficient was even higher in 1994, at 0.7 (NPC 2006)), implying that the distribution of income has become since independence a little less skewed towards the upper percentile groups. Moreover, between 1994 and 2004 the proportion of Namibian households which spent 80-100% of income on food decreased from 8.7% to 3.9%, whilst the proportion spending 0-39% increased from 34.8 to 44.9% It remains hard at present, nonetheless, to interpret these figures as a ringing endorsement of the potential for current or historical patterns of livelihoods diversification in Namibia to bring about substantial and rapid reductions in poverty.

Table 6 – Annual household income by adjusted per capita income percentile (APCI) groups

Household APCI percentile groups	H'holds %	Pop. %	Avg. h'hold size	Total income (million N$) & % of nat. income		Avg. h'hold income (N$)	Avg. income per capita (N$)	APCI (N$)
0 - <25	24	33.5	6.9	1019	6.3	11,417	1,662	2,004
90 - 100	11	6.3	2.7	7414	45.9	181,392	63,996	70,312
Omusati	10.6	12.3	5.7	1034	6.4	26,340	4,586	5,460
Namibia average	100	100	4.9	16,175	100	43,520	8,839	10,357

Data from: Namibia Household & Income expenditure survey (NPC 2006)

Even in those cases where diversification *does* reduce the vulnerability of at least some household members to climate change impacts, it may adversely impact the vulnerability of other members. Migration to other cities (or countries) can leave rural households short of labour for farming. For instance, an elderly woman interviewed during a farm visit in Omufitugwanauyala recounted how, in the run-up to the 2007-2008 growing season, she had decided to plant her crops much earlier than everyone else. Although her strategy did in fact provide her with a harvest before the onset of the floods – for which she was awarded a prize from Ministry of Agriculture officials – her decision was based on necessity, rather than a clairvoyant-like reading on the coming rainy season. She was obliged to plant early because the grandchildren she was caring for were going to leave to return to school, and she would have been unable to prepare and sow the field by herself. The parents of the grandchildren were not available to assist because they lived and worked in Windhoek, at a distance of 900km from the village. The woman, who received remittances, was therefore not only engaged primarily in a livelihood that is dependent upon the climate, but which also required labour inputs to which her access was erratic. Whilst the remittances she received probably reduced her need to produce her own food, if they were sent by family members who had found themselves diversifying into other forms of poverty, her own situation may well have been worse than if she had better access to labour on the farm.

5. Discussion and conclusion

Considering the results and analysis above, three related themes emerge. The first relates to the seeming contradiction between the utility and potentially enduring quality of local agro-ecological knowledge on the one hand, and the picture of degradation and decline widely held of North-Central Namibia. Second, how can or should agro-ecological knowledge fit within the work of the agricultural extension services, who will be critical in any attempts to strengthen adaptive capacity amongst Omusati farmers? Third, given the increasing importance of diversification into off-farm livelihood activities, what kind of broad adaptation strategy would best suit most people who currently see farming as their most important form of income? Is it better to help North Central Namibia's smallholder farmers strengthen the resilience of agricultural practice? Or is it more advisable to encourage farmers to diversify into livelihood activities that are less sensitive to climate change impacts?

Agro-ecological knowledge, adaptive capacity and land degradation

Clearly, the land unit system, deeply-rooted across Owambo societies, is in one sense a sophisticated, tried and tested form of adaptive capacity to a wide range of climate variability. On one level it can be seen as a means to deal with uncertainty, and as such may offer insights for decision-making in response to climate change, which sooner or later is going to come up against the limitations in predictive capacity inherent in current climate science. Employed consistently, it also seems likely that the land unit system may also provide adaptive capacity to at least some manifestations of future climate change. There has already been effective adaptation to more recent variations in the climate, such as the rapid uptake of the early maturing varieties of pearl millet in the fieldsites and across North-Central Namibia, in response to changes in the length of the rainy season, as well as the quantity and distribution of rainfall across the rainy season.

And yet there have also been practices we might view as forms of mal-adaptation. Whether seen as a breakdown in a transhumance system, or as a migration pattern which can expand no further without encroaching on land used by other farmers for cropping, the level of concern about the impacts of current livestock farming is understandable. This concern was present also in Omufitugwanauyala and Oshikulufitu, with farmers less certain about where the next reliable supply of grazing would be found. In this context, the high level of private fencing around significant tracts of ostensibly communal land raises important questions about who has access to grazing resources and on what basis. In the worst-case scenario, current farming practice is wholly unsustainable and radical changes have to be introduced in order to avoid a collapse of the farming system. The concerns currently held about the state of farming in Namibia may, then, lead one to conclude that the land unit system, which has permitted permanent settled agriculture for centuries in areas of considerable climate variability, has not adapted well to the changes – i.e. in population growth, water availability, resource access – that have occurred in North-Central Namibia in recent decades even before a consideration of the potential impacts of climate change is taken into account. This seeming contradiction is not easily reconciled.

