Adaptation to Climate Change and Variability: Farmer Responses to Intra-seasonal Precipitation Trends in South Africa

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Abstract We describe the nature of recent (50 year) rainfall variability in the summer rainfall zone, South Africa, and how variability is recognised and responded to on the ground by farmers. Using daily rainfall data and self organising mapping (SOM) we identify 12 internally homogeneous rainfall regions displaying differing parameters of precipitation change. Three regions, characterised by changing onset and timing of rains, rainfall frequencies and intensities, in Limpopo, North West and KwaZulu Natal provinces, were selected to investigate farmer perceptions of, and responses to, rainfall parameter changes. Village and household level analyses demonstrate that the trends and variabilities in precipitation parameters differentiated by the SOM analysis were clearly recognised by people living in the areas in which they occurred. A range of specific coping and adaptation strategies are employed by farmers to respond to climate shifts, some generic across regions and some facilitated by specific local factors. The study has begun to understand the complexity of coping and adaptation, and the factors that influence the decisions that are taken.

Keywords South Africa · Climate change · Adaptation strategies · Coping mechanisms · Farmer responses · Perception · Self-organising mapping

1 Introduction

Individuals, communities, and nations have to varying degrees had to cope with and adapt to climate variability and change for centuries (e.g. Tyson et al. 2002, O'Connor and Kiker 2004). For societies that directly utilise natural resources within livelihoods, for example through farming, changes in climate during the twenty-first century may represent significant disturbances and threats, especially where changes may be significant and pervasive and incorporate elements of

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surprise through the occurrence of extreme events. Many climate models and predictions suggest that this will be the widespread case in significant areas of Africa (e.g. Desanker et al. 2001), where many societies still rely on rural livelihoods and the use of natural resources.

Being able to adapt to climate change and variability may be linked closely to vulnerability (Few 2003), with the ability to withstand shocks and stresses to livelihoods considered especially important (Moser 1998, Adger 2000, Sokona and Denton 2001, Beg et al. 2002, Metz et al. 2002). High levels of vulnerability and low adaptive capacity in the developing world have been linked to factors including reliance on natural resources (World Bank 2000), a limited ability to adapt financially and institutionally (Beg et al. 2002), low per capita GDP and a lack of safety nets (Desanker et al. 2001). The 'flip side' of vulnerability is resilience, (Klein et al. 2003), with growing evidence that people may act positively to enhance their resilience (Salinger et al. 2005, Tompkins 2005) if wider dimensions of livelihood change permit this (Robledo et al. 2004).

In subtropical areas of Africa climate variability, uncertainty and events such as drought are phenomena that some societies have coped with for many generations and even centuries (e.g. Nicholson 2001, Vogel 2005, Washington et al. 2005). There is a view however that many groups in the developing world are amongst the most vulnerable and helpless in the face of climate change (Sokona and Denton 2001), in part due to their vulnerability to changes in the natural resource base. Given the paradox between views of present day helplessness and historical adaptability, it is vital to investigate how exposure to climatically driven changes in the environment can affect both its use and people's livelihoods. An understanding so gained could make a contribution to facilitating and informing reactions to developing changes and uncertainties within climate systems more widely.

Progressing our understanding of both the science of climate change and societal responses is fraught with theoretical, conceptual and empirical challenges. One of the most pertinent is how to deal with uncertainty and variability. That climate is changing is a certainty (IPCC 2001). However knowing what this change will comprise in different places is uncertain, with different models and scenarios generating different and sometimes contradictory outcomes (IPCC 2001). Arguably it is becoming increasingly important to recognise the limits of our scientific knowledge (Brown 2004) and interrogate our understanding of what uncertainty and variability mean to how people live their everyday lives.

In this paper we investigate the nature of recent rainfall variability in part of southern Africa, and how, if at all, this variability is recognised and responded to on the ground by natural resource users. We have conducted research within part of the summer rainfall zone of South Africa, as part of a larger project investigating the adaptive capacity of natural-resource dependent societies to future climate changes. We take a research approach informed by political ecology and embedded in the discipline of geography, combining deep statistical analysis of climate data and the application of the livelihoods framework (e.g. Chambers 1995) for social data collection and analysis. Research in the overall project falls into four components, investigating (1) dimensions of recent historical climate variability, change and extreme events in the region; (2) recent and contemporary responses and coping strategies to these parameters by farmers, including whether or not these climate parameters were expressly recognised (cf Meze-Hausken 2004 in Ethiopia); (3) the processes that facilitate societal responses to changes in climate parameters, and (4) the transferability of any generic characteristics of learning and response, with a view to investigating whether the capacity to adapt to future changes can be identified or even facilitated in areas that may be 'at risk' in the future. In this paper we focus on the first two components.

We first identify and characterise spatial dimensions of climate phenomena that may have changed or varied within the recent historical past (defined as the last 50 years). Second we investigate, through qualitative and quantitative household level research within three regions that have experienced particular dimensions of climate variability, the ways in which climate dynamics are recognised and have been responded to in terms of adaptations in natural resource use and agricultural practices. The information gained may then be useful in beginning to understand why and how natural resource users make particular decisions, which is relatively poorly understood, particularly in Africa (Thomas and Sumberg 1995).

2 Climate Variability, Uncertainty and Change

A number of scales, approaches and organising frameworks have been employed to structure investigations of the relationships between environmental change and social behaviour (see Olson et al. 2004 for a review). Household-level studies have proved valuable for understanding the nuances of responses to environmental change, with for example several. studies of drought in Africa taking this approach (e.g. Bratton 1987, Corbett 1988, Campbell 1999). Household analyses need however to be situated in an understanding of the larger scale frameworks that impact on choice and behaviour, as illustrated in Campbell and Olsson's (1991) 'kite framework' of spiralling multiscalar interactions, an approach closely related to the political ecology framework (e.g. Zimmerer 1994, Rocheleau et al. 1996).

Our investigation is framed to enhance understanding of how societies may adapt to future climate change, and is strongly informed by political ecology, especially in the ideal of integrating environmental and societal processes in a balanced manner (Walker 2005). The research is also strongly framed by the traditions of geography (e.g. Turner 2002), whereby we sequence our analyses to first investigate climate trends and then secondly people's recognition of and reactions to these trends.

2.1 Climate Variables: Informing Adaptation Research

It would not be sufficient to consider changes over time in mean annual climate parameters alone. Variations about the mean are neither sufficient to capture the attributes of climate than impact on natural resource users (Usman and Reason 2004), nor do they indicate the day-to-day conditions faced by farmers (Mortimore and Adams 2001). Actual climate phenomena, and their temporal and spatial dynamics, are more critical to understanding the triggers to behavioural responses

(Smit et al. 2001). The magnitude of variability, frequency of event occurrence and rate of change within climate systems are examples of important attributes as they can affect people's ability to respond, cope and to adapt (Dessai and Hulme 2003, Hulme 2003).

