Fredelien Kotze offloads a sheaf of rooibos at the Heiveld's tea court. Photo: Bettina Koelle.

# 'Farming on the edge' in arid western South Africa: climate change and agriculture in marginal environments

E.R.M. Archer, N.M. Oettlé, R. Louw and M.A. Tadross

Bet Sass proudly holds a sheaf of her rooibos tea. Photo: Bettina Koelle.

*ABSTRACT: Agriculture in southern Africa is predicted to be particularly severely affected by climate change, and hence is considered a priority area for creating an enabling environment for adaptation. The study presented here, based in the arid Suid Bokkeveld region of South Africa, aims to increase the resilience of small-scale tea farmers in responding to climate change, using as a starting point existing local adaptive capacity, while recognising the utility of external knowledge such as climate projections. Using participatory research methods as well as biophysical monitoring of rooibos tea (*Aspalathus linearis*), results presented in this article show current and projected impacts of climate variability and climate change, as well as current adaptive strategies and gaps, or constraints, in farmers' ability to adapt.*

## Introduction

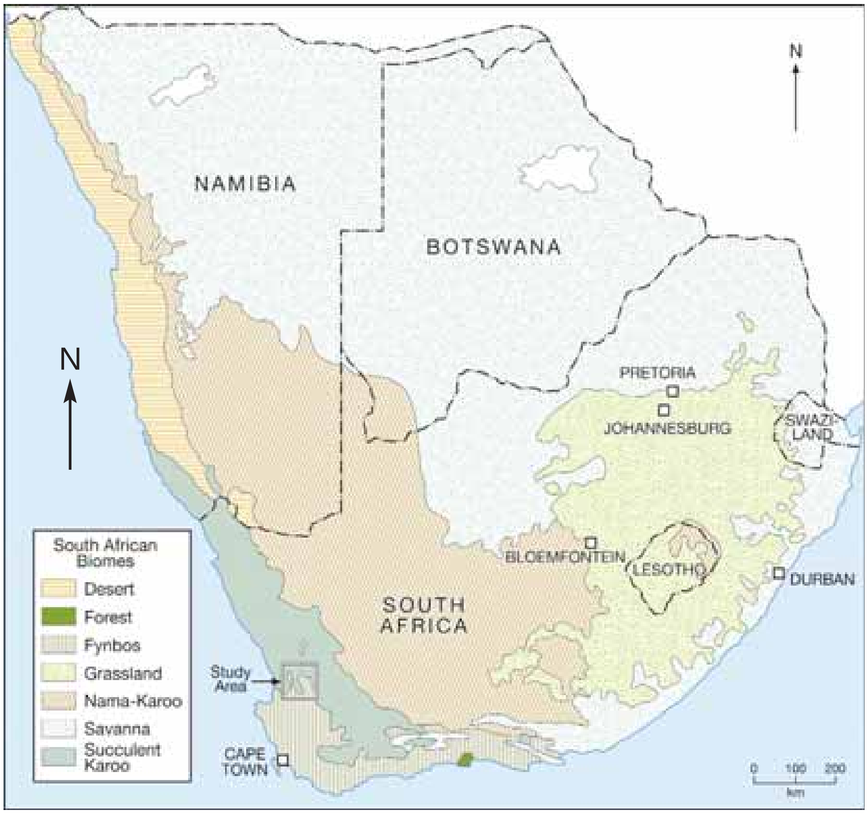
The Intergovernmental Panel on Climate Change (IPCC), as well as numerous authors (e.g. Aggarwal *et al.*, 2004; Antle *et al.*, 2004; Easterling *et al.*, 2004; Easterling and Aggarwal, 2007; Fischer *et al.*, 2002; Jones and Thornton, 2003; Parry *et al.*, 1999; Parry *et al.*, 2004; Parry *et al.*, 2005; Reid and Vogel, 2006; Seo and Mendelsohn, 2007; Thomas *et al.*, 2005), document significant and worrying climate change impacts on agriculture (both experienced and projected). The latest report of the IPCC predicts critical negative yield impacts in areas where food security is already challenged and the natural resource base is already poor (Boko *et al.*, 2007; Easterling and Aggarwal, 2007). Such areas certainly include southern Africa, explaining in part the enhanced activity in science and policy of late to address the effects of climate change on agriculture in the region. Responses to climate change in agriculture in South Africa have, however, generally been presented in rather top-down, sectoral ways, with limited recognition of the extent to which adaptation to climate change is often a simple extension of existing risk management activities (Easterling and Aggarwal, 2007).

This article describes the implications of climate change for small-scale rooibos (*Aspalathus linearis*) tea farmers in western semi-arid South Africa. It further discusses the ways in which farmers are adapting to current climate variability, aspects of which are projected to be more frequent and/or more severe in the future. Although recommendations are made to build resilience to climate change amongst these farmers, the study uses as its starting point existing knowledge regarding adaptation to climate risk, cognisant of calls such as those of Mortimore and Adams (2001), Thomas *et al.* (2005) and Osman-Elasha *et al.* (2006) systematically to understand indigenous adaptive capabilities. Adaptive strategies of particular significance are *in situ* conservation and promotion of agricultural biodiversity, as well as soil and water conservation using existing (and often long-used) practices. It should be emphasised that local knowledge is certainly not seen, here, as being in opposition to external knowledge, rather it is understood that the two can co-exist in productive ways.

