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The 2015-19 multi year drought in the Eastern Cape, South Africa: it's evolution and impacts on agriculture

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ABSTRACT

The Eastern Cape Province, and in particular, it's interior western Karoo region, has long been subject to periodic droughts, with significant implications for it's agricultural sector. From 2015, with some recovery in 2020, the area experienced a severe multi year drought, with negative impacts for a range of sectors, including extensive livestock farming. At the time of the drought, a common narrative in the media stated that the drought was unprecedented. In this paper, we analyze how the drought evolved climatically, as well as its impacts on vegetation and farming conditions. Our findings indicate that it would appear that the drought was not unprecedented. It was, however, considered to be extremely severe – with some local impacts found to be critical. Loss of production impacts, and loss of income, now compounded by the difficulties resulting from the COVID19 pandemic (which has impacted the South African economy severely) are likely to continue to impact the agricultural sector in the Eastern Cape for some time – and given the likelihood of increased frequency of extreme events in southern Africa in the future, we may see more frequent subsequent severe multi-year events.

1. Introduction

The Eastern Cape Province, and, in particular, the western more arid interior, was subject to a severe multi year drought, from 2015 through to early 2020, when some recovery was seen. The drought received a significant amount of public attention, with the frequent statement that the drought was unprecedented, and/or the most severe on record.

In this short communication, we analyze the evolution of the drought, including the issue of whether it was truly unprecedented. Secondly, we consider impacts of the multi-year drought on key sectors (including water and grazing); using a range of methods. We conclude with recommendations for how future multi-year droughts might be better managed, particularly given the likelihood of a higher frequency of such events in the future.

2. How the drought evolved

The Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) rainfall dataset (Funk et al., 2015) is used to investigate how the drought experienced from 2015 through to early 2020 over the Eastern Cape evolved. We adopted an approach to consider the seasons of September-October-November (SON), December-January-February (DJF), March-April-May (MAM) and June-July-August (JJA) for the rainfall analysis. A regionalization based on rainfall characteristics is performed in order to construct a rainfall timeseries for the various homogenous rainfall regions over the western interior of the Eastern Cape. Cluster analysis is frequently used for the identification of homogeneous rainfall regions over southern Africa (e.g. Mason 1998; Mimmack et al., 2001; Landman et al., 2009; Philippon et al., 2012;

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Conway et al., 2017) and are applied in this study as well.

Before application of the cluster analysis, a Self Organizing Map (Kohonen 1984) in this case, the rainfall data - was standardized following the method of Mimmack et al., (2001) to retain the annual rainfall cycle. As in Philippon et al., (2012), the cluster analysis is performed on 365 daily long-term means based on a 30-day moving average. A 3 × 3 SOM is found to be well suited for the delineation of homogenous rainfall regions over the area of interest. The all-year rainfall region (clusters 7 and 8 in Fig. 1b), defined as where at least 5% of the annual rainfall occurs during all the calendar months (Taljaard, 1996), is distinguished from the areas that receives most of its rainfall during the austral summer months. The regional differences within the summer rainfall region is captured, e.g. the late summer rainfall maximum over clusters 1, 2, 3 and 4 and the more even distribution towards the eastern areas of the domain (eg. Taljaard 1986) (see Fig. 1).

The region under investigation in this study is mostly situated over the western interior of the Eastern Cape, westward of the 500 mm isohyet and are grouped into two regions for the purpose of the rainfall time series analysis. Region 1 is the rainfall clusters 5 and 9 and Region 2 of rainfall cluster 3 (Fig. 1b) west of the 500 mm isohyet (Fig. 1a) and with the western boundaries of both Region 1 and 2 within the Eastern Cape geographical domain.

