Climate Change and Desertification in South Africa – science and response

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Abstract

Despite significant attention paid to desertification and climate change in the last few decades, interactions between the phenomena, as well as implications thereof, have received less of a focus. Such a trend is particularly marked in the science-policy arena, at multiple scales. Reynolds *et al* (2007) observe, for example, the lack of a focused international science programme in desertification – a gap which may compound the problem. This article seeks to unpack two-way interactions between climate change and desertification, using selected case studies from the South and southern African, and global contexts. It considers emerging approaches to responding to climate change in the context of desertification, emphasizing the need for improved integrated biophysical and social science approaches, a focus on multiple synergies and cross sectoral strategies, and the need for improved communication across the science-policy divide.

Keywords: climate change, land degradation, southern Africa

Introduction

Desertification has been increasingly well documented and defined in the scientific and policy –relevant literature of the last several decades. Using UNCCD's 1995 definition of desertification as comprising land degradation in arid, semi-arid and sub –humid lands, desertification has been recognized as a key challenge to environment and development in South Africa (see, for example, Hoffman and Ashwell 2001, Meadows and Hoffman 2003, and further papers in this volume).

Most recent literature on desertification, including the discussions at the November 2008 workshop on desertification described in this volume, acknowledges a clear role of particular limits and thresholds in understanding both the processes of desertification, and the possibility of recovery (see, for example, Verstraete *et al* 2008 and Reynolds *et al* 2007; with particular relevance to the 'Drylands Development Paradigm'). Climate change, an area of critical interest in South Africa for scientists and national government, can change both the magnitude of and frequency with which such limits and thresholds are exceeded, with implications for science and policy.

This article seeks to unpack the two way relationship between climate change and desertification, using selected South African, African and other case studies. The article briefly clarifies the essentials of climate change, as well as the latest findings from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, material presented at South Africa's Climate Change Summit (March 2009) and selected focused climate change studies. The article then considers key aspects of the relationship between climate change and desertification, illustrating several points with case studies. We then conclude with a discussion of key policy directions with regard to climate change that are further critical to addressing desertification.

Climate Change Essentials

In 2007, the Fourth Assessment Report (AR4) of the IPCC achieved unprecedented consensus on the extent to which, unlike previous variations in the planet's climate, the changes experienced today have a clear anthropogenic component. AR4 shows further that climate change is already occurring, with global average surface temperatures having increased over the 20th century by approximately 0.6 C (Figure 1).

Figure 1: Temperature anomalies 1000 - 2000

AR4 indicates that temperatures in the lower troposphere have risen during the past four decades, global average sea level and ocean heat content have increased, and snow cover and ice extent have decreased [approximately 10% of snow cover extent has been lost in the last four decades and there has been a retreat of mountain glaciers in non-polar regions (IPCC 2007)].

Global IPCC predictions include a 'best case' scenario of temperature increases between 1.1 and 1.8 °C and sea level rise of up to 0.38m (a conservative estimate), whereas in a 'business as usual' scenario global temperatures increase by 4 – 6.4 °C (IPCC 2007). The key finding here is that even the most stringent emissions reductions potentially adopted during the United National Framework Convention on Climate Change negotiations in Copenhagen at the end of the year will still commit the planet to a significant amount of climate change.

Chapter 11 of the IPCC (Christensen *et al* 2007) states that 'All of Africa is likely to warm during this century' (pg 866); with warming in excess of the global annual mean likely in continental regions during all seasons. Greater warming is expected in the drier subtropics than in the moister tropics, with key implications for South Africa. Projected temperature anomalies for Africa (Figure 2) provided for the 2091 – 2100 period indicate clear increases relative to observations.

Figure 2: Projected temperature anomalies for Africa

Projected precipitation anomalies for Africa show that rainfall in southern Africa is likely to decrease in much of the winter rainfall region and on the western margins (Archer *et al* 2009, Christensen *et al* 2007, MacKellar *et al* 2007). MacKellar *et al* (2007) describe one of the mechanisms responsible for regional climate change as the retreat polewards of the westerlies and rain-bearing frontal systems associated with precipitation in these areas. Christensen *et al* (2007) further describe significant hydrological changes for southern Africa (Figure 3), including a highly likely decrease in precipitation for the June-July-August season for the western part of Southern Africa, where precipitation decrease is shown in more than 90% of simulations.

Figure 3: Significant projected hydrological changes for Southern Africa

For the savanna and grassland areas of South Africa, Tadross and Archer (2009) show for selected stations in Gauteng, Limpopo and Mpumalanga provinces consistent increases in temperature, as well as increases in potential evapotranspiration (PET) and a zero to negative Potential Moisture Index (PMI) (with the exception of stations further east). Further, increases in extreme temperatures are shown for all stations, including a greater frequency in exceedance of thresholds critical to human and livestock health. Davis (2008), using an earlier set of downscaled climate change projections, considers predicted changes in two key sites in the Kruger National Park as a result of carbon dioxide anomalies and climate change induced rainfall and temperature anomalies, using the ‘reduced form’ ecosystem model developed by Scholes (2006). While acknowledging the simplifications and limitations inherent in the approach taken, Davis’s research raises interesting questions regarding possible significant alterations in the tree-grass ratio (one scenario indicates possible conversion, given very particular assumptions, of the Skukuza and Satara savanna systems to open grassland-savannas).