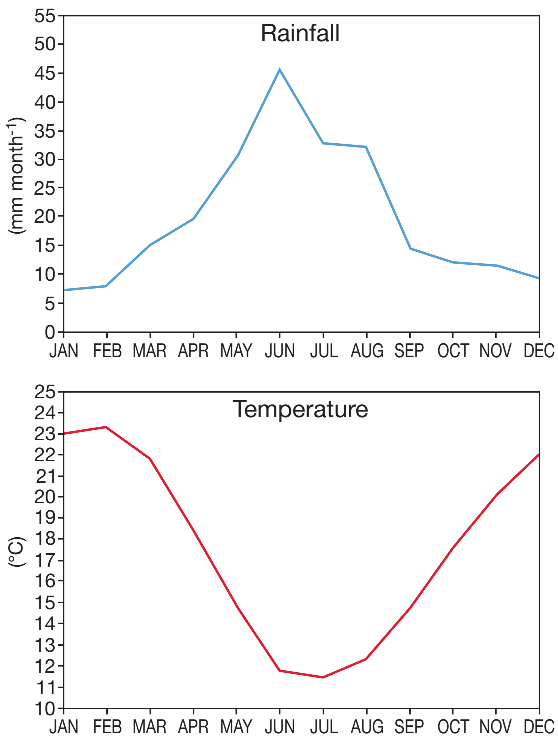
## Study site and methods

The small-scale farmers of the Suid Bokkeveld make their living from small stock (e.g. sheep and goats) and indigenous rooibos tea production on the drought-prone western margins of the Karoo plateau in the Northern Cape Province, South Africa (Figure 1). The area lies within the transition zone between the Fynbos and the Succulent Karoo biomes (Cowling *et al.*, 1997). Both biomes have great ecological significance. The Fynbos biome, comprising 71,337km$^2$ of the extreme south-western and southern parts of southern Africa, coincides spatially with the Cape Floristic Region – recognised as one of the world's major floristic kingdoms (Cowling *et al.*, 1997). The biome comprises approximately 7300 species, of which more than 80% are endemic. The Succulent Karoo biome, occupying western arid South Africa and Namibia, comprises more than 5000 species, of which more than 50% are endemic (Milton *et al.*, 1997). In the Suid Bokkeveld, at the transition zone, winter rainfall of between 150 and 300mm supports Fynbos vegetation on soils derived from Table Mountain Sandstone, and succulents, geophytes and shrubs on the clay loams derived from Bokkeveld and Karoo series sediments. Figure 2 shows average monthly rainfall and temperature for the region, derived from the Climatic Research Unit observations dataset (New *et al.*, 2000).

*Aspalathus linearis* (Burm.f) Dahlg. (rooibos tea) is indigenous to the Fynbos biome. Characterisation and classification of the species can be challenging, since it is highly variable morphologically, and has tended to be treated taxonomically in varying ways (Van der Bank *et al.*, 1999). Van der Bank *et al.* (1995) make a first attempt at characterising genetic diversity in *Aspalathus linearis*, partly in response to the recognition that genetic integrity of various types may be at risk. A range of wild forms and varying tea types (including red, black, grey and red-brown) are




*Above:*
**Figure 1**: *The Suid Bokkeveld study area, South Africa. Source: Cowling et al., 1997.*




*Left:*
**Figure 2**: *Average monthly rainfall and temperature for the Suid Bokkeveld. Source: Climatic Research Unit; New et al., 2000.*

described, including one of the red tea types – the 'Rocklands' type – which is the only tea type selected for commercial cultivation (Van der Bank *et al.,* 1995). In the case of the red tea types, leaves turn red and aromatic on drying, enabling commercial use (Van der Bank *et al.,* 1995). Debate still exists as to the characteristics and numbers of wild tea types. At least four wild populations were found in the study area by Louw (2006). Sprouting and seeding aspects, as well as possibly associated resilience characteristics of different types of rooibos, will be discussed later.

As mentioned earlier, livelihood systems for the farmers in the Suid Bokkeveld comprise rooibos tea cultivation (both wild and cultivated types) and livestock. Formal education levels in the area are fairly low, and employment opportunities for unskilled workers are limited (Malgas *et al.,* 2007). The study described here focused on the farm members of a particular rooibos farming co-operative, the Heiveld Co-operative. Almost all Heiveld members are non-white small-scale farmers. Malgas *et al.* (2007) observe that 'Most small-scale farmers work for between one and six months tending their own crops and livestock on land that they own … The rest of their time is spent as seasonal labourers on neighbouring farms or further afield' (p. 3). Heiveld members are typical of such varied livelihood bundles per family and farm, although the main Co-op commodity is rooibos. Thus, this article will focus mainly on rooibos but will also describe climate impacts on stock and other livelihood strategies (e.g. wage labour on neighbouring farms), in acknowledgement of what Anseeu and Laurent (2007) refer to as pluriactivity.