Normalized rainfall anomalies for Region 1 and Region 2 for SON, DJF, MAM and JJA are shown in Fig. 1c for the period of SON 1981 through to DJF 2019–2020. The 2015 to early 2020 drought started over both Region 1 and 2 during the DJF season of 2015–2016. The following MAM and JJA seasons were dry and no relief came at the start of the next summer rainfall season. Near-normal rainfall occurred over both regions during DJF of 2016–2017, but was followed by a dry 2017 MAM season (normalized rain anomalies of about −1.5), a dry 2017 JJA season as well as a dry 2017 SON season. Some relief was experienced during DJF of 2017–2018 with near-normal to slightly above-normal rainfall that occurred. Rainfall during MAM and JJA of 2018 failed. The 2018–2019 rainfall season also failed, with SON and DJF that experience below-normal rainfall, while MAM of 2019 received near-normal rainfall. The winter of 2019 was one of the driest winters over both Region 1 and 2 since 1981. The onset of the summer rainfall failed in 2019. Relief of the dry conditions were experienced over Region 2 during the DJF season of 2019–2020, and to a lesser extent over Region 1.

Apart from the multi-year drought from 2015 to early 2020, the preceding years are characterized by an absence of good rainfall seasons during the peak rainfall periods. For example, the start of the rainfall season failed from 2008 through to 2019, with the exception of the SON seasons of 2014 and 2015. The last substantial DJF rainfall season over Region 1 was in 2013–2014, while over Region 2 it was in 2010–2011. For MAM, 2012 was the last good autumn rainfall season. This translates to relatively below normal rainfall in general over the western interior of the Eastern Cape prior to the multi-year drought of 2015 through to early 2020. Of interest however is the DJF seasons during 2015/2016 to 2019/2020 that were not unprecedently dry since the start of the rainfall timeseries analyzed, even for DJF of 2015/2016, considering that the El Niño of 2015/2016 was one of the strongest events on record (L'Heureux et al., 2017). Usually, South Africa's summer rainfall areas experience drier than normal conditions during the mid-summer months of El Niño years (Landman and Beraki, 2012). The DJF seasons of the early 1980's and early 1990's that include the El Niño's of 1982/1983 and 1991/1992 were notably drier than the DJF seasons during the drought of 2015 to early 2020. For Region 2 (cluster 3), DJF is the main rainfall season.

By ranking each of the above 3-month seasons from driest to wettest, the last 4 years of the analysis are not particularly dry for either DJF or MAM. The exception is MAM 2017, for which the regions are ranked 4th driest for region 1 and 2nd for region 2. However, the SON season experienced severe droughts in both 2016 and in 2019. In fact, region 1 during this season is ranked 1st and region 2 3rd driest in 2016, while in 2019 the ranking is 2nd driest for region 1, and driest for region 2. Also, JJA of 2019 is found to be the 2nd driest for region 1 and the driest for region 2. To further emphasize the intensity of these JJA and SON recent dry years, a return period analysis is performed. Through maximum likelihood estimation (Wilks, 2011) the theoretical distributions considered presented the following return periods in years: SON region 1 (generalised extreme value), 239 years for 2016, and 21 years for 2019; SON region 2 (gamma), 61 years for 2019, and 32 years for 2016; JJA region 1 (lognormal), 45 years for 2019; and JJA region 2 (gamma), 74 years for 2019.

3. Impacts of the drought in the interior Eastern Cape

We considered the drought from a range of different angles; in an attempt to truly understand it's impacts, and its severity. We first consider vegetation conditions over the area, using both analysis of remote sensed imagery and repeat photography. We then look at responses to a farmer survey in a sub-region of the Eastern Cape.

3.1. *Vegetation conditions*

Firstly, vegetation response to the multi-year drought situation indicates the intensifying grip that prolonged dry conditions had. Vegetation response to drought differ according to biome, season and drought duration (Vicente-Serrano et al., 2013; Lawal et al., 2019) but activity is positively correlated with rainfall anomalies for the entire arid to semi-arid region, with strongest correlation on intra-annual timescales for most of the Karoo biomes (Lawal et al., 2019). Fig. 2 shows a time series of 6-monthly (January–June and July to December) cumulative vegetation, as reflected by the Normalized Difference Vegetation Index (NDVI), expressed as a percentage of the long-term average (calculated over the period 1998–2019) per pixel. The January–June cumulative vegetation is in response to mid-and late summer rainfall, while the July–December activity gives an indication of the strength of the early summer rainfall. Much of the interior in this area is a summer-rainfall region.

