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Understanding the evolution of the 2014–2016 summer rainfall seasons in southern Africa: Key lessons

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A B S T R A C T

The recent 2015/16 summer rainfall season in the terrestrial Southern African Development Community (SADC) region appears to be the most severe since the droughts of the early 1980s and 1990s; with well-publicized significant impacts on agriculture and food security. Impacts have been particularly concerning since the 2015/6 season followed a poor rainy season in 2014/15, in certain areas compounding already compromised production (total maize production was, for example, down 40% relative to the previous 5 year average). This paper reviews climate forecasts and observations of the two seasons, and presents examples of the resulting impacts on agriculture within the region. We conclude by considering what may be learnt from this experience, focussing on operational recommendations for early warning within SADC, as well as longstanding needs for awareness raising and capacity building.

1. Introduction

The 2015/16 summer rainfall season in the terrestrial Southern African Development Community (SADC) region appears to be the driest on record since the well-publicized droughts of the early 1980s and 1990s; with critical impacts on agriculture, water and food security well covered in the media. It has had particularly significant impacts, since it followed on from a poor rainy season in 2014/15. In this paper, we review climate forecasts and observations of the two seasons, and present selected examples of the resulting impacts on agriculture within SADC. We reflect on what may be learnt from this experience, focussing on operational recommendations for early warning within SADC.

2. Review of the 2014/15 and 2015/16 summer rainfall seasons

Southern Africa's seasonal rainfall and temperatures are strongly linked to ENSO (e.g. Mason and Jury, 1997), with predominantly dry and hot (wet and cool) conditions associated with El Niño (La Niña) events respectively. In addition to this

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observed association, seasonal rainfall forecasts for southern Africa work best when there is either an El Niño or a La Niña event, while they show less skill during ENSO-neutral seasons (Landman and Beraki, 2012). Moreover, it is during the austral mid-summer (December – February; DJF), when seasonal rainfall (Landman et al., 2012) and temperature (Lazenby et al., 2014) forecasts are most skilful, that ENSO events reach their peak in the tropical Pacific. Since seasonal rainfall forecasts for southern Africa are mostly skilful at 1–2 months lead-time (Landman et al., 2012), longer lead-time forecasts for the expected evolution of ENSO events, while potentially providing additional societal benefits if they support longer term planning, may be more difficult to use effectively.

Notwithstanding the ENSO focus of this paper as a consequence of the strong 2015/16 El Niño event and its impacts on southern Africa, ENSO is not the only seasonal climate driver of southern African seasonal-to-interannual variability. For example, the subtropical Indian Ocean SST Dipole (IOD) events also influence southern African rainfall variations and there is demonstrable co-variability between the basin-scale IOD and ENSO (Behera and Yamagata, 2003). One noteworthy difference between the strong 1997/98 El Niño and that during 2015/16 was the warmer Indian Ocean SSTs during 2015/16, which may explain some of the differences in resulting rainfall (the 1997/98 rainfall deficit was not as severe).

2.1. Comparing forecasts of El Niño and its evolution

Early in the 2014 calendar year, predictions gave a 50% chance that the 2014/15 austral summer season would be associated with an El Niño event (http://www.cpc.ncep.noaa.gov). The predicted probabilities of this El Niño event to occur continued to increase considerably over the following few months, even though the observed atmosphere and oceanic state remained ENSO-neutral throughout the austral mid-summer period. Ultimately, the 2014/15 season was not considered to be an El Niño season, because this event was associated with a notable absence of El Niño-like surface winds and convective anomalies. Notwithstanding, according to the most recent Oceanic Niño Index (ONI; http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml), the 2014/15 season may be considered to be a marginal El Niño event. However, such borderline events could swap around in terminology as reference climatologies and datasets change in the future.