Nonetheless, as it currently stands, statements that presume degradation to be widespread across North-Central Namibia would be more compelling if the evidence base were less patchy, more consistently considered abiotic as well as human-related drivers of landscape change, and did so in greater historical depth. Given the high levels of good will and desire to set natural-resource based livelihoods in Namibia on as sustainable footing as possible, and given a policy and legislative framework which is much more conducive to local participation than in many other parts of Africa, it would be unfortunate not to settle this question more conclusively. Doing so would better resolve related questions around the opportunities and constraints involved in the land unit system as a resource to draw upon in formulating adaptation policy in North-Central Namibia.

Agro-ecological knowledge and agricultural science – ignorance or knowledge 'co-production'?

Whatever the potential contributions or drawbacks of bringing the land unit system into attempts to strengthen farmers' adaptive capacity to climate change, they will inevitably be mediated through agricultural extension policy and intervention in North-Central Namibia. Verlinden and Dayot suggest that a lack of understanding of and engagement with the land unit system is frequently detrimental both to agricultural extension research and to the dissemination of the techniques and methods that it points towards. They note that experiments involving fertiliser, at an agricultural experimental station situated exclusively on the *Omufitu* land unit, would have benefitted from farmers' knowledge that the effects of fertiliser on *Omufitu* would be of comparatively short duration, disinclining them to use such a scarce resource on that particular land unit (2005:165). Elsewhere, Hillyer *et al* (2006) make a similar argument about an agricultural extension programme which sought to persuade people to use legumes and animal manure to boost soil fertility, with a view to strengthening yields of pearl millet. A central reason why farmers did not adopt the suggested practices, even when doing so appeared to be in their interests, was that their current decisions about where and where not to plant legumes, and for what reasons, was determined by the land unit framework, which was not taken into account in the extension programme.

Given the widespread use by farmers of the land unit system, it is surprising that it does not appear to find its way more systematically into agricultural extension, or indeed into agricultural policy more broadly. Verlinden and Dayot attribute this lack of uptake to "scepticism" on the part of scientists and extensionists (2005:166). This is not an implausible explanation, but there remains room for further enquiry. The nature of my own fieldwork brought me into frequent contact with agricultural extension workers in Omusati and other Northern regions. This contact tended to confirm the lack of engagement with the land unit system, but it also underlined that it was not, on the whole, as a result of lack of exposure to it. Many of the extensionists – if not the majority – hail from, as well as work in, Northern Namibia and grew up with the ILU system prior to attending agricultural college. Such conditions might even be considered propitious for a cross-fertilisation of two partially separate, partially convergent knowledge sets.

In the light of well-rehearsed critiques of arrogant development intervention which failed to recognise knowledge and skills held by local people across the world (i.e. Chambers 1983; Nelson & Wright 1995; Escobar 1995), this apparent lack of cross-over could well be interpreted as par for the course. Nonetheless, the familiarity of extensionists with the contexts in which they operated clearly assisted them to identify activities which – at least in the village of Oshikulufitu, with a history of agricultural extension presence – were deemed locally useful and employed by considerable numbers of farmers to whom they were introduced. Indeed, local demand for agricultural extension services considerably outstripped supply, suggesting its value at the local level. Therefore it may be precipitate to characterise current agricultural extension in northern Namibia as wholly insensitive to local knowledge.

There is, too, an important gain from the tendency of local farmers to incorporate what they learn from agricultural extension work into their farming practice. This report has argued that in some instances – such as the introduction of early-maturing varieties of *mahangu* (pearl millet) – mixing agricultural science with agro-ecological knowledge has strengthened resilience to climate variability. Where this does happen, it is in effect is a fruitful 'co-production' of knowledge between farmers and extension workers. It is, moreover, a more legitimate way of changing agricultural practice because it includes what farmers know and allows them to extend their existing repertoire in ways that fit with what they already know, instead of a straight imposition of a supposedly 'superior' way of doing things. What is less clear are the conditions that encourage this kind of knowledge co-production. Understanding these conditions better would make for a promising line of further research.

Getting more from mixing agro-ecological knowledge with agricultural science: interactional expertise

One avenue for further research into the interaction between agricultural science and local agro-ecological knowledge is the work of Harry Collins different types of expertise (Collins 2004; Collins & Evans 2002). Collins distinguishes between three states of expertise, which are defined in relation to specific bodies of knowledge *and*, critically, the actions that holders of that knowledge can perform. These are:

1. 'No expertise', which refers, common-sensically enough, to the state of having little or no understanding of a particular body of knowledge.
2. 'Contributory expertise', which refers to having sufficient expertise to be able practice a given body of knowledge, and also to *add to or modify it* in ways that other expert users of that knowledge can engage with critically. An academic with specific disciplinary expertise is the kind of holder of contributory expertise Collins has primarily in mind. Agricultural extensionists or farmers in Omusati are the more apt examples for our purposes.
3. 'Interactional expertise', an 'in-between' state in which an individual possesses enough expertise to understand what holders of a particular body of knowledge communicate or do and, therein, can interact with them, but without being able to use and do with that knowledge what contributory experts – "full-blown practitioners" – can (Collins 2004: 125-127).

