Impacts of Drought Induced Water Shortages in South Africa: Economic Analysis

Report to the
Water Research Commission

by

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- Impacts of Drought Induced Water Shortages in South Africa: Sector Policy Briefs (WRC Report No. 2604/2/18);
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1. Introduction

In South Africa, drought is a very important phenomenon that affects not only agricultural production but also society. It is a recurring phenomenon, with spatial and temporal characteristics that vary significantly from one region to another (NOAA, 2006; Runtunuwu, 2005; Loukas and Vasiliades, 2004; Wilhelmi and Wilhite, 2002).

Drought is a disastrous natural phenomenon that has significant impact on socio-economic, agricultural, and environmental spheres (Bhuiyan, 2004; Loukas and Vasiliades, 2004; Finan and Nelson, 2001). Damages due to drought depend on its intensity, duration, frequency and the affected area (Scripcariu et al., undated), and its effects are evident even in subsequent periods when precipitation occurs normally.

Drought is associated with precipitation that is below what a region perceives as "normal" and if this situation is sustained over a prolonged period, it results in water supply shortages thus impacting consumption possibilities, production possibilities and environmental water requirements (e.g. see Garrido and Hernandez-Mora, 2013; Wilhite and Glantz, 1985). Because normal precipitation and water use expectations greatly vary across regions even within the same country, the specific definition of drought is often a matter of where the water comes from and how it is being used (Hayes and Widhalm, 2013). More importantly, unlike other natural disasters such as flooding, drought develops slowly and quietly, lacking highly visible and structural impacts for some time, meaning that developing drought conditions often go unnoticed until precipitation shortages become severe and impacts begin to occur (Hayes and Widhalm, 2013).

The literature is generally in agreement that the total economic effects of a drought can be divided into the direct effect, the indirect effect and the induced effect (e.g. Garrido and Hernandez-Mora, 2013, Hayes and Widhalm, 2013, Diersen and Taylor, 2003)[1]. The direct effect of a drought captures the immediate or physical impacts of water supply shortages on production. In the agriculture sector for example, the direct physical impacts could be manifested in the wilting of crops and crop losses. The indirect effect captures impact of the drought on sectors that are downstream or upstream of the primary production sector. The agriculture sector, for example, has businesses that are located upstream (e.g. input supply) and downstream (e.g. the agro-processor). A drought that directly hits the primary agriculture sector will have implications on primary and secondary sectors along its supply chain, such

[1] These studies do not use the same terminologies but they agree on what the total economic impact of a drought ought to measure.

as seed supplier, agro-processors, supermarkets, or the bio-energy industry. Finally, the induced effect of a drought captures the impact on consumers and businesses further upstream and downstream. Thus, for example, a drought that hits the agriculture sector will impact on the welfare of maize consumers and of enterprises whose operations rely on output from the agro-processor (e.g. retailers).

The purpose of the document is to: (1) review past studies on the economic impacts of drought in South Africa (SA) by economic sectors; (2) outline the approaches used assess the impacts of policy interventions and shocks (including those for assessing the direct, indirect and induced effects of droughts); (3) provide the methodology used to assess the economic impacts of drought in this report; and finally, (4) provide the results and discussions.

2. Overview of the South African Economy and Sectors for Analysis

2.1 Overview of the South African Economy

The diverse structure of the South African economy is a critical aspect of its historical and current growth performance.[2]The South African economy is tertiary-based, with the tertiary sectors (trade, catering and accommodation; transport, storage and communication; finance, real estate and business services; government services and personal services) accounting for 69% of GDP in South Africa in 2015. The primary sectors – mining; and agriculture, forestry and fishing – accounted for just 10% of the economy in 2015, while the secondary sectors (manufacturing; electricity, gas and water; and construction) accounted for 21% of GDP.

In addition, three provinces (Gauteng, KwaZulu-Natal and Western Cape) collectively contribute a significant portion to the country's value added, reported at over 60 percent.[3] They are seen as the three power houses of the country. In these three provinces though, the share of different sectors contribution to gross value-added differs.

2.2 Sectors for Analysis

Drought impacts on different sectors of the economy are dependent – in part – on the role of water resources in production. Put differently, since some sectors of the economy are more dependent on water resources than others, the severity of drought impacts on different sectors of the economy differ. Furthermore, water risks are felt at different points of the production chain for different sectors, including raw material production, supply, and direct operations.

In South Africa, the agricultural sector is the biggest user of water (accounting for 60% of water demand), followed by the municipal sector (27%), power generation (4.3%), mining (3.3%), and industrial demand (+/-3%). The main driver of municipal water demand is the size of a country's urban population, while the driver for agricultural water demand comes from the 1.6 million hectares of land equipped for irrigation (DWA, 2013).

[2] Stats SA. 2016. Economic Growth. http://www.statssa.gov.za/?page_id=735&id=1
[3] Stats SA. 2016. Economic Growth. http://www.statssa.gov.za/?page_id=735&id=1

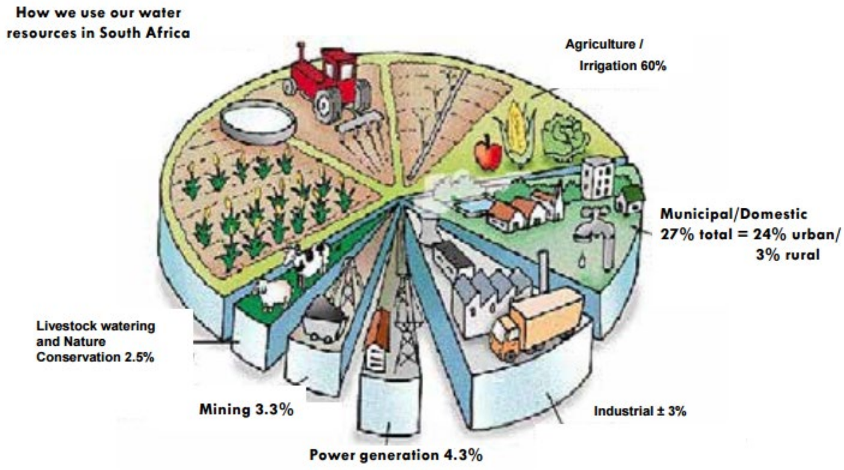

Figure 1: South African Water Sector Demand (DWA, 2013)

In looking at the economic impacts of drought on the economy, we chose eight sectors to focus on. These sectors were chosen based on selection criteria, including the following:

- the sector's economic contribution;
- the sector's social importance, including employment and source of livelihoods;
- the sector's dependence on water resources; and
- the sector's supply chain, and its dependence on water resources

Based on these selection criteria, the following sectors were chosen: i) irrigated agriculture; ii) livestock; iii) mining; iv) tourism; v) agro-processing; vi) industries in secondary cities; vi) small businesses in secondary cities; vii) water quality.

3. Review of past studies on economic impacts of drought in South Africa

To the best of our knowledge, only a few studies have attempted to assess the economic impacts of drought in South Africa. These include: BFAP (2016), Agri SA (2016), Hlalele, Makhatle and Motlogeloa (2016), Maré and Willemse (2016) and Pretorius and Smal (1992). Of these, most are focused on the agricultural sector and the rural economy. Much less work has been done around the impacts on the urban economy (including the secondary and tertiary sectors), **thus justifying a more inclusive study like the current one**.

The main objective of BFAP (2016) was to evaluate the impact of the current drought on the South African economy, on commercial and smallholder producers, and on consumers. The study had the following specific objectives: (i) to determine the value of imports and exports of maize in South Africa, (ii) to determine the impact of drought on farm/agricultural businesses, and (iii) to determine the price effect on drought induced production decline.

BFAP (2016) found that total import volumes in South Africa in the current year were expected to increase rapidly, while the exports were expected to decline tremendously due to the drought. About 856 000 tons of white maize and 1.9 million tons of yellow maize were expected to be imported under the CEC baseline scenario at a cost of R11.5 billion, while under the alternative scenario imports will increase to 1.2 million tons and 2.2 million tons respectively, at a cost R14.5 billion.

Table 1: Projected import volumes for key crops in 2016 (BFAP, 2016)

Commodity	Import Requirement (1000 tons)		Price (R/ton)
	CEC Baseline	Reduced Yield Scenario	CEC Baseline (Annual Avg. 2016)
White Maize	856	1 240	R 4 751
Yellow Maize	1 932	2 236	R 3 613
Soya Beans	223	299	R 6 414
Sunflower	42	134	R 6 575
Wheat	1 753	1 753	R 5 206
TOTAL	**4 806**	**5 662**	

In response to the second objective (to determine the impact of drought on farm/agricultural businesses), BFAP (2016) established that more than 1.2 million individuals were affected by the drought, which inevitably had a significant impact on maize yields and also gave rise to food insecurity. Further, the current drought might also have long term financial and debt implications on farm businesses.

Finally, in response to the third objective (to determine the price effect on drought induced production decline) BFAP (2016), established that the price of the staple food basket increased by approximately 19% from January 2015 to January 2016 with a further increase of 10% in quarter one of 2016 is expected.

In summary, BFAP (2016) showed that due to reduced domestic production, South Africa was likely to experience substantial price increases and significant quantities of maize being imported – BFAP (2016) gives a predicted amount of 7.4 million tons being imported. More than 1.2 million individuals will be affected by the drought that will inevitably have a significant impact on maize yields and this will give rise to increased food insecurity. In addition to commodity prices, the weaker exchange rate will impact on the supply chain component of food products. Thus, supporting the primary agricultural sector to overcome the short-term effects is important to ensure that long-term agricultural production, growth and food security are not compromised. BFAP (2016) thus concluded that rapid decision making was needed at regulatory and legislative level regarding the possible need for white maize imports from the USA as a supplementary resource to white maize from Mexico. There was also a need for efficient planning and coordination of logistical, infrastructural and transport resources to ensure the availability of maize and maize meal in South Africa. That said, increased white maize production for the 2017 season will result in a reduction in maize prices.

The main objective of Agri SA (2016) was to meaningfully contribute to the national discussion on South Africa's drought as it pertains to the agricultural sector. The specific objectives were (i) to outline the effects of South Africa's drought crisis on the agricultural sector and (ii) to present proposals on actions to effectively support farmers as they recover from the crisis.

In response to the first objective (i.e. to outline the effects of South Africa's drought crisis), Agri SA (2016) found that drought resulted in reduced plantings of summer cash crops, particularly in the western regions. The Crops Estimates Committee (CEC) estimated that the area of maize planted for the 2016/17 season was likely to be around 2 million hectares, 25% lower than the area planted in the 2015/16 season. Cane production decreased in all cane growing areas and estimates of sugar cane production were estimated to decline from an annual norm of 19 million tons to 14 million tons, and the South African Cane Growers Association estimated that more than 6500 seasonal jobs would be lost because of decreased cane production. Extremely high above-normal temperatures, especially in December 2015 and January 2016, affected pollination in several areas (including irrigation areas), likely to result in lower yields.

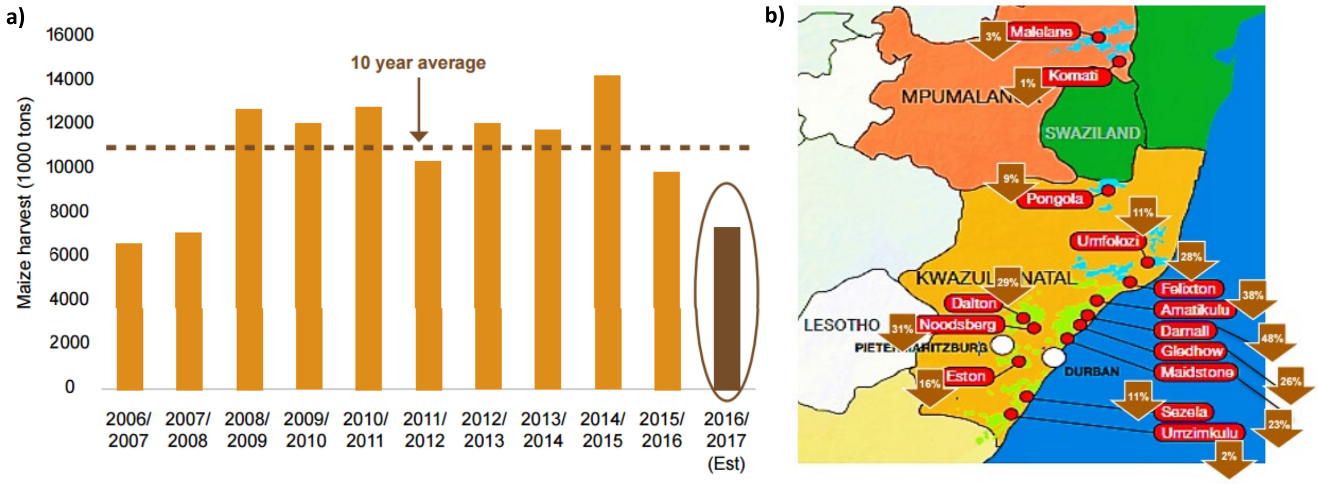

Figure 2: (a) Maize crop harvested; (b) Changes in sugar cane production (2014/15 to 2015/16) in growing regions (Agri SA, 2016)

In the livestock sector, drought resulted in natural grazing areas becoming seriously depleted leading to the forced slaughtering of livestock, and livestock deaths due to fodder unavailability. Increases in red meat slaughter rates of 23% (cattle), 37% (sheep) and 12% (pigs) were reported for November 2015 to December 2015. The South African Agricultural Machinery Association (SAAMA, undated) reported that due to the drought, yearly tractor sales were down 11% and sales of combine harvesters declined by 30% as at January 2016. Producers of seeds reported severe increases in unsold maize seed stocks that will not be fit for resale in the next production season.

South Africa moved from a net exporter position to a net importer position regarding maize (as shown in the figure below), and the drought led to an increase in imports of wheat, from 1.8 million tons in 2014/15 to 2 million tons in 2015/16, at a cost of approximately R5.5 to R6 billion. The spot price for white maize was trading well above import parity prices (i.e. domestic prices are much higher than world prices, even when taking transport and currency factors into consideration). Drought events increased the financial liability of farming enterprises and to the extent that relief efforts are introduced, put a strain on fiscal resources.

