



The immediate and long-term effects of aridification in a developing country context: The Karoo, South Africa

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Abstract

In January 2017 the Karoo entered a 58-month drought that destroyed 30% of livestock in the region. Grazing declined by 40-60%, but recovered within two years after the rains returned. Feeding costs ate into profits and real net farm income tracked SPI-12 closely on the way down. While grazing capacity recovered, livestock numbers have not, and financial data must still be collected before financial recovery can be assessed. The government provided adequate drought relief but too little technical support, and limited data collection undermines our ability to evaluate and improve adaptation going forward.

Introduction

Wool provided the foundation for commercial agriculture in the Cape Colony in the 19th century. The Colony's 12 million sheep of 1904 doubled to 25.6 million by 1935, where it remained until 1965 (Department of Agricultural Economics and Marketing 1962; Republic of South Africa Department of Statistics 1964/65). Much of this was in the Karoo, the arid hinterland to Cape Town. After 1965 official sources show the Cape Province⁹ losing sheep at a rate of 2.83% per annum (pa) due to drought and other factors (Statistics South Africa 2002, 2017).

The Karoo is an open landscape loosely bounded by the 400 mm isohyet and is spread across the Northern, Eastern and Western Cape Provinces. The winter-rainfall Succulent Karoo transitions into a summer-rainfall Nama Karoo biome (Mucina and Rutherford 2006). The matrix of dwarf shrubs is interspersed with mesembs in the former and grasses in the latter. Despite two centuries of commercial exploitation, farmland supports as much mammal diversity as protected areas (Drouilly et al. 2019). Freehold is the dominant tenure system. Fencing began in the 19th century and paddocks are still being improved. Modern animal husbandry sits along transhumance enabled by proximity to the rainfall divide, although selective purchases by lifestyle investors is disruptive (Reed and Kleynhans 2009) and damaging to the vegetation (Milton et al. 2023).

⁹ [The Cape Colony, Natal and the Boer Republics unified in 1910. The Cape became a province in the Republic of South Africa after 1961 and divided into three provinces in \(Northern, Western and Eastern Cape\) in 1998. The switch from singular to plural in the text below is therefore deliberate.](#)

It is difficult to determine the contribution of climate to developments in this rapidly changing landscape (Kiem and Austin 2013). This study brings together weather data, data from ongoing vegetation monitoring and one community's farm management data to assess the extent and impact of the 2017 drought.

Methods

A standard precipitation index (SPI-12) measures the severity and duration of the drought. It was fitted to a rainfall series that dates to 1927. Droughts are defined as beginning with $SPI-12 < -0.5$ and ending with $SPI-12 > 0$ for a sustained period. Vegetation monitoring commenced in 2017. Line point surveys are conducted at 500 points taken along a 900 m transect running from watering points towards paddock boundaries to capture local grazing gradients. The precise transect is resurveyed every three years and grazing capacity is calculated from a species list according to the method described in du Toit (1998).

The Karoo Management Panel (2012 – 2021) represents a convenience sample of 86 family farms (Conradie et al. 2019). It covers 420 000 ha. This study limits analysis to units whose wool and mutton income exceeds 67% of gross farm income. The observations were partitioned into baseline (control) and drought (treatment) groups whose means were compared using t-tests. There were $n = 249$ farm-years in the control group and $n = 337$ farm-years in the treatment group. Five variables were analysed including farm and flock size, stocking density, real feed cost and net farm income. Stocking density is measured in large stock units (LSU) per hectare, with an LSU defined in terms of the energy requirement of a growing ox. Meissner et al. (1983) tabulated LSU coefficients for a range of livestock types from which standard stocking units can be compiled to feed into stocking density calculations. Feed cost and farm income is expressed in ZAR (USD = ZAR 14.50 in December 2020) with a CPI deflator converting nominal to real values. Net farm income was computed in the usual way; gross income minus enterprise-specific costs gives gross margin and net farm income is obtained by subtracting overheads such as labour and machinery cost from total gross margin. Revenues include livestock, crops, farm-based tourism and light manufacturing but ignores salaries and investments. Land is owned and rented, with quality unadjusted.