*Rooibos protected by natural belts of indigenous vegetation. Photo: Rhoda Louw.*

In recent years local farmers have begun to redress the endemic poverty of their community by exporting high quality organic rooibos to niche fair trade and organic markets in the northern hemisphere. The Heiveld Co-operative was organised to assist small-scale growers from the Suid Bokkeveld in producing and marketing both cultivated and wild rooibos tea (Malgas *et al.,* 2007). The co-operative was formed in 2001 with the assistance of the Environmental Monitoring Group (an NGO) to facilitate better market access. The Co-op produces approximately 40 tons of rooibos a year, and exports to seven countries; thus providing a significant source of income to members (although, as noted above, farms typically have other income sources as well).

In line with the requirements of organic markets, Co-op farmers use organic production methods and practise sustainable harvesting and farming methods that conserve biodiversity, soil and water. Community-based efforts to reduce soil degradation (for example, the erection of windbreaks using indigenous plant material) and enhance soil carbon have shown promising initial results. These efforts have been further supported by local NGOs and university-based researchers within the context of a Participatory Action Research approach. As local 'problem holders', who must respond to problems related to the sustainability of their farming enterprises, the farmers have been supported in their efforts to define research questions and to design and implement potential solutions. Central to this approach is knowledge sharing with other farmers (Oettlé and Koelle, 2003), as well as regular reflection to enhance learning from experience and inform future actions.

As part of the World Wide Fund for Nature (WWF-SA) funded study 'Increasing the resilience of small-scale tea farmers in responding to climate change', focus groups were formed with small-scale farmers from the area using a decision/activity calendar methodology. One focus group was formed per farm in attendance – usually between 6 and 10. All farms represented were members of the Heiveld Co-op. The groups met iteratively to identify the impacts of climate extremes, during the 18-month period January 2003–June 2004, on rooibos tea farming systems, as well as other livelihood strategies considered to be important. This enabled the identification of existing and desired adaptation measures and the identification of gaps (institutional, training, knowledge) in farmers' ability to undertake suitable adaptation strategies in the light of climate risk. Such an 'analogue'[1] method provides an indication of impacts and adaptation possibilities regarding future climate change, particularly since predicted climate changes of concern for the area (see below) are already being reported.

During the project's lifetime, wild populations as well as cultivated fields of rooibos tea were monitored and periodic assessments of their status in terms of resilience to climate risk, and to pests and pathogens, were undertaken. Wild rooibos has traditionally been cultivated in the area by poor landless people and is harvested less frequently due to its slower growth. Observations of the relationship between precipitation and phenology sheds light on the feasibility for wild rooibos tea to act as a monitoring species for the effects of climate change. In addition, the study shows how wild rooibos responds to changing weather patterns – allowing scientists and farmers to ascertain the long-term effects of predicted climate changes on wild rooibos and plants similar in form and function.

Finally, in the ongoing study (five years and continuing), farmers have worked with researchers to monitor on-farm climate conditions (through keeping rainfall records) and climate impacts on farming (measuring plant growth, for example, of cultivated versus wild rooibos), and to identify successful adaptation strategies. Climate conditions, impacts, and adaptation strategy track records are reported on and documented regularly. Farmers and researchers consult frequently, and farmer groups discuss observations and compare data amongst themselves. A record of rainfall data for each participating farmer is being made available for use in national datasets and other relevant modelling databases.

Further work on refining the bioclimatic envelope for different types of rooibos is planned, to be combined with improved climate change scenarios, to better quantify climate change impacts on rooibos. A key focus here is the possible shift in areas suitable for rooibos growth under different climate change scenarios, and how farmer adaptation may be supported under such conditions.

## Current and future climate and impacts for the Suid Bokkeveld area

The Suid Bokkeveld experienced severe drought in 2003, due particularly to late starts and dry spells experienced during the critical winter rainfall season. To illustrate, Louw (2006) collected rainfall data for the

**Figure 3**: *Example of a 2003 climatic calendar prepared by Suid Bokkeveld small-scale farmer group.*

| **2003** | Jan | Feb | March | April | May | June | July | August | September | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *What do you remember about the weather conditions for this period?* | Dry and windy | | | First rain, but insufficient<br><br>Thunderstorms | | Small amount of rain; below average – insufficient to plough | | | Increased fire risk (due to dryness); financial hardship | | | Small amount of rain |
| *What were the impacts of the weather conditions for this period?* | Water shortages for people and livestock; tea production low; forage shortage; poor road conditions as a result of drought (potholes); livestock mortality | | | Pest infestation: ticks affecting livestock | | Unable to plough; reduced work opportunities | | | | | | Stock condition poorly affected |
| *How did you respond to these conditions?* | | | | Reduced stock; dipping | | Land preparation and wind erosion prevention measures | | | | | | Supplemental feed provided to stock |
| *Were there responses you would have liked to have undertaken but could not?* | | | | Would have liked to have ploughed | | Would have liked to have prepared more areas of land | | | Would have liked to have prepared more areas of land | | | |
| *Why were you unable to undertake such a response?* | | | | Insufficient soil moisture | | Increased fire risk (due to dryness); financial hardship | | | | | | |