Within South Africa, key climate change areas of research include monitoring of the observed climate, ecology and hydrological flows as well as decadal and climate change projections for the future (Tadross *et al* 2009). Research in the field of climate change has strategically focussed on downscaling climate change projections to scales of relevance and translating such projections to understand impacts in different sectors, including agriculture and water resources. Downscaling climate change projections has proceeded through the use of both dynamical Regional Climate Models (RCMs; Tadross *et al*. 2005) and statistical methods (Hewitson and Crane, 2006) which has resulted in a wealth of climate data available for research (e.g. http://data.csag.uct.ac.za), including the research undertaken by Tadross and Archer (2009) and Davis (2008) described earlier. Such a wealth of data represents a challenge for the scientific community in that the value of such data for informing adaptation and policy arguably relies on it's uptake within other sectors and communities. Research on changes in the South African climate during the instrumental period (observed climate and climate histories) has noted increases in surface temperature (Kruger and Shongwe 2004); and in the variability of rainfall in particular regions. Climate in South Africa is clearly already undergoing significant changes.

Climate change and desertification

Sivakumar (2007) states that it is critical to consider two way interactions between desertification and climate, focussing on feedbacks from desertification processes to climate, and climate impacts in turn on soils, ecosystems, the regional water balance and human use (or limitations thereof) in the aforementioned arid, semi-arid and sub-humid lands where desertification occurs. Possible effects of desertification on climate will be described here, followed by selected climate change interactions with key ecosystem services, with selected studies provided to illustrate certain of these processes.

Firstly, changes in land use/cover change and associated degradation and desertification can play a key role in climate feedbacks and microclimate modification. In the Sahel, for example, Taylor *et al* (2002) show that although land use changes (specifically agricultural intensification) in the Sahelian zone have not been significant enough to cause observed negative precipitation anomalies, natural vegetation variability in the region is likely to comprise a key component of recent drought, in agreement with other studies. Liu *et al* (2006) and Wang *et al* (2008) investigate vegetation-rainfall feedbacks during the mid-Holocene period in northern Africa. The more recent study uses the Fast-Ocean-Atmosphere-Model (FOAM) and the Community Climate System Model (CCSM, version 2), observing negative feedbacks on an annual scale. The authors observe, however, that such a feedback seems to decrease as timescales of interest increase. Over southern Africa, Mackellar *et al* (2008) showed that going from a natural vegetation state to a land surface affected by anthropogenic disturbance (such as clearing for cultivation) resulted in high pressure circulation anomalies that can result in drier conditions at particular times of year.

Nicholson (2002) critiques earlier models representing relationships between desertification and climate as oversimplistic and insufficiently cognizant of key processes (Nicholson's critique of Charney's albedo scenario is particularly well known, and has inspired long standing and rich debate in this area). Nicholson proposes rather a focus on local components of land degradation, stating that '..in meteorological terms, this translates into a patchwork of surface characteristics such as soil moisture, temperature, and increased atmospheric aerosol content. These are far more likely to influence meteorological processes than the associated changes in surface albedo.' (Nicholson 2002, pg 53).

Xue and Fennessy (2002) further illustrate the requirement to increase the sophistication of land-surface model design. Considering a range of experiments with coupled GCM/biosphere models in Sahel, east Asia and the central United States, the authors found that land degradation processes tend to decrease precipitation, evapotranspiration, soil moisture and runoff – functions that clearly have further feedbacks to land degradation processes. Findings show that the critical aspect of change to consider (in this study) constitutes hydrological cycle anomalies (driven by evaporation anomalies) – a finding the somewhat counters the argument that changes in the radiative balance are most significant. Such a proposition is not inconsistent with certain of Nicholson's arguments.

Anthropogenic biomass burning, a key process in land degradation and desertification under particular circumstances, may have critical implications for atmospheric emissions. For example, Mead *et al* 2008 measure methyl halide emissions from domestic biomass burning sources on the African continent. The authors observe a clear increase in such emissions, suggesting that such an increase could ultimately comprise a significant component of the overall global methyl halide budget. Methyl halide comprises a significant source of atmospheric inorganic halogen compounds which in turn affect many stratospheric and tropospheric chemical processes (for example, decreasing stratospheric ozone) (Redeker *et al* 2004).

Thirdly, anthropogenic disturbances of the land surface may result in wind erosion, increasing, for example, atmospheric dust loads. Korcz *et al* (2009) used a mesoscale model to assess wind blown dust emission for Europe, and selected areas in Africa and Asia. The authors conclude that despite challenges inherent in such assessments, the dust emission model is useful in differentiating between natural and anthropogenic emissions.