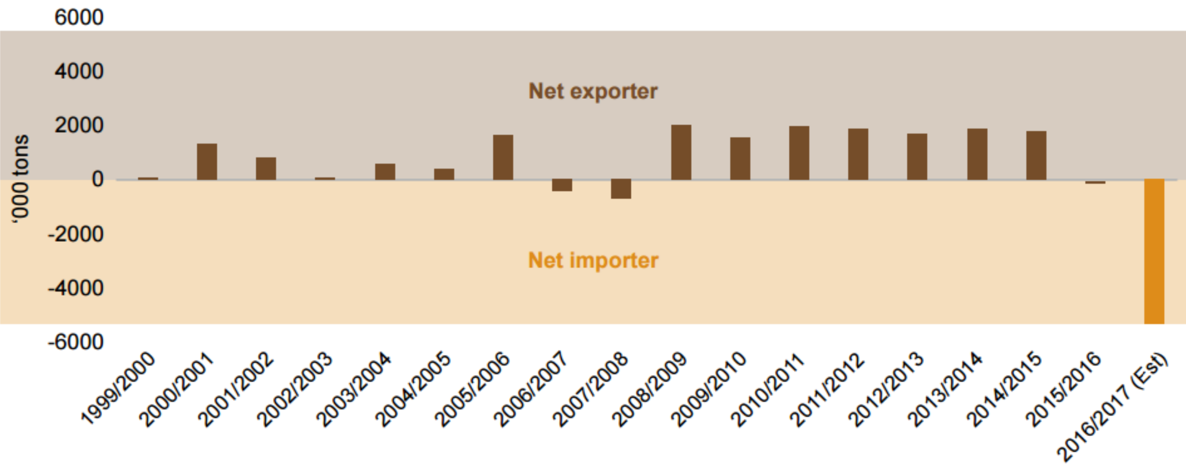

Figure 3: Net trade – Maize (Agri SA, 2016)

In response to the second objective (present proposals regarding necessary actions to effectively support farmers as they recover from the crisis), Agri SA (2016) proposed a drought relief package for the State to implement. The first sub-objective of the proposed drought relief package is to assist farmers in severe financial distress to survive the current drought conditions while the second sub-objective seeks to facilitate drought recovery for other distressed farmers in disaster-declared areas.

For the first sub-objective of the proposed drought relief package, the following interventions were proposed: (i) State guarantees for outstanding and overdue farmer debt; (ii) subsidising the purchase of feed and fodder for a period of six months for farmers currently hard hit by the drought; and (iii) helping farmers in severe financial distress for six months to retain farmworkers by means of a wages cash grant. For the second sub-objective, the following interventions were proposed: (i) providing soft loans for farmers in severe financial distress who will not be able to access production credit for 2016/17; (ii) providing an interest rate subsidy for herd rebuilding for livestock farmers (up to the average herd size/stocking rate for the business over the last three years); (iii) providing an interest rate subsidy to assist commercial crop farmers in financial distress with the purchase of inputs for the new season; and (iv) direct cash grant/providing of inputs to small-scale farmers in serious financial need.

Agri SA (2016) concludes that the current drought is on a national scale and has affected many if not all South Africans. It has resulted in serious depletion of natural grazing, reduced planting of summer crops, extremely high temperatures affecting pollination, and a looming grain deficit. The actions recommended to respond to the current drought crisis would require all stakeholders to work together and engage the State. All farmers should be accounted for in the drought relief package regardless of the size of their operations. Urgent and decisive action is needed from regional structures to prevent further deterioration of the situation.

The main objective of Hlalele et al. (2016) was to alert South Africa government authorities of the prevailing conditions of droughts impacts for possible drought relief assistance. The specific objective was to assess the economic impact of the current drought disaster on agriculture dependent formal and informal businesses in the Free State. Hlalele et al. (2016) found that about 80% of the businesses lost above 50% of their employees due to the drought in the Free State. Moreover, about 87% of these businesses lost over 50% of their revenue.

Table 2: Employee and estimated revenue loss (Hlalele et al., 2016)

Employee loss since dry conditions started and estimated revenue loss (%)	Frequency of Employee loss	Frequency of estimated loss of revenue
20	2	1
30	2	1
40	0	0
50	3	4
60	2	3
70	0	4
80	0	2
90	0	0
100	6	0
Total	**15**	**15**

The most affected businesses were agri-businesses and agriculture related businesses such as butcheries which use a lot of water for, inter alia, boerewors production, and fruit and vegetable businesses which use water for keeping vegetables fresh. Hlalele et al. (2016) conclude that the current drought has had significant adverse effects on agriculture dependent businesses. In terms of both employee and revenue losses, the economic losses were above 50%.

The study by Maré and Willemse (2016) sought to answer the following questions (i) what are the implications of drought on the maize market for feedlot demand for weaners? (ii), what are the implications of drought on consumer demand for red meat? and finally, (iii) what are the implications of drought on the livestock farmers who supply red meat?

In response to the first question (what are implications of drought on maize market for feedlot demand for weaners?), Maré and Willemse (2016) establish that due to the drought, maize imports are expected to increase from 980,000 tons to 6 million tons depending on the availability of white maize during 2016/2017. This severely increases the pressure on harbour and rail/road logistics which are in poor state resulting in delays in the supply of maize domestically and increasing the risk of food insecurity.

Table 3: Current and expected maize volumes and trade (Maré and Willemse, 2016)

	2015 Crop	2016 Crop*	2015 Imports	2016 Imports*
Yellow maize (ton)	5 238 000	4 000 000	900 000	>2 500 000
White maize (ton)	4 702 000	1 800 000	80 000	>3 500 000**
Total (ton)	**9 940 000**	**5 800 000**	**980 000**	**>6 000 000**

*Own estimates for 2016

**White maize imports depends on international availability

Maré and Willemse (2016) established that the domestic shortages have led to substantial increases in the price of both yellow and white maize. The price of yellow and white maize is expected to continue to increase, adding financial stress to the owners of feedlots for weaners. The price of yellow maize increased by more than 75% on a year-to-year basis, while that of white maize increased to levels above R5 000/ton (in July 2016). The price of yellow maize is further expected to increase by 10-15% thus putting more stress on feedlots for weaners.

Maré and Willemse (2016) also show that maize and its by-products (hominy chop) are the most important input price measure used by feedlot owners to determine the maximum price that they can pay for a weaned calf. Hominy chop is becoming a scarce commodity as millers report that the sales of maize meal dropped by 10-15% due to the high prices and the strain it puts on the lower income groups. Millers will have to scale down their activities as it becomes more expensive to store maize meal than maize.

The domestic shortage of maize has a tremendous impact on the price of maize and other grain crops which are used for feeding animals, putting pressure on the feedlot industry in as the variable costs increase significantly. The resulting increase in the price of meat results in a decline in the demand for calves and lambs, which can then impact on the weaner price expectation in the future. This forces the smaller feedlots out of the market while the larger, integrated feedlots absorb the expected financial losses during 2016/17 (Maré and Willemse, 2016).

In response to the second question (what are the implications of drought on consumer demand for red meat?), Maré and Willemse (2016) established that the cost of the basic food basket was likely to increase by 30%. This increases the burden on consumers, as unemployment and inflation are at the highest level, which makes people with limited resources more vulnerable to food insecurity.

The severe economic climate in South Africa (i.e. the high and growing unemployment rate), the slowing economy, and expected increases in interest rates are putting consumers and the economy under unbearable pressure (Maré and Willemse, 2016), coupled with a devaluation of the Rand to the US Dollar by 45% over the past 12 months. The economic contribution of farmers declines as production declines due to the drought. Equally, due to the drought, the cost of a basic basket food for consumers is expected to increase by 30%. This increases the burden on consumers, many of whom are unemployed in relation to food shortages and escalating inflation. Consequently, consumers change their spending and eating habits as they move away from luxury items and spend more on basic food. The demand for red meat is expected to reduce in two years' time due to escalating prices (Maré and Willemse, 2016).

In response to the third question (the implications of drought on the livestock farmers who supply red meat), Maré and Willemse (2016) established that due to drought induced challenges, 40,000 cattle died in KwaZulu-Natal in 2015. This contributed to an increase in the price of red meat due to lower supply. The price of female cows reached record high levels in 2014-2015. It is estimated that the number of cattle slaughtered from January to November 2015 was 8% per month higher than in 2014, while that of sheep was 4% per month higher than in 2014.

A slow increase on a year-to-year basis in the standing stock show that the national herd is slowly increasing. A sharp increase in the standing stock (as is evident in the figure below) from the year 2014 to 2015 may be an indication of a shock in the market such as drought, that causes primary producers to sell more of their animals to the feedlot. In 2015 there were on average 30% more cattle in feedlots at any given time than during 2014 per month. The large number of cattle that was fed during 2015 in comparison with 2014 shows that very little replacement stock was kept on farms. Farmers thus desperately decreased their herd size to survive the drought (Maré and Willemse, 2016).

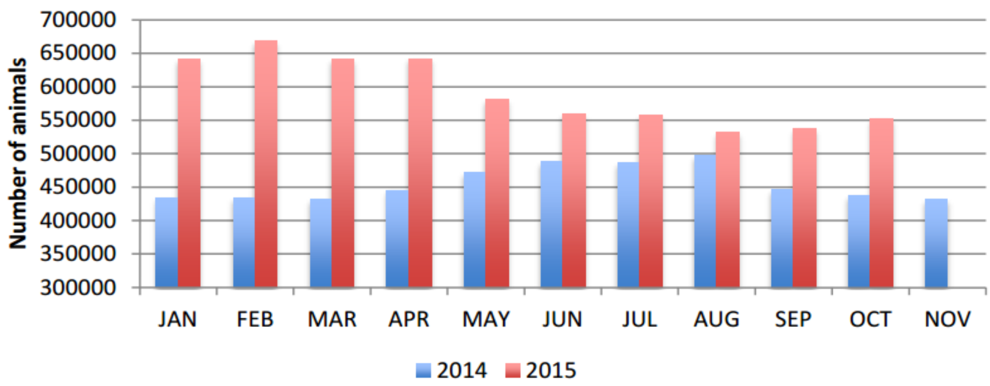

Figure 4: Monthly cattle feedlot standing stock in South Africa (SAFA, 2016 in Maré and Willemse, 2016)

The challenge that drought imposes on the livestock sector is that due to feed shortages, farmers tend to slaughter or cull more animals to manage the required rations for their animals (Maré and Willemse, 2016). Additionally, an increased number of animals die because of drought and increased vulnerability to disease arising from poor nutritional condition. This is a critical problem as the rebuilding of stock takes about 7 years to complete, as has been proven in United States. Farmers are also getting less money from the sale of animals due to the increased cost of feed. After a period of 6 months of drought, however, the price of red meat increases due to supply shortages in feedlots and slaughter houses. Exports are expected to increase due to high prices in the international market, and in 2015 South Africa exported on average 65% more bovine meat per month than during 2014, resulting in increased income for farmers from this source (Maré and Willemse, 2016).

In conclusion, the study used market prices and descriptive statistics to draw conclusions about the impact of drought on the red meat industry. The study showed that dying, culling and slaughtering of animals reduced the national stock size in 2016. Feedlots and slaughtering are expected to reduce significantly in 2017/2018 due to animal shortages. This will further increase the price of weaned lambs, calves and red meat. Exports will also increase due to better prices in the international market, increasing the shortage of red meat in the domestic market.

Pretorius and Smal (1992) used the macro-econometric model of the South African Reserve Bank to simulate the effects of the 1992 drought on the following macro-economic variables: economic growth rate, investment, the current account of the balance of payments, inflation and employment. Following their simulations, Pretorius and Smal (1992) show that as a result of the drought, growth in real GDP might have been as much as 1.8 percentage points lower, as many as 69,000 job opportunities may have been declared redundant, average inflation rate could have been approximately 0.8 percentage points higher, and the current account balance of payments could have suffered a negative effect of about R1,200 million.
For the remainder of this section, we review sector specific literature on the economic impacts of drought.

3.1 Economic impacts of drought on the irrigated agriculture sector

Irrigated agriculture is a major contributor to the national food basket in South Africa, with the sector accounting for more than 60% of national water use (DWA, 2004). Among other crops, maize is significant, as it is the staple food for more than 70% of the South African population

(BFAP, 2012). South Africa is the major maize producer in the Southern Africa Development Community (SADC), with average production of about 10.6 million tons a year over the past 10 years (GCIS, 2015). Maize production decreased from about 10 million tons to 7.3 million tons for the years 2014/15 and 2015/2016, respectively (DAFF, 2015).

The maize industry stimulates the economy directly by providing secondary industries with over R1.5 billion worth of business each year (NDA, 2001). According to BFAP (2012), white maize is important for human consumption while yellow maize is mostly used for animal feeds. South Africa is the largest producer of maize on the African continent and, in a normal production season, 40% of maize produced in South Africa is traded in the Southern African Development Community (SADC) region (Agri SA, 2016).

The irrigated agriculture sector is more vulnerable to water shortages than other sectors (DWAF, 2004). In a study conducted by Cimmyt (2001), it was found that drought had a significant impact on maize production in Lesotho, South Africa, Swaziland and Zimbabwe during the 1984/85 and 1991/92 droughts. Exports decreased due to reduced plantings during the 1991/92 drought (NDA, 2001). The brief decline in maize yield of commercial farmers caused by the drought in 1991/1992 and 1994/1995 was addressed through government subsidies which were instituted through the Maize Board. These were initiated specifically to boost maize production and existed until 1996-1997, after which the Maize Control Board ceased to operate and "free agricultural trade policies" were then introduced (Essinger et al*.,* 1998).

In South Africa, the current drought has resulted in reduced acreage planted in 2016/17. The area of maize planted is approximately 2 million hectares, which is 25% lower the area planted in 2015/16 (Agri SA, 2016). Further, extremely high temperatures have affected pollination which has also impacted on yields. In a normal (non-drought) year, South Africa is self-sufficient in its maize production, and exports excess maize (Agri SA, 2016). During the current drought however, South Africa has moved from being a net exporter of maize to a net importer of maize. For instance, Grain SA – using the market price method – estimated that South Africa will need to import an unprecedented 3.8 million tons of maize in the 2016/17 season at a cost of approximately R3 800 per ton between May 2016 and April 2017 (Agri SA, 2016).

3.2 Economic impacts of drought on the livestock sector

The livestock sector is the largest contributor to total agricultural gross domestic product accounting for about 48% of South Africa's agricultural output in terms of value (GCIS, 2015).

Further, cattle and calves slaughtered contribute about 9.7% to the total gross value of agricultural production (DAFF, 2014). The sector supports about 500,000 jobs, with milk producers employing some 60,000 farmworkers and providing 40,000 indirect jobs within the milk processing value chain (GCIS, 2015).

Drought causes long-term impacts on livestock production, which might linger for many years. Drought-induced production losses cause negative supply shocks, but the amount of incurred economic impacts and distribution losses depends on the market structure and interaction between supply and demand of agricultural products. Drought-induced losses are not completely borne by farmers; instead, a portion of the losses are passed on to consumers through increased prices. Furthermore, due to the localised impact of weather, local droughts impacts might be cancelled out when evaluated at regional or national level.

There are two distinct impacts of drought on the cattle sector that are dependent on the magnitude of drought. First, mild drought results in cattle losing weight which affects revenue and household income, and second, harsh droughts results in cattle perishing from the lack of feed (Masike and Urich, 2008). Ranches are directly affected by drought in terms of water availability to livestock and amount of forage produced. Lost forage is the most important aspect. Ranches are faced with the following options during a drought episode: (1) continue to graze the same number of animals, (2) reduce the herd size to match the amount of forage produced, (3) seek additional forage sources, and (4) feed hay of other harvested feed (e.g. yellow maize).