farms Landskloof to the south of the study area, and Glen Lyon to the north. Compared to the 'normal' average monthly amounts that would be expected for the area (see Figure 2), for 2003, Landskloof received almost 0% of its normal winter rainfall up until August. Landskloof thus effectively missed almost an entire winter season of rain. Glen Lyon received a third of its normal expected rainfall in April, a third in May, almost 0% of normal in June, and a third of the normal rainfall in July. Like Landskloof, Glen Lyon finally received substantial rainfall in August, late in the winter rainfall season.

The drought adversely affected agriculture and livelihoods in a number of ways, which can be described in part by direct biophysical monitoring of rooibos stands, and also with reference to the climatic calendars kept by farmers for the 18-month period January 2003–June 2004. A simplified example of such a calendar (illustrative rather than representative) is shown in Figure 3. It describes climate conditions per month, the impacts of such conditions, response/adaptation strategies, and adaptation strategies that were desired but were not achievable. Impacts described by all farms are considered below. As mentioned earlier, given that farms engage in multiple livelihood activities, impacts noted were not just direct impacts on rooibos yield, but also indirect impacts, as well as impacts on other livelihood strategies.

With reference to the example in Figure 3, monthly weather conditions have had specific effects, not only directly on agriculture but also on activities which in turn impact on agriculture and livelihoods.
All responding farms observed severe drought impacts for the period May–July 2003. All farms observed drought stress in their tea crops, mostly in the form of diminished yield. Drought and water shortages in January 2003 had severe implications for human and stock consumption and production. In addition, weather conditions contributed to increased frequency of potholes in roads, complicating transport. It was argued in the group that the tick infestation that affected livestock in April was a direct result of the pattern of weather events of the previous several months (below average rainfall and dryness, followed by insufficient yet intense late summer rainfall in the form of thunderstorms). Farmers were able to respond (in this case) by stock reduction and dipping.

In June, below average winter rainfall prevented farmers from ploughing. Additionally, insufficient rain during this critical period adversely affected off-farm work opportunities. One response from farmers was to take measures to prevent wind erosion of the dry soils, but they were prevented from preparing and protecting more land in this way due to increased fire risk and financial constraints. Finally, in December, continued below average rainfall for the year resulted in livestock being in a poor condition, to which farms responded by providing supplemental feed.
All farms surveyed reported climate-related heat stress to livestock, livestock water shortages (related to rainfall, without supplemental irrigation), and climate-related increases in pests and pathogens (affecting rooibos and stock). All farms further reported uncertainty in the timing of agricultural activities as a direct result of late starts to the winter rainfall season and increased frequency of dry spells during the season. For example, in many cases land preparation and tea planting had to be delayed. Additionally, all farms reported decreased external work availability as a direct result of drought (large-scale commercial farms were themselves adversely affected by drought).

Further impacts detailed by farmers during the continuing drought (in ongoing focus groups and participatory workshops with member farms in late 2004 and throughout 2005) include a 40% decrease in cultivated rooibos yield for the 2004/5 season and decreased yields for farmers as a result of a severe dry spell in July 2005. Maintenance costs also increased, for example where machine processing of tea became more difficult due to drier biomass (Louw *et al*., 2005).

The biophysical component of the study produced impact results specific to rooibos. Again, it should be emphasised that rooibos is the focus of the Heiveld

*Spreading fermented rooibos to dry in the sun. Photo: Noel Oettlé.*

Co-op, hence the focus of the biophysical study – but, in recognition of multiple livelihoods strategies mentioned earlier, we describe climate impacts on multiple strategies, as well as direct impacts.

It is clear that rooibos leaf growth is highly responsive to precipitation. Leaf budding occurs throughout the year in response to rain, mist and dew. Such processes are further subject to the plant growth cycle or seasonal growth patterns. Shoot growth and leaf elongation, however, appear to be more closely related to seasonal variations and genetic make-up. A decrease in harvest yield per hectare since the start of the drought period in 2002 is a strong indicator of the effects of changes in climate on rooibos tea growth. More indirectly, but no less significantly, variations in seasonal weather patterns (e.g. uncharacteristically mild winters, the late onset of minimal winter rains as described for 2003) also affect the impact and prevalence of pests in the field. Differential resilience in cultivated versus wild rooibos is discussed below in the context of adaptation to climate risk.

Given these documented impacts of current climate variability, climate change projections for western South Africa are of particular concern. Overall projections to date have included increased variability of precipitation, a possible increase in the length of dry spells, and a possible later shift in the start of the winter rainfall season (Hewitson and Crane, 2006; Midgley *et al.,* 2005). Rutherford *et al.* (1999) observe, for example, projected increased aridity under climate change, with severe impacts on a range of Succulent Karoo species.