Rainfall has been regarded as the most significant climate parameter affecting human activities (Vogel 2000). The southern African summer rainfall zone has a relatively dry climate with a spatial patterning of mean annual rainfall, predominantly in the October-March summer months, that reflects factors including the penetration of moisture from sources in the southwest Indian Ocean associated with movements of the ITCZ, moisture penetration from the southeast tropical Atlantic (Reason 2001, Cook et al. 2004) and topographic effects. The consistency of rainfall within the wet season also varies, with dry spells being associated with shifts in the tropical temperate trough over the region (Washington and Todd 1999, Usman and Reason 2004). There is also a high degree of interannual variability reflecting ENSO events and regional SST effects (e.g. Mason and Jury 1997, Todd and Washington 1998). Droughts, linked to the failure of rains within the expected October-March period, and extreme rainfall events (Mason et al. 1999), such as that associated with cyclone Eline that brought flooding to parts of Limpopo Province (South Africa) and Gaza District (Mozambique) in February 2000, are not unexpected either. There are distinctions between these two extreme event phenomena because meteorological droughts are not unexpected, and which forecasting strategies are attempting to allow better prediction of, while extreme rainfall represents the type of 'surprise' event that is even less predictable than drought.

For farmers and other land users, the concepts of drought and extreme rainfall are not necessarily sufficient to fully capture the dynamics and characteristics of climate variability that are critical to decision making. Within the general phenomena of rainfall variability, intra-seasonal factors (Tennant and Hewitson 2002) including the timing of the onset of first rains, which affects crop planting regimes, the distribution and periodicity of rain events within the growing season (Mortimore and Adams 2001), and the effectiveness of the rains in each precipitation event (e.g. Usman and Reason 2004), represent real criteria that impinge of the effectiveness and success of farming (Levey and Jury 1996). These parameters can embody elements of uncertainty and unpredictability (or surprise), but also may experience trends in occurrence that could lead to changes in natural resource use and behaviour over and above those that might be facilitated by better drought forecasting.

3 Investigating Climate Variability Through Self Organising Mapping

Crane and Hewitson (2003) used self-organising maps (SOMs) to examine spatial and temporal dimensions of larger scale climate data sets. The SOM approach classifies and groups data into meaningful homogeneous regional representations of the variability within the total data. For precipitation data SOMs proportionally integrate rainfall records from station data into a regional data set. This is achieved by taking the shared regional variability from the locally derived variability in each station record. Nodal data points are identified statistically within the total area covered by the spatial data set, with the nodes representing the observed data distribution (Hewitson and Crane 2002). The number of nodes can be chosen manually, depending on the level of regionalisation that is required for a particular study. This formulates a method by which the total data set is then trained to produce a number of regions, each with distinctive criteria identified from within the data. This regionalisation is therefore based on the occurrence of rainfall events, so that stations within the data set that receive rainfall under related synoptic conditions fall within the same region (Tennant and Hewitson 2002).

Using a 276-record northeastern summer rainfall zone daily rainfall data set, part of the country-wide data of Tennant and Hewitson (2002), we focused on 1950–1999, the period of historical memory in the population, to produce a 12 region SOM analysis for the area 24°–35°E to 20°–30°S (Fig. 1). To understand the climatic underpinning of the regionalisation, it was necessary to calculate key rainfall parameters from the original station data from each region. Following Tennant and Hewitson (2002). we selected eight factors considered to capture components of rainfall relevant to farming activities and other forms of natural resource use:

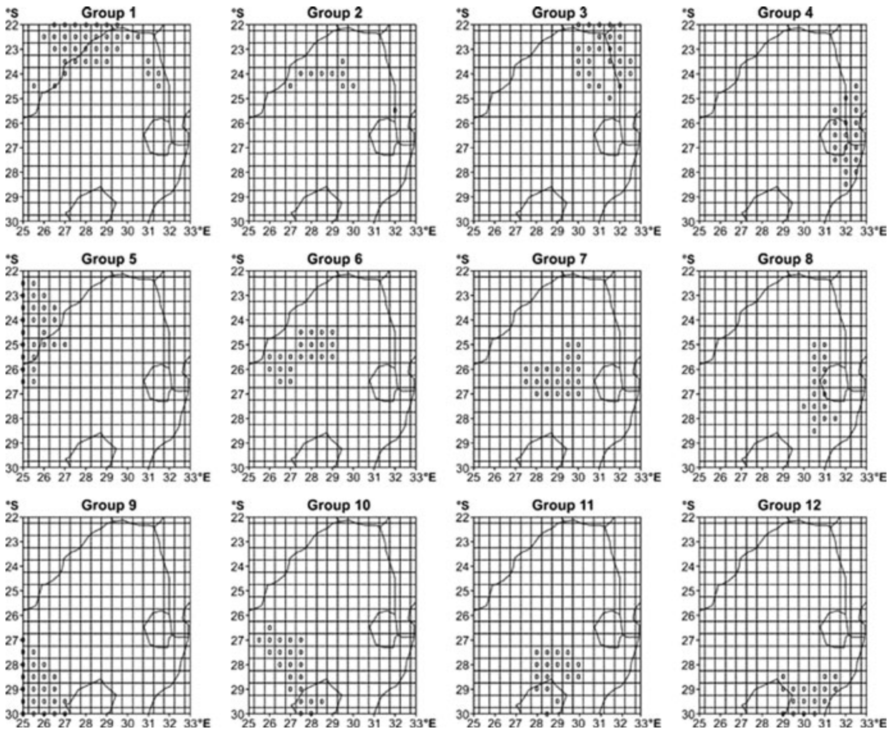

Fig. 1 The twelve homogeneous rainfall regions produced by the SOM exercise for northeast South Africa rainfall data, 1950–1999. After analysis of the underlying data and trends in precipitation, regions 1, 6 and 11 were selected for further investigation

- mean rainfall per day (mean)
- maximum rainfall event per month (xmax)
- total number of rain days per month (rda)
- rain days exceeding 2 mm per month (rdb)
- rain days exceeding 20 mm per month (rdc)
- dry spell factor: the number of consecutive days without rainfall between station rain days with 2 mm or more rainfall (dfac)
- wet spell factor: the number of consecutive station rain days exceeding 2 and 20 mm (wfac)
- 80th percentile rainfall event (nth)

For each parameter, mean value and trend plots for the 50 year data set were produced. Figure 2 exemplifies this for the mean number of monthly rain days, showing 50 year mean values and the monthly trend plots. For each of the twelve regions, values for each parameter were calculated using a weighted mean of all station values from the region. Time-time plots, with the x axis representing years and the y axis months, were produced to allow trends in the parameters to be identified by region (Fig. 3). Taking the mean and trend plots for all eight parameters for the overall study area and the parameter plots for each of the twelve SOM regions, three regions, 1, 6 and 11, were selected for further investigations on the basis of the precipitation variability characteristics they possess.