This index is an indicator for monitoring El Niño and La Niña events. The ONI represents the running 3-month average sea-surface temperature (SST) of the Niño3.4 region (5°N-5°S, 120°W-170°W) and compared to a 30-year average. This difference from the average in that region is the ONI value for that 3-month season. El Niño conditions are considered to be present when the ONI is +0.5 °C or higher; La Niña conditions exist when the ONI is −0.5 °C or lower. Periods are regarded as warm episodes (El Niño) or cold episodes (La Niña) when the ±0.5 °C threshold is met for a minimum of 5 consecutive overlapping seasons.

Conversely, the weak central equatorial Pacific Ocean SST warming at the beginning of 2015 developed into a strong El Niño event by the end of that year. Forecast models picked up on the evolution towards an event of unprecedented strength at least six months prior to its peak at the end of 2015. Fig. 1 provides a comparison of observations and of multi-model forecasts of Niño3.4 SST (details of this multi-model approach is found in Beraki et al., 2013). The observed ONI values, as well as Niño3.4 SST forecasts produced by the multi-model forecast system (Beraki et al., 2013) of the Applied Centre for Climate and Earth System Science in South Africa (see forecasts produced via ACCESS; http://www.access.ac.za/), show the difference between the 2014/15 and 2015/16 events. The overly optimistic forecast for an El Niño event to occur in 2014/15 and the underestimation of the strong event of 2015/16 are particularly evident. Note that the forecasts presented in the figure

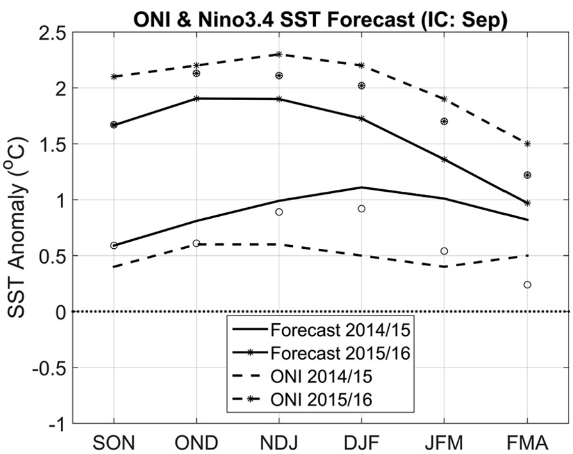

Fig. 1. Niño3.4 SST anomaly forecasts initialised in September (thick black lines) and ONI values (dashed lines) for the 2014/15 ENSO-neutral and 2015/16 El Niño seasons. The open circles and asterisked circles are Niño3.4 SST anomaly forecasts produced at a 0-month lead for the two seasons.

are routinely included in the IRI/CPC ENSO forecast plume and are labelled "CS-IRI-MM" (http://iri.columbia.edu/our-expertise/climate/forecasts/#ENSO_Forecasts).

2.2. Comparing SADC rainfall forecasts and related impacts

Even though an ENSO-neutral state was observed over the equatorial Pacific Ocean during 2014/15, El Niño-like impacts (e.g. droughts) may nonetheless be observed over SADC. Fig. 2 shows DJF rainfall indices (area-averages, normalised) for three sub-regions over SADC with latitude-longitude specification of respectively 26.25°E to 33.75°E, 16.25°S to 16.25°S (Limpopo, South Africa and Zimbabwe – N-East), 13.75°E to 26.25°E, 13.75°S to 21.25°S (northern Namibia, southern Angola – N-West) and 21.25°E to 28.75°E, 26.25°S to 31.25°S (central South Africa – Cent SA), using estimates from the Climate Anomaly Monitoring System – OLR Precipitation Index (CAMS-OPI) dataset (http://www.cpc.ncep.noaa.gov/products/global_precip/html/wpage.cams_opi.html). For these three regions, 2014/15 DJF rainfall was observed to have been below the mean during this ENSO-neutral season. Worse was to follow. Severe drought conditions (<25th percentile value of the climatological record) occurred during the 2015/16 El Niño event, which at least for the Limpopo province and Zimbabwe, can be seen to have been the driest since the severe droughts of the 1980s and early 1990s (Fig. 2). Notwithstanding, above average rainfall was observed over the North-West region, which is in contrast to most of the El Niño seasons for that region as presented in Fig. 2.