Christensen *et al.* (2007) state that warming for the African continent is very likely to exceed global annual mean warming for all seasons; while southern African precipitation is likely to decrease in much of the winter rainfall region and western margins. A poleward displacement of mid-latitude westerlies and associated storm tracks is further observed.

In their analysis of recent historical change and future projected changes for the Namaqualand area (bordered to the south by this study area), MacKellar *et al.* (2007) similarly observe a projected poleward retreat of rain-bearing mid-latitude cyclones (with reasonable agreement across the models) by the late twenty-first century. In particular, this retreat of mid-latitude cyclones and reduction in rainfall is most consistently projected during early winter, with indications of reduced rainfall later in the winter season. Together, these projected changes suggest a shift in the timing of seasonal rainfall, with late summer rainfall heavier than present and extending to later months, and reduced winter rainfall arriving later[2].

Clearly rooibos tea farmers in the Suid Bokkeveld are currently adversely affected by changes in climate. The projected changes for the climate of the area – showing an increase in frequency and intensity of precisely those climate parameters already shown to have a negative effect on agriculture and livelihoods are a matter of great concern. How then should farmers respond?

In responding to climate change and climate risk, rather than taking an approach per climate sensitive sector (agriculture, water) that may take limited cognisance of unique experiences on the ground, our study seeks to work with often (although not always) overlooked local knowledge and practice around responding to climate risk. Such an approach is embedded in the notion that adaptation to climate change may often be nested within, or an extension of, existing risk management strategies.

## Indigenous adaptation: strategies and gaps

Farmers were asked to document current adaptation strategies, as well as those they would have liked to have undertaken. With regard to rooibos, adaptation strategies undertaken by all farms included: changes in ground preparation (earlier preparation and/or deeper ploughing; as well as ploughing more than once) and tea harvesting times; wind erosion prevention measures (retaining bushed strips in lands,

*Farmers in the Suid Bokkeveld, South Africa, preparing land for planting rooibos. Photo: Bettina Koelle.*

or planting of wind breaks, which reduced loss of tea due to wind); and water conservation measures. With regard to stock farming, adaptation strategies undertaken by all farms for the 2003-4 period comprised stock reduction, the shifting of stock to camps with a higher carrying capacity, and supplemental feeding and water provision (for example, stock were taken directly to the river in the canyon, or extra water was brought to the camps).

Among the adaptation strategies that farmers said they would have liked, but were unable, to undertake was the earlier preparation of land. This was not possible due to their inability simultaneously to pay labour and buy petrol (petrol prices in South Africa have increased markedly in the last few years, with adverse impacts for agriculture, amongst other sectors). All farmers would have liked to change tea planting times, but could not (due to, for example, a water shortage, which forced a delay in planting). Two farmers said they would have liked to have marketed their lambs earlier, but could not – in both cases due to poor stock condition, but also, in one case, as a result of predator problems. Lastly, about half the farmers would have liked to have provided more supplemental feed to their livestock, but lacked the resources to do so.

In 2005, farmers undertook extended adaptation strategies using as a basis their local knowledge about managing climate risk, conserving biodiversity and conserving soil and water. These were not new activities; they comprised existing activities and strategies. Windbreaks continued to be planted, using indigenous vegetation planted in rows angled (to prevent soil build-up against the barrier) to the direction of the dominant drying wind. The windbreaks have been instrumental in reducing tea loss. Alien vegetation was removed, to aid water conservation. Lastly, alternative income sources continued to be developed, including ecotourism initiatives, and the collection of indigenous medicinal plants and seeds.

The aforementioned ongoing biophysical monitoring component of the study, comparing the resilience of cultivated versus wild rooibos to climate change and pests and pathogens, has shown that wild rooibos individuals are more resilient than cultivated plants to the impacts of the current drought (Table 1). This has implications for viewing the cultivation of wild rooibos as an adaptive strategy under conditions of climate change. With the low levels of rainfall during the 2005 winter rainfall season, the wild rooibos was observed to be growing well, and to be retaining superior resistance to pests and disease when compared to cultivated individuals.

| Trait | Wild | Cultivated |
|---|---|---|
| Morphology | Prostrate growth form | Erect growth form |
| Growth | Post-fire sprouting from basal stem<br>Slow-growing | Post-fire mortality<br>Fast-growing |
| Reproduction | Post-fire seed germination<br>Low seed output | Post-fire seed germination<br>High seed output |
| Resilience | Resilient against pests, drought and disease | Susceptible to pests, drought and disease |
| Harvest regime | Generally harvest once every two years | Harvest once every year |

**Table 1**: *Differences between wild and cultivated* A. linearis *(rooibos). Source: Louw, 2006*.

Table 1 presents information summarised from interviews conducted with 10 harvesters and farmers in the Suid Bokkeveld. In reviewing the general literature on the phenology of Fynbos species, Louw (2006) finds that rooibos in the Suid Bokkeveld exhibits both seeding and sprouting characteristics. Wild populations of rooibos seem to be sprouters, where the plants are able to regenerate despite severe damage to the individual plant. In the case of sprouters, the plant has slower shoot growth rates, and greater underground root storage facilities. The apparent advantage of wild rooibos over cultivated varieties in its resilience to severe climatic events can be ascribed to the carbohydrate reserves held in the subterranean lignotuber of the specific sub-species of wild rooibos in the Suid Bokkeveld area. This enhances its ability to resprout after fire, a severe harvest or grazing.