3.1 Study Region Characteristics

Region 1, in northern Limpopo Province, north of the Soutpansberg, has a long term mean annual rainfall of 400–500 mm. The climate data show evidence of a growing length to the dry season, resulting in a later start to the wet season, in late October-early November. Within the wet season there has been a trend towards fewer rain days in November and December and an increase in the overall occurrence of dry spells, in effect representing potentially damaging rainless spells within the growing season. Droughts have been frequent in the last two decades (1982–1983, 1987, 1990 and 1994 in particular).

Region 6 covers parts of North West Province, extending from Mafikeng in the west to the border area with Gauteng in the east. This is a dry region with 500–600 mm mean annual rainfall, and regular droughts. In the last 50 years early-season rain days have been increasing (September and October), but in the main wet season the principle characteristic has been interannual variability in rainfall amounts and distributions, without any specific trends in wetting or drying being identifiable.

Region 11 is in northwest KwaZulu Natal and has a recent historical mean rainfall in the 800–900 mm pa range. There has been increasing interannual variability in the rainfall record and a trend towards higher rainfall in the first half of the growing season, with an increase in early season rain days and a decline in late season (February and March) rains. This is further represented by an increase in heavier rainfall events in the early season and a predominance of low volume rain events

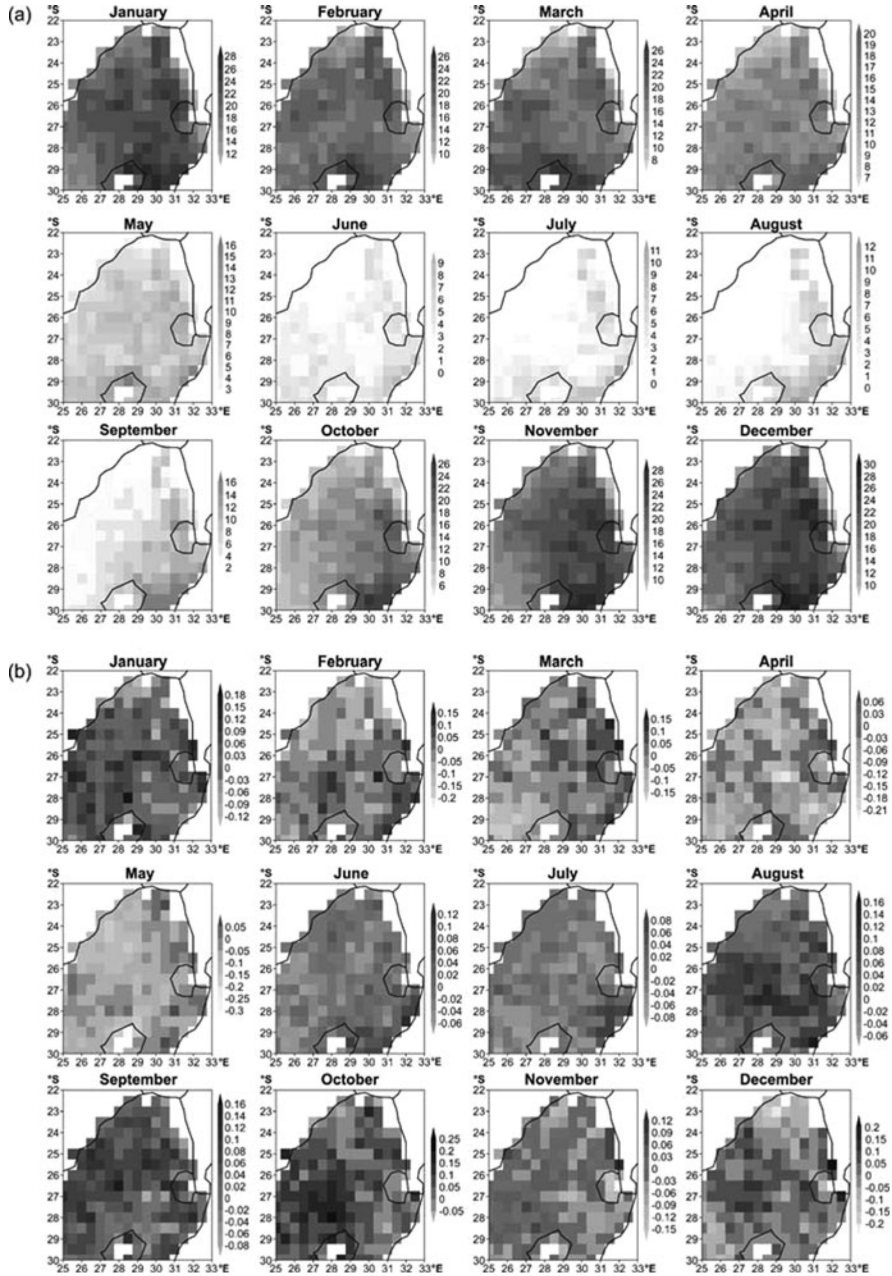

Fig. 2 **a** Mean number of rain days per month by 0.5° grid cells, 1950–1999. **b** Trend plot for the total monthly number of rain days, 1950–1999. *Darker shades* indicate an increasing number of rain days per month over the 50 year period, *paler shades* a decreasing number. The data clearly show a declining number of rain days per month in all months in northern Limpopo Province, but a notable increase in early rain season (Sept–Oct) monthly rain days in western areas