From an economic standpoint, each of these options will affect the ranch but in different ways. Rangelands will be overgrazed and eventually result in reduced animal production, either in weight gained or in reproductive rates, if the same number of animals continue to graze on drought-affected rangelands. Short-term income can be increased by reducing the herd through the sale of livestock but future income will be reduced due to fewer calves being produced. Further, when the drought ends more replacement animals will be retained, reducing income. As a secondary effect the market price for livestock will be reduced if several ranches seek to reduce their herds at the same time. Seeking additional forage sources through avenues such as private land leases or buying hay are generally costly options. Similar to the logic in livestock sales, if everyone is seeking private land leases or to buy hay, prices of those will increase. If a ranch must sell livestock that is suited to their particular landscape and resources to match forage availability, the loss of those livestock may have longer-term impacts on what the ranch can produce. Production and reproduction of cattle are usually affected by drought as they get ill more easily (i.e. from heat stress and poor nutrition).

Lactating cows, late pregnant heifers and weaners are the most vulnerable because of their higher nutrient requirements. In sectors where intensive production systems dominate such as feedlots, the impact of grazing conditions is lower (BFAP, 2016).

Natural grazing in South Africa has become seriously depleted leading to the forced slaughtering of livestock and livestock deaths due to fodder unavailability (Agri SA, 2016). Commercial beef slaughters increased by 8% year on year in 2015; rising almost 18% above the 5-year average (BFAP, 2016). With limited grazing capacity, farmers have been attempting to keep nucleus herds alive amidst escalating feed prices (Agri SA, 2016). The Red Meat Producers' Organisation (RPO, undated) estimates that over 40,000 cattle died because of drought by the end of 2015 in Kwa-Zulu Natal alone. According to the Red Meat Industry Forum (RMIF), increases in red meat slaughter rates of 23% (cattle), 37% (sheep) and 12% (pigs) were reported from November 2015 to December 2015. Livestock farmers had to move their livestock to other camps with favourable grazing conditions thus transport cost put pressure on farming operations (Agri-SA, 2016). In addition to the reduced calving rate, farmers bear the risk of physical livestock injury and stress-induced livestock abortions. Milk intake decreased by 4.9% from January 2014 to January 2016 and this trend is asserted to continue with estimates of the 2016 milk production at least 3% lower than in 2015 (ARC, 2016).

3.3 Economic impacts of drought on the tourism sector

Tourism's direct gross domestic product was R103.6 billion (2.9% of the total gross domestic product) for 2013 (Stats SA, 2015). The sector contributed about 4.4% to total employment, with approximately 655,609 people engaged in producing goods and services purchased by visitors in 2013 (Stats SA, 2015). In 2014, tourism's direct contribution increased slightly to about R113.4 billion (3.0% of the total gross domestic product) (WTTC, 2015). In a similar fashion, the contribution of the tourism sector to total employment slightly increased to 4.5%, supporting about 679,500 jobs (WTTC, 2015).

Drought has both direct and indirect impacts on the tourism/recreation sector, and can span all seasons. The direct impacts are reductions in water dependent activities such as rafting, boating, canoeing, or fishing resulting from lower water levels, as well as from shortened or shifted seasons (Thomas et al., 2013). Water restrictions can also pose challenges to water-reliant recreation. Intangible relationships such as decreased visitor numbers, cancellations in hotel stays, or a reduction in booked holidays are more difficult to quantify and link to drought. Changes in animal and bird migratory patterns affect wildlife viewing or hunting, causing reduced revenues for nearby towns and communities (Thomas et al. 2013). If drought results in negative experiences (for example, viewing a drought-stressed, brown landscape when visitors think it should be green), people may convey this to others, thereby reducing future visits from formerly interested visitors. The ultimate outcome results in decreased tourist Rands earned for the local economy and a reduction in sales taxes, potentially leading to unemployment (Thomas et al., 2013).

The link between critical tourism/recreation activities and drought has been captured through stakeholder engagement processes (Thomas et al., 2013). This information is combined with systematically collected drought monitoring data to evaluate potential impacts and to arrive at a comprehensive planning and climate adaptation solutions. In Kenya, the impact of drought on Amboseli National Park and ecosystem resulted in heavy losses (deaths) in zebra, wildebeest, buffalo, hippos and elephants (Kenya Wildlife Service, 2009). A decline in herbivore numbers affects carnivore populations causing additional pressure on herbivores. In some instances, culling should be considered, for example, if the number of hyenas threaten lions (given their precarious status in Kenya and the ecosystem) and other locally endangered species, hyenas should be culled (Kenya Wildlife Service, 2009). In South Africa, game reserves and parks were left with few options faced with a drought episode: (1) reducing the number animals by relocating them to places where there is still grazing, (2) reducing the numbers of animals by disposing them off through live sale, and (3) hunting where it is necessary (SABC, 2015). For herbivores, an additional option is to bring in feed such as hay to supplement the limited grazing available in the veld.

3.4 Economic impacts of drought on the mining sector

The South African mining industry contributed about 7.6% to the gross domestic product, supporting about 1.4 million jobs in 2014 (CMSA, 2015). Mining refers to the extraction of minerals or other geological materials from the earth, and encompasses the multiple stages of exploration, extraction, and processing (BFAP, 2015). The mining sector is broadly classified into open cast and deep mining. Open cast mines refers to extraction of minerals which are fairly close to the surface. Deep mining is also referred to as underground mining. A major decision to operate by means of underground mining rather than open cast is the strip ration or the number of units of waste material in a surface mine that must be removed to extract one unit of ore. The two kinds of mines produce a variety of rock residuals. Both mines could be affected by drought induced water shortages.

Mining accounts for 2.5% of a country's total water consumption on average, even in semi-arid to arid countries like Australia, Chile and South Africa (Turton, 2008). In South Africa, mining uses about 3% of the total country water. Although mining utilises little water (relatively), sufficient water supply is critical to sustainable future mining activity. Shepherd (undated) indicates that water has become a key risk for mining companies in South Africa. Mines dewater, and use water for transporting extracted material, facilitating separation of minerals from waste material, transporting and storing tailings, supressing dust, and in other associated industrial uses such as cooling power systems and washing equipment. The Stats SA (2009) water accounts reveal that gold and uranium were the biggest water users, followed sequentially by chrome, manganese, other metal ores, platinum group metals, iron ore, and finally coal. Mining is widely considered to have the greatest impact on water quality.

Eary and Watson (2009) indicates that mines should plan for water management throughout the mine life-cycle, decrease their water footprint, and involve communities, government and NGOs in their water management plans. To overcome water challenges, mines are also encouraged to think about new methods of extraction and other ways to reduce their water dependency. The shortage of water in mining caused by drought, places additional pressure on the supply of raw water.

Shepherd (undated) shows that severe water shortages result in the cut back of mines on the processing rates of their concentrators, which could lead to a reduction of tonnages processed or even the closure of some concentrators for short periods. Mines are vulnerable to drought to the extent that mines compete with other sectors of the economy for water, and authorities are likely to ask mines to cut back on usage of water before they ask communities to cut back (Shepherd, undated).

In South Africa, some recommended methods of minimising water use in mines include using open pits as water buffer reservoirs provided that the quality of water is approved by the Department of Water and Sanitation, reuse of municipal sewage water from nearby towns, and reducing the surface area of dams (as a way to cut down the amount of water lost through evaporation). Moreover, mines also dig boreholes and well-fields as a long-term response to drought challenges.

The direct costs of drought on the mining sector are multi-fold, including production decline, revenue losses, and increase costs for water treatment. Moreover, the drought induced water deficiency can indirectly affect workers' quality of life, lead to unemployment, starvation, disease, and risk of conflict, all triggering humanitarian and human development concerns. A decrease in water supply resulting from drought can lead to a limited market supply of minerals, thus directly impacting their market prices. The domestic market developments might also have repercussions for international trade and exported or imported quantities.

3.5 Economic impacts of drought on the agro-processing sector

The agro-processing industry is a subset of manufacturing that processes raw materials and intermediate products derived from the agricultural sector. Agro-processing means transforming products that originate from agriculture, forestry and fisheries. The Standard Industrial Classification categorises the following eleven divisions under the agro-processing industry: food, beverages, paper and paper products, wood and wood products, textiles, wearing apparel, furniture, tobacco, rubber products, footwear and leather, and leather products. In South Africa, the average contribution of agro-processing to the output and value added of the manufacturing sector was 29,3% and 29,1%, respectively, during 2006-2010. Its contribution to domestic fixed investment and export was 28,5% and 13,6%, respectively, during the same period. The relative contribution of the agro-processing sector in the manufacturing sector is shown below (DAFF, undated)[4].

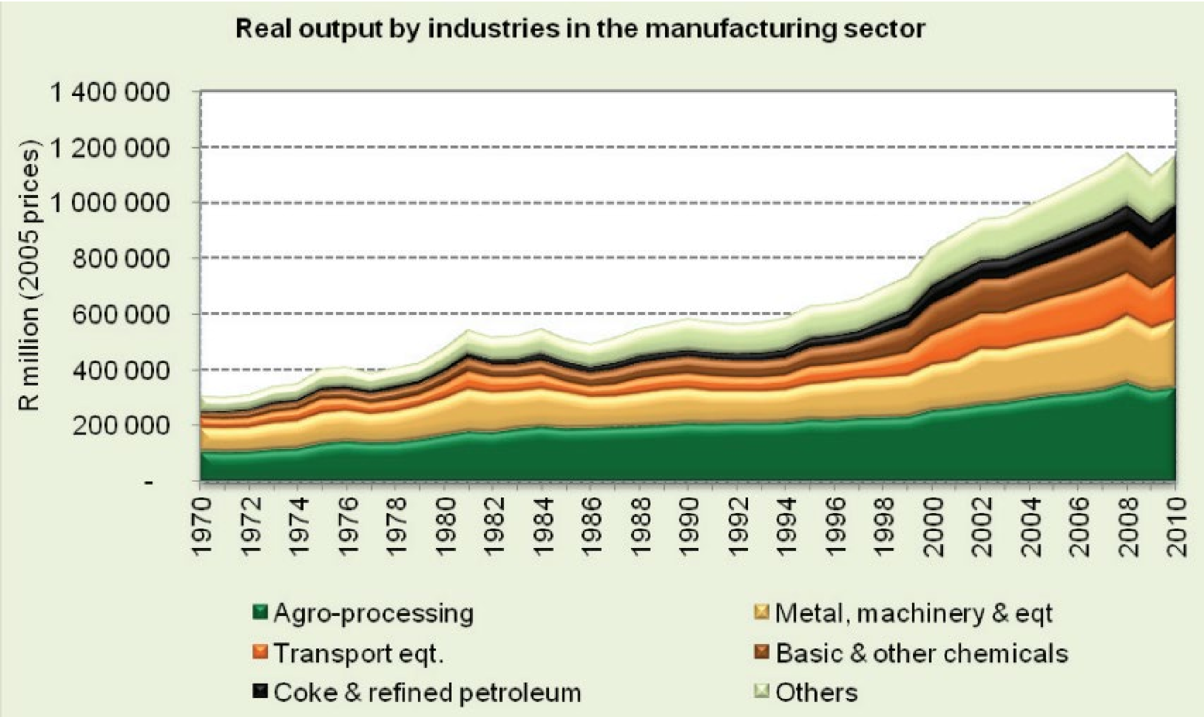

Figure 5: Real output by industries in the manufacturing sector (DAFF, undated)

[4] Department of Agriculture, Forestry and Fisheries, n.d. Introducing agro-processing: The status of the agro-processing industry in South Africa. http://www.nda.agric.za/doaDev/sideMenu/AgroProcessingSupport/docs/Brief_introducting%20agro%20processing.pdf

The world-class infrastructure, counter-seasonality to Europe, vast biodiversity and marine resources, and competitive input costs make South Africa a major player on the world's markets. The government plans to exploit South Africa's competitive advantages that – if fully exploited – would place South Africa among the top 10 export producers in high-value agricultural products. Excellent wines, indigenous rooibos and honeybush teas, and certain fruits are highly sought after in export markets.

The agro-processing sector comprises of a highly diverse group of sub-sectors and industries. The major sub-sectors include: food processing, beverages, aquaculture, horticulture & medicinal plants, aromatics and flavourants. The agro-processing sector has particularly strong linkages both up and downstream. Up-stream, the sector links to agriculture across a wide variety of farming models and products. Down-stream, the sector's products are marketed across both wholesale and retail chains, as well as through a diverse array of restaurants, pubs, shebeens and fast food franchises. Moreover, the food processing sector is now the largest manufacturing sector in employment terms with some 300 000 employees at a national level. Gauteng makes up the biggest contribution to this figure at 91 000 (in 2015), followed by the Western Cape (SAG, 2016). Aquaculture (fish farming) is regarded as priority sector, largely because of its potential for job creation as it scales up to meet increasing domestic demand. But, in general, greater focus is being paid to processed goods and domestic processing capabilities to help boost the value of exports.

According to Kilimani et al. (2016), in Sub-Saharan Africa, drought occurrences coupled with the low investment in water supply infrastructure, i.e. irrigation systems, limits the economic performance of, especially the agro-based economies (Faurès and Santini, 2008). Approximately 97 percent of total cropland in Sub-Saharan Africa is dependent on rain-fed subsistence agriculture. This has adverse implications for agricultural production whenever there are episodes of high seasonal rainfall variability (Calzadilla et al., 2013). Kilimani et al. (2016) found that in the agro-processing sector, the impact of the productivity shocks is conveyed through factor returns, employment and commodity prices, among other critical macroeconomic variables.

The effect of the drought was clearly visible in most retail prices for food. In the case of super maize meal, prices for June 2016 were approximately 41 % higher compared to June 2015 for a 5 kg bag. High maize prices have had a knock-on effect on the maize meal price, a staple food for many South Africans. It was expected that this trajectory will persist until the harvest period of May 2017. Looking ahead, there is a high probability of above-normal rainfall early in summer as an El Nino pattern continues to weaken and transitions into La Nina, which would lead to a good 2016/2017 crop. Should weather forecasts remain on course, we can expect agricultural production to bounce back by mid-2017, resulting in significant moderation in food prices, particularly grain (SAG, 2016).

Agro-processing in South Africa is dominated by the food industry which, between 2006 and 2010, represented the largest proportion of output (42%). Food sector agro-processing also represented 31% of employment, 37% of value added, 32% of domestic fixed investments and 29% of exports. The paper and paper products division is the second significant contributor to the total output (14,3%), domestic fixed investment (29,5%) and exports (18,7%) of the agro-processing industry followed by the beverages division whose output (11,9%), domestic fixed investment (15,9%) and export (17,3%) share are the third largest. These statistics are indicated in the figure below (DAFF, undated)[5].