Irrigated agriculture in drylands may critically impact on surface conditions. In the semi-arid northern Sandveld in South Africa, for example, an area of high ecological significance at the transition between two internationally recognized biomes, the land surface has been substantively transformed (largely by clearing for cultivation) by the presence of intensive commercial agriculture (Archer *et al* 2009). The provincial nature conservation agency for the area, Cape Nature, indicates that more than half the natural habitat in the area has already been transformed, with clear implications for natural habitat retention, water security and site vulnerability to climate change (Archer *et al* 2009).

Finally, climate change may critically impact on existing processes of desertification if, for example, a higher frequency of dry spells or a lower critical rainfall season (such as that projected for the western parts of Southern Africa, see above) occur. In an area under pressure from overgrazing, for example, or over- or inappropriate use of water; thus resulting in desertification processes; climate change can act as an additional pressure or stressor that can amplify such a phenomenon. Sivakumar (2007) observes that climate change can further exacerbate desertification processes through changes in temperature, precipitation, solar isolation and winds. Tadross and Archer (2009) observe, for example, that changes in wind dynamics may have implications for coal mining operations in the arid and semi-arid regions of South Africa. Such a dynamic has implications for mining personnel and local communities (e.g. more frequent use of dust filters, dust inhalational problems in environmental health), but it also complicates the process of addressing desertification through reversing or restoring local ecology after possible negative ecological impacts of mines, particularly if changes in wind dynamics are coupled with a higher probability of desiccation.

Responding to climate change in the context of desertification

Reynolds *et al* (2007) observe the lack of a focused international science program in desertification, and propose the aforementioned Drylands Development Paradigm (DDP) as a useful framework in which to consider coupled human-environment systems in arid areas. Although not yet rigorously tested in applied situations (Verstraete *et al* 2008), the five general lessons for undertaking work in these areas provide a useful way to frame thinking around responses to climate change in the context of desertification. The lessons comprise the need for an integrated ecological-social approach, a call for increased recognition of slowly evolving conditions, the recognition of non-linear processes (including the aforementioned key role of thresholds), a call for the increased recognition of cross scale interactions, and increased value being placed on local environmental knowledge (LEK) (Reynolds *et al* 2007, Verstraete *et al* 2008).

The South African government are at a critical stage in planning around climate change response, as they move towards translating climate change science into sector specific policies and strategies. South and southern Africa are thus at the stage described by both Reynolds *et al* (2007) and Verstraete *et al* (2008) as they call for the bridging of the gap between science and policy, and increased accessibility of scientific information to users and policymakers. A number of sectoral responses may also have relevance to responses to desertification, thus allowing multiple benefits in different problem areas – this resonates well with the focus in the DDP on the need for integrated ecological-social research, focusing, for example, on strategies that simultaneously support livelihoods and ecological management (Reynolds *et al* 2007). For example, sectoral responses in agriculture may include strategies to address wind and water erosion as a result of increased desiccation and wind dynamics in parts of South Africa (examples here would include the Department of Agriculture's Integrated Soil Protection Strategy, which focuses on maintaining land production potential; or the former Department of Water Affairs and Forestry's Working for Water and Working for Wetlands initiatives – see below). Since such phenomena are a critical component of desertification processes, such efforts would dually respond to climate change stressors and desertification; and might further support local livelihoods by falling within, for example, the Working for Water Programme of the former Department of Water Affairs and Forestry (where water conservation activities were presented as employment generation opportunities, amongst other priorities).

Sectoral responses in the area of biodiversity typically tend to focus on ecosystem health, and ecosystem services – thus a climate change response in the conservation sector could, again, additionally focus on restoring ecosystem services lost under climate change. Lastly, sectoral responses in the area of water, such as in the Sandveld example provided above; would focus, in all likelihood, on improved water use efficiency and better coordination between water users, given projected future water shortages.

Such a strategy would simultaneously address the issue of anthropogenic transformation of the land surface in dryland areas.

A review of the sectoral policy response examples provided above should indicate that most are not restricted to the sector in which they have been suggested. A purely sectoral approach, whether targeting climate change, desertification, or amply addressing both phenomena, would be flawed and limited in it's ability to address cross-sectoral and cross-scale (Reynolds *et al* 2007) processes (for example, the protection and restoration of ecosystem services). As a result, a multi-sectoral approach to strategy development is critical here. As mentioned earlier, climate change generally forms one of a range of external stressors that can, for example, exacerbate or amplify an existing situation of desertification. As a result, and as emphasized in the DDP, an integrated approach needs to be undertaken, acknowledging the challenge of multiple stressor phenomena. Verstraete *et al* (2008) further emphasize the need for such an approach, as they observe that a particular adaptation strategy may often be a strategy that addresses several factors.

Lastly, again whether in the area of climate change, desertification or, preferably, considering strategies that address more than one of such challenges; it is essential to root understanding and design of response within what stakeholders in dryland areas are currently doing (see for example, Archer *et al* 2008); further emphasizing the DDP's focus on local environmental knowledge (Reynolds et al 2007). From the communal farmer to the mining consortium in a dryland area, dryland stakeholders frequently have substantive experience in responding to the challenges of climate risk (whether short term, or longer term climate variability) and/or desertification. A successful response strategy will build on and (where necessary) add value to what is already planned or under way.

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