For the period since January 2014, the only half-year with widespread above-normal vegetation activity as reflected by the PASG was January–June 2014. During most of these, the most intense drought conditions are indicated over the area Calvinia, south-eastwards into the Great Karoo and Little Karoo. The second half of 2015 and first half of 2017 benefitted from more favourable conditions. However, during the rest of the 6-year period, most of the area experienced drought-related impacts on vegetation. The largest extent of negative anomalies clearly occurred during both the first and second halves of 2019 when the drought footprint expanded into the entire Eastern Cape. This is an indication of the drought reaching a maximum intensity and extent during 2019. This is a factor of both the intensity of drought conditions in 2019 as well as the cumulative effect of the prolonged dry conditions since 2014.

3.2. *Repeat photography*

Secondly, we used repeat photography to estimate changes in cover of vegetation life forms in the Upper Karoo during and after the drought. Photographs were taken at 51 sites (November–December 2019) from 21° to 25.5° E and 30.5°–31.5° S (Fig. 3) and repeated between March and July 2020 following significant rains. Total cover of grasses, dwarf-shrubs, and trees, and individual mortality in dwarf-shrubs and trees, were estimated in both sets photographs. Changes in the cover of life-forms in the paired photographs were analyzed using paired t-tests. The relationship between longitude and change in grass cover was assessed using linear regression.

Total vegetation cover was higher in 2020 (50.9 ± 15.9%) than 2019 (31.7 ± 10.2%); t_{50} = 10.1, grass cover was higher in 2020 (27.5 ± 17.9%) than in 2019 (6.3 ± 8.5%); t_{51} = 10.1, and shrub cover was