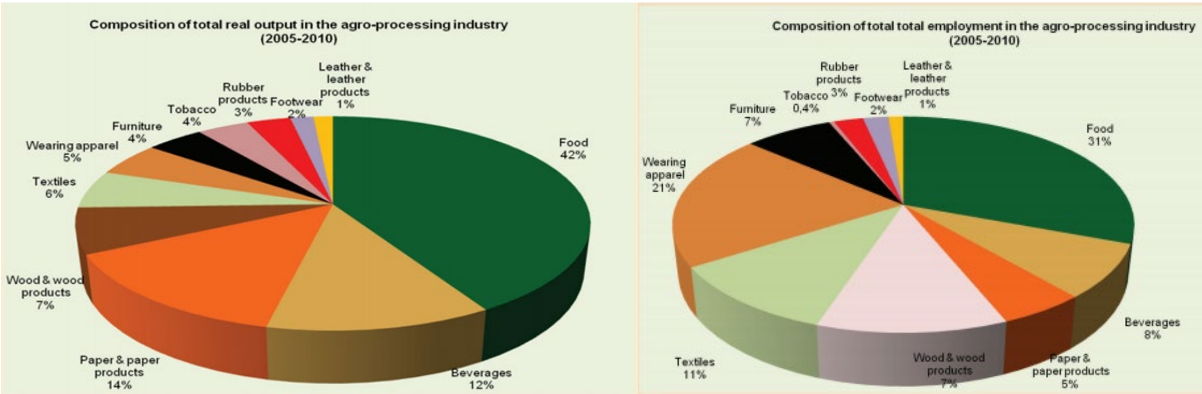

Figure 6: Composition of total real output and employment in the agro-processing industry (2005-2010)

The impact of drought on each of these sub-sectors of agro-processing is experienced differently. For the purposes of this document, only three major agro-processing sectors will be investigated: the beverage industry, the paper and pulp industry, and the sugar industry. It is also important to note that the primary water-related risks associated with the primary production of agricultural products are not considered in this review.

Beverage industry: The beverage industry has a distinct physical reliance on water because the beverage industry's ultimate product is a liquid of which water is the single largest ingredient and secondly, most of the non-water ingredients used by the beverage industry (such as sugar, oranges, wheat, barley, or tea) are products of the agricultural industry, which

[5] Department of Agriculture, Forestry and Fisheries, n.d. Introducing agro-processing: The status of the agro-processing industry in South Africa.
http://www.nda.agric.za/doaDev/sideMenu/AgroProcessingSupport/docs/Brief_introducting%20agro%20processing.pdf

as an industrial sector is the single largest consumer of water (Dolder et al., 2012)[6]. For beverages that require water as an input, such as bottled water[7] or beer, a stable supply of good quality water is fundamental to their business.

Paper and pulp industry: The paper and pulp industry, besides from the rainfall required for the growing of plantations, is heavily dependent upon water for processing. One of the major examples of where this has been experienced is with Sappi during the recent drought. "The drought slowed production at the Siaccor mill for a few weeks and reduced earnings before interest, taxes, depreciation and amortisation [Ebitda] excluding special items of the South African business by R87 million [for the quarter to December 2015]," Sappi said in an interview with City Press (City Press, 2016)[8]. "Andre Oberholzer, a Sappi spokesperson, said the lower production at the Siaccor mill on the KwaZulu-Natal south coast, near Umkomaas, was due to the fact that Sappi had to slow down production to two-thirds of normal production rates over October and November because of the low levels of water in the Umkomazi River, which prevented the mill from abstracting the usual amount of water." (City Press, 2016)[9].

Sugar industry: Although the sugar industry is sensitive to rainfall and water supply through primary production, mills are also sensitive to water shortages. In addition, the effluent produced by mills becomes more problematic during the dry season when there is less attenuation possible by normal water flows.

3.6 Economic impacts of drought on small businesses

The national development plan articulates the important role of small businesses and cooperatives in achieving inclusive economic growth, and that these small enterprises are key to achieving the plan's job creation target for 2030. According to the Finscope Survey 2010, South Africa had 5 979 510 small businesses; over 60% of the owners had less than a matric certificate, whilst 58% of small business owners were women. Most small businesses, according to the Finscope Survey, are informal SMMEs (Amra et al., 2013).

The impact of drought on the sector is dependent on the importance of water for various types of small businesses. For small businesses that are particularly dependent on water for operations, water restrictions (or disruptions in the supply of water) could impact on revenue and income. Over time, the viability of businesses may also be threatened. The types of

[6] Dolder, S. Hillman, A. Passinsky, V. Wooster, K. 2012. Strategic analysis of water use and risk in the beverage industry. https://deepblue.lib.umich.edu/bitstream/handle/2027.42/90925/mp_waterriskreport_final_delivered.pdf?sequence=1
[7] http://www.infrastructurene.ws/2016/11/01/continued-drought-could-severely-affect-sas-bottled-water-industry/
[8] City Press, 2016. Drought fells R87m off Sappi's earnings.
[9] City Press, 2016. Drought fells R87m off Sappi's earnings.

businesses that may be most affected by droughts include food businesses, hairdressers and car washing businesses.

There is a dearth of studies on the impact of drought on small businesses. One study was conducted on agriculture-dependent small businesses in the town of Thaba Nchu, where most small businesses surveyed were in the informal sector, and had a turnover of less than R50,000 per annum (Hlalele et al., 2016). The study found that butcheries use a lot of water for production purposes (including boerewors production), while fruit and vegetable businesses use water for keeping vegetables fresh. Respondents indicated that the drought negatively impacted on their businesses; for instance, vegetables withered due to lack of water. 87% of businesses reported losing over 50% of their revenue due to the drought (Hlalele et al., 2016). There is also anecdotal evidence of the impact of drought on small businesses. For instance, newspaper articles cite businesses on the East Rand reporting losing clients due do water shortages[10], while guesthouse owners in Bela-Bela[11] also reported that they have been impacted. More comprehensive studies on the impact of water shortages on small businesses are required.

3.7 Economic impacts of drought on large businesses

Just like the case of small businesses, published studies on the economic impact of drought on large businesses are scarce. We did not find any study that assessed the economic impacts of drought on the large business sector in South Africa.

3.8 Economic impacts of drought in relation to water quality

The economic impacts of drought in relation to water quality are under-researched and difficult to quantify, not least because of insufficient research on the economic impacts of deteriorating water quality even in the absence of drought. Secondly, understanding the impacts of drought on water quality is extremely complex, and again, under-researched in the South African context. The complexity is partly due to the number of variables to be taken into account in water quality, including dissolved oxygen, nutrients, sediments, dissolved organic carbon, pH, metals, organics and ecology.

In general droughts, and the wetter period immediately after a drought, tend to have profound water quality effects, with the actual effects dependent on the characteristics of the water body

[10] http://www.news24.com/SouthAfrica/News/east-rand-businesses-hit-hard-by-water-shortages-20151111
[11] https://www.enca.com/south-africa/drought-hits-tourism-bela-bela

and its catchment (Mosley, 2015). Work done by Mosley (2015) in Australia showed that reduced water flow and volume during drought generally resulted in increased salinity as a result of reduced dilution and increased concentration. Increased temperatures and enhanced stratification resulted in increased algal production, more toxic cyanobacterial blooms, and lower dissolved oxygen concentrations. On the other hand, nutrients and turbidity often decreased in water courses during droughts because of reduced loads from agricultural sources. Point sources of pollution generally showed deterioration in water quality due to a lowered dilution factor (Mosley, 2015).

In addition, however, post drought floods can result in pollution spikes, due to storage and build-up of material and changed geochemistry (such as sulphide oxidation) during drought. In some cases, Mosley notes, this resulted in severe downstream impacts such as deoxygenation. A study on Flag Boshielo Dam (Dabrowski et al., 2014), showed that during a severe drought between November 2002 and December 2005, water quality deteriorated, with high levels of dissolved salts, especially K, Na, Cl, F, and total alkalinity. Following the drought, dissolved salt concentrations dropped, and there was a short flush of inorganic N and P.

There is little research in South Africa on the water quality impacts of drought. Initial investigations by Andrew Slaughter (Institute for Water Research, Rhodes University) of three sites in the Crocodile Catchment indicate a complex water quality response to drought, depending on the land-use upstream of the monitoring point. His investigations, which are in an early stage and are not for publication yet indicate that the issue of drought impacts on water quality is complex and site specific.

In summary, very limited work has been done on the economic impacts of deteriorating water quality and drought in South Africa, either in specific catchments or at a national level. The relationship between water quality and drought is still not well understood. A research question then arises as to what are the economic costs of deteriorating water quality attributed to drought or at least during dry years?

4. Approaches to assessing impacts of policy interventions and shocks

4.1 Introduction

Three non-econometric approaches can be used to assess the impacts of policy interventions or shocks. In “before” and “after” comparisons, the analyst will study a household before the intervention and what happens to the same household after the intervention. In “with” and "without" comparisons, the analyst collects cross sectional data that comprises of households that have received the intervention and those that have not received the intervention. The "target" and "achievement" comparisons are self-explanatory. Given resources, one could also use robust approaches from econometrics (e.g. propensity matching strategies, endogenous switching regression) to isolate the causal effects of interventions. Since this study was conducted at a time of a drought episode (households were experiencing drought during the data collection), the only approach that was practical was "before" and "after" comparisons, where households were required to use recall in making statements about the most recent normal year.

4.2 Measurement of the direct impacts of drought

We know from Section 4 that the magnitude of the direct impact of a drought is estimated by a simple comparison between some measure of the economic outputs of a specific sector in drought years with that of the previous non-drought years (e.g. Klein and Kulshreshtha, 1989; Richter and Semenov, 2005; Xiao-jun et al., 2012; Garrido and Hernandez-Mora, 2013). Thus, to the extent one can observe stakeholders behaviourally respond to decreases in the quantity and quality of water assuming it is drought induced, measuring the direct effects is fairly straightforward. The key limitation with this approach is that attribution may be inaccurate without considering time trends or other factors that might influence economic results. Furthermore, the intensity of drought felt is not equal amongst regions across South Africa, and therefore an average cannot be drawn across the country.

4.3 Measurement of the indirect and induced impacts of drought

The measurement of indirect and induced effects uses the direct impacts as the starting point, in combination with social accounting and impact analysis software packages like IMPLAN Pro, to derive forward and backward economic linkages in the economy. IMPLAN Pro for example can be used to create predictive models of local economies, which can then be used to analyse shocks to economic systems. IMPLAN Pro can use data from different industrial sectors including employment, value added activities and business to business transactions, to create a baseline economy. Impacts to the system, which could be increases or decreases in economic activity or investment, may then be compared to the baseline scenario.

Indirect and induced drought impacts have been analysed using linear mathematical programming models (Dono and Mazzapicchio, 2010; Peck and Adams, 2010), non-linear mathematical programming models (Jenkins et al., 2003; Booker et al., 2005), hydro-

economic models (Ward and Pulido-Velázquez, 2012), econometric models (Alcalá Agulló and Sancho Portero, 2002; Martínez-Cachá, 2004; Rubio Calvo et al., 2006; Lorite et al., 2007; Quiroga and Iglesias, 2009), computable genera equilibrium models (CGE) or input-output (IO) models (Goodman, 2000; Gómez et al., 2004; Berrittella et al., 2007; Pérez y Pérez and Barreiro-Hurlé, 2009), and choice experiments (Martin-Ortega and Berbel, 2010).
This study will only be limited to the measurement of the direct impacts of drought in South Africa.

4.4 Overall framework for the measurement of drought impacts in South Africa

For this study, the direct impact of the drought for the selected sectors (irrigated agriculture; livestock; mining; tourism; agro-processing; small and large businesses; water quality) will be measured by comparing **sector relevant indicators of performance** in the **most recent drought year** and the **most recent normal year**.

5. Measurement of the economic impacts of drought

5.1 Measurement of the impact on the irrigated agriculture sector (white and yellow maize)

To estimate the impact of drought induced water shortages on white and yellow maize grown under irrigation, a structured questionnaire (see appendix 1) was used to collect the following data: data on output (in tonnes and in value units), and data on inputs use (land area, number of employees, quantity & expenditure on irrigation water use, quantity & expenditure on fertilizer use, quantity & expenditure on herbicide use, quantity & expenditure on pesticide use, and quantity & expenditure on electricity use). Data were also collected on management actions taken immediately by the farmer in response to the current drought (i.e. short run responses) and management actions the farmer proposes to take in the long-run in anticipation of future drought incidences.

5.2 Measurement of the impact on the rain-fed agriculture sector (white and yellow maize)

To estimate the impact of drought induced water shortages on white and yellow maize grown under rain-fed conditions, a structured questionnaire (see appendix 2) was used to collect the following data: data on output (in tonnes and in value units), and data on inputs use (land area, number of employees, quantity & expenditure on fertilizer use, quantity & expenditure on herbicide use, and quantity & expenditure on pesticide use). Data were also collected on management actions taken immediately by the farmer in response to the current drought (i.e. short run responses) and management actions the farmer proposes to take in the long-run in anticipation of future drought incidences.

5.3 Measurement on livestock production (extensive cattle, goat and sheep production)

To estimate the impact of drought induced water shortages on extensive livestock production, a structured questionnaire (see appendix 3) was used to collect the following data: data on livestock units owned (number and current value units when sold), and data on inputs use (number of employees). Additional data collected included number of animals sold, number of animals slaughtered, number of animal's dead. Data were also collected on management actions taken immediately by the farmer in response to the current drought (i.e. short run responses) and management actions the farmer proposes to take in the long-run in anticipation of future drought incidences.

5.4 Measurement on the mining sector

To estimate the impact of drought induced water shortages on the mining sector, a structured questionnaire (see appendix 4) was used to collect the following data: whether the firm had open cast or underground operations, whether the firm engaged in dry or wet mining, the management actions taken immediately by the firm in response to the current drought (i.e. short run responses) and the management actions the firm proposes to take in the long-run in anticipation of future drought incidences.

5.5 Measurement on the tourism sector

To estimate the impact of drought induced water shortages on the tourism sector, a structured questionnaire (see appendix 5) was used to collect the following data: sensitivity of the sector to water shortages, the management actions taken immediately by the sector in response to the current drought (i.e. short run responses) and the management actions the firm proposes to take in the long-run in anticipation of future drought incidences.

5.6 Measurement on the agro-processing sector

To estimate the impact of drought induced water shortages on the tourism sector, a structured questionnaire (see appendix 6) was used to collect the following data: sensitivity of the sector to water shortages, the management actions taken immediately by the sector in response to the current drought (i.e. short run responses) and the management actions the firm proposes to take in the long-run in anticipation of future drought incidences.

5.7 Measurement on the small-business sector

In the National Small Business Amendment Act 26 of 2003, micro-businesses in the different sectors, varying from the manufacturing to the retail sectors, are defined as businesses with five or fewer employees and a turnover of up to R100 000 ZAR. Very small businesses employ between 6 and 20 employees, small businesses employ between 21 and 50 employees.

To estimate the impact of drought induced water shortages on the small business sector, a structured questionnaire (see appendix 7) was used to collect the following data from a grocery store, a taxi operator and a small scale fashion designer in Lady Smith: sensitivity of the sector to water shortages, the management actions taken immediately by the sector in response to the current drought (i.e. short run responses) and the management actions the firm proposes to take in the long-run in anticipation of future drought incidences.