Ultimately, Collins wants to use these concepts to explore fundamental questions within the domain of phenomenology. Most relevant to this research is, more simply, his call to recognise both the existence and implications of interactional expertise. In a (2006) paper on sustainable agriculture in Iowa, USA, Michael Carolan deploys Collins' work on expertise to demonstrate its utility in an agricultural setting. He argues that those local farmers with 'interactional' expertise in agricultural science had more helpful exchanges with agricultural scientists than did farmers without such interactional expertise. Likewise, agricultural scientists with interactional expertise of "farmers' talk" were able to make more targeted, intelligible suggestions to farmers; and in turn gained insights which made them rethink, and in some cases modify, agricultural science. One highly useful advantage of interactional expertise lies, then, in getting people who are contributory experts in different bodies of knowledge to understand each other better and benefit from that deeper understanding.

Interactional expertise and hybrid knowledge in Namibia and Southern Africa

In the case of Omufitugwanauyala and Oshikulufitu, we could argue that farmers and agricultural extension workers have, respectively, contributory expertise in relation to agro-ecological knowledge and agricultural science. But, given the knowledge-technology transfer objectives underpinning agricultural extension, and the extent of its local uptake, it seems reasonable to suggest that some local farmers *also* have some level of interactional expertise about agricultural science. Further, in those techniques that they deploy on the basis of what they have learned from agricultural extension workers, they even have some contributory expertise in agricultural science, as well as contributory expertise in agro-ecological knowledge. For those agricultural extension workers who hail from North-Central Namibia and work there, it would also seem that they have at the very least interactional expertise in agro-ecological knowledge, in addition to their contributory expertise in agricultural science. However, the distribution of these kinds of interactional and contributory expertise across farmers and extension workers is not well understood, and is therefore a worthy subject for further research.

These considerations link up to another research agenda important in Southern Africa, and further afield. A number of commentators hold that not only can there often be a significant amount of overlap between local and scientific knowledge, but that bringing both to bear consecutively is more effective than employing either in parallel. This is in part because a 'hybrid' knowledge base of this kind offers the scope to use advantages and avoid limitations found in scientific or local knowledge (cf. Thomas & Twyman 2004; Reed et al. 2007; Reed et al. 2008). Moreover, if it entails the 'co-production' of new knowledge between farmers and agricultural extensionists, it encourages a more inclusive – and more legitimate – decision-making process for making changes to agricultural practice. Work in Botswana to bring together scientific and local knowledge appears to have served as an inclusive exercise in knowledge co-production (Reed et al 2007, 2008). A review of the potential salience of the Botswana experience in the Namibian context may prove a good launchpad for fruitful research into the interactions between local agro-ecological knowledge and agricultural science as used by the extension services. It may even provide a model for 'getting the balance right' between local and scientific knowledge in setting agricultural activity on a more sustainable footing. Getting extension workers and farmers to understand and respect each others' expertise is surely the first step in knowledge co-production processes. Finding out how to make it easier for both sets of 'practitioners' to acquire interactional expertise may therefore be a useful policy objective.

However, asserting that hybrid knowledge is *better* than scientific or local variants on their own raises difficulties. To claim such knowledge to be better than either component alone is in itself a knowledge claim which draws somewhat eclectically on belief systems which, whilst convergent in some aspects, may be contradictory in others. Establishing the basis for making such a claim may, therefore, be considerably more difficult than making the claim itself. Moreover, where 'scientific' and 'local' knowledge claims are in conflict in a hybrid system, deciding which one to accept returns us to the question of whose knowledge counts, but does not resolve it. This raises a caveat also with use of interactional expertise to foster knowledge co-production. On the face of it, it seems likely that the scientific knowledge of agricultural extensionists will count for more than that of local farmers – especially when their farming practice is blamed for widespread land degradation. The important point must, therefore, be made that this kind of power dynamic might inhibit extension workers from wanting to acquire (or reacquaint themselves with) interactional or contributory expertise in the land unit system. For this reason, it is also important to understand better *what* local agro-ecological knowledge counts for, and with whom. For better or for worse, the land unit system is what farmers use to make farming decisions. Bringing it more consistently into processes which attempt to bring about change in farming practice can only increase the legitimacy of the decision-making processes underpinning those changes.

Broad objectives for adaptation policy: strengthen agricultural resilience or diversify away from agriculture?

Ultimately, considerations of how implicit current farming practice is in widespread degradation in North Central Namibia, and how to incorporate local agro-ecological knowledge into future changes to farming present policymakers with a choice over broader adaptation pathways. Does the government seek to target interventions on contributing to building resilience agriculture in the face of climate change? Or does it target its efforts on diversifying into livelihood activities that are less sensitive to the direct impacts of climate change?