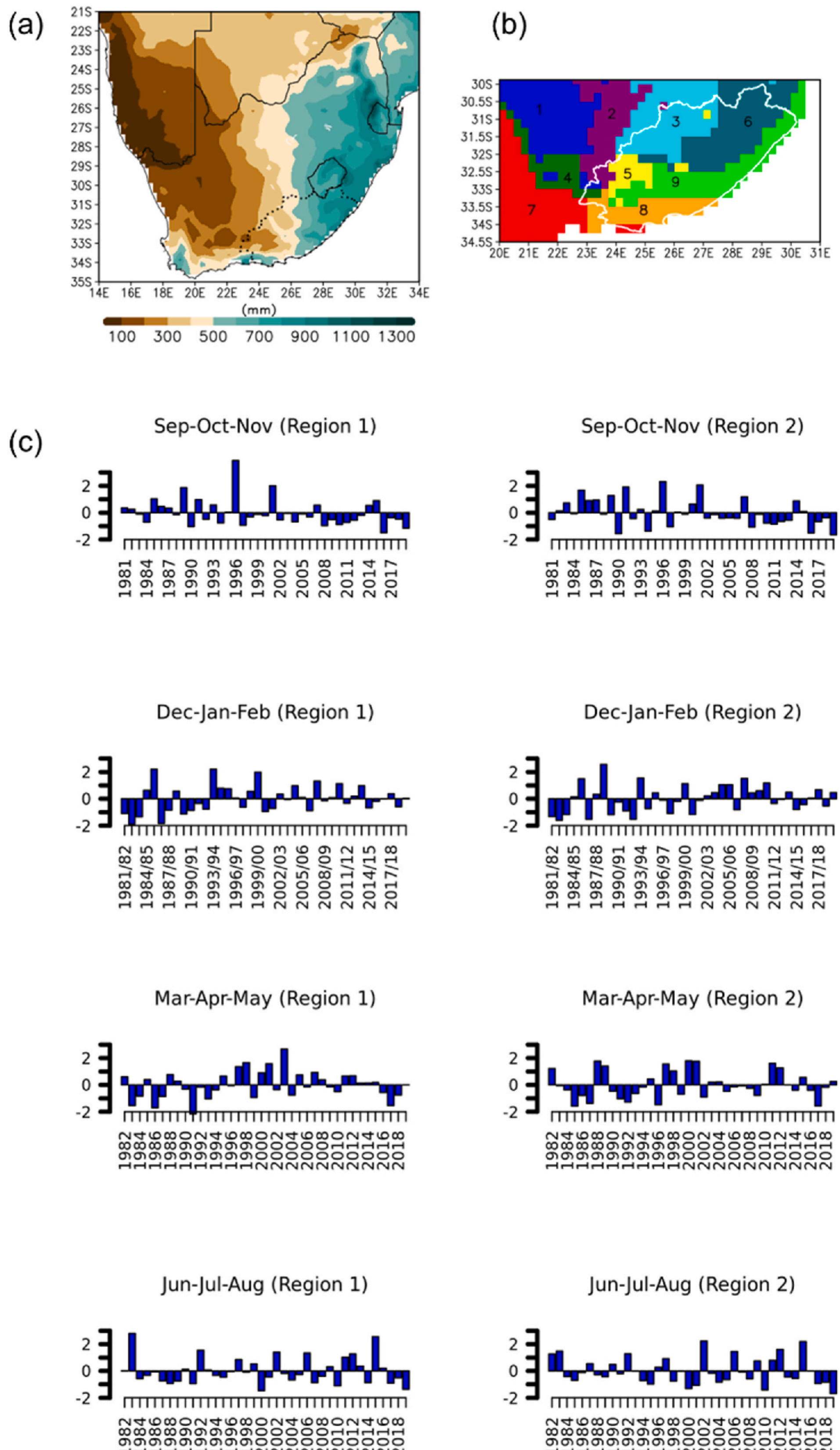

Fig. 1. (a) Mean annual rainfall (mm) over South Africa as determined from CHIRPS rainfall data. (b) Regionalization of rainfall over South Africa east of 20°E and south of 30°S to include the Eastern Cape and Karoo regions to the west of the Eastern Cape as determined by a Self Organizing Map, (c) Normalized rainfall anomalies for Region 1 and 2 for the SON, DJF, MAM and JJA seasons from SON 1981 to DJF 2019–2020.