5.8 Measurement on the large-business sector

To estimate the impact of drought induced water shortages on the large business sector, a structured questionnaire (see appendix 8) was used to collect the following data: sensitivity of the sector to water shortages, the management actions taken immediately by the sector in response to the current drought (i.e. short run responses) and the management actions the firm proposes to take in the long-run in anticipation of future drought incidences.

5.9 Measurement on water quality

The impacts of drought induced water shortages on water quality was entirely based on a literature survey.

5.10 Data used to estimate impact of drought induced water shortages

Table 4 provides a summary of the stakeholders that were approached to provide the data that was required to support the analysis, and the stakeholders that accepted to participate in this study.

Table 4: Stakeholders approached to provide data

Sector	Stakeholders approached	Resources used to provide information
Irrigated white and yellow maize Rain-fed white and yellow maize	Agriculture Research Council (ARC) Agri SA Grain SA LIMA Rural Development Senwes BFAP Stellenbosch University ZZ2 18 farmers	• ARC provided secondary data. • 3 farmers provided information
Livestock	Red Meat Producers Association Klein River Cheese Animal Feed Manufacturers Association 14 farmers	• 5 farmers provided information
Mining	Department of Mineral Resources Chamber of Mines Anglo American Golder South32 Exxaro Eskom Xstrata Coaltech University of Witwatersrand\ Richards Bay Minerals	• 3 key informant interview. • Published case study from the Richard's Bay Mine (KZN)
Tourism	SANParks Incomati-Usuthu Catchment Management Agency iSimangaliso Wetland Park	Key informant interview with: • Kruger National Park • iSimangaliso Wetland Park.

	Department of Tourism Tourism Business Council of South Africa Fedhasa	
Agro-processing	RCL Foods Sugar GreenCape SAB Miller Illovo South African Sugar Association Citrus Growers Association SA Fruit and Vegetable Canners Association Department of Trade and Industry Tobacco Institute of South Africa Tongaat	Key informant interviews with: Published case study by Manqele, Zuma and Ninela (2016)
Small-businesses	10 small-business owners	Key informant interviews with the following businesses in Ladysmith: • Grocery store • Taxi operator • Small scale fashion designer
Large-businesses	Department of Water Affairs and Sanitation National Business Initiative Carbon Disclosure Project (South Africa) Ladysmith Chamber of Commerce Eskom	Key informant interviews with: • Chamber of Commerce in Ladysmith. • Eskom
Water quality		Key informant interviews with: • 1 Published case study.
General drought information	Engelhart Commodities Trading Partners	

As can be seen from Table 4, an attempt to consult widely was made but the response rate was very limited. Consequently, the results and discussions to follow are necessarily limited by data availability and should be interpreted with caution. This was an extremely constrained study that was limited by a small budget, which necessarily ruled out design of samples using the random approach and the possibility of collecting data by face to face interviews (all interviews with farmers were done telephonically).

6. Results and Discussions

6.1 Impact of drought induced water shortages on the irrigated agriculture sector

Table 5 presents results for changes in indicators of **white maize output** grown under irrigation conditions. The results are based on a telephone interview with 1 small scale maize farmer, who had 0.25 ha of land in 2011 and 0.5 ha of land in 2016, 3 employees in 2011 and 2 employees in 2016, used 1 bag of manure in 2011 and 1.5 bags of manure in 2016, and had an output of 3 (50 kg) bags of maize in 2011 and 5 (50 kg) bags of maize in 2016.

Table 5: Changes in output indicators in physical units (white maize)

Indicators	Change in measure of performance	Conclusion
1. Change in white maize output **per hectare**.	2	White maize **output decreased** by **2 bags per hectare**, consistent with expectation during drought.
2. Change in white maize output **per employee**.	1.5	**Labour productivity** in white maize production **increased** by **1.5 bags**, inconsistent with expectation during drought[12].
3. Change in white maize output **per bag of fertilizer**.	NA	Farmer did not apply fertilizer.
4. Change in white maize output **per litre of herbicide**.	NA	Farmer did not use herbicide.
5. Change in white maize output **per litre of pesticide**.	NA	Farmer did not use pesticide.
6. Change in white maize output **per bag of manure**.	0.0	**Manure productivity** in white maize production **remained almost constant**.

Table 5 shows that drought induced water shortages reduce white maize output per hectare in response to drought induced water shortages. With the exception of labour productivity which shows an increase, manure productivity remained almost constant while the farmer did not use other purchased inputs. The results for changes in input use indicators presented in Table 6 generally agree with the conclusions of Table 5.

[12] This increase could be driven by the larger area in 2011 relative to 2016.

Table 6: Changes in indicators of input use in physical units (white maize)

Indicators	Change in measure of performance	Conclusion
1. Change in land area allocated to white maize production (ha)	0.25	The **land area** allocated to white maize production **increased by 0.25 ha**.
2. Change in number of employees **per hectare** in white maize production (number)	8	The **number of employees** in white maize production **decreased** by 8 persons per hectare, which is consistent.[13]
3. Change in fertilizer quantity **per hectare** used in white maize production (bags)	NA	Farmer did not apply fertilizer.
4. Change in herbicide quantity used **per hectare** in white maize production (litres)	NA	Farmer did not use herbicide.
5. Change in pesticides quantity used **per hectare** in white maize production (litres)	NA	Farmer did not use pesticide.
6. Change in manure quantity used **per hectare** in white maize production (bags)	0.00	**Manure quantity** used in white maize production remained **almost constant**.

Table 7 converts the physical changes of Tables 5 and 6 into monetary units. A 50 kg bag of maize retailed for R250 in 2011, while a 50 kg bag of maize retailed for R350 in 2016.

[13] Assuming land area and labour are substitutes, if area increases, labour decreases for the same level of output.

Table 7: Changes in indicators of input and output use in monetary units (white maize)

Indicators	Change in measure of performance	Conclusion
Change in output indicators for 2011-2016 in monetary units (Rand)		
1. Change in value of output **per hectare**.	R500	The value of white maize output **per hectare increased** by R500, consistent with expectation[14].
Change in inputs indicators for 2011-2016 in monetary units (Rand)		
2. Change in value of **fertilizer input use per hectare**.	NA	Farmer did not apply fertilizer.
3. Change in value of **herbicides input use per hectare**.	NA	Farmer did not use herbicide.
4. Change in value of **pesticides input use per hectare**.	NA	Farmer did not use pesticide.
5. Change in value of **manure input use per hectare**.	0.00	The value of manure input use **remained almost constant**.

Since we interviewed only 1 farmer, the calculations to follow are only indicative. Table 5 shows white maize output decreased by 2 bags per hectare. Data obtained from AGRI SA show that in the 2015/2016 growing season, 92,000 ha of land were planted with white maize under irrigation. Using the 2 (50 kg) bags of maize reduction per hectare, our data suggests a reduction of around 184 000 (50 kg) bags or 9 200 000 kgs for the entire area planted. At a cost of R350 per 50 kg bag in 2016 (R7 per kg), this translates to a loss of R64 400 000.

To put this figure in perspective, consider the AGRI SA data which shows that white maize output in the 2015/2016 season was 702 180 000 kgs. If the output lost due to drought had

[14] If maize becomes scarce in the event of a drought, the theory predicts the price of maize would go up.

been mitigated, the potential total output would have been 711 380 000 kgs. It follows that the reduction of white maize attributed to drought induced water shortages amount to about 1%.

The farmer reported that as a result of dams drying up and reduced river water levels, irrigation water was inadequate leading to the maize crop being burnt. As a short-term response, he colluded with others and volunteered to dig up furrows that bring water to dams, and they also cleared the pipes for easy water flow. As a result of the drought, farmers observed livestock encroachment into maize fields and this led to conflicts. Fences around maize fields were reported stolen. In response, the farmers as a group discussed these problems with livestock owners and almost took the issue to court. However, it was possible to find out of court resolutions.

The farmer suggested the following long term response options to future drought induced water shortages: (i) expand the storage capacity of existing dams, (ii) build more dams and boreholes, (iii) conserve water especially when irrigating. To be specific, farmers should be compelled to irrigate for not more than three hours per day.

6.2 Impact of drought induced water shortages on the rain-fed agriculture sector

Table 8 presents the results for changes in indicators of **yellow maize output** grown under rain-fed conditions. The results are based on a telephone interview with 2 small scale maize farmers, whose average maize output was 1,215 (50 kg) bags in 2011 and 626 (50 kg) bags in 2016. Following are the average statistics for input use: area (26 ha in 2011 and 26 ha in 2016), number of employees (5 in 2011 and 12 in 2016), fertilizer use (3 bags in 2011 and 3 bags in 2016), herbicide use (2litres in 2011 and 1litre in 2016), pesticide use (11litres in 2011 and 1litre in 2016), and manure use (2 bags in 2011 and 2 bags in 2016).

Table 8: Changes in output indicators in physical units (yellow maize)

Indicators	Change in measure of performance	Conclusion
1. Change in output of yellow maize **per farmer**.	294.50	Yellow maize **output decreased** by **294.5 bags per farmer** on average.
2. Change in output of yellow maize **per hectare** cultivated.	13	Yellow maize **output decreased** by **13 bags per hectare** on average.
3. Change in output of yellow maize **per employee** used in production.	112.15	**Labour productivity** in yellow maize production **decreased** by **112.15 bags** on average.
4. Change in output of yellow maize **per bag of fertilizer** used in production.	98.08	**Fertilizer productivity** in yellow maize production **decreased** by **98.08 bags** on average.
5. Change in output of yellow maize **per litre of herbicide** used in production.	46.00	**Herbicide productivity** in yellow maize production **decreased** by **46.00 bags** on average.
6. Change in output of yellow maize **per litre of pesticide** used in production.	110.38	**Pesticide productivity** in yellow maize production **decreased** by **110.38 bags** on average.
7. Change in output of yellow maize **per bag of manure** used in production.	165.83	**Manure productivity** in yellow maize production **decreased** by **165.83 bags** on average.

All the indicators presented in Table 8 are consistent with what we would expect given drought induced water shortages. The results for changes in input indicators are presented in Table 9.

Table 9: Changes in indicators of input use in physical units (yellow maize)

Indicators	Change in measure of performance	Conclusion
1. Change in land area **per farmer** allocated to yellow maize production (ha)	0.00	The **land area** per farmer allocated to yellow maize production **remained almost constant** on average.
2. Change in number of employees **per hectare** in yellow maize production (number)	2.27	**Number of employees** in yellow maize production **increased** by 2.27 persons per hectare on average.
3. Change in fertilizer quantity **per hectare** used in yellow maize production (bags)	0.50	**Fertilizer quantity** used in yellow maize production **decreased** by 0.25 bags per hectare on average.
4. Change in herbicide quantity used **per hectare** in yellow maize production (litres)	0.00	**Herbicides quantity** used in yellow maize production **decreased** by 0.25 litres per hectare on average.
5. Change in pesticides quantity used **per hectare** in yellow maize production (litres)	5.00	**Pesticides quantity** used in yellow maize production **decreased** by 5 litres per hectare on average.
6. Change in manure quantity used **per hectare** in yellow maize production (bags)	0.00	**Manure quantity** used in yellow maize production remained **almost constant** on average.

With the exception of labour use productivity which increased, all indicators listed in Table 9 are consistent with what one would expect under conditions of drought induced water shortages. The physical changes in output and input indicators are converted to monetary units in Table 10. A 50 kg bag of maize retailed for an average price of R130 in 2011, while a 50 kg bag of yellow maize retailed for R135 in 2016.

Table 10: Change in output and input indicators in monetary units (yellow maize)

Indicators	Change in measure of performance	Conclusion
Change in output indicators for 2011-2016 in monetary units (Rand)		
1. Change in value of output **per farmer**.	R41,400	Value of yellow maize output **per farmer reduced** by R41,400 on average.
2. Change in value of output **per hectare**.	R1,748	Value of yellow maize output **per hectare reduced** by R1,748 on average.
Change in inputs indicators for 2011-2016 in monetary units (Rand)		
3. Change in value of **fertilizer input use per hectare**.	R50	Value of fertilizer use per hectare **reduced** by R50.
4. Change in value of **herbicides input use per hectare**.	0	Value of herbicides input per hectare **remained almost constant**.
5. Change in value of **pesticides input use per hectare**.	R250	Value of pesticides input use **reduced** by R250.
6. Change in value of **manure input use per hectare**.	0	Value of manure input use **remained almost constant**.

Farmers on average lost yellow maize output worth R1,748 per hectare following the drought induced water shortages. The value of fertilizers demanded by farmers reduced by R50 per hectare, while the value pesticides demanded by farmers reduced by R250 per hectare. The reduction in the value of output has direct consequences on the welfare of the farmer, while the reduction in the demand for inputs has consequences for the welfare of the input supplier.

Since we interviewed only 2 farmers, the calculations to follow are only indicative. Table 8 shows yellow maize output decreased by 13 bags per hectare. Data obtained from AGRI SA show that in the 2015/2016 growing season, 162,000 ha of land were planted with yellow maize under irrigation[15]. Using the 13 (50 kg) bags of yellow maize reduction per hectare, our data shows a reduction of around 2,106,000 (50 kg) bags or 105,300,000 kgs (105,300 tons) for the entire area planted. At a cost of R135 per 50 kg bag of yellow maize in 2016 (R2.7 per kg), this translates to a loss of R284,310,000.

To put this figure in perspective, consider the BFAP projections[16] which show that yellow maize output in the 2015/2016 season was expected to be 6,385,000,000 kgs (6,385,000 tons). If the output lost due to drought had been mitigated, the potential total output would have been 6,490,300,000 kgs. It follows that the reduction of yellow maize that could be attributed to drought induced water shortages amount to about 2% of potential output. Similar reasoning can be used to estimate economy-wide loses likely to have been suffered by fertilizer and pesticide suppliers.

Farmers reported that the drought induced water shortage resulted in increased sprouting of weeds which substantially increased the labour costs for weeding by R2,500 per hectare as a short-term response. The drought induced some farmers to plant late as a short-term response. Farmers suggested the following long-term response options to future drought incidences: (i) building of dams, (ii) government to provide funds to facilitate farmers to switch from rain-fed to irrigated production, and (iii) funding support and subsidies from farmer associations to cushion farmers during drought episodes.

6.3 Impact of drought induced water shortages on livestock production

The results to follow are based on interviews with 2 farmers practising extensive cattle production, 1 farmer practising extensive goat production, and 1 farmer practising extensive sheep production.

Table 11 presents the results for changes in indicators of **extensive cattle production**. Following is a summary for the two farmers: cattle owned on average: 81 head (2011) and 62 head (2016), number of employees on average: 2 (2011) and 2 (2016), cattle sold on average: 31 head (2011) and 11 head (2016), cattle slaughtered on average: 0 head (2011) and 0 head (2016), and cattle dead on average: 0 head (2011) and 17 head (2016).