In many ways, it is tempting to recommend concentrating on the second of these two options, in large measure because of the current prognosis coming from the climate change scientific community. There are already fundamental questions about the sustainability of much current farming practice in the North – albeit ones in search of more comprehensive answers – even before the potential impacts of climate change are taken into account. It is true that attempts to downscale climate projections to the national and sub-national level in Namibia have not produced the kind of certainty, especially in respect of future rainfall levels, about climate impacts on agricultural production that would give policymakers a clear basis for decision-making. But the comparatively greater concurrence between projected temperature increases for Southern Africa and those for Namibia more specifically are worrying. Higher temperatures are often associated with the kinds of increase in intense rainfall events that the IPCC suggests is "very likely" to occur (IPCC 2007:52), and which have caused such serious and widespread damage across the north of Namibia in 2008 and 2009. Compounding these concerns, the Synthesis Report of the high-level meeting of scientists in Copenhagen, March 2009, suggests that greenhouse gas emissions are still steadily increasing, and at a rate which falls within "the upper boundary of the IPCC range of projections" (Richardson et al. 2009:6). Continuing to emit greenhouse gases at this rate increases the risks of causing abrupt and irreversible climatic shifts (ibid), and on a shorter timescale than previously envisaged, with a 4ºC average global temperature increase (ibid).

Gloomier still, a recent Tyndall Centre analysis casts doubt on the likelihood of realising the kinds of emissions reductions required to keep global temperature increases over the twenty-first century below 2ºC (Anderson & Bows 2008). They argue that stabilising greenhouse gas concentrations in the atmosphere at 450 parts per million – which in itself would offer only a 46% chance of achieving the 2ºC target – would require emissions reductions of around 6-8% per year between 2020 and 2040, and total decarbonisation not long after 2050. To put these reductions in context, they note that even the economic collapse that occurred in Russia in the 1990s saw annual emissions drop by 5%. In other words, not even during periods of intense and politically unacceptable reductions of economic activity, with all of the painful social costs attached, are there precedents for the scale of reduction required to have any chance of keeping the temperature increase below 2ºC. They suggest that, given current emissions levels and the global economic order as it stands, 4ºC may be the best to be hoped for, and that adaptation strategies should be planned accordingly. It is not clear at the global level, let alone the Namibian level, what the impacts would be at 4ºC, but it is well into the range at which climate changes are thought to be dangerous.

Nicholas Stern points out that there is no analogue in human history from which we can glean an idea of what living in such a warmer world would be like. However, the last time the temperature was 4-5ºC lower than the current average was during an ice age (Stern 2009:32). It seems intuitively likely that the difference between our experience of our current climate and one 4-5ºC hotter would be comparably dramatic. Moreover, the more sensitive an activity to climatic variables, the greater the uncertainty (and possible catastrophe) to which it would be exposed.

There would appear to be, furthermore, momentum in the political arena for livelihoods diversification away from the farm setting. Namibia's third National Development Plan (NDP) seems to diverge significantly from its predecessor in downplaying the importance of smallholder farming, just like larger scale commercial agriculture as an engine of economic growth, as an engine of economic growth. Noting the decline in production in subsistence agriculture since 2000, as well as the decline in agriculture as a source of employment, the report suggests "Perhaps, moving the people out of subsistence agriculture is a more appropriate means for reducing poverty in the country" (GRN 2008b:21).

For these reasons alone it is difficult to see how to make the case for strengthening agricultural resilience in the face of climate change as the primary adaptation response. Indeed, the presence of such high levels of uncertainty surrounding the future of agriculture might be dealt with more effectively by attempting to help people diversify into livelihood activities that are less sensitive to climate impacts. Another factor which would also appear to favour diversification away from agriculture as the primary adaptation response is that it is already occurring, and has a longer history than one might expect, given the importance imputed to farming in popular constructions of Owambo identities.

Yet it remains the case that experience of livelihoods diversification in North-Central Namibia, as in many other countries, has often been one of switching or complementing one form of entrenched poverty with another. The evidence, both historical and current, does not suggest that diversification always leads to big increases in the economic wellbeing of the household. Recent reductions of inequity in the distribution of Namibia's income are to be welcomed, but in spite of them the country remains one of the most inequitable in the world. In this context, any adaptation strategy based on diversification needs to find ways not just of steering people towards low-carbon development, important though this is. It also has to contribute to addressing inequality. It has to find mechanisms that give more people access to better-paid forms of diversification.

Of course, there is clearly still some way to go before subsistence farming ceases to be an important livelihood strategy for such a large percentage of the population. Increasing agricultural resilience to climate impacts is an important short-to-medium term goal for adaptation policy, perhaps in combination with diversification-focused policy. Because of this it will remain useful to engage with agro-ecological knowledge. It remains a basis for decision-making for farmers, and thereby needs to be part of any attempts to bring about fundamental changes to the balance between off- and on-farm contributions to household economic wellbeing. Any strengthening of agricultural resilience in the face of climate change is likely to be more effective by engagement with agro-ecological knowledge. In the long run, it seems unwise to recommend farming as a viable source of livelihood. Diversification away from climate sensitive activities makes more sense as an adaptation strategy over the long term. Yet whatever pathway Namibian development takes, its legitimacy will be in question if it does not reflect the desires of the people who are supposed to benefit from it.

References

Adger, W.N., Arnell, N.W. & Tompkins, E.L., 2005. Adapting to climate change: perspectives across scales. *Global Environmental Change Part A*, 15(2), 75-76.