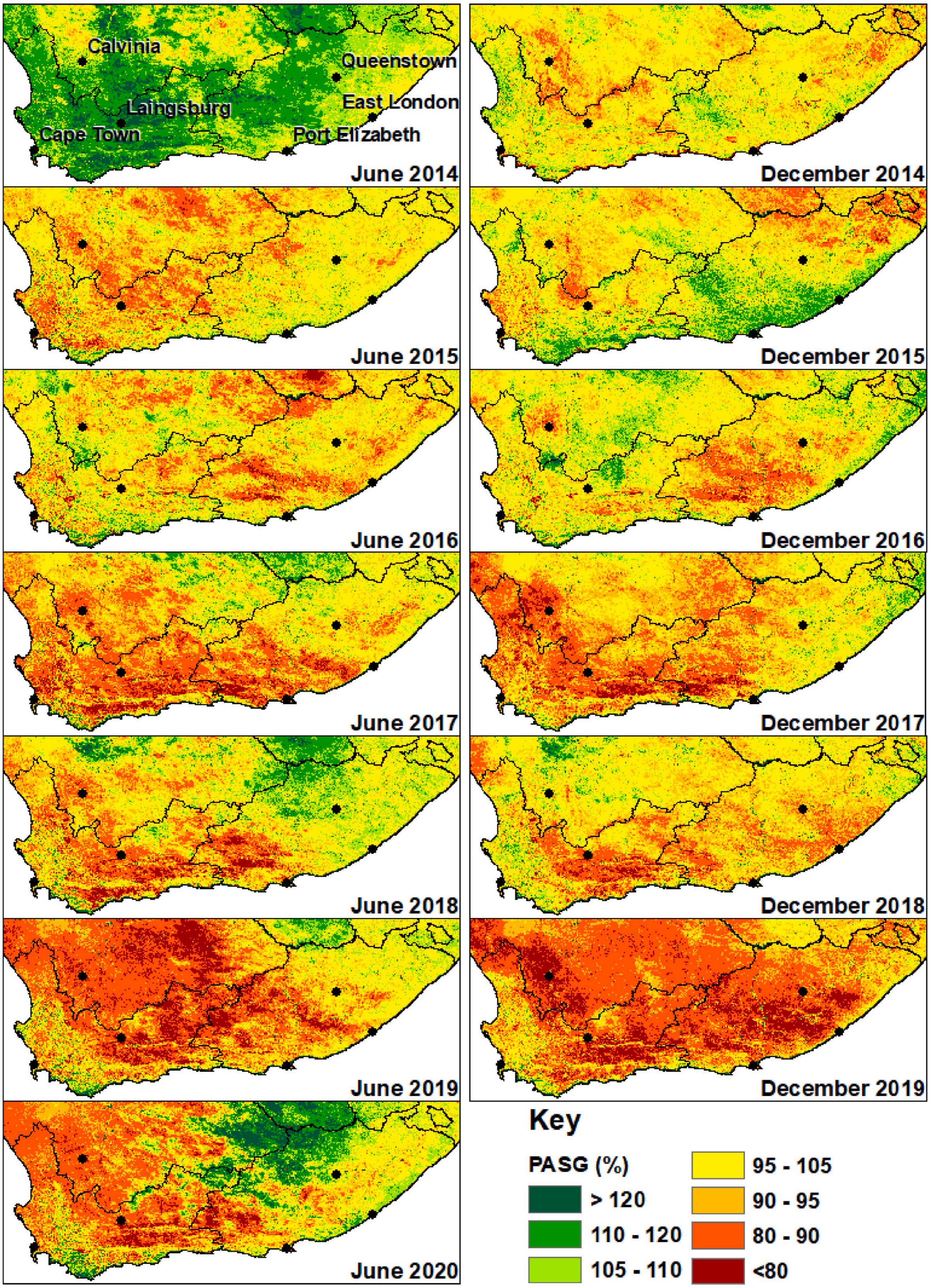

Fig. 2. Percentage of average seasonal greenness (PASG), for 6-month periods terminating in the months indicated, for 2014–2020.

lower in 2020 (18.3 ± 10.2%) than in and 2019 (20.4 ± 9.7%); $t_{50} = -4.42$ ($P < 0.001$ in all cases). Tree cover remained constant, and there was no evidence of shrub or tree mortality. Grassiness increased from west to east ($F_{1,49} = 59.9$; $P < 0.0001$; $y = 7.03x - 146$; $R^2 = 0.55$).

Rain-induced increases in grassiness are consistent with other findings (Bedford and Roberts, 1975; O'Connor and Roux, 1995; du Toit & O'Connor, 2019). Both resprouting and mortality of perennial grass tufts occurred, suggesting that the drought was not sufficient to extirpate