[15] Since we do not have the area of land planted with yellow maize under **rainfed** conditions, this calculation is based on the **area of land planted with yellow maize under irrigation conditions**.
[16]http://www.bfap.co.za/documents/research%20reports/BFAP_Drought%20Policy%20Brief_5%20February%202016.pdf

Table 11: Changes in output indicators in physical units (extensive cattle production)

Indicators	Change in measure of performance	Conclusion
1. Change in **number of cattle owned** per farmer.	19	The **number of cattle owned** per farmer **decreased** by **19** on average.
2. Change in **number of cattle sold** per farmer.	20	The **number of cattle sold** per farmer **decreased** by **20** on average.
3. Change in **number of cattle slaughtered** per farmer.	0	The **number of cattle slaughtered** per farmer **remained constant** on average.
4. Change in **number of cattle dead** per farmer.	17	**Cattle deaths increased** by **17 units** on average.

All indicators listed in Table 11 are consistent with what one would expect under conditions of drought induced water shortages. Table 12 converts the physical indicators into commensurate monetary units. The average price of a mature animal was R6,750 in 2011 and R8,250 in 2016.

Table 12: Changes in output indicators in monetary units (extensive cattle production)

Indicators	Change in measure of performance	Conclusion
Change in output indicators for 2011-2016 in monetary units (Rand)		
1. Change in **value of cattle owned** per farmer.	R73,500	The **value of cattle owned** per farmer **decreased** by **R73,500** on average.
2. Change in **value of cattle sold** per farmer.	R1,500	The **value of cattle sold** per farmer **increased** by **R1,500** on average.
3. Change in **value of cattle slaughtered** per farmer.	0	The **value of cattle slaughtered** per farmer **remained constant** on average.
4. Change in **value of cattle dead** per farmer.	R174,000	The **value of cattle deaths increased** by **R174,000** on average.

Farmers reported the following short-term responses to mitigate impacts pf the drought induced water shortages: additional expenditure on feed (cultivating grass, maize for feeding, buying grass, buying feedlot) at an average cost of R186,000 per farmer, buying water by tank and transport it to the farm at an average cost of R2,500 per farmer, moved animals to another pasture at an average cost R4,500 per farmer, and spent on vaccinations and treatment at a cost of R5,000 per farmer. Farmers suggested the following long-term plans to mitigate impacts of future drought incidences: (i) government to build more water reservoirs, government to increase the capacity of existing dams, (iii) government to dig boreholes, (iv) planting grass under irrigation, and (vi) practice rotational grazing. A farmer noted that he was very devastated by the drought since he sought some financial resources from LIMA but is now facing difficulties to pay back the loan.

Table 13 presents the results for changes in indicators of **extensive goat production**. Following is a summary for the farmer: goats owned: 11 (2011) and 30 (2016), number of employees: 1 (2011) and 1 (2016), goats sold: 4 (2011) and 14 (2016), goats slaughtered: 0 (2011) and 0 (2016), and goat's dead: 6 (2011) and 0 (2016), i.e. more goats reported dead during the normal year.

Table 13: Changes in output indicators in physical units (extensive goat production)

Indicators	Change in measure of performance	Conclusion
1. Change in **number of goat owned**.	19	The **number of goat owned increased** by **19**.
2. Change in **number of goat sold**.	10	The **number of goat sold increased** by **10**.
3. Change in **number of goat slaughtered**.	0	The **number of goat slaughtered remained constant**.
4. Change in **number of goat dead**.	6	The **goats reported dead decreased** by **6**.

Table 13 apparently shows the number of goats owned increased, number of goats sold increased, while the number of goats slaughtered remained constant. While these results may suggest goats may be drought tolerant, it will be misleading drawing such a conclusion based on an interview with 1 farmer. Table 14 converts the physical changes into commensurate monetary values. The price of a mature animal was R1,100 in 2011 and R1,300 in 2016.

Table 14: Changes in indicators of output in monetary units (extensive goat production)

Indicators	Change in measure of performance	Conclusion
Change in output indicators for 2011-2016 in monetary units (Rand)		
1. Change in **value of goat owned**.	R26,900	The **value of goat owned increased** by **R26,900**.
2. Change in **value of goat sold**.	R13,800	The **value of goat units sold increased** by **R13,800**.
3. Change in **value of goat slaughtered**.	0	The **value of goat slaughtered remained constant**.
4. Change in **value of units dead**.	R7,800	The **value of goat dead increased** by **R7,800**.

The farmer reported the following short term responses to mitigate the impacts of drought induced water shortages: buying good pasture for grazing goats from tribal land at a cost of R5,000, buying livestock feeds (bail & hay) at a cost of R26,000 and extra vaccination at a cost of R2,500. The farmer plans to buy more land that is for good grazing goats (with shrubs), and divide it into paddocks to facilitate the practise rational grazing as a long-term response. Finally, the farmer noted that assistance from farmer associations during the drought are very helpful. For instance, in 2016, he received livestock feed worth R9,000.

Table 15 presents the results for changes in indicators of **extensive sheep production**. Following is a summary for the farmer: sheep owned: 100 (2011) and 150 (2016), i.e. the sheep were more during the drought year, number of employees: 2 (2011) and 3 (2016), i.e. employees were more during the drought year, sheep sold: 20 (2011) and 20 (2016), sheep slaughtered: 3 (2011) and 5 (2016), and sheep dead: 6 (2011) and 11 (2016).

Table 15: Changes in output indicators in physical units (extensive sheep production)

Indicators	Change in measure of performance	Conclusion
1. Change in **number of sheep owned**.	50	The **number of sheep owned increased** by **50**.
2. Change in **number of sheep sold**.	0	The **number of sheep sold remained constant**.
3. Change in **number of sheep slaughtered**.	2	The **number of sheep slaughtered increased** by **2**.
4. Change in **number of sheep dead**.	4	**Sheep deaths increased** by **4 units**.

Similar to the discussion on goats, the results in Table 15 are based on only 1 interview. Table 16 converts the physical changes into commensurate monetary equivalents. The price of a mature animal was R950 in 2011 and R1,500 in 2016.

Table 16: Changes in indicators of output use in monetary units (extensive sheep production)

Indicators	Change in measure of performance	Conclusion
Change in output indicators for 2011-2016 in monetary units (Rand)		
1. Change in **value of sheep owned**.	R130,000	The **value of sheep owned increased** by **R130,000**.
2. Change in **value of sheep sold**.	0	The **value of sheep sold remained constant**.
3. Change in **value of sheep slaughtered**.	R4,650	The **value of sheep slaughtered increased** by **R4,650**.
4. Change in **value of sheep reported dead**.	R9,300	The **value of sheep deaths increased** by **R9,300**.

The farmer reported the following short term responses to mitigate the impacts of drought induced water shortages: buying more feeds at a cost of R3,500, plant reddish at a cost of R1,250 and buying more vaccination at a cost of R600. The farmer noted that he did not sell more sheep during drought because they were not in good condition for sale and most were sick hence invested more money in treatment.

6.4 Impact of drought induced water shortages on the mining sector

Water plays a critical role in the mining extraction and processing chain. To begin with, dust suppression[17] in mineral extraction requires a plenty of water for health and safety reasons. Just as in other regular industrial processes, the mineral processing chain requires an adequate water supply, of particular mention being beneficiation or beneficiation. Beneficiation in mining is any process that improves the economic value of the raw ore resulting in a higher-grade product or concentrate. In the coal industry for example, beneficiation is a process that is very water intensive.

For the purposes of understanding the impacts of drought induced water shortages on the mining sector, it is important to distinguish between two broad types of mining operations: (i) open cast vs. underground mining operations (defined in Section 3.4), and (ii) dry and wet mining operations. A dry mining operation is one that produces a negative water balance (the amount of water externally abstracted upstream is greater than the amount of water externally supplied downstream). Dry mines in South Africa are located in the remote drier regions of the country, for example in the Western Cape. A wet mining operation produces a positive water balance (the amount of water externally abstracted upstream is less than the amount of water externally supplied downstream). Wet mines in South Africa include the coal mining operations in eMalahleni. The ideal situation is when a mining operation neither externally abstracts nor externally discharges water.

The effects of drought induced water shortages on the mining sector depend on whether a dry or wet mining operation is under consideration. The impacts of water shortages on dry mining operations can be analysed the way one would analyse this impact in other sectors (e.g. agriculture). Dry mining operation respond to water shortages as one witnesses in other sectors: conserving water, recycling water, etc. A recent development in the coal sector is the use of dry coal beneficiation, a technology designed to improve the quality of raw coal with minimal abstract and discharge water. In South Africa, dry coal beneficiation is at experimental stage, with potential to expand coal mining to arid areas where mining is currently limited by water availability.

[17] Mining generates a lot of dust requiring water to suppress the dust.

The impacts of drought induced water shortages on wet mining operations relates to the fact that wet mines have considerable discharge that must be treated for onward transmission to municipalities and other consumer groups. The capital and maintenance costs of such large treatment water plants is very high. Drought has the effect of making the concentration of pollutants in the effluent higher, thus compromising the quality of the effluent even after treatment, with impacts on downstream water users. Thus, drought substantially increases water treatment costs for the wet mines.

Finally, large open cast mines have to be dewatered to facilitate the mining, with consequences for water availability to surrounding communities. Legislation requires the mine to clean and process the extracted water for onward supply to user communities. As expected, drought induced water supply shortages have a tendency to concentrate dissolved salts in water and thus increase the cost of cleaning and processing the extracted water. Besides, as water is extracted from the pit, the ground water table will continue to decrease, a situation that is exacerbated by drought. This means that wells in downstream communities will dry, which implies that the mining firm will be obliged to provide alternative sources of water (portable, irrigation, livestock) to communities downstream.

The following account is based on published impacts of drought induced water shortages on Richard Bay Mine (RBM) in KwaZulu-Natal. RBM obtains water from three sources namely Umfolozi River (sporadic), Lake Nhlabane (main source) and Lake Nsezi, which is fed by the Tugela-Goedertrouw Transfer system and managed by Mhlathuse Water Board. From the beginning of the drought in 2014 till recently, RBM solely relied on water from Lake Nsezi as the other two sources were too low to use. RBM uses water throughout its operations from the mining process for separation of heavy minerals and the beneficiation process.

The mining process in RBM can be described as follows. Low-clay Richard Bay sands that suit a wet-mining process create artificial freshwater ponds in the dunes, which are located several kilometres from the shoreline. On each pond floats one or more dredgers and a concentrator plant. The dredgers burrow into faces of dunes, advancing at a rate of a few metres a day. The sand face collapses into a pond and is sucked up and pumped into a concentrator plant. The heavy minerals are separated from the sand through a series of sieves and sluices. The sand is pumped behind the plant for dune rehabilitation, and the valuable heavy mineral concentrate is deposited next to each pond for transportation to the mineral separation plant. In RBM, water use, energy use, air quality and waste levels are carefully monitored and managed. Technological advances and innovative systems have been successfully exploited to reduce consumption and maximise reuse of resources.

A newly-opened R74m desalination plant allows South32 to maintain operations at its Hillside Aluminium Shelter Complex during drought, which resulted in the implementation of stringent water restrictions in the Richard Bay domestic and industrial sector. Desalinating seawater was identified as the preferred alternative as it will supply adequate water to ensure operations are maintained and it will also be able to supplement the municipality water supply in times of critical shortage (South32 president for South Africa region, Mike Fraser).

6.5 Impact of drought induced water shortages on the tourism sector

The following accounts of the impacts of drought induced water shortages on the tourism sector are based on key informant interviews from the Kruger National Park and the iSimangaliso Wetland Park. The accounts from these two protected areas generally share a story that implies drought has positive and negative impacts on the tourism sector. It is not the case that tourism is a loser in the event of a drought. That said, there also exist many impacts of drought induced water shortages on the tourism sector that would benefit from further scientific investigations, since they just emerge as hypotheses when one analyses the responses from these two protected areas.

Kruger National Park

Unlike hotels and restaurants which rely on municipal water supplies, Kruger National Park obtains and treats its own water. It follows that water supplies were not particularly interrupted by the 2016 drought. The main impact of the drought in so far as water supply is concerned was to **increase pumping costs** because the Crocodile and Letaba rivers were very low (expensive to extract water from very low river levels). The also drought necessitated KNP to open boreholes that were not currently in use, which had impacts on expenditure. Since Kruger National Park extracting water from extremely low flows during the drought, there were worries about water quality issues. However, with effective water quality monitoring, no water quality related issues arose following the drought. But the drought **resulted in an increase in water quality monitoring costs**. A positive outcome of the drought in so far as water supply is concerned was to increase water conservation awareness.

With respect to hotel occupancy rates, Kruger National Park **did not experience any drop in hotel occupancy rates** following the drought. This could probably be attribute this to the fact that KNP actively communicated to clients that they did not have a water supply problem in the midst of the drought.

The drought appears to have had **positive impact on game viewing opportunities and visitor numbers** in KNP It is hypothesized that drought enhances game viewing: drought implies decreased vegetation density and better game viewing. One would hypothesize that since the number of carcasses during a drought increase, in particular because of hippo and buffalo die-offs, visitation would go down. However, KNP hypothesizes that increased social media exposure and marketing may have mitigated this potential. In general **day visitors and occupancy went slightly up during the drought year**. But since this is just a hypothesis, it should be tested using a visitor survey to establish broad trends: is there a relationship between drought and enhanced (i) visitor numbers, and (ii) game viewing experience?

The impact of the drought on **tour operators or tourism outside Kruger National Parks is not clear**. The question is: as a result of the drought, did tourism outside KNP increase, decrease or it had no impact? This is also a subject of further scientific investigation.

The **impact of the drought on communities surrounding KNP remain to be investigated**. KNP usually allows harvesting of grass during non-drought years, but this activity is disallowed during drought events: what is the impact of disallowing grass harvesting following the drought? KNP usually allows harvesting of mopane worms in normal years, but this activity is disallowed during drought events: what is the impact of disallowing harvesting of mopane worms as a result of the drought? Communities surrounding KNP are affected by the drought following cattle deaths. KNP hypothesizes that there might be relationship between drought intensity, cattle deaths and increased incidences of snaring at the KNP periphery. This follows increased snaring incidences on the periphery of KNP during drought events, but this is a matter for scientific investigation. **KNP hypothesizes that the drought may be associated with the significant reduction in the number of rhinos poached**: the vegetation is sparse, it is easier to track poachers and it is more difficult for them to hide: what is the impact of the drought on rhino poaching? Finally following drought, KNP decided to do some hippo and buffalo off-take to supplement food to schools and orphanages in surrounding communities. KNP processed the meat before offering it to communities. Data available from KNP show that **72** hippos were culled and processed at a cost of **R833,244** and **104** buffalo were culled and processed at a cost of **R499,946.52.** All the above considered: what is the impact of drought induced water shortages on communities surrounding KNP?