Seasonal rainfall forecasts over the larger part of SADC were for predominantly drought conditions to occur for both the 2014/15 and the 2015/16 DJF seasons (e.g. http://www.ecmwf.int/en/forecasts/charts/seasonal/; http://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/), although there were larger drought anomalies forecasted and greater confidence in the drought forecasts associated with the 2015/16 El Niño season. The probabilistic nature of the forecasts is also reflected in the "flexible" seasonal forecasts of the International Research Institute for Climate and Society (IRI).

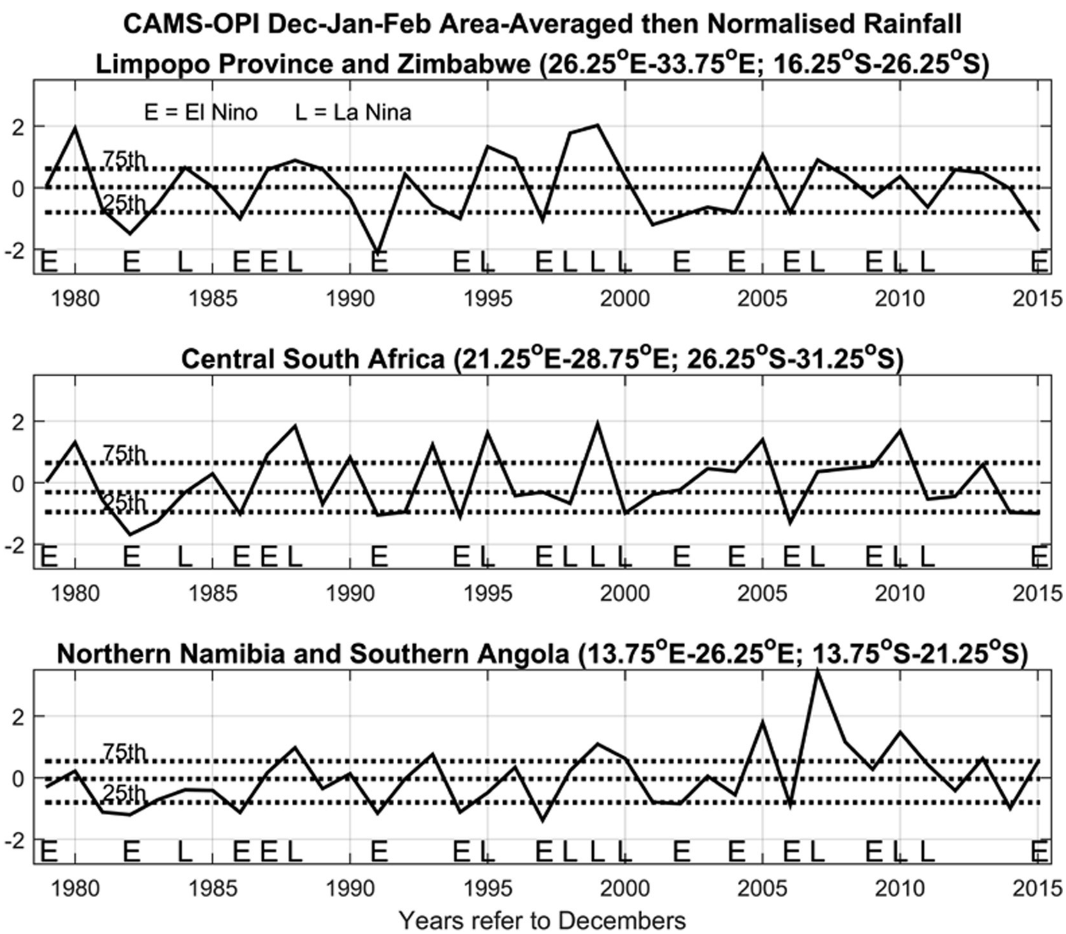

Fig. 2. DJF rainfall indices for the southern African regions specified in the text obtained by area-averaging and then normalising CAMS_OPI rainfall totals (Janowiak and Xie, 1999). The horizontal dashed lines represent the median, 25th and 75th percentile values of the climatological record.