With regard to wild rooibos, monthly field observations confirm statements by farmers that while wild rooibos plants have slower growth than cultivated plants, they exhibit more sustainable growth during periods of severe drought. Cultivated plants appear more sensitive to drought, as partly exhibited by their higher flowering rates – intense flowering is a manifestation of drought stress in *Aspalathus linearis* (Louw, 2006). Wild rooibos tea is clearly more consistent in its growth than cultivated rooibos (Louw, 2006).

Farmers in the area are assisting in this study by undertaking to harvest wild rooibos. Harvesting is undertaken every second year because wild rooibos is slower to produce above-ground biomass than cultivated plants. Respondents interviewed (Louw, 2006) indicated that wild rooibos tea yields optimal harvestable biomass only if harvested once every two years. Most respondents observed that harvesting rates should be closely linked to received rainfall. The production of wild rooibos (which has long been harvested in the area, traditionally by poor landless people) therefore provides a classic example of an adaptation strategy that is nested within existing local knowledge around climate risk management procedures, but is also one that can be fruitfully integrated with external knowledge such as climate forecasting and long-term climate change projection.

The opportunities provided by the adaptation processes described in this article have stimulated farmers to learn from one another's approaches, and to develop further their own adaptation strategies. However, insufficient access to resources has limited their ability to implement these strategies. In 2005, participants in the climate change focus group decided that they would seek outside assistance to implement some of their adaptation strategies more extensively. The Heiveld Co-operative agreed to host a project funded by the Global Environment Facility (GEF) Small Grants Programme. Implementation has been guided by two community members who have been appointed as mentors to assist their fellow farmers to assess environmental problems relating to soil and water loss, and design measures that can be expected to improve the situation. Although technical support is provided by an NGO, problem identification and design of adaptation measures is undertaken largely independently, and is richly informed by local and external knowledge.

It should be noted that one significant gap in adaptation support is the lack of engagement by the Department of Agriculture in the area. This stands in contrast to the substantive activity by the Department at the national scale – for example, in February 2006 the Directorate of Agricultural Risk Management of the National Department of Agriculture hosted a sectoral workshop on managing climate change in agriculture, and continues to host further workshops. The district in which the study is located lacks an extension officer, and many of the support functions for farmers, as shown above, are undertaken by non-governmental agents. Non-governmental agents have essentially played the adaptation supporting role that would ideally be undertaken by extension services – combining local adaptation knowledge with external knowledge (such as climate forecasting and long-term climate projection) to better enable adaptation. Although discussions with the provincial Department of Agriculture have been promising, weaknesses in governmental support that might enable adaptation, given the increasing climate risks, remain, and are of particular concern. This situation is, unfortunately, by no means unique to the Suid Bokkeveld area (Akpalu, 2006; Vogel *et al.,* forthcoming; Vogel, Reid and Massey, 2005).

## Enabling adaptation in a marginal environment

As shown in this study, small-scale farming in the Suid Bokkeveld is already severely affected by climate variability. Drought characteristics of particular concern for the area include late onset of and reduced winter rainfall, as well as an increased frequency of dry spells. The latest climate change projections for South Africa show a likely increase in the frequency of such seasonal characteristics, rather than a reduction. Projected increases in late summer rainfall may offer further adaptation options, such as more frequent ploughing at this time of year to aid water infiltration. The application of soil conservation measures would, however, be essential here, as an increase in the intensity of late summer rainfall could lead to increased runoff and an increased risk of erosion. As mentioned earlier, the low cost soil and water conservation techniques are already in use.

To conclude, small-scale farmers in the Suid Bokkeveld have substantial experience in adapting to adverse climatic conditions. The study reported in this article has mapped out existing adaptation strategies, and has partnered farmers and scientists to continue to monitor climate conditions, impacts on crops such as rooibos tea, and on livestock, and the relative success of different adaptation strategies within an action research context. This learning approach has enhanced local knowledge and broadened farmers' capacities to respond in a proactive manner. Using indigenous adaptive capacity as a starting point, combined with relevant external knowledge, rather than imposing adaptation plans in a top-down manner, we hope that adaptation to current and future climate change in this marginal environment may be enabled in a more realistic and participatory way.



*George Gouws reports back to a climate change adaptation workshop on the strategy planned by Melkkraal farmers. Photo: Noel Oettlé.*


## Acknowledgements

The authors would like to thank the WWF-SA Climate Change Programme (project ZA1361: *Increasing the resilience of small-scale tea farmers in responding to climate change*), the Desert Margins Programme, the Assessments of Impacts and Adaptation to Climate Change (AIACC) project AF07, and the GEF Small Grants Fund for supporting the study. We would like to thank Mrs Wendy Job of the University of the Witwatersrand for her able graphic design contributions. Lastly, sincere thanks are due to the Heiveld Co-operative who are central to all work described here.