Kruger National Park hypothesizes that there might exist some cases of smaller parks (e.g. the Mokala south of Kimberley), where drought might also have had a direct impact. Such specialist parks breed and feed animals (like rhino), which is very expensive affair. The drought might substantially increase the feeding costs, but this is an issue for investigation.

iSimangaliso Wetland Park

The following is a key informant account of the impact of the drought on iSimangaliso Wetland Park.

On the overall, visitor numbers were steady and there was been a significant positive spike in international visitors, the drought notwithstanding. It is hypothesized that increases in international visitor numbers could be explained by the weakening Rand and the 2016 World AIDS Day. Domestic visitors may have been discouraged from visiting the park as they may have been affected by the drought. Visitors in the park were not affected by the drought as the park has an alternative source of water, a borehole.

Game viewing was improved as animals would cluster around available water points. Contrary, fishing in the northern part of the park was negatively affected as the lake dried out.

Natural resources harvesting, for example, ‘incema’ (a rush used for making mats) was negatively affected by drought to the point that it could not take place in 2016 as the ‘incema’ was not enough for sustainable harvesting. The common finger grass ‘isikonko’ was also threatened by drought and as a result was not available for harvesting in 2016.

Businesses around the iSimangaliso Wetland Park were negatively affected as they had to find alternative sources of water. Some of the business dug boreholes while other opted to purchase water. Visitors to park were therefore indirectly affected by the drought. For example, one lodge was shut down as getting water was costly. It seems that businesses had to absorb the cost associated with water shortages and in turn not offer accommodation discounts where they could have done so in a normal year. The accommodation prices did increase following the drought.

Social unrest and public protest near the park especially the central and northern parts did not appear to have affected visitation levels. Drought did not seem to have had an impact on employment opportunities offered by the park. There was pressure on the park by local communities to allow cattle to graze in the park during the drought.

The impacts of drought could have been minimised if there was better catchment management. Taking action against illegal woodlot farmers could also minimise the impact of drought, in addition to licencing of legitimate woodlots which has continued. The other factor that would have had an effect was the imposition of water restrictions by municipalities in the earlier period of the drought. Water use continued unregulated. Arguably specifically in the south the water crunch was due to water service maintenance issues. In effect 'the drought was the straw that broke the camels' back. Better water reticulation and maintenance of water plants at the various municipalities could have limited or reduced leakages (some 40% of available water is lost through poor municipal maintenance of water infrastructure).

6.6 Impact of drought induced water shortages on the agro-processing sector

Situated on the KwaZulu-Natal North Coast between Durban and Empangeni, Amatikulu Sugar Mill is one of the four mills operated by Tongaat Hulett Sugar South Africa, with a milling capacity of 365 tonnes per hour. The supply chain for the sugar business starts with the supply of sugar cane as raw material. A large percentage of the cane growing land that feeds Amatikulu is not irrigated. Like any other crop, sugarcane is dependent on rain for growth. If rainfall is below average as was the case in 2016 (the lowest average in 112 years), sugarcane does not grow. The worst case is that the roots start dying, to be followed by decreased cane supply. If the sugar cane survives the drought, the quality is severely affected, with implications for downstream processing. In short, drought induced water shortages affect the supply chain, all the way from the farms through sugar processing.

Sugar processing relies heavily on water for extraction of juice, steam production and other internal processes. Much as the process itself (within the factory fence) is a net water producer. Manqele, Zuma and Ninela (2016) use a scenario to demonstrate this phenomenon. A mill with a 340 tonnes per hour milling capacity produces 442 tonnes of juice translating to a required 255 tonnes of exhaust steam, which processes the juice to produce 80 tonnes of syrup at 65 degrees Brix (degrees Brix is the sugar content of an aqueous solution). The 255 tonnes of exhaust steam is the minimum amount of condensate that must be returned to the boilers to keep the water and steam balance. About 120 tonnes per hour of excess water is produced as effluent and is eventually used for irrigation in Amatikulu. If there are no disturbances in the process, the water balance is well maintained. Moreover, there were about 1.8% evaporation losses from steam or vapour to condensate.

Manqele et al. (2016) record that in Amatikulu during the drought, the moisture content in the cane dropped from about 68% (2012/2013) to 66% (2015/2016), while the fibre increased from 16% (2012/2013) to 19% (2015/2016). There was a shortage of raw water supply. For example, the river went completely dry meaning there was no input water to the mill. Areas that were affected and their respective processes included the extraction plant, boilers, cooling towers, and cooling water systems. There was no water available for human consumption.

The mill experienced a number of mechanical challenges which caused milling stoppages. Note that every disruption in the process triggered an imbalance in the water and steam balance.

According to Manqele et al. (2016), the direct effect of the current drought of on sugarcane production resulted to an estimated loss in gross revenue of R2 billion at industry level. On the other hand, the indirect and induced effect of drought on sugarcane production resulted to an estimated loss of revenue into rural economies of R6 billion.

As a short-term response to the current drought, about 8 boreholes were erected in strategic areas which were estimated to supply the mill with a minimum of 61m^3/hour of water. The mill also implemented water rationing (potable water) to consumers like the mill villages, primary school and four farms around the mill. Well points in river beds were installed to abstract water into the sugar mill. Water was also abstracted from two neighbouring farms with healthy size dams. Purified water was bought from commercial suppliers like Mandini Municipality, which is 24 kilometres from the mill costing about R4.2 million in months. The mill converted the 5,000 tonnes molasses tank into a strategic storage for water. The mill also installed an effluent pipe to recycle all the effluent back into the diffuser and as make up to the injection water cooling towers. Lastly, water was piped and pumped from nearby dams. These immediate and long term actions presented challenges like compromised quality of recycled effluent, condensate quality, and carry over into turbine control valves.

6.7 Impact of drought induced water shortages on the small-business sector

Although the small-businesses sector was negatively impacted by the recent drought induced water shortages, details of the specific impact on depend on the business in question. The **grocery operator** stated that the impact of the drought was mainly experienced in the ablution facilities where there was no adequate water. The facility could only deliver poor service and this negatively affected customers and staff. As a short-term response, the grocer bought a 2,000 litres Jojo tank. The **taxi operator** stated that the impact of the drought was mostly felt on the customers. Since they did not have money to afford taxi fares, there were very few customers asking for a ride (business was very poor). The lack of water also had an impact on sanitation: it was not possible to wash and keep clean the taxi, which negatively impacted on business. The **small-scale fashion designer** stated that a consistent water supply was fundamental to its core business, which involves ironing and washing. Since water was in short supply, they had to fetch it from a stand pipe tap located a 5-minute walk distance as a short-term response. However, the queue at the stand pipe lasted for about 30 minutes, thus wasting business time. The fetched water was not sufficient for bathing, drinking, cleaning, cooking for the 4 employees, activities they needed to do in the course of routine business. Thus, the business to make trade-offs: employees had to stop bathing at work, with the saved water used for cleaning the business premises.

6.8 Impact of drought induced water shortages on the large-business sector

The majority of Eskom's coal fired stations are located in Mpumalanga and receive water from the Vaal River System which is supported by water transfers from other river systems including the Lesotho Highlands Water Transfer Scheme and Thukela River transfer from Kwa-Zulu Natal.

Eskom experienced a range of impacts following impacts from the drought induced water shortages. Water levels in the two dams (Gariep dam and Vanderkloof dam) along Orange River were below volumes required for power generation. Declining dam levels in the Orange River and Vaal River System led to water restrictions and/or curtailments to users, with impacts on the capacity to generate electricity.

Eskom experienced increased costs for electricity generation from power stations. There was a power shutdown at administration building in Bloemfontein (no business could be transacted at the building). The impacts of drought were more apparent in hydropower stations. Increased costs for transmission and distribution of electricity were also experienced.

Increased pumping and maintenance costs: as a result of drought, there were low water inflows which led to increased pumping and maintenance costs, including costs from inter-basin transfers of water, e.g., in Mpumalanga the pumping and maintenance costs were high. There was also insufficient generation capacity to conduct the water transfers from Thukela River to Vaal River System via the Drakensberg Pumped Storage Scheme.

Responses to the drought induced water shortages included power stations received water from more than one source, e.g. two or more dams as an immediate response. A Drought Disaster Recovery Committee has now been established to manage the risks associated with drought as long-term response to future impacts of drought.

6.9 Impact of drought induced water shortages on water quality

Deterioration in water quality has significant, if insufficiently quantified impacts:

- it **reduces the amount of water available** for use as more water must be retained in our river systems to dilute pollution to acceptable standards;
- it **increases the costs of doing business** as many enterprises are forced to treat water before being able to use it in their industrial processes and the cost of municipal water treatment increases;
- it **reduces economic productivity** as an increased number of work days are lost due to water-related illnesses and as poor water quality reduces productivity in certain sectors (e.g. poor water quality impacts on crop yields and makes crops vulnerable to import restrictions from countries with strict quality standards; and on recreation and tourism);
- it **threatens human health and livelihoods** where people are exposed to poor water quality for consumptive or domestic usage; and
- it **has environmental implications** where biological and chemical contamination of water can impact on important aquatic species.

Some of these impacts are clearly visible, such as major fish kills, whilst others are more insidious and long term. Combined, however, they are already having a significant negative impact on socio-economic development in South Africa.

A study conducted by Dearmont et al. (1998) on the impacts of water quality on municipal water treatment costs revealed that that when chemical contamination was present in groundwater, the chemical cost of water treatment rose by $95 per million gallons from a base of $75. In other words, the cost more than doubled. A 1% increase in turbidity was shown to increase chemical costs by 0.25%.

In Harare, the cost of pollution led to a doubling of expenditure on water treatment chemicals due to severe contamination of most of the city's water sources.[18]

Researchers from Kansas State University in the USA estimated that pollution of fresh water with agricultural nutrients costs government agencies, drinking water facilities and individual Americans at least $4.3 billion a year in total. They calculated this cost by looking at factors such as decreasing lakefront property values, the cost of treating drinking water and lost revenue from reduced recreational activities.[19]

[18] https://www.newsday.co.zw/2015/06/29/pollution-doubles-water-treatment-costs/
[19] http://www.alternet.org/story/108856/how_much_does_it_really_cost_us_to_clean_up_our_waterways_from_farm_runoff

In the agricultural sector, deteriorating water quality impacts on crop yields: for example, heavy-metal pollution can not only result in lower plant growth rates (ranging from 13% to 70%), but also in a decrease in the yield of wheat (40% to 83%) (Athar and Ahmad (2002)). It also impacts on long-term soil productivity through, for example, salinization of land, and, critically, on export of crops where irrigation water quality does not meet the stringent standards of the EU or the USA.

Farmers risk losing contracts with international clients because of poor water quality. In 2012, it was reported that water pollution was “a growing threat to the livelihood of emerging tobacco farmers in Groblersdal, as this affects the contracts the farmers have with British American Tobacco”. The farmers claimed that their previous year’s crop had been rejected because of “chemical residues on the tobacco leaves”. In 2014, it was reported that the European Union had given a final warning that it would “stop imports from crops irrigated with water from the Olifants because of the level of health-threatening pollutants from mines seeping into the river”. Later that year, the non-profit Bench Marks Foundation released a statement about the impact of poor water quality on the economy, saying that farming exports were “affected by the influx of collieries with many vegetable farmers downstream from the mines in the Kendal Ogies area losing European clients due to the bad quality of water used for irrigation” (CER, 2016).

In the tourism sector, water pollution may cause loss of wildlife sanctuaries and degradation of protected areas, fish kills, health impacts for tourists, and visual impairment of water resources, discouraging tourist activity in affected areas. It is estimated that the U.S. tourism industry loses close to $1 billion each year, mostly from losses in fishing and recreational activities because of nutrient-polluted water bodies. In the Philippines, tourism losses due to water pollution represent around 70 percent of the total US$ 1.3 billion annual economic losses from water pollution (WB, 2003).

More broadly, in the South African context, the direct and indirect costs of contamination in the form of salinisation in the Middle Vaal River, which is an area with particularly high urban, mining and industrial pollution, were estimated by Urban Econ in 2000: it was estimated that direct costs of R80.5 million per annum would be saved if levels dropped to 200 mg/l TDS while increasing salinity to 1,200 mg/l TDS would increase salinity-related costs to R183 million. (Nieuwoudt et al., 2004).

Every year, more people around the world die from the consequences of unsafe water than from all forms of violence, including war – and the greatest impacts are on children under the age of five. Diarrhoeal disease causes an estimated 3.6 % of the total disability-adjusted life year (DALY) global burden of disease and results in the deaths of around 1.5 million people each year (WHO 2012). Estimate are that 58% of that figure, or 842 000 deaths per year, results from unsafe water supply, sanitation and hygiene. This includes the death of 361 000 children under the age of five, mostly in developing countries (WHO 2014). While over 95% of South Africans have access to water supply infrastructure, aging infrastructure and poor management of water services in many municipalities means that the quality of water provided is not always adequate, and deteriorating raw water quality increases the costs and complexities of treating water to potable standards.

Poor water quality increases the incidences of water borne diseases, resulting in costs to households in medical treatment, and lost working days, costs to the public and private health care systems, and costs associated with deaths from water borne diseases. For example, in 2005, an outbreak of typhoid in Delmas resulted in five deaths, 596 cases of typhoid and by 3,346 cases of diarrhoea. In 2003, nearly 4000 cases of cholera were reported in South Africa. A recent WRC study shows cholera, shigella, salmonella and other harmful viruses and bacteria at every sampling point on the Umgeni River between the Inanda Dam and Blue Lagoon in Durban. In June 2014, three babies died in Bloemhof from drinking contaminated water.

Poor resource water quality often results in poor drinking water quality where municipal treatment systems are not sufficiently sophisticated or well-managed to remove all pathogens. In the UK, for example, the most common source of cryptosporidium infections is tap water. People in rural areas and isolated communities are particularly at risk of exposure to waterborne pathogens due to lower capacity for treatment of water quality and poor water services. These same communities are often also disadvantaged by geographical and economic isolation and poor health care services.

In 2010 it was estimated that hospitalizations for three common waterborne diseases, Legionnaires' disease, cryptosporidiosis and giardiasis, cost the US health care system as much as $539 million annually. Estimates suggest waterborne pathogens are the cause of between 12 million and 19.5 million cases of illness per year in the USA. In Dutch coastal bathing waters, halving the risk of infection would save around US$ 256 million per year. Human health-related costs can be highly significant – for example, economic losses as a result of the mortality and morbidity impacts due to the lack of water and sanitation in Africa are estimated at US$ 28.4 billion or about 5 percent of GDP (UN WWAP, 2009).

There is an increasing problem of bacterial growth in water resources, including Escherichia coli, Aeromonas, Pseudomonas, Salmonella, Shigella and Vibrio spp. In 2010, the quantity of bacteria found was more than five times the concentration that the World Health Organization (WHO) recommends (Mellor et al., 2013). This can cause intestinal deterioration, bacterial diarrhoea, arthritis, and kidney disease. Chemical and heavy metal pollution also pose health concerns in South Africa, in relation to consumption of polluted water whether as a result of poor treatment of domestic water supplies, taking water directly from an untreated source, or through leisure, recreational or religious activities conducted in or near water. There may also be impacts arising from long-term consumption of food contaminated by irrigation with polluted water. Some health impacts may only manifest over time as a result of bioaccumulation of low-doses of hazardous chemicals and metals.