AFP, 2009. Southern Africa hit by worst floods in years. *AFP*. Available at: http://www.google.com/hostednews/afp/article/ALeqM5i8IZT0UAjQcp29zy217ZGb2ZhFDg [Accessed August 20, 2009].

Anderson, K. & Bows, A., 2008. Reframing the climate change challenge in light of post-2000 emission trends. *Philosphical Transactions of the Royal Society A*, 366(1882), 3863-3882.

Barnes, B. & Bloor, D., 1982. Rationalism, Relativism and the Sociology of Knowledge. In M. Hollis & S. Lukes, eds. *Rationality and Relativism*.

Benhin, J., 2006. *Climate change and South African agriculture: impacts and adaptation options*, South Africa: Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Berkes, F. et al., 2003. *Navigating social-ecological systems : building resilience for complexity and change*, Cambridge ; New York: Cambridge University Press. Available at: http://site.ebrary.com/lib/aberdeenuniv/Doc?id=10069848 .

Bester, J. et al., 2001. The Nguni: a case study. In *Proceedings of International Symposium "Managing Biodiversity in Agricultural Ecosystems"*. Montreal, Canada. Available at: http://www.amatava.com/nguni_j_bester.htm [Accessed August 24, 2009].

Brown, C., 1992. *Namibia's Green Plan to Ensure for Present and Future Generation a Safe and Healthy Environment and a Prosperous Country*, Windhoek, Namibia: Ministry of Wildlife, Conservation and Tourism.

Bryceson, D.F., 2004. Agrarian Vista or Vortex: African rural livelihood policies. *Review of African Political Economy*, 31(102), 617.

Bryceson, D.F., 2002. The Scramble in Africa: Reorienting Rural Livelihoods. *World Development*, 30(5), 725-739.

Bunch, R., 1985. *Two Ears of Corn: A Guide to People-Centred Agricultural Improvement*, Oklahoma: World Neighbours.

Carney, D. et al., 1999. *Livelihood approaches compared: a brief comparison of the livelihoods approaches of the UK Department for International Development (DFID), CARE, Oxfam and the UNDP. A brief review of the fundamental principles behind the sustainable livelihood approach of donor agencies.*, London: Department for International Development.

Carolan, M.S., 2006. Sustainable agriculture, science and the co-production of ‘expert’ knowledge: The value of interactional expertise. *Local Environment: The International Journal of Justice and Sustainability*, 11(4), 421.

Chambers, R., 1983. *Rural Development: Putting the Last First*, Harlow: Longman.

Christensen, J.H. et al., 2007. Regional Climate Projections. In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambride University Press, pp. 847-940.

Clarence-Smith, W.G. & Moorsom, R., 1975. Underdevelopment and Class Formation in Ovamboland, 1845?1915. *The Journal of African History*, 16(03), 365-381.

Collins, H.M. & Evans, R., 2002. The Third Wave of Science Studies: Studies of Expertise and Experience. *Social Studies of Science*, 32(2), 235-296.

Collins, H., 2004. Interactional expertise as a third kind of knowledge. *Phenomenology and the Cognitive Sciences*, 3(2), 125-143.

Darwin, R., 1999. A farmer's view of the Ricardian approach to measuring agricultural effects of climatic change. *Climatic Change*, 41, 371-411.

Dirkx, E. et al., 2008. *Climate change vulnerability & adaptation assessment Namibia*, Windhoek, Namibia: Desert Research Foundation Namibia & Climate Systems Analysis Group, UCT.

Dobell, L., 1998. *Swapo's struggle for Namibia, 1960-1991: War by other means*, Basel (Switzerland): P. Schlettwein .

Donald R. Nelson, W. Neil Adger & Katrina Brown, 2007. Adaptation to Environmental Change: Contributions of a Resilience Framework. Available at: http://arjournals.annualreviews.org/doi/full/10.1146/annurev.energy.32.051807.090348?amp;searchHistoryKey=%24%7BsearchHistoryKey%7D [Accessed August 27, 2009].

Eakin, H., 2005. Institutional change, climate risk, and rural vulnerability: Cases from Central Mexico. *World Development*, 33(11), 1923-1938.

Eder, J.F., 1999. *A Generation Later: Household Strategies and Economic Change in the Rural Philippines* , Honolulu: University of Hawaii Press.

Eisler, M.C. et al., 2003. Integrated control of vector-borne diseases of livestock - pyrethroids: panacea or poison? *Trends in Parasitology*, 19(8), 341-345.

Ellis, H. & Matjila, J., 2008. After devastating floods, Namibians fight cholera and wait for a return to normalcy. *UNICEF info by country*.

Erkkila, A., 2001. Living on the land: change in forest cover in north central Namibia 1943–1996. *Silva Carelica*, 37, 118-139.

Escobar, A., 1995. *Encountering Development: The Making and Unmaking of the Third World,*, Princeton: Princeton University Press.

Francks, P., Boestel, J. & Kim, C.H., 1999. *Agriculture and economic development in East Asia*, Routledge.