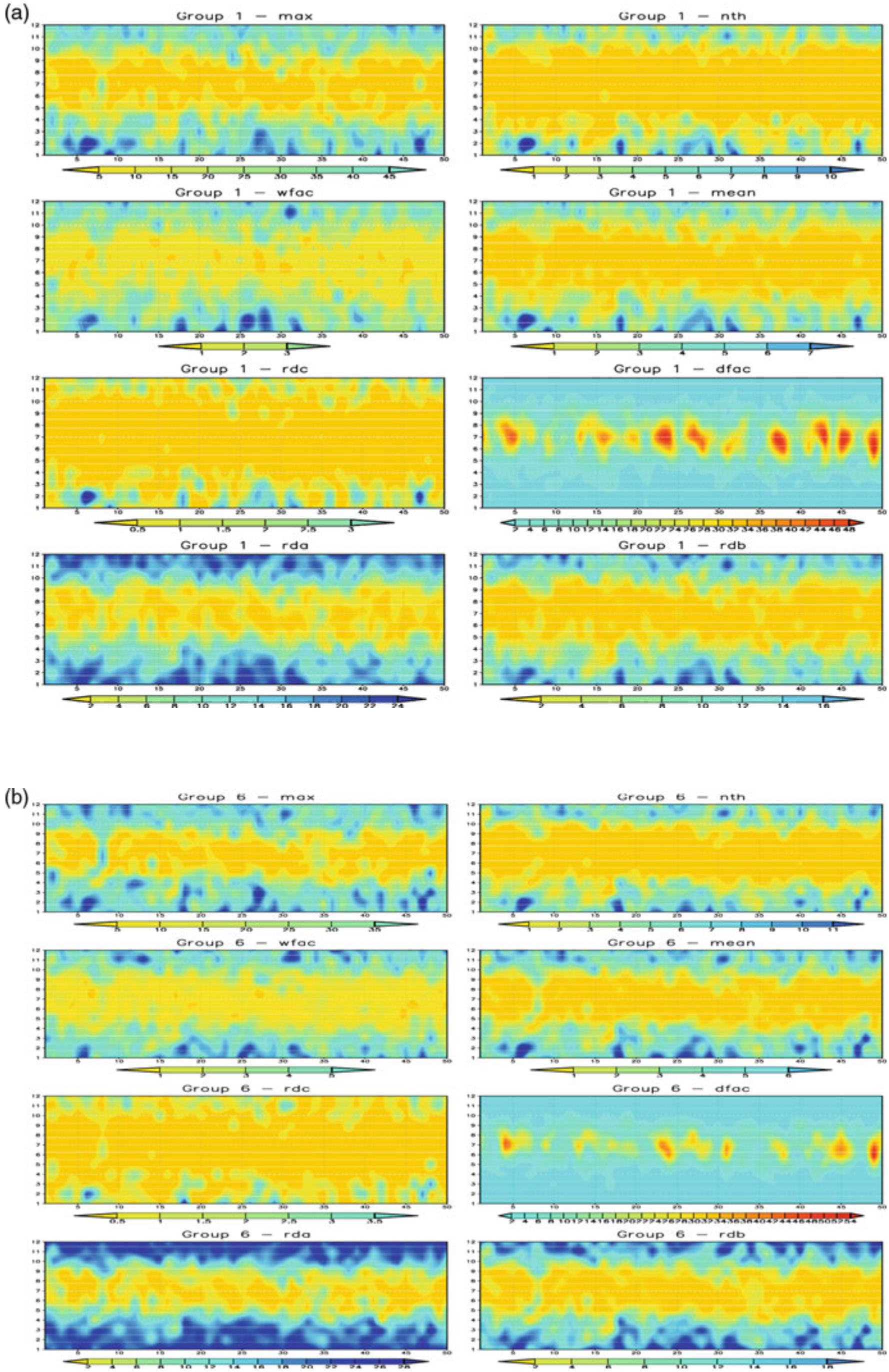

Fig. 3 (continued)

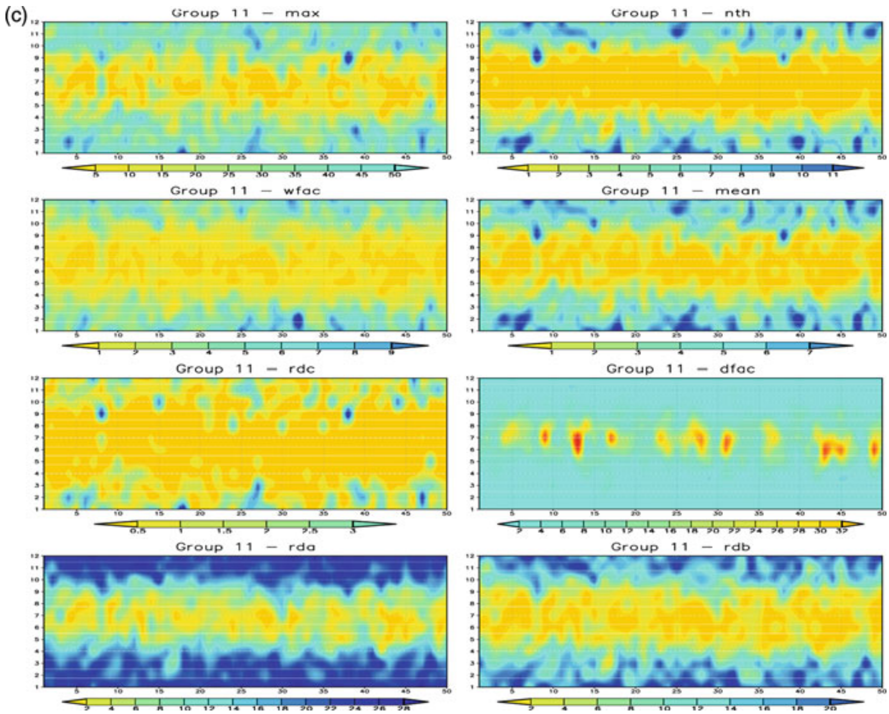

Fig. 3 Time-time plots for the eight precipitation parameters (detailed in the text) for each region selected for the study: **a** Region 1, northern Limpopo Province, **b** Region 6, North West Province, **c** Region 11 Northwest KwaZulu Natal. On each graph the *x axis* represents years, starting from year 1, 1950. The *y axis* represents months of the year. The plots visualise complex data sets, such that for each parameter, *paler shades* represent lower numbers on the relevant scale and *darker shades* higher values. For example, on plot **a** Group 1-max, in year 1 (1950), the maximum rainfall event in months 6 (June) to 9 (September) was less than 10 mm; on plot **a** Group 1- rda, the total number of rain days in year 5 (1955) in month 12 (December) was over 22; on plot **c** Group 11 – rdb, the total number of days with more than 2 mm rainfall in month 1 of year 25 (January 1975) exceeded 20. The plots can be used to visualise year-to -year variability in each parameter in each of the study regions

later in the season. The growing variability in rains is illustrated by for example, rains starting late in 1990 and 1994, while in 1991 rains commenced in September but were subsequently limited until January 1992.

4 Living with Risk and Uncertainty

To investigate recognition of climate trends and to explore behaviour that may ultimately impact on resilience to climate changes, data were collected in March–July 2003 in the rural communities of Khomele (Dzanani District Limpopo Province: region 1), Mantsie (Lehurutshe District, North West Province, region 6) and eMcitsheni, (uThekula District, KwaZulu Natal, region 11).

In each village, community meetings were first held to give villagers the opportunity to raise questions about the research and to discuss perceptions of livelihood issues and the local environment. Fifty focus groups were used for repeated exercises, with people from all sectors of the communities, embracing both genders, different age groups, social statuses, and livelihood activities (Table 1), were held around specific topics. Meetings and exercises were conducted by an experienced researcher assisted by a trained translator, facilitating full group involvement and minimising dominance by individuals. Exercises were repeated between groups, some of which had overlapping membership that facilitated triangulation of findings. Participatory farm visits and the time spent in each village, plus repeat visits, enabled further triangulation and cross-checking of findings.