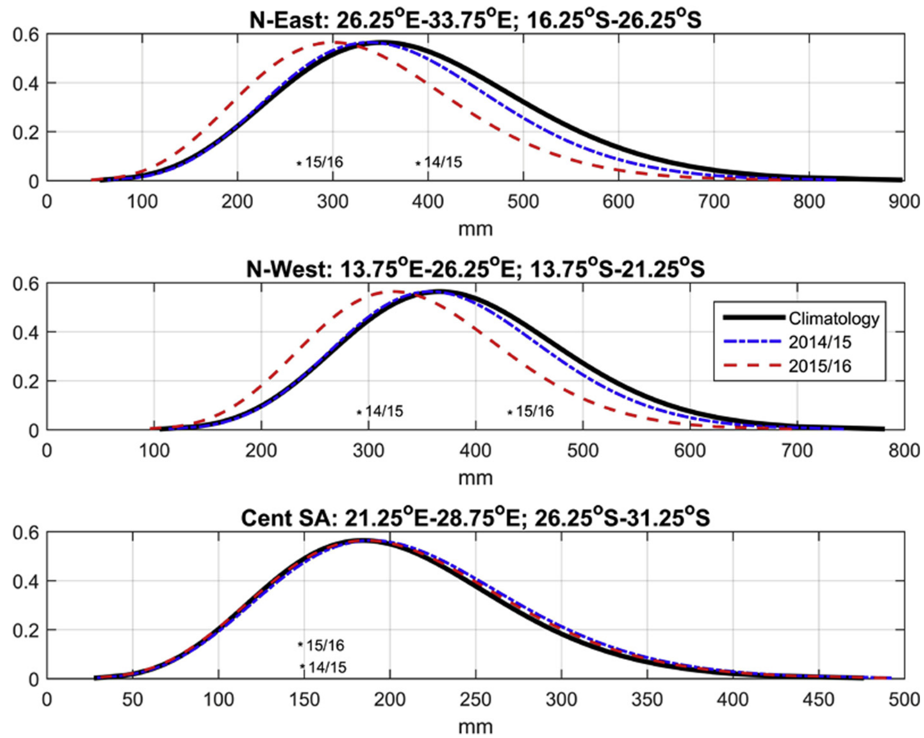

Fig. 3. Forecast and observed PDFs for the two seasons and for the three sub-regions. See text for details. The observed rainfall totals for the two seasons are respectively marked by 14/15 and 15/16.

Such forecasts are based on the full estimate of the probability distribution (the explanation on how these forecasts are produced is found here: http://iridl.ldeo.columbia.edu/maproom/Global/Forecasts/index.html). Fig. 3 shows the probability distribution functions (PDFs) of the DJF rainfall "flexible" forecasts issued in October together with their climatological distributions, for both mid-summer seasons and for the three sub-regions. The contrast between the two seasons in terms of the forecasted shifts in the PDFs towards drought outcomes is clearly seen for the N-East and for the N-West regions, but the central southern African region's forecasts suggest a forecast of climatology for both seasons.