### Notes

1. The process of analogy comprises using comparative cases to make an argument. In climate change impact assessment, an analogue approach essentially consists of using current impacts and experiences of climate variability to make assumptions regarding impacts and experiences of future climate change.
2. These projected changes are further complicated by the Suid Bokkeveld's elevated topography, with a low-lying coastal strip immediately to the west (mostly experiencing frontal rainfall during winter) and the arid Karoo to the east (mostly experiencing summer convective rainfall). Whether winter rainfall reaches the Suid Bokkeveld therefore depends on the intensity of mid-latitude frontal systems and their ability to penetrate and extend over the 800-900m escarpment.

## References


Aggarwal, P.K., Joshi, P.K., Ingram, J.S. and Gupta, R.K. (2004) 'Adapting food systems of the Indo-Gangetic plains to global environmental change: key information needs to improve policy formulation', *Environmental Science and Policy*, 7, pp. 487-98.

Akpalu, D.A. (2006) *Response Scenarios of Households to Drought-driven Food Shortage in a Semi-arid Area in South Africa*. Unpublished MA research report, School of Development Studies, Faculty of Humanities, University of the Witwatersrand.

Anseeu, W. and Laurent, C. (2007) 'Occupational paths towards commercial agriculture: the key role of farm pluriactivity and the commons', *Journal of Arid Environments*, 70, 4, pp. 659-71.

Antle, J.M., Capalbo, S.M. and Hewitt, J. (2004) 'Adaptation, spatial heterogeneity and the vulnerability of agricultural systems to climate change and $CO^2$ fertilization: an integrated assessment approach', *Climatic Change*, 64, 3, pp. 289-315.

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R. and Yanda, P. (2007) 'Africa', in Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (eds) *Climate Change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press, pp. 433-67.

Christensen, J.H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kolli, R.K., Kwon, W.-T., Laprise, R., Magaña Rueda, V., Mearns, L., Menéndez, C.G., Räisänen, J., Rinke, A., Sarr, A. and Whetton, P. (2007) 'Regional climate projections', in Solomon, S., Qin, D., Manning, M., Chen, A., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L. (eds) *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: Cambridge University Press.

Cowling, R.M., Richardson, D.M. and Pierce, S.M. (eds) (1997) *Vegetation of Southern Africa.* Cambridge:


*Homesteads nestled in a valley in the Suid Bokkeveld, South Africa. Photo: Emma Archer.*

Cambridge University Press, p. 649.

Easterling, W.E., Hurd, B. and Smith, J. (2004) *Coping with Global Climate Change: The role of adaptation in the United States.* Arlington, VA: Pew Center on Global Climate Change.

Easterling, W.E. and Aggarwal, P.K. (2007) 'Food, fiber and forest products', Chapter 5 of *Working Group 2 of the Intergovernmental Panel on Climate Change Fourth Assessment Report.* Cambridge: Cambridge University Press.

Fischer, G., Shah, M. and van Velthuizen, H. (2002) *Climate Change and Agricultural Vulnerability.* Laxenburg, Austria: International Institute for Applied Systems Analysis.

Hewitson, B.C. (2005) *Intergovernmental Panel on Climate Change Working Group I Scenarios*. Presented at the South African National Conference on Climate Change, Department of Environmental Affairs and Tourism, 18-20 October, Gallagher Estate, South Africa.

Hewitson, B.C. and Crane, R.G. (2006) 'Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa', *International Journal of Climatology*, 26, 10, pp. 1315-37.

Jones, P.G. and Thornton, P.K. (2003) 'The potential impacts of climate change on maize production in Africa and Latin America in 2055', *Global Environmental Change,* 13, pp. 51–9.

Louw, R., Louw, L. and Koopman, J. (2005) *Climate Change Adaptation and Rooibos: Research in action.* Presented at the South African National Conference on Climate Change, Department of Environmental Affairs and Tourism, 18-20 October, Gallagher Estate, South Africa.

Louw, R.R. (2006) *Sustainable Harvesting of Wild Rooibos (Aspalathus linearis) in the Suid Bokkeveld, Northern Cape*. Unpublished MSc. thesis, Leslie Hill Institute for Plant Conservation, Botany Department, University of Cape Town.

MacKellar, N.C., Hewitson, B.C. and Tadross, M.A. (2007) 'Namaqualand's climate: recent historical changes and future scenarios', *Journal of Arid Environments*, 70, 4, pp. 604-14.

Malgas, R.R., Koelle, R.R.I., Oettlé, N.M. and Archer, E.R.M. (2007) 'Quenching the thirst of an arid landscape: a case study on the local adaptation strategies adopted by small-scale rooibos tea farmers in response to climate change in the Suid Bokkeveld, Northern Cape, South Africa', in *Adaptation to Climate Change: how local experiences can shape the debate.* Both Ends Briefing Paper, August 2007, pp. 17.