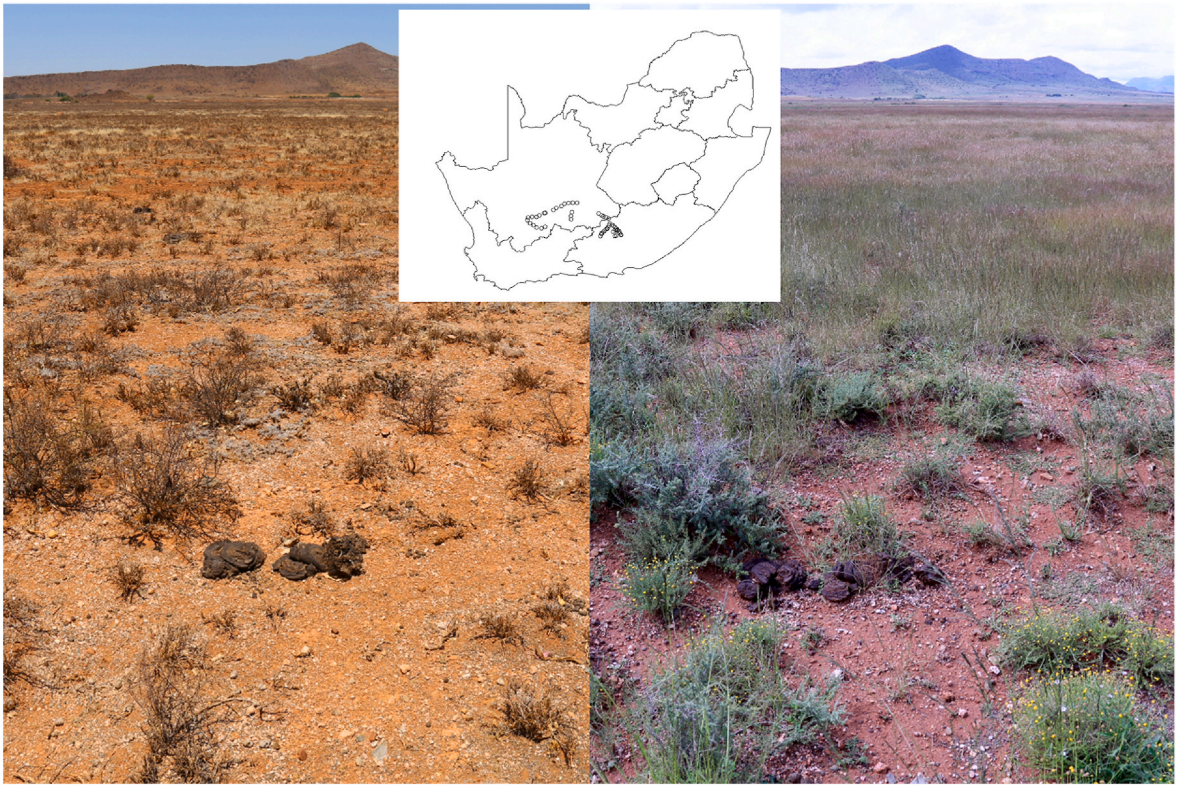

Fig. 3. Locations of repeat photography sites (black circles; inset) and repeat matched photographs of a site between Middelburg and Graaff-Reinet taken in November 2019 (left) and March 2020 (right).

grasses at landscape levels, and surviving tufts should produce seed for future distribution and establishment. The drought was not severe enough to reverse the general trend of increased grassiness observed in the Karoo (Masubelele et al., 2015; du Toit et al., 2018) that has been explained by the increase of rainfall in the region since the mid-1970s (du Toit & O'Connor, 2014; Harmse et al., 2020). Future research attention on the responses of individual plants and species to drought is needed.

Shrubs survived the drought, and it is likely that their apparent decrease (from 20 to 18%) was because grasses slightly obscured them in the 2020 photographs. Dwarf shrubs usually survive droughts better than perennial grasses (du Toit & O'Connor, 2019). There was no evidence of mortality of individual shrubs, indicating that this key growth-form was not unduly affected by the drought. However, mortality may have been higher further west where the drought was more severe. Trees, where they occurred, showed the same response as dwarf-shrubs, with cover and survival remaining approximately constant.

3.3. Farmers' surveys

Finally, in assessing the effect that the drought had on livestock production systems, farmers in the area were surveyed directly; in terms of how they had been impacted by the drought period. Almost no direct livestock deaths due to the drought were reported from farmers surveyed in the Eastern Cape (in the Nieu Bethesda, Graaff Reinet, Cradock, Pearston, Murraysburg Road-districts).