Structured questionnaires and semi-structured interviews were conducted with thirty key informants at each village, providing detailed livelihoods information and perceptions of risk and change, social capital, institutions and capacity (Table 1). A cross-section of each community was selected using wealth-proxy records and advice from NGO and agricultural extension officials and local leaders. Interviews were also conducted with different institutions and officials working in the area and province level authorities. Importantly for the goals of this research, early questions to communities were not expressly directed towards climate. Instead, questions addressed wider themes including environmental risk, uncertainty, and food security. Climate issues were only introduced into questioning when raised by respondents, or in the later stages of the process when different climate characteristics were considered, and when questions were asked relating to forecasting

Table 1 Structure of the village-level research and data collection

Research component	Content/activity
Introductory community meeting	Introductions, links with NGOs & ministries. Village mapping activity, history timeline for village, structure of village, associations & activities, Positives and negative of living in the village
Focus groups Examples of groups: • School, church, women and horticulture, tribal authorities, crop farmers, livestock farmer, irrigation groups, dryland farmers, youth, poultry and pig farmers, business, no participation	Specific exercises (timelines, ranking activities, network diagrams): • History of the group • Farming calendar (when relevant to group) • Social and environmental changes • Past, current, future responses to changes
Semi-structured questionnaires & follow-up interviews 30 key informants per village	• Baseline livelihood information, including household income & costs, livelihood components, farming activities • Food security • Trust, solidarity, reciprocity • Understanding uncertainty • Managing risks • Forecasting

(cf Eakin 2000, Ziervogel and Downing 2004). Questions relating to climate parameters were non-directional: for example, respondents were asked, in questions about uncertainty, what they considered normal rainfall to be in their community, and whether any changes appeared to have occurred over a range of different timescales. When respondents themselves introduced climate related issues into discussion, these were followed up in the same manner as other environmental and socio-economic factors relating to risk and uncertainty. Climate change and risk was therefore able to emerge within the analysis when included in the responses of those questioned, avoiding the possibility of researcher-directed responses, or the possibility that respondents would give answers ‘preferred’ by the researchers.

Data analysis comprised complementary qualitative and quantitative techniques, comparing statistical patterns in the data with patterns in coded thematic interview narratives, interpretation of participatory and ranking exercises. Such a mixed methods approach is seen as fundamental to challenging received wisdoms about the ‘validity’ and ‘truth’ associated with quantitative analyses and the ‘soft’ and ‘subjective’ accounts associated with qualitative analyses (Philip 1998, Valsiner 2000). By integrating data analyses rigorously, both across the quantitative and qualitative spectrum and across the social and natural sciences, these assumptions can be challenged (Demeritt and Dyer 2002). Articulating this process as we have done allows real progress to be made in addressing and understanding complex phenomenological issues such as adaptation to climate change.

5 Recognising Changes in Climate

Respondents showed an acute awareness of the changing climate trends around them, with for example, 80% of respondents across the three locations relating changes in long-term patterns to increased variability and unpredictability. Table 2 shows how climate characteristics are recognised in each area and illustrates the notable differences in the responses regarding the nature of these changes.

Analysis specifically aimed to distinguish between *variability* as an expected climate phenomenon and *increased variability* linked with unpredictability (Table 2). Importantly, people’s knowledge of changes in climate in the recent past corresponds well, in terms of the phenomena recognised, with the outputs of the SOM analysis. In Khomele drought and dryness are seen as normal and expected events (70% of respondents). The main perceptions of change are in the increased variability and uncertainty of specific climate parameters (Table 2). Rains starting later, shorter wet seasons characterised by little but intense rainfall, and more intense heat in the summer were expressed as the key concerns about observed changes in, and unpredictability of, patterns of seasonality. It was reported that “*October used to be the start of the rains. The rain is not in a reliable pattern. . .not like before.*” *(respondent K22.061–64)*. Again, local views of changes in climate parameters correspond well with the regionalisation scenarios.

In Mantsie, dry conditions and drought were recognised as a normal climate characteristic by almost all respondents (Table 2). However, the periodicity of drought

Table 2 Local recognition of changes in climate characteristics

	Mantsie (region 6)	Khomele (region 1)	eMcitsheni (region 11)
Characteristics from SOM analysis	Dry, regular drought, no discernable wetting/drying trend, slight increase in inter-annual variation	Dry, regular drought, drying trend, shorter rainy seasons, increase in inter/intra-annual variability, hotter dry season	Increase in inter-annual variability and intensity of weather events, slight wetting trend
Familiarity with:			
Dry conditions	93%	70%	–
Sufficient rain/limited variability	–	–	90%
Surprise extremes:			
Heavy rain/wind	23%	60%	70%
More intense weather/unusual times	–	–	
Recognised change during the last 20 years:	5–7 yr cycle of drought less predictable	3 yr cyclic pattern drought extended	5–10 yr cycle of drought unpredictable
Later onset rainy season	67%	86%	–
Increased variability	73%	83%	77%
Total rainfall higher	–	–	56%
Total rainfall less	60% (in last 5 yrs)	83%	–
Shorter rainy season	30% (in last 5 yrs)	40%	–
Hotter dry season	13% (in last 10 yrs)	23%	–

was seen as becoming more uncertain by 73% of respondents, comparable with the increased interannual variability identified in the SOM analysis. One farmer commented "*I remember when there were heavy rains 7 years ago and the sorghum was badly damaged. It takes the 7 year cycle, this heavy rain. But now I think it takes longer between the cycles.*" *(respondent M06.065–68)*. Within eMcitsheni increased variability and uncertainty was again raised as a key concern amongst local populations, with 40% commenting upon specific changes to climate patterns over a 5–10 year period. The following respondent details the changes in rainfall parameters that he has experienced: "*normally the rains start in September, they stop in December. In January there is a little and in February and March the main rains. Now the rains start later, often in November, or some years they are early with heavy rain.*" *(respondent E14.065–67).*

5.1 Changing Climate Risk

Risk is an understanding of *threat* (Kasperson and Kasperson 2001): that is, a product of both the probability or likelihood of a particular occurrence and the related consequences perceived to affect people's livelihoods (Stirling 2003). Awareness of climate risks is complicated when the nature of these risks evolves, for example as climate changes, which may result in differences developing from place to place in the significance attached to particular risks and the responses that develop to these risks (Bulkeley 2001).

Table 3 shows the most pertinent perceptions of risks today and the responses in the three study areas from the focus group discussions. The data in the lower part of Table 3 show differences in the recognition of distinctive risks between different groups in each village. Some of this differentiation can be explained by the relevance of different risks to particular farming activities: for example, in eMcitsheni heavy rain is not perceived as a major risk by livestock farmers but, because of its potential to damage plants, it is seen as a greater risk by crop growers, including those who run commercial gardens. The variation in the overall perception of risk between villages is also notable, with for example drought being most frequently cited as a risk in Mantsie, even though it was recognised to occur regularly and thus was a familiar event (Table 2). However, it is the enhanced unpredictability of climate, as identified by 77% of respondents (Table 3), that has turned it into a major risk, i.e. there is now an uncertainly associated drought that impacts upon farming activities. Over the last 20 years, inter- and intra-annual variability were viewed as increasing, illustrated by reports of a more erratic rainfall pattern which started late and only gave light showers and increased heat in summer months.