Most of the seasonal rainfall forecast skill for the mid-summer period is found over the north-eastern parts of South Africa and areas north of that, i.e. the N-East region (Engelbrecht et al., 2011; Landman et al., 2012). Notwithstanding, in the absence of a strong signal from the central Pacific, even current state-of-the-art models were not particularly useful in providing forecast guidance for the N-East region during the ENSO-neutral season of 2014/15, which is expected given previous work (Landman and Beraki, 2012). These recent seasonal forecasts have thus largely provided useful guidance to the SADC user community over areas where the forecast skill is high, with the further restriction that a strong climate forcing from the equatorial Pacific Ocean is established. However, results are in line with current knowledge, and were not unexpected.

3. Impacts on agriculture

Impacts on agriculture were evident early in the cumulatively poor rainfall season of 2014/15, with a late onset of the rains over Malawi and other areas, often compounded by devastating floods later in the season. In the 2015/6 rainy season, above-normal maximum temperatures, especially during early- and mid-summer, exacerbated the longer term effect of below-normal rainfall, particularly in areas where the previous season had already been poor. The percentage of average seasonal greenness (PASG) is an index representing the cumulative vegetation activity during a specific period relative to the long-term average. Fig. 4 shows the PASG for the period November 2015 to April 2016. The strong negative impact of drought conditions was particularly evident over the central parts of South Africa into central Botswana, as well as southern Mozambique into the extreme eastern parts of South Africa.

Heat and drought stress, occurring at different times in the growing season, can have significantly negative impacts on crop production (e.g. Al-Kaisi et al., 2013; Malherbe et al., 2015; Mittler, 2006; Wilhelm et al., 1999). The impact of a drought that occurs in the beginning of the season (as was the case in parts of the subcontinent in 2015/6) differs from droughts that happen later in the season (compounded here, of course, in areas where the preceding season had already been poor). Hot and dry spells, a late onset (in certain areas) to the rainy season and that this summer was preceded by another dry period (as mentioned earlier), amplified agricultural and hydrological impacts.

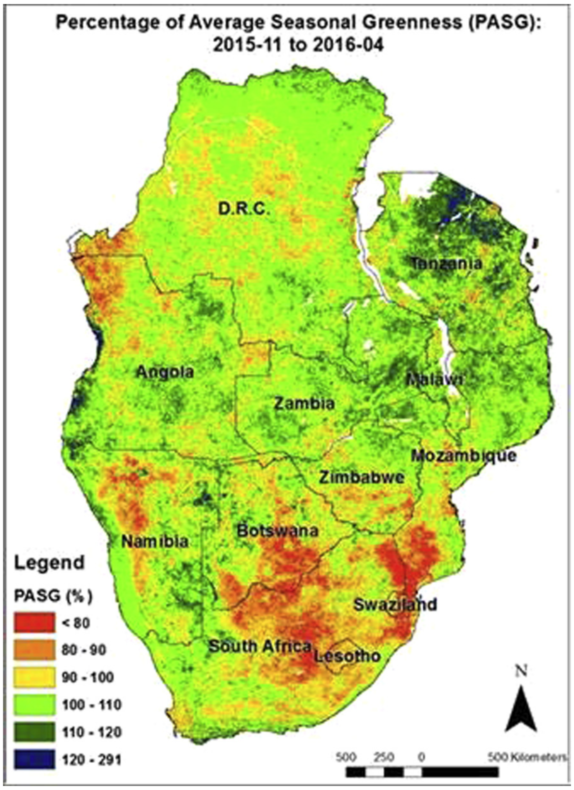

Fig. 4. Percentage of Average Seasonal Greenness (PASG) for November 2015 to April 2016. Produced through the Coarse Resolution Imagery Database Project at the Agricultural Research Council, South Africa. Normalized Difference Vegetation Index (NDVI) courtesy of the PROBA-V Programme of the Copernicus Global Land Service.