Gewald, J., 1998. *Herero heroes : a socio-political history of the Herero of Namibia, 1890-1923*, Athens, Ohio ; Oxford: Ohio University Press : James Currey.

Gewald, J., 2003. Near death in the streets of Karibib: famine, labour and the coming of the Ovambo to Central Namibia. *Journal of African History*, 44, 211-239.

GRN, 2002. Initial National Communication to the United Nations Framework Convention on Climate Change.

GRN, 2008a. *Press conference by His Excellency Hifikipunye Pohamba, President of the Republic of Namibia, on the ememergency situation caused by drought and floods in the North and North Eastern parts of Namibia*, State House, Windhoek, Namibia: Government of Republic of Namibia. Available at: http://209.88.21.55/opencms/export/sites/default/grnnet/GRNNews/grnnews/2008/March/downloads/Floods_in_the_north_declared_an_emergency_situation.pdf [Accessed August 20, 2009].

GRN, 2008b. *Third National Development Plan (NDP3), 2007/2008-2011/12, Volume I*
, Windhoek, Namibia: Government of Republic of Namibia.

Harvell, C.D. et al., 2002. Climate Warming and Disease Risks for Terrestrial and Marine Biota. *Science*, 296(5576), 2158-2162.

Hayami, Y. & Kikuchi, M., 2000. *A rice village saga: Three decades of green revolution in the Philippines*, Basingstoke: Macmillan.

Hayes, P., 1992. A history of the Ovambo of Namibia, c. 1880-1935 /--by Patricia Hayes.

Hewitson, B.C. & Crane, R.G., 2006. Consensus between GCM Climate Change Projections with Empirical Downscaling: Precipitation Downscaling over South
Africa. *International Journal of Climatology*, 26(10), 1315-1337.

Hillyer, A., McDonagh, J. & Verlinden, A., 2006. Land-use and legumes in northern Namibia - The value of a local classification system. *Agriculture Ecosystems & Environment*, 117, 251-265.

Howden, S. & Turnpenny, J., 1998. *Modelling Heat Stress and Water Loss of Beef Cattle in Subtropical Queensland Under Current Climates and Climate Change*, CSIRO Wildlife & Ecology Resource Futures Program.

Huq, S. & Reid, H., 2007. *A Vital Approach to the Threat Climate Change Poses to the Poor. Community-Based Adaptation: An IIED Briefing*, London: IIED.

IECN, 2008. *Collecting baseline data for climate change adaptation in Omusati Region, Namibia* , Windhoek, Namibia: Integrated Environmental Consultants Namibia.

IPCC, 2007. *Climate Change 2007: The Physical Science Basis*, Cambridge, UK: Published for the.

Ipinge, S., 1998. *A proposal for release of pearl millet varieties* , Windhoek, Namibia: Ministry of Agriculture, Water & Forestry. Available at: http://www.mawf.gov.na/Documents/proposal.pdf.

IPPR, 2001. Namibia Labour Force Survey 1997. Available at: http://www.ippr.org.na/Database%20files/page3.html [Accessed June 23, 2009].

IPPR, 2002. Namibia Labour Force survey 2002. Available at: http://www.ippr.org.na/Database%20files/page3.html.

IPPR, 2006. Namibia Labour Force Survey 2004. Available at: http://www.ippr.org.na/Database%20files/page3.html.

Jasoni, R.L., Smith, S.D. & III, J.A.A., 2005. Net ecosystem CO₂ exchange in Mojave Desert shrublands during the eighth year of exposure to elevated CO₂. *Global Change Biology*, 11(5), 749-756.

Jones, P.G. & Thornton, P.K., 2009. Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. *Environmental Science & Policy*, 12(4), 427-437.

Katjavivi, P., 1988. *A history of resistance in Namibia*, London: Currey.

Kerven, C., 1997. *The Knife Cuts on Both Blades: Redefining Property Rights in Eastern Oshikoto Region, Namibia*, London, UK: Overseas Development Institute.

Kock, R., Wambua, J. & Mwanzia, J., 1999. Rinderpest Epidemic in Wild Ruminants in Kenya 1993-97. *The Veterinary Record*, 145, 275-283.

Leichenko, R. & O'Brien, K., 2008. *Environmental Change and Globalization: Double Exposures.*, Oxford: Oxford University Press.

Lugo, A.E., 1995. Management of Tropical Biodiversity. *Ecological Applications*, 5(4), 956-961.

Marsh, A. & Seely, M., 1992. *Oshanas: Sustaining People, Environment and Development in Central Owambo, Namibia*, Windhoek, Namibia: Desert Research Foundation and SIDA.

McKittrick, M., 1998. Generational struggles and social mobility in Western Owambo communities. In P. Hayes et al., eds. *Namibia under South African Rule. Mobility & Containment 1915-46*. Oxford: James Currey , pp. 241-262.

Mendelsohn, J. et al., 2006. *Farming systems in Namibia*, Windhoek, Namibia: Research & Information Services of Namibia. Available at: http://www.loc.gov/catdir/toc/fy0710/2006316112.html .