Results

SPI-12 identifies January 2017 as the beginning of the drought which lasted until October 2021. The index averaged at -1.46 ± 0.67 , hovering around -2 from July 2019 to February 2021. The lowest value of -2.56 was recorded 42 months into the drought. Table 1 relates grazing capacity to rainfall and temperature. Long-term grazing capacity equals the legal limit (RSA 2018), while observations for 2018-20 coincide with the drought and the period 2021-23 reflects the degree of recovery. At baseline, site A was 12% below its long-term average capacity with the other sites 22% above capacity. The drought destroyed 30% of measured capacity at sites C and D and twice as much at sites A and B. During the driest periods (2015-2020) all four sites also experienced the most extreme warm days that intensify the impact of the drought. Twenty-four months after the rains returned, grazing capacity was back at 98% of its long-term level at site A and more than 10% above at the other sites. Crown cover, the most important contributor to grazing capacity, improved more quickly than species richness (Table 1).

Table 1: Rainfall, temperature, grazing capacity, species richness, and % perennial crown cover at four Karoo sites before during and after the drought.

	Period	Site A	Site B	Site C	Site D
Rainfall	Long-term	120	230	230	270
mm per annum	2015 – 2017	84	224	248	284
	2018 – 2020	47	198	229	229
	2021 – 2023	148	343	360	299
Temperature	Long-term	149	77	126	87
Days >30°C	2015 – 2017	151	86	134	91
	2018 – 2020	160	86	132	109
	2021 – 2023	145	69	110	96
Grazing capacity	Long-term	42	28	24	22
ha/LSU	2015 – 2017	47	23	18	17
	2018 – 2020	101	69	34	31
	2021 – 2023	43	25	25	18
Species richness	2015 – 2017	13	24	20	26
(perennial plants)	2018 – 2020	10	15	14	19
	2021 – 2023	15	22	13	21
% crown cover	2015 – 2017	15.4	36.8	59.2	70.6
(perennial plants)	2018 – 2020	9.0	17.4	92.6	81.6
	2021 – 2023	19.8	43.6	89.8	70.4

The 2017 drought is one of four major events recorded in the Karoo since 1927 (Table 2). The first drought lasted for most of the 1940s at a low intensity. It reduced Karoo flocks by 14%. Drought relief, if any, was not recorded in the sources we had. The second drought was shorter but more intense. The Cape Province entered it with 21.3 million sheep in April 1968 and lost 3.8 million sheep over the following 35 months. The government spent the current equivalent of ZAR1.7 billion on feed subsidies and railway transport rebates to mitigate its effects, approximately 40% of the value of the national wool crop in 1970. The third major drought occurred in the early 1990s. Conditions deteriorated quickly from February 1991, with the lowest index value reached five months later (SPI-12 = -2.36). The Cape Provinces entered this drought with a third fewer sheep than it had at the beginning of the previous drought but lost the same percentage as in the 1960s. The Cape Provinces entered the 2017 drought with 6.6 million sheep. There is no official record of how many survived, but the Karoo Management Panel can provide anecdotal evidence of how one community was affected by the drought. This panel dates to 2012, with the most recent wave coinciding with the end of the drought. At baseline (2012 – 2016) farms typically ran flocks of 1200 stock sheep on 10 000 ha, stocking at 11% above the legal limit. As rental contracts were abandoned farm size decreased by 12.8% during the drought (t-stat = 2.118). Flocks shrank by 30% (t-stat = 3.761) and consequently stocking density fell to 79.5% of the legal limit (t-stat = 8.526). Feed cost increased threefold, from ZAR430/LSU to ZAR1198/LSU (t-stat = -6.106), rendering many profitable farms unviable. Net farm income dropped from ZAR30/ha to ZAR-1.11/ha (t-stat = 5.457).

Table 2: Four historical Karoo droughts

Period	Drought index SPI-12	Cape Provinces' sheep numbers in each drought		Drought relief ZAR million (2020)
		Beginning	End	
Aug 1940 – Oct 1949	-0.55 ± 0.82	24	20.6	
Apr 1968 – Jan 1971	-1.37 ± 1.12	21.3	17.5	1703
Feb 1991 – Apr 1995	-0.47 ± 0.79	13.8	11.9	1677
Jan 2017 – Oct 2021	-1.46 ± 0.64	6.6		521

In Figure 1 the available farm income data overlay the SPI-12 index for the period 2010 to the present. Single variable analysis of variance indicates year-on-year differences in profitability ($F = 4.59$) with Bonferroni correlations confirming a structural break in 2017, which supports the SPI-12 data. The break in feed cost is in 2018 while stocking densities were adjusted in 2016 in anticipation of the drought. We are still awaiting the data with which to analyse possible financial recovery.