In Khomele and eMcitsheni, the most frequently cited climate characteristic causing a risk to livelihoods is uncertainty and unpredictability (90 and 73% respectively, Table 3). In eMcitsheni this is associated with extreme events (70% of respondents, Table 2) notably snow, frost, drought, and heavy rains while in Khomele changes in the pattern of the rainy season are seen as the most significant contributor (e.g. 86% cite a later onset of the rainy season: Table 2).

6 Strategies in Response to Disturbance and Change

While the focus of group discussions was explicitly on climate events, it was also clear that many of the impacts and responses transcend the climate dimension and actions are clearly played out within the context of other pressures and disturbances on livelihoods. For example, the perceived impact of animals dying may be co-related to disease issues and lack of access to veterinary care within the area, or a lack of financial capital to pay for medicines. The entwined nature of disturbances and change-inducing factors in livelihoods cannot be ignored and is widely recognised in the literature (e.g. Campbell 1999), including in attempts to disaggregate effects and show their linkages. In our analysis, we used coding that allowed climate dimensions to be identified in both the focus group discussions and questionnaire and interview responses. For adaptation to climate change to occur, it is not necessary for households and communities to ignore other livelihood disturbances. Indeed, to be successful, adaptation arguably needs to be embedded in the full milieu of life-affecting processes. However, it is important for climate to be recognised as a significant factor, and as noted earlier, for the subtle dimensions of

Table 3 Local understandings/experience of risk and uncertainty in climate

	Mantsie (region 6)	Khomele (region 1)	eMcitsheni (region 11)
Drought experienced as problematic/negative impact on livelihoods	Yes 1957, 1977, 1979, 1981–1985, 1992–1993, 2001–2003	Yes 1974, 1982–1984, 1990–1993, 1997–1998, 2001–2003	Yes 1983, 1999–1991, 1994, 2002–2003
Heavy rain experienced as a problematic/negative impact on livelihoods	Sometimes 1994, 1999, 2000	Occasionally 1958, 1977, 2000	Yes 1996, 1998, 2001
Drought occurrence viewed as a distinctive risk	87	53	47
(by % of household total)			
Women (as % of respondents recognising this characteristic)	38	37	35
Men (as % of respondents recognising this characteristic)	62	63	65
Livestock[a] (%)	39	50	29
Cropping[a] (%)	56	69	64
Off-farm[a] (%)	35	19	21
Heavy rain occurrence viewed as a distinctive risk	23	63	53
(by % of household total)			
Women (as % of respondents recognising this characteristic)	71	47	69
Men (as % of respondents recognising this characteristic)	29	53	31
Livestock [a] (%)	0	31	13
Cropping[a] (%)	57	68	88
Off-farm[a] (%)	43	5	0
Increased variability and unpredictability of climate viewed as a risk to livelihoods	77	90	73
(by % of household total)			
Women (as % of respondents recognising this characteristic)	44	45	59
Men (as % of respondents recognising this characteristic)	56	55	41
Livestock[a] (%)	38	38	23
Cropping[a] (%)	42	63	86
Off-farm[a] (%)	20	0	9

[a]Livestock, cropping and off-farm categories represent dominant livelihood activities (by time) of respondent households who recognised each climate characteristic (i.e. for some locations this is more than 100% because some households devoted similar time to more than one type of livelihood activity).

Table 4 The perception of livelihood-affecting risks: percentage of households identifying different risks

Risk	Mantsie (region 6)	Khomele (region 1)	eMcitsheni (region 11)
Lack of capital	57%	–	–
Political factors, inherited or current	37%	–	47%
Illness	57%	–	47%
Theft	37%	–	–
Wildlife	50%	33%	–
Climate	87%	97%	77%
Economy instability or legacies	23%	–	53%
Labour shortages	–	23%	30%
Crime	–	–	67%

climate parameter change, which are the experienced realities, to be understood and reacted to.

Table 4 shows the relative importance of different risks to livelihood decision making at the household level. Information from questionnaires and follow up discussions was coded into common themes. There are regional differences that reflect the situation of each study village, for example their rural isolation (regions 1 and 6), and in KwaZulu Natal (region 11) crime associated with proximity to an urban area. Amongst the milieu of risks recognised by people in each village, however, climate is presently identified as a highly significant factor. These data highlight that decisions are influenced by a range of factors, and while climate does not operate in isolation from other factors, it does play a significant role in how people attempt to shape their livelihoods for the future.

Table 5 shows the responses to risk that households employ, with activities falling into short-term coping mechanisms and longer-term adaptation measures. We have categorised them into four groups: changes to farming practices (coping); utilising the spatial and temporal diversity of the landscape (adapting); commercialising livelihoods (adapting); and, utilising networks (both coping and adapting). Of these, the first three can be linked most closely as specific responses to changes in climate parameters, and are therefore dealt with in this paper, with networks being addressed in a further project output.

6.1 Changes to Farming Practices: Short-Term Coping

When short-term environmental variability occurs, rapid coping strategies (Berry 1989, Ellis 1998, Roncoli and Ingram 2001, Huq and Reid 2004) are employed, with similarities in actions across all three regions, During dry spells, the immediate farming response in Mantsie is to reduce investment or even to stop cropping and focus on livestock management. Half of the 80% of households with livestock in their farming portfolio chose to invest in animals during the last 5 years. An extract from a group interview illustrates this shift in focus: "*It has been some years since*

Table 5 Impacts of, and responses to, locally identified climate parameters in the study villages