Dry conditions especially during the early-to-mid-summer, and especially over the areas with below-normal cumulative vegetation activity shown in Fig. 4, resulted in a much reduced area planted. Together with major yield decreases related to hot conditions, particularly early in the summer growing season, this led to an estimated 40% reduction in maize production in South Africa, the main regional exporter of maize. Expert opinion, together with remote sensing products produced by the Group on Earth Observations – Global Agricultural Monitoring (Geoglam, 2016) initiative, point towards poor agricultural conditions and even crop failure in Mozambique, Zimbabwe, Botswana, Lesotho, Swaziland and Angola by the end of the 2015/16 summer growing season. As this followed a summer with significantly-reduced production, food security thus became a major concern in SADC. Such a phenomenon is borne out by crop statistics published in South Africa through the National Crop Estimates Committee, under the auspices of the Department of Agriculture, Forestry and Fisheries. Additionally, provinces in the main production region over the central to northeastern parts of South Africa (KwaZulu-Natal, North West, Free State, Limpopo and the Northern Cape) were declared disaster drought areas during the 2015/16 summer. Maize yields were as low as last seen in 2007 (during another El Niño event), while yields for other major crops were also drastically reduced relative to previous summers (Fig. 5).

4. Conclusions & recommendations

It is clear that over the 2014–6 period, the SADC region has experienced two consecutively poor summer rainfall seasons, and in 2015/16 the most severe drought conditions since those of the early 1980s and 1990s. This has had critical impacts on agriculture (examples of which are shown here), and has affected the food security situation over the longer term. The reduced rainfall situation for most areas was predicted two months in advance, however – more clearly and emphatically for the later 2015/16 season, which suggests that information regarding future drought conditions was available. That this information was in certain areas ignored or not taken sufficiently on board can be attributed to a range of factors, detailed discussion of which is beyond the scope of this paper.

Nevertheless, we have clearly shown that these impacts are at least partly dependent on conditions during the preceding season, which suggests that current methods for using and making seasonal forecasts should be extended to utilise and account for antecedent conditions that affect agricultural production. This is currently an area of research being addressed through a range of regional science initiatives (including, but not limited to SASSCAL, UMFULA and the FRACTAL programmes