Mendelsohn, J., El Obeid, S. & Roberts, C., 2000. *A profile of north-central Namibia*, Windhoek, Namibia: Gamsberg Macmillan.

Mendelsohn, J. et al., 2002. Atlas of Namibia : A portrait of the land and its people.

Mendelsohn, R., Nordhaus, W. & Shaw, D., 1994. The Impact of GlobalWarming on Agriculture: A Ricardian Analysis. *American Economic Review*, 84, 753-771.

Midgley, G. et al., 2005. *Assessment of potential climate change impacts on Namibia's floristic diversity, ecosystem structure and function*, Kirstenbosch Botanical Garden, Cape Town: South African National Biodiversity Institute.

Miller, R., 1997. The Owambo basin of northern Namibia. In R. Selley, ed. *African basins: sedimentary basins of the world*. Amsterdam: Elsevier, pp. 237-268.

Ministry of Agriculture, Water and Rural Development, 1995. *Namibia Agricultural Policy*, Windhoek.

Nangolo, E.N., Willemse, N. & Mwya, S., 2006. *Vital Signs of Namibia 2004: An Integrated State of the Environment Report*, Windhoek, Namibia: Ministry of Environment & Tourism .

NANGULA, S. & OBA, G., 2004. Effects of Artificial Water Points on the Oshana Ecosystem in Namibia. *Environmental Conservation*, 31(01), 47-54.

Nelson, N. & Wright, S., 1995. *Power & Participatory Development*, London: IT Publications.

NPC, 2006. *Namibia Household Income & Expenditure Survey 2003/2004*, Windhoek, Namibia: Central Bureau of Statistics, National Planning Commission.

O'Brien, K. et al., 2004. Mapping vulnerability to multiple stressors: climate change and globalization in India. *Global Environmental Change Part A*, 14(4), 303-313.

Parsons, D.J. et al., 2001. Integrated models of livestock systems for climate change studies. 1. Grazing systems. *Global Change Biology*, 7(1), 93-112.

Reed, M.S., Dougill, A.J. & Taylor, M.J., 2007. Integrating local and scientific knowledge for adaptation to land degradation: Kalahari rangeland management options. *Land Degradation & Development*, 18(3), 249-268.

Reed, M.S., Dougil, A.J. & Baker, T.R., 2008. Participatory indicator development: what can ecologists and local communities learn from each other? . *Ecological Applications*, 18(5), 1253-1269.

Reilly, J.M. & Schimmelpfennig, D., 1999. agricultural impact assessment, vulnerability and the scope for adaptation. *Climatic Change*, 43, 745-788.

Relief Web, 2009. Report on the flooding in Namibia and Angola. *Relief Web Latest Updates*. Available at: http://www.reliefweb.int/rw/rwb.nsf/db900SID/EDIS-7QBPWA?OpenDocument [Accessed August 20, 2009].

Richards, P., 1985. *Indigenous agricultural revolution: ecology and food production in West Africa*, London: Hutchinson.

Richardson, K. et al., 2009. *Synthesis Report: Global risks, challenges & decisions, Copenhagen 2009, 10-12 March*, Copenhagen, Denmark: International Alliance of Research Universities. Available at: http://climatecongress.ku.dk/pdf/synthesisreport/ [Accessed August 15, 2009].

Rigg, J., 2006. Land, farming, livelihoods, and poverty: Rethinking the links in the Rural South. *World Development*, 34(1), 180-202.

Robbins, P., 2008. *Policitcal Ecology* 2nd ed., Oxford: Blackwell.

Rohde, R., 1997. *Nature, cattle thieves and various other midnight robbers: Images of people, place and landscape in Damaraland, Namibia*. University of Edinburgh, .

Rukandema, M. et al., 2009. *FAO/WFP Crop, livestock and food security assessment mission to Namibia*, Rome, Italy: Food and Agriculture Organisation.

Scoones, I., 1998. *Sustainable rural livelihoods: a framework for analysis*, Brighton, Sussex: Institute of Development Studies.

Seo, S.N. & Mendelsohn, R., 2006. *The impact of climate change on livestock management in Africa: a structural Ricardian analysis*, Pretoria, South Africa: Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Shitundeni, J. & Marsh, A., 1999. *Indigenous Soil Classification and its Possible Relevance to Forestry Extension in Central North Namibia*, Ongwediva, Namibia: CFEDP.

Siiskonen, H., 1990. *Trade and socioeconomic change in Ovamboland, 1850-1906*, Helsinki: Societas Historica Fennica.

Stern, N., 2009. *Blueprint for a Safer Planet: How to Manage Climate Change and Create a New Era of Progress and Prosperity*, The Bodley Head Ltd.

Stige, L.C. et al., 2006. The effect of climate variation on agro-pastoral production in Africa. *Proceedings of the National Academy of Sciences of the United States of America*, 103(9), 3049-3053.

Sullivan, S., Konstant, T.L. & Cunningham, A.B., 1995. The Impact of Utilization of Palm Products on the Population Structure of the Vegetable Ivory Palm (Hyphaene petersiana, Arecaceae) in North-Central Namibia. *Economic Botany*, 49(4), 357-370.