MANTSIE Parameters identified by focus group	Perceived impacts	Range of responses – rapid (coping) and longer-term (adaptation)
Little rain Breaks in rainy season	• On welfare of household (e.g. hunger, family obligations, sickness/tiredness) • On NR based livelihoods (e.g. crops/livestock die, loss of seeds/animal fodder, debt)	• Change a farming practice – coping (e.g. store fodder) • Spatial/temp diversity-adapting (e.g. Take smallstock to river area or other villages, buy short-maturing crop varieties) • Commercialising –adapting (e.g. sell animals, start business, get work) • Networks- coping and adapting (e.g. community member to ask government for help, go to church, rely on relatives, collect welfare, steal)
KHOMELE **Parameters**	**Impacts**	**Responses**
Less rain Period of no rain Unpredictable Rain our of season Late rain	• On welfare of household (eg. tiredness and hunger) • On NR based livelihoods (e.g. loss of seeds/fodder, dryland crops/livestock die, more pests, soil unproductive, changes in vegetation species)	• Change a farming practice – coping (e.g. grind maize stalks as feed, use resistant maize, plant late-maturing fruit trees) • Spatial/temp diversity-adapting (e.g. use irrigated land, cut fodder/wild plants) • Commercialising –adapting (e.g. gardening projects, new business, sell livestock, get work, plant winter crops/late-maturing fruit trees, breed indigenous species) • Networks- coping and adapting (e.g. rely on relatives/government, village meetings, go to church)
EMCITSHENI **Parameters**	**Impacts**	**Responses**
Changing seasons Hail Drought Frost Heavy rain snow	• On NR based livelihoods (e.g. loss of crops/animal feed, unproductive soils, no cash-crops, animals die, lack money for transport/seeds)	• Change a farming practice – coping (e.g. store fodder, build cattle shelter) • Spatial/temp diversity-adapting (e.g. change vegetable or maize type – performance) • Commercialising –adapting (change vegetable or maize type – sale opportunities, sell livestock/goods, start projects, find work) • Networks- coping and adapting (e.g. rely on relatives, apply for government grant for vegetable project, village meetings, go to church, ask extension officer for information)

Source: Focus group discussion in each village, 2003

I farmed [grew crops] *and I think the rains are too unpredictable to farm here. I think that livestock farming is more important and I will increase my goats if I can." (Respondent M04.011–13)... "It is very risky investing in ploughing only to lose your money. I think we should invest in livestock." (Respondent M08.035–36).* The average number of livestock per household was 19, with 30% of households exceeding this number up to a maximum of 57 head of cattle.

Some respondents noted the complex environmental pressures facing livestock farmers, particularly changes in grazing resources and plant communities. These changes are described in this detailed response from one farmer in Mantsie: *"There are twelve cattle which get kept in the kraal next to the house...we also have four sheep and fifteen goats which live in this kraal nearer the house...we spend money on feed for the livestock. I used to hire a shepherd to look after them...in the last five years [grazing has] got worse. Now the grasses are thinner and more easily destroyed with fewer cattle... we are always suffering from drought...my husband thinks we should increase the number of livestock that we have to cope with this risk...right now we have stopped ploughing because there is no rain...it is best to stop cropping and save your livestock" (Respondent M11.023–24/34–36/76–95).*

There are now fewer paid labouring opportunities available locally. This is partly because during a poor rain year people who can afford to hire labour stop cropping, and partly because more people are choosing to hire tractors from commercial farmers in the area during better rainfall years. Vegetables are sold to local markets and smallstock sold to commercial farmers with the profit used to buy replacement seeds for later planting of the fields.

In eMcitsheni, coping strategies include the storing of fodder prior to the end of the wet season, in preparation for drought events, the building of cattle shelters to protect animals from snow or cold, and in some cases, the selling of extra livestock and vegetables.

6.2 Exploiting the Spatial and Temporal Diversity of the Landscape

Optimising livelihood outcomes by utilising spatial and temporal diversity in the landscape is one way in which people can spread the risks associated with climate variability and unpredictability (Eakin 2000). In eMcitsheni agricultural experimentation was viewed as a risk reduction strategy. Of the respondents, 53% noted that they had started to increase planting distances of some crops in response to perceived seasonal changes in moisture availability during the last 5 years. Others had introduced short-maturing varieties of maize in an attempt to respond to declining rainfall at the end of the growing season. Other new practices included building stone bunds to reduce soil erosion which was perceived to have increased in the last 5 years linked directly to changes in weather patterns (i.e. more intense and earlier rainfall events). The following respondent demonstrates how his farming practices have changed in direct response to the rainfall parameter changes he has experienced: *"I think it is a better strategy to start cropping earlier than September because the rains come earlier. We get more early rain. You can use this rain and* *then there is often a drought...I have also used some stone bunding to stop soil erosion when it rains." (Respondent E09.023–25/34–35).*

While these changing practices occur over relativity short temporal and spatial scales, they nevertheless demonstrate that people are making small adjustments to their farming practices in response to their understanding of changes in certain climate parameters. Changes in climate are very real to the people of eMcitsheni.

In Mantsie, 57% of respondents have also been experimenting. They have reacted to the shortening of the rainy season by the occasional use of winter maize and by trialling quick-maturing crop varieties, using seed bought in nearby towns during visits for piecework. With a growing time of three months, these reduce the risk of exposure to drought. The widely-held view in Mantsie is that drought-tolerant species offer greater flexibility in planting times. The following three cases show how attuned farmers are to the need to experiment: *"I think we need to have the correct varieties of seed to cope with this drier weather. You can get short varieties from the cooperative." (Respondent M09.037–39). "My son gets the seed to plant...he goes in September to buy them from Zeerust. I have a new mealie to plant...it grows in 3 months. This is better as it is less dependent on the rain." (Respondent M16.032–34/46–47). "We will be planting watermelons on the field because they survive in the dry...I bought some yellow maize...my friend said we should plant more crops in the winter." (Respondent M30.035/61).*

In Khomele the scale of response has been somewhat different. People have gained access to land beyond the village in attempts to tackle the problems associated with the drying trend through either exploiting the local spatial variability of rainfall or gaining access to alternative water resources. This has either been through utilising existing friendship networks and forming small groups for projects, or through drawing on extended family in nearby areas to gain access to land. The ability to access this land has also been made possible by the land redistribution policy of the post-apartheid government. Five young farmers from Khomele were successful in getting 10 ha plots in the Nwanedi farm area, which has given them regular access to river water that is used to irrigate large fields, a resource not available in Khomele.

By spreading risk in this way it is possible for households to take advantage of the often patchy nature of rainfall in the region. Whilst neighbouring villages are able to utilise land near water courses for small scale irrigated garden projects, few people in Mantsie have access to land with irrigation, and fewer still have business experience to exploit these commercial opportunities despite the close proximity to a market.

6.3 Commercialising Livelihoods Through Individual and Collective Action

Collective action has emerged as a key way to set up new opportunities to reduce vulnerability to the risks associated with climate uncertainty. This has emerged very strongly in Khomele and eMcitsheni, two communities with strong profiles of community cohesion and consensus around livelihood issues. Agricultural projects which utilised local knowledge and had a market base were the most successful. In Khomele the focus was principally on pig and cattle production to improve livelihood resilience and food security. Poultry and egg schemes were set up by government programmes as general poverty alleviation projects. Deliberate attempts to improve the resilience of these farming strategies by the government extension service has also led to a return to the incorporation of indigenous livestock breeds that are more drought resistant. Small-scale horticulture projects have also emerged to supplement the staple crops of sorghum and maize. Species of tomatoes were deliberately chosen for their drought resistant properties even though overall yields were lower than other varieties in good years, as illustrated by one entrepreneur: *"I use HTX14 tomatoes because I can sell them quickly, these tomatoes have a short growing time. This reduces the risk to me." (Respondent K18.N135–136).* Many of these projects built on existing groups of people who had built up trust over time so that experimentation and innovation were viewed as risk-averse rather than risk-prone strategies.