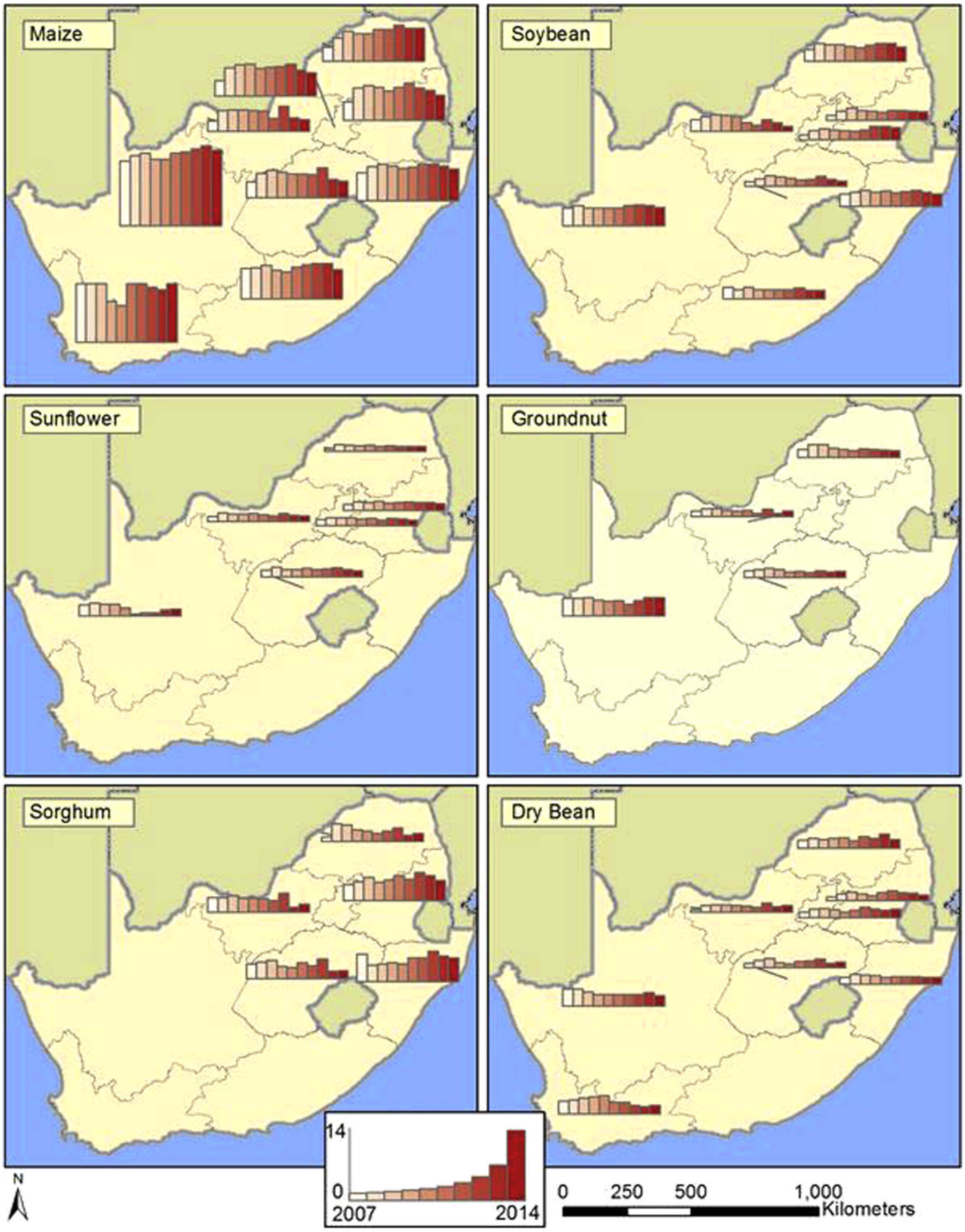

Fig. 5. Yield (t/ha) for the previous ten seasons for maize, soybean, sunflower, groundnut, sorghum and dry beans at provincial level (CEC, 2016).

under the DFiD funded Future Climate for Africa initiative, as well as work areas under and aligned to the Global Framework for Climate Services), and it remains an area of critical need.

The issue of more comprehensive and adaptive response planning is beyond the scope of this paper (although the topic of complementary work in this regard), but we need to carefully consider what has been learnt from these two seasons in terms of effective operational recommendations to improve early warning. A range of products addressing monitoring and early warning already exist in the region – including (not an exhaustive list), those produced under auspices of the Monitoring for Environment and Security in Africa (MESA) SADC project, the Famine Early Warning Systems Network (FEWSNET) and SADC themselves, as well as that undertaken as part of the Southern Africa Regional Climate Outlook Forum (SARCOF) process. There is a clear and frequently documented need to integrate and continue efforts to translate the seasonal forecasting information into impacts for agriculture and other related sectors. Such an approach should be complemented with well targeted and designed iterative awareness workshops for decision makers such that the seasonal forecasting/early warning information be meaningfully and practically integrated into regional and national plans on a range of timescales. Early work on media training should also be continued, such that journalists could be assisted in packaging the seasonal forecast information in simple terms that can be easily understood by local farmers. In addition, advisories on what crops can be grown, adaptive grazing strategies and livestock protection measures, and regular updates on the evolution of the situation should also be made available (building on programmes currently under way).

To conclude, the occurrence of low seasonal rainfall totals together with high seasonal temperatures during preceding seasons are likely to be more frequent under future climate change and some may, indeed, already be more frequent (see, amongst others, Winsemius et al., 2014). It is thus particularly critical that scientists and those working on regional response are able to work together to truly consider informed response over both the seasonal and the longer term timescales. Regional science approaches are beginning to take cognizance of such a need, and include such work within their mandates, but such work needs to be significantly expanded and strategic in nature.

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