Midgley, G., Chapman, R., Hewitson, B., Johnston, P., De Wit, M., Ziervogel, G., Mukheiber, P., Van Niekerk, L., Tadross, M., Van Wilgen, B., Kgope, B., Morant, P., Theron, A., Scholes, R. and Forsyth, G. (2005) *Western Cape Report: a status quo, vulnerability and adaptation assessment of the physical and socio-economic effects of climate change in the Western Cape.* Report commissioned by the Provincial Government of the Western Cape: Department of Environmental Affairs and Development Planning.

Milton, S.J., Yeaton, R.I., Dean, W.R.J. and Vlok, J.H.J. (1997) 'Succulent Karoo', in Cowling, R.M., Richardson, D.M. and Pierce, S.M. (eds) *Vegetation of Southern Africa.* Cambridge: Cambridge University Press, p. 649.

Mortimore, M.J. and Adams, W.M. (2001) 'Farmer adaptation, change and "crisis" in the Sahel', *Global Environmental Change*, 11, pp. 49–57.

New, M., Hulme, M. and Jones, P. (2000) 'Representing twentieth-century space-time climate variability. Part II: Development of 1901-1996 monthly grids of terrestrial surface climate', *Journal of Climate*, 13, pp. 2217-38.

Oettlé, N. and Koelle, B. (2003) *Capitalising on Local Knowledge: Community knowledge exchange.* Washington, DC: The World Bank.

Osman-Elasha, B., Goutbi, N., Spanger-Siegfried, E., Dougherty, W., Hanafi, A., Zakieldeen, S., Sanjak, A., Abdel Atti, H. and Elhassan, H.M. (2006) 'Adaptation strategies to increase human resilience against climate variability and change: lessons from the arid regions of Sudan', *Working Paper 42, AIACC,* p. 44.

Parry, M.L., Rosenzweig, C., Iglesias, A., Fischer, G. and Livermore, M. (1999) 'Climate change and world food security: a new assessment', *Global Environmental Change*, 9, pp. 51-67.

Parry, M.L., Rosenzweig, C., Iglesias, A., Livermore, M. and Fischer, G. (2004) 'Effects of climate change on global food production under SRES emissions and socio-economic scenarios', *Global Environmental Change*, 14, 1, pp. 53-68.

Parry, M.L., Rosenzweig, C. and Livermore, M. (2005) 'Climate change, global food supply and the risk of hunger', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360, 1463, pp. 2125–38.

Reid, P. and Vogel, C. (2006) 'Living and responding to multiple stressors in South Africa – glimpses from KwaZulu-Natal', *Global Environmental Change*, 16, 2, pp. 195-206.

Rutherford, M.C., Midgley, G.F., Bond, W.J., Powrie, L.W., Musil, C.F., Roberts, R. and Allsopp, J. (1999) *South African Country Study on Climate Change. Terrestrial Plant Diversity Section, Vulnerability and Adaptation.* Pretoria, South Africa: Department of Environmental Affairs and Tourism.

Seo, N. and Mendelsohn, R. (2007) *An Analysis of Crop Choice: Adapting to climate change in Latin American farms*. World Bank Policy Research Working Paper 4162, March 2007, p. 24.

Thomas, D., Osbahr, H., Twyman, C., Adger, N. and Hewitson, B. (2005) *Adaptations to Climate Change amongst Natural Resource-dependent Societies in the Developing World: Across the Southern African climate gradient.* Tyndall Centre for Climate Change Research Technical Report 35, November 2005, p. 47.

Van der Bank, M., Van Wyk, B. and Van der Bank, H. (1995) 'Biochemical genetic variation of four wild populations of *Aspalathus linearis* (Rooibos Tea)', *Biochemical Systematics and Ecology*, 23, 3, pp. 257–62.

Van der Bank, M., van der Bank, F.H. and van Wyk, B. (1999) 'Evolution of sprouting versus seeding in *Aspalathus Linearis*', *Plant Systematics and Evolution*, 219, pp. 27–38.

Vogel, C., O'Brien, K., Ziervogel, G., Archer, E., Misselhorn, A., Schneg, M., Eriksen, S. and Gandure, S. (in preparation) 'Responding to multiple stressors in southern Africa: implications for sustainable development', W*orld Development*.

Vogel, C., Reid, P. and Massey, R. (2005) in Schulze, R. (ed) *Climate Change and Water Resources in South Africa. Studies on scenarios, impacts and vulnerabilities and adaptation.* Water Research Commission Report, Pietermaritzburg: University of Kwazulu-Natal.

Emma Archer (corresponding author) is in the School of Geography, Archaeology and Environmental Studies at the University of the Witwatersrand, South Africa (tel: +27 11 717 6522; fax +27 11 717 6529; e-mail: Emma.Archer@wits.ac.za). Noel Oettlé is with the Environmental Monitoring Group, Nieuwoudtville and Cape Town, South Africa. Rhoda Louw-Malgas is with Indigo Development Consulting, Nieuwoudtville and Cape Town, South Africa. Mark Tadross is with the Climate System Analysis Group, University of Cape Town, South Africa.