In eMcitsheni a maize cooperative has been established, to address marketing risks and reduce collective production and transport costs. The key to the success of the project has been cooperation and sharing of information and members all reported that it had significantly increased their resilience to adverse or unexpected weather conditions by smoothing costs and sharing risks. The following farmer demonstrates this by his emphasis on the group network: "*I only plant maize on the fields because I am part of a group of men who are my friends…we buy the maize together…we pool our resources to buy the right type…I discuss the forecast with my friends…I trust their advice. Experience has shown their advice to be reliable." (Respondent E05.010–13).*

However, by reducing individual risk, members of the group are also increasing their collective risk, for example by relying on one variety of maize rather than diversifying. Thus there is evidence that people weigh up the risks associated with different actions and make their decisions accordingly. Community horticulture projects for example were specifically set up to reduce food insecurity by reducing the vulnerability of people to the unpredictable weather. By irrigating and using collective labour supplies, these projects are seen as less sensitive to unpredictable weather patterns. These have proved exceedingly popular within the village, especially amongst women, with 87% of respondents reporting participation by household members. The women felt that these initiatives have endured because they reduce dependence on rainfed crops, which are vulnerable to damage by drought or heavy rain, and allow irrigated vegetables such as potatoes to be grown to compensate for lower maize production. The following two respondents highlight how this project has increased their food security as a direct response to unpredictable weather: "*The last three years have been successful in growing many types of vegetables…they can survive the droughts because people collect water from the taps and take it in donkey carts to the garden." (Respondent E14.096–98). "The best thing that we have done to make sure that we have food for most of the year is to become part of a vegetable project." (Respondent E20.055–56).*

In Mantsie many of the commercial activities that make overall livelihood portfolios more resilient revolve around individual rather than collective action. The village lacks effective leadership and has weak ties with external agencies such as government and non-governmental organisations. Exposure to successful projects is low and through sporadic family connections rather than more formalised networks as in other areas. Furthermore out migration of young men is still high and thus the stimulus for innovation here is low. Investments in livestock and poultry were seen as good ways for individuals to increase income during drought periods when crops were less reliable, thus acting as a buffer. Interestingly the closure of the government run cooperative forced small groups of friends to work together and two successful vegetable projects have emerged. Though mainly for home use to improve food security, surpluses have been successfully sold to local shops.

7 Discussion

The data we present illustrate that concerns about the effects of climate change on rural societies in the developing world, expressly Africa in this case, are justified: climate changes are occurring, and they are affecting activities that depend on the natural environment. Previous analyses of population responses to droughts have shown that coping strategies reflect opportunities framed by policy contexts and mediated by local circumstances (Campbell 1999), and involve trade-offs between immediate needs and future opportunities (Corbett 1988). In this study we have found adaptation to relate to expected or anticipated longer term climate changes, and to experienced changes.

Rather than being trapped in 'perennial cycles of destitution and impoverishment at the mercy of climate events' (Sokona and Denton 2001, p 120), our data illustrate that rural farmers in Africa recognise even subtle changes in climate parameters, and take steps to respond to these changes. The trends and variabilities in precipitation parameters that were identified in this study and spatially differentiated by the SOM analysis were recognised by people living in the areas in which they occurred. Furthermore, climate matters: amongst the plethora of disturbances that affect African societies today, including the impacts of HIV-AIDS and political changes, climate is recognised as significant, as demonstrated by the focus group discussions that we conducted and the data in Table 4.

The work within rural communities has allowed differing forms of responses to climate variability and change to be identified. These are outlined in Table 5, where we represent responses in terms of strategies that are simply means of 'getting by', or coping, and those that represent real forms of adaptation to the changes in precipitation parameters that have been occurring. Some of these adaptations, such as diversifying livelihoods, are not responses unique to climate disturbances, and all are embedded in the full range of livelihood-changing factors. However, as the data show, climate factors have been a significant trigger for changes that alter the nature of the risks associated with living in a variable and changing climate regime. It was also found that some forms of response are common across the range of risks and climatic changes in the three investigated regions. For example, commercialising small scale agricultural production is important in all areas, and is significant because it creates a source of cash that can then be used flexibly to meet household needs.

It is hard to argue a case for 'generic' adaptations solely being driven by climate factors, and we do not do so, because they are framed within the wider agendas of rural and economic change that form part of South Africa's development. Importantly however, these 'generic' changes are made at the local level with a clear knowledge of climate factors being present in the communities and households that are participating in them. Furthermore, along side these 'generic' adaptations we also found responses unique to each region. This can be explained by these responses being targeted to the specific regional characteristics of the changes in precipitation parameters, but also as a consequence of spatial differences in sociopolitical structures and the availability of information that facilitates adaptation opportunities. Therefore while the recognition of climate dynamics was prevalent in all our study areas, the ability to respond and the nature of adaptations has both generic and specific elements with some marked place-based differences occurring in what people were able or chose to do.

8 Conclusion

Research agendas that aim to improve understanding of people's potential to adapt to climate change require both appropriate frameworks for analysis and empirical data to interrogate questions about how adaptation occurs. These requirements can be met if research embodies (1) tools for climate data analysis, in order to identify the details of changes in climate parameters, and (2) methods for identifying and then exploring responses to the climate factors relevant to people's livelihoods. In this paper we have attempted to show how these requirements can be met, through an analysis of responses to scientifically identified climate dynamics.

The framework used to do this, involving initial climate data analysis and subsequent social enquiry and analysis, has embodied a balance of natural and social science analysis. By interrogating climate data with a methodology that unravels the subtle dimensions of precipitation variability and change, we have been able to identify the parameters of rainfall that impact on people's natural resource-based activities in South Africa. Combined with the application of qualitative and quantitative social science techniques at household and community levels, the complexity of coping and adaptation strategies have begun to be understood in ways that are potentially valuable for policy and decision makers throughout the developing world.

The initial climate data analysis and the subtleties of climate change that it revealed in terms of precipitation parameters, provided information that allowed aspects of the climate-led changes in livelihoods to be recognised. Livelihoods change and people adapt to the pressures and opportunities provided by many variables operating at a range of scales, of which climate is only one (e.g. Campbell and Olson 1991). Our findings suggest that with appropriate methodologies, climate contributions can be disaggregated and identified, facilitating understanding of the details and drivers of place-specific differences in adaptations. We have found that the farmers in our case studies recognise changes in climate that are subtle, and then respond to these changes. Even amongst the complex array of factors that bring disturbance to their livelihoods, including health and political changes, climate is recognised as significant, and is then responded to.

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