Sullivan, S., 2000. Myth and Science; Getting Science Right or Introducing Science in the First Place? Local Facts, Global Discourse and Desertification in North-West Namibia - . In P. Stott & S. Sullivan, eds. *Political Ecology: Science, Myth and Power*. London: Arnold.

Sullivan, S., 1999. The Impacts of People and Livestock on Topographically Diverse Open Wood- and Shrub-Lands in Arid North-West Namibia. *Global Ecology and Biogeography*, 8(3/4), 257-277.

Swift, J., 1996. Desertification narratives, winners and losers. In M. Leach & R. Mearns, eds. *The lie of the land. Challenging received wisdoms on the African environment*. Oxford: James Currey, pp. 73-90.

Tadross, M. et al., 2007. *Changes in Daily Rainfall Characteristics Affecting Agriculture: Observations and Projections for Malawi, Mozambique and Zambia*, Washington D.C.: World Bank.

Tapscot, C. & Hangula, L., 1994. *Fencing of Communal Rangeland in Northern Namibia: Social and Ecological Implications*, Windhoek, Namibia: University of Namibia: Social sciences division.

The Namibian, 2009. Food security prospects in central north looks bleak. *The Namibian*. Available at: http://www.namibian.com.na/news/full-story/archive/2009/january/article/food-security-prospects-in-central-north-looks-bleak/ [Accessed August 24, 2009].

Thomas, D.S.G. & Twyman, C., 2004. Good or bad rangeland? Hybrid knowledge, science, and local understandings of vegetation dynamics in the Kalahari. *Land Degradation & Development*, 15(3), 215-231.

Thomas, D. & Middleton, N., 1994. *Desertification: Exploding the Myth*, Chichester: Wiley.

Thomas, D.S.G., 1997. Science and the desertification debate. *Journal of Arid Environments*, 37(4), 599 - 608.

University of Namibia, 2008. *Research on Farming Systems Change to Enable Adaptation to Climate Change*, Namibia: UNAM.

Uno, D., 2005. Farmer's selection of local and improved pearl millet varieties in Ovamboland, Northern Namibia. *African Study Monographs*, 30, 107-117.

Verlinden, A. & Kruger, A.S., 2007. Changing grazing systems in central north Namibia. *Land Degradation & Development*, 18(2), 179-197.

Verlinden, A., Seely, M. & Hillyer, A., 2006. Settlement, trees and termites in Central North Namibia: A case of indigenous resource management. *Journal of Arid Environments*, 66(2), 307-335.

Verlinden, A. & Dayot, B., 2005. A comparison between indigenous environmental knowledge and a conventional vegetation analysis in north central Namibia. *Journal of Arid Environments*, 62, 143-175.

Verlinden, A. & Dayot, B., 2000. Working with local knowledge systems in a GIS for natural resource assessment, planning and management in North-Central Namibia. In *Proceedings of the Regional Workshop on Spatial Approaches for Land Use and Local Governance*. pp. 63–78.

Walker, B. et al., 2004. Resilience, Adaptability and Transformability in Social–ecological Systems. , 9(2), 5.

Ward, J.K. et al., 1999. Comparative responses of model C3 and C4 plants to drought in low and elevated CO₂. *Global Change Biology*, 5(8), 857-867.

Weidlich, B., 2008. Namibia: 65 000 Affected By Floods. *The Namibian*. Available at: http://allafrica.com/stories/200803260446.html.

Weinstock, J., 1984. Getting the right feel for soil: traditional methods of crop management. *The Ecologist*, 14, 146-149.

Werner, W., 1998. *'No one will become rich'. Economy and society in the Herero reserves in Namibia, 1915-1946*, Basel (Switzerland): P. Schlettwein.

Werner, W., Adams, F. & Vale, P., 1990. The land issue in Namibia: an enquiry.

Werner, W. & Kruger, B., 2007. *Redistributive Land Reform and Poverty Reduction in Namibia*, Windhoek, Namibia: Livelihoods after land reform/Desert research Foundation Namibia. Available at: http://www.lalr.org.za/namibia/redistributive-land-reform-and-poverty-reduction-in-namibia/view.

Williams, F., 1994. *Precolonial communities of Southwestern Africa: A history of Owambo Kingdoms 1600-1920*, Windhoek, Namibia: National Archives of Namibia.

Williams, N. & Baines, G. eds., 1993. *Traditional ecological knowledge: Wisdom for sustainable development*
, Canberra, Australia: Centre for Resource and Environmental Studies, Australian National University.

Woodward, F.I. & Lomas, M.R., 2004. Simulating vegetation processes along the Kalahari transect. *Global Change Biology*, 10(3), 383-392.

Ziervogel, G., Bharwani, S. & Downing, T.E., 2006. Adapting to climate variability: Pumpkins, people and policy. *Natural Resources Forum*, 30(4), 294-305.

Ziervogel, G. & Taylor, A., 2008. Feeling stressed:Integrating climate change adaptation with other priorities in South Africa. *Environment*, 50(2), 32-41.

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