There were, however, many indirect losses as a result of drought, including loss of condition of livestock which led to loss of production with very low conception rates (conception as low as 10% was reported). Farmers reported little or no milk production increasing kids/lambs mortality (when mothers walk away because of no milk) and poor weaning percentages. Higher livestock losses than normal occurred due to higher pressure from predators. Farmers experienced a loss of income due to the destocking of animals. A further loss of income was experienced due to having to feed animals to maintain their condition. Internal parasites were significantly higher, which resulted in stock losses. Strikingly, loss of natural game was also reported - especially kudu (that sometimes form part of secondary business on farms, i.e. hunting/tourism). Game farmers in the area also reported low conception amongst game animals due to the drought.

Loss of income also occurred due to poor stock and wool/mohair prices during drought (e.g. mohair dropped by 30% in price during this time); and weights shorn were also lower (a farmer south of Graaff Reinet mentioned that his 'clip' were down 25%). Wool farmers indicated similar results. The price of feedlot lambs also decreased from R40/kg to R27/kg, while input costs, of course, remained stable. One farmer mentioned that he has effectively spent twice the value of his stock (in terms of the spend on feed and loss of production) over the past four years.

A number of farms reported water resources (i.e. natural fountains, dams and key boreholes) drying up or being under increased stress – at the time of writing, a number had not yet recovered. Some farmers found that more pipeline would be needed for boreholes, or had to make other investments to provide water for stock.

In terms of the direct question "Was the recent multi year drought in the Eastern Cape unprecedented?"; feedback from farmers differed. One farmer mentioned that comparisons are difficult due to the subjective perceptions of a drought, as well as the time periods in-between, further explaining that the 1966 to 1970 drought was 'as bad if not worse' for some farmers. The severity of this drought was, however, localized, and worse on the "flats", as compared to the mountains. Some farmers did believe that the number of consecutive years of below average rainfall make this drought unprecedented. Most farmers agreed that it certainly was extremely severe and that a few good seasons would be needed for recovery.

4. Conclusions and recommendations

From the mixed methods approach we have taken to understanding the recent multi-year drought in the Eastern Cape, South Africa, it would appear that the drought was not unprecedented. It was, however, considered to be extremely severe – with some local impacts found to be critical. Loss of production impacts, and loss of income, now compounded by the difficulties resulting from the COVID19 pandemic (which has impacted the South African economy severely) are likely to continue to impact the agricultural sector in the Eastern Cape for some time.

Much of the work on climate change indicates that severe droughts and their impacts are likely to be more severe in the future (IPCC 2018; Pörtner et al., 2021). As a result, characterizing such impacts provides us with a useful perspective on how the sector in this area is likely to be challenged in the years to come.

Credit Author Statement

Archer Emma: Conceptualization, Writing – orignal draft, lead author, corresponding author, writing of this paper, All authors contributed to the analysis, as well as the interpretation of results. du Toit. Justin: Conceptualization, Writing – orignal draft, repeat photography, writing of this paper, All authors contributed to the analysis, as well as the interpretation of results. Engelbrecht. Christien: Conceptualization, Writing – orignal draft, Formal analysis, climate data analysis, writing of this paper, All authors contributed to the analysis, as well as the interpretation of results. Hoffman. Michael Timm: Conceptualization, Writing – orignal draft, repeat photography, writing of this paper, All authors contributed to the analysis, as well as the interpretation of results. Landman. Willem: Conceptualization, Writing – orignal draft, Formal analysis, climate analysis, writing of this paper, All authors contributed to the analysis, as well as the interpretation of results. Malherbe. Johan: Conceptualization, Writing – orignal draft, imagery and climate analysis, writing of this paper, All authors contributed to the analysis, as well as the interpretation of results. Stern. Maryke: Conceptualization, Writing – orignal draft, Formal analysis, interviews, and qualitative data interpretation, writing of this paper, All authors contributed to the analysis, as well as the interpretation of results.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Emma Archer (contributing author).

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