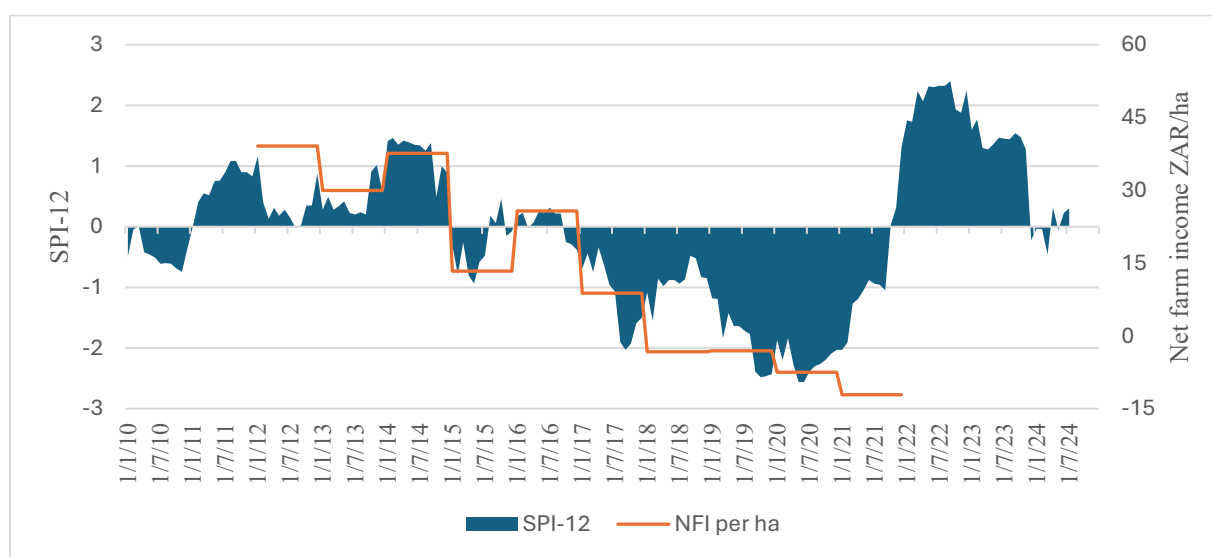


Fig. 1: Correspondence of SPI-12 drought index with net farm income (NFI) per hectare from survey data.

Discussion

The recovery of grazing capacity after the 2017 drought reported in Table 1 is different from how most rangeland ecologists see the effects of drought in the Karoo. In the Succulent Karoo mortality rates varied by species from 9-82% after the 2017 drought (Milton et al. 2023). Expected recovery is predicated on a “recruitment event”, i.e. sustained rainfall over several months for shrub seedlings to become established. Excluding all herbivores would be ideal at this time (Milton and Wiegand 2001), but for game farmers it is technically infeasible and for sheep farmers it is unwise to give up the benefits of years of genetic selection even if other investment opportunities existed. Experience suggests that conditions for recruitment were poor at the end of the 1990s drought, which might explain the sharp decline in flock size since, although this is still an open question. Continuous grazing decreases palatability and, in a drought, lowers the perennial fraction of the vegetation (Milton et al. 2024; Wiegand

and Milton 1996). With more short-lived species in the mix, the rangeland becomes less productive and less resilient (Milton et al. 2023).

The 2017 drought was long and intense. It hit an industry that had become a shadow of its former self. The losses suffered remain uncertain as there has not been a census since 2017. Disaster relief decreased drastically in absolute terms, returning to a rate of support provided during the 1960s drought. This has implications for the number of livelihoods the Karoo can support. As the number of livelihoods decline, farm size must rise (Asghari et al. 2021). There are already farms of >20 000 ha spread over several cadastres, units that are rapidly becoming too expensive and time-consuming to operate. Moreover, drought relief was actively biased against large operators (Conradie 2019) which hindered the adaptation needed to bring management systems in line with the expected ecological changes.

Conclusion

The priors for this study were that the 2017 drought was the worst on record, that it permanently damaged the rangeland and that farmers were severely compromised by a lack of drought relief. The analysis showed that 2017 was just one of several serious droughts, that the rangeland recovered quickly and that farmers received the same level of support as before. But we do not know what contributed to the collapse of the industry before 1990, if changes in the weather accelerated the collapse since, or how farmers are faring now. We cannot act on the sound advice to prepare for the next drought now because we missed the opportunity to collect the data for a proper postmortem of the 2017 event. While South Africa's climate change adaptation efforts could benefit from technical assistance to our institutions, we remain the most technically proficient in the region. Colleagues in Namibia, Botswana, Zambia, and Zimbabwe likely face similar technical challenges as we do and almost certainly must contend with more serious funding problems than us. However, funds without proper implementation will achieve little.

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