In areas where water services are poorly managed, or where people are still dependent on untreated water, or where people are exposed to untreated water through recreational or water-related work, there may be a range of health impacts, including:

- Water borne diseases resulting from water such contaminated with pathogens such as typhoid, cholera, and dysentery;
- Damage to the nervous system from organophosphates and lead;
- Reproductive and endocrinal disruption from endocrine disrupting chemicals;
- Cancer from a range of chemicals; and
- Rashes and skin problems.

Agricultural land irrigated with contaminated water can result in increased levels of metal bioaccumulation in crops, with potential health hazards to humans including the possibility of chronic toxicity and ultimately organ failure from high doses and prolonged exposure. Livestock fed on crops containing heavy metals may accumulate these metals in their meat, with subsequent risks to humans from the consumption of this meat.

Importantly, emerging research indicates that pollutants have different impacts on women and men, and this is an area where significantly more research is needed to ensure the protection of both women and men from water pollution.

6.10 Summary

This document attempts to estimate the economic impacts of drought induced waters shortages on the SA economy using quantitative and qualitative approaches. The quantitative approaches were used to measure the impacts on white maize output grown under irrigation, yellow-maize grown under rain fed conditions, extensive cattle production, extensive goat production and extensive sheep production. The quantitative approaches were used to measure the impacts on the mining sector, the tourism sector, the agro-processing sector, the small-businesses sector and the large businesses sector and water quality.

Our indicative calculations suggest that drought episodes can be correlated with a decrease of 2 (50 bag) kilograms of white maize output per hectare, a decrease of 13 (50 bag) kilograms of yellow maize output per hectare and a decrease of 19 heads of cattle per farmer. The qualitative results on the other sectors also show that drought induced water shortages substantially constrains production possibilities of many sector, with impacts on consumption. This study builds a case for pro-active policy action to mitigate the potential impacts of drought induced water shortages.

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Appendices

Appendix 1: Questionnaire on impact of drought on irrigated agriculture sector (white and yellow)

Data requirements for irrigated maize production in the most recent normal year (2011) and in the most recent drought year (2016)

THE STUDY: The Pegasys Institute is conducting a study for the Water Research Commission on the economic impact of the recent drought on different sectors of the economy in South Africa.

AIM OF THE STUDY: South Africa's current drought has resulted in significant economic losses to the economy, most notably to the agricultural sector, which is highly dependent on water. However, a wide range of sectors are impacted on by droughts, and droughts typically have a range of direct, indirect and induced impacts. These include impacts on production, employment, downstream and upstream industries, prices, inflation, exports and imports, and long-term investment. The aim of this project is to highlight the economic impacts of the recent/current drought on 8 South African sectors to highlight the economic risks associated with droughts to businesses and the economy. The sectors are as follows: irrigated agriculture; livestock farming; mining; agro-processing; tourism; industries in small towns; small businesses; and water quality. The study will culminate in the publishing of Fact Sheets for each of the 8 sectors, which will provide compelling arguments for early action.

Section A: Data on input use and output for 2011 and 2016

1 Output data

1.1 Total output for irrigated WHITE maize (tonnes)

- Output for 2011:………………………………….
- Output for 2016:………………………………….

1.2 Total output for irrigated YELLOW maize (tonnes)

- Output for 2011:………………………………….
- Output for 2016:………………………………….

1.3 Value of output for irrigated WHITE maize (tonnes)

- Output for 2011:………………………………….
- Output for 2016:………………………………….

1.4 Value of output for irrigated YELLOW maize (tonnes)

- Output for 2011:………………………………….
- Output for 2016:………………………………….

2 Input data

2.1 Land area under irrigated WHITE maize (hectares)

- Area 2011:………………………………….
- Area 2016:………………………………….

2.2 Land area under irrigated YELLOW maize (hectares)

- Area 2011:………………………………….
- Area 2016:………………………………….

2.3 Total employees working in irrigated WHITE maize production (number)

- Employees 2011:………………………………….
- Employees 2016:………………………………….

2.4 Total employees working in irrigated WHITE maize production (number)

- Employees 2011:………………………………….
- Employees 2016:………………………………….

2.5 Total quantity of irrigation water use for WHITE maize production (cubic metres)

- Irrigation water use 2011:………………………………….
- Irrigation water use 2016:………………………………….

2.6 Total quantity of irrigation water use for YELLOW maize production (cubic metres)

- Irrigation water use 2011:………………………………….
- Irrigation water use 2016:………………………………….

2.7 Expenditure on irrigation water for WHITE maize produced (Rand)

- Expenditure 2011:………………………………….
- Expenditure 2016:………………………………….

2.8 Expenditure on irrigation water for YELLOW maize produced (Rand)

- Expenditure 2011:………………………………….
- Expenditure 2016:………………………………….

2.9 Were there restrictions on how much water you could use for irrigation (YES/NO)?

- Water use restrictions 2011:………………………………….
- Water use restrictions 2016:………………………………….

2.10 Quantity of fertilizer used to produce irrigated WHITE maize (Kg)

- Fertilizer use 2011:………………………………….
- Fertilizer use 2016:………………………………….

2.11 Quantity of fertilizer used to produce irrigated YELLOW maize (Kg)

- Fertilizer use 2011:………………………………….
- Fertilizer use 2016:………………………………….

2.12 Value of fertilizer used in irrigated WHITE maize production (Rand)

- Fertilizer use 2011:………………………………….
- Fertilizer use 2016:………………………………….

2.13 Value of fertilizer used in irrigated YELLOW maize production (Rand)

- Fertilizer use 2011:………………………………….
- Fertilizer use 2016:………………………………….

2.14 Quantity of herbicides use in irrigated WHITE maize production (litres)

- Herbicide use 2011:………………………………….
- Herbicide use 2016:………………………………….

2.15 Quantity of herbicides use in irrigated YELLOW maize production (litres)

- Herbicide use 2011:………………………………….
- Herbicide use 2016:………………………………….

2.16 Value of herbicides use in irrigated WHITE maize production (Rand)

- Herbicide use 2011:………………………………….
- Herbicide use 2016:………………………………….

2.17 Value of herbicides use in irrigated WHITE maize production (Rand)

- Herbicide use 2011:………………………………….
- Herbicide use 2016:………………………………….

2.18 Quantity of pesticides use in irrigated WHITE maize production (litres)

- Pesticide use 2011:………………………………….
- Pesticide use 2016:………………………………….

2.19 Quantity of pesticides use in irrigated YELLOW maize production (litres)

- Pesticide use 2011:………………………………….
- Pesticide use 2016:………………………………….

2.20 Value of pesticides use in irrigated WHITE maize production (Rand)

- Pesticide use 2011:………………………………….
- Pesticide use 2016:………………………………….

2.21 Value of pesticides use in irrigated YELLOW maize production (Rand)

- Pesticide use 2011:………………………………….
- Pesticide use 2016:………………………………….

2.22 Value of electricity used in irrigated WHITE maize production (Rand)

- Electricity use 2011:…………………………………
- Electricity use 2016:………………………………….

2.23 Value of electricity used in irrigated YELLOW maize production (Rand)

- Electricity use 2011:………………………………….
- Electricity use 2016:………………………………….

Section B: IMMEDIATE responses by farmer to irrigation water supply shortages and restrictions

3.1 Did the farmer take any management actions/decisions **in response to water supply shortages and restrictions in 2016**, YES or NO?

3.2 If YES to Q4.1, please specify the management actions that were taken. **Be specific about the expenditures incurred as a result of taking these management actions**.

Response management action 1

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Response management action 2

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Response management action 3

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Section C: Long-run responses by farmer to FUTURE irrigation water supply shortages and restrictions

4.1 Does the farmer plan to take any management actions/decisions **in anticipation of FUTURE water supply shortages and restrictions**, YES or NO?

4.2 If YES to Q4.1, please specify the management actions that were taken. **Be specific about the expenditures incurred as a result of taking these management actions**.

Response management action 1

……………………………………………………………………………………………………

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Response management action 2

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Response management action 3

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THANK YOU VERY MUCH FOR PARTICIPATING IN THIS INTERVIEW

Appendix 2: Questionnaire on impact of drought on rainfed agriculture sector (white and yellow)

Data requirements for rainfed maize production in the most recent normal year (2011) and in the most recent drought year (2016)

THE STUDY: The Pegasys Institute is conducting a study for the Water Research Commission on the economic impact of the recent drought on different sectors of the economy in South Africa.

AIM OF THE STUDY: South Africa's current drought has resulted in significant economic losses to the economy, most notably to the agricultural sector, which is highly dependent on water. However, a wide range of sectors are impacted on by droughts, and droughts typically have a range of direct, indirect and induced impacts. These include impacts on production, employment, downstream and upstream industries, prices, inflation, exports and imports, and long-term investment. The aim of this project is to highlight the economic impacts of the recent/current drought on 8 South African sectors to highlight the economic risks associated with droughts to businesses and the economy. The sectors are as follows: rainfed agriculture; livestock farming; mining; agro-processing; tourism; industries in small towns; small businesses; and water quality. The study will culminate in the publishing of Fact Sheets for each of the 8 sectors, which will provide compelling arguments for early action.

Section A: Data on input use and output for 2011 and 2016

1 Output data

1.1 Total output for rainfed WHITE maize (tonnes)

- Output for 2011:…………………………………
- Output for 2016:…………………………………

1.2 Total output for rainfed YELLOW maize (tonnes)

- Output for 2011:…………………………………
- Output for 2016:…………………………………

1.3 Value of output for rainfed WHITE maize (tonnes)

- Output for 2011:…………………………………
- Output for 2016:…………………………………

1.4 Value of output for rainfed YELLOW maize (tonnes)

- Output for 2011:…………………………………
- Output for 2016:…………………………………

2 Input data

2.1 Land area under rainfed WHITE maize (hectares)

- Area 2011:………………………………….
- Area 2016:………………………………….

2.2 Land area under rainfed YELLOW maize (hectares)

- Area 2011:………………………………….
- Area 2016:………………………………….

2.3 Total employees working in rainfed WHITE maize production (number)

- Employees 2011:…………………………………
- Employees 2016:…………………………………

2.4 Total employees working in rainfed WHITE maize production (number)

- Employees 2011:…………………………………
- Employees 2016:…………………………………

2.5 Quantity of fertilizer used to produce rainfed WHITE maize (Kg)

- Fertilizer use 2011:………………………………….
- Fertilizer use 2016:………………………………….

2.6 Quantity of fertilizer used to produce rainfed YELLOW maize (Kg)

- Fertilizer use 2011:………………………………….
- Fertilizer use 2016:………………………………….

2.7 Value of fertilizer used in rainfed WHITE maize production (Rand)

- Fertilizer use 2011:………………………………….
- Fertilizer use 2016:………………………………….

2.8 Value of fertilizer used in rainfed YELLOW maize production (Rand)

- Fertilizer use 2011:………………………………….
- Fertilizer use 2016:………………………………….

2.9 Quantity of herbicides use in rainfed WHITE maize production (litres)

- Herbicide use 2011:………………………………….
- Herbicide use 2016:………………………………….

2.10 Quantity of herbicides use in rainfed YELLOW maize production (litres)

- Herbicide use 2011:…………………………………
- Herbicide use 2016:…………………………………

2.11 Value of herbicides use in rainfed WHITE maize production (Rand)

- Herbicide use 2011:………………………………….
- Herbicide use 2016:………………………………….

2.12 Value of herbicides use in rainfed WHITE maize production (Rand)

- Herbicide use 2011:………………………………….
- Herbicide use 2016:………………………………….

2.13 Quantity of pesticides use in rainfed WHITE maize production (litres)

- Pesticide use 2011:………………………………….
- Pesticide use 2016:………………………………….

2.14 Quantity of pesticides use in rainfed YELLOW maize production (litres)

- Pesticide use 2011:………………………………….
- Pesticide use 2016:………………………………….

2.15 Value of pesticides use in rainfed WHITE maize production (Rand)

- Pesticide use 2011:………………………………….
- Pesticide use 2016:………………………………….

2.16 Value of pesticides use in rainfed YELLOW maize production (Rand)

- Pesticide use 2011:………………………………….
- Pesticide use 2016:………………………………….

Section B: IMMEDIATE responses by farmer to the impact of the worsening drought conditions on the maize

3.1 Did the farmer take any management actions/decisions **in response to impact that the worsening drought condition was having on the maize** in 2016, YES or NO?

3.2 If YES to Q3.1, please specify the management actions that were taken. **Be specific about the expenditures incurred as a result of taking these management actions**.

Response management action 1

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Response management action 2

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Response management action 3

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Section C: Long-run responses by farmer to FUTURE impact that the worsening drought conditions will have on maize

4.1 Does the farmer plan to take any management actions/decisions **in anticipation of FUTURE drought conditions**, YES or NO?

4.2 If YES to Q4.1, please specify the management actions that were taken. **Be specific about the expenditures incurred as a result of taking these management actions**.

Response management action 1

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Response management action 2

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Response management action 3

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THANK YOU VERY MUCH FOR PARTICIPATING IN THIS INTERVIEW

Appendix 3: Questionnaire on impact of drought on livestock production sector (extensive cattle, goat and sheep production)

Data requirements for livestock production in the most recent normal year (2011) and in the most recent drought year (2016)

THE STUDY: The Pegasys Institute is conducting a study for the Water Research Commission on the economic impact of the recent drought on different sectors of the economy in South Africa.

AIM OF THE STUDY: South Africa's current drought has resulted in significant economic losses to the economy, most notably to the agricultural sector, which is highly dependent on water. However, a wide range of sectors are impacted on by droughts, and droughts typically have a range of direct, indirect and induced impacts. These include impacts on production, employment, downstream and upstream industries, prices, inflation, exports and imports, and long-term investment. The aim of this project is to highlight the economic impacts of the recent/current drought on 8 South African sectors to highlight the economic risks associated with droughts to businesses and the economy. The sectors are as follows: irrigated agriculture; livestock farming; mining; agro-processing; tourism; industries in small towns; small businesses; and water quality. The study will culminate in the publishing of Fact Sheets for each of the 8 sectors, which will provide compelling arguments for early action.

Section A: Data on input use and output for 2011 and 2016

__Instructions:__ Please indicate with a tick the MAIN TYPE of livestock produced in your farm. If you produce more than 1 livestock species, take MAIN TYPE to mean **the most abundant**.

- CATTLE [ ]
- SHEEP [ ]
- GOATS [ ]

__Instructions:__ The rest of the questions in Section A will ONLY REFER to the MAIN TYPE of livestock produced in your farm.

1 Output data

1.1 Total output of livestock produced (number)

- Output for 2011:………………………………….
- Output for 2016:………………………………….

1.2 Value of output for livestock production (Rands)

- Output value for 2011:………………………………….
- Output value for 2016:………………………………….

2 Input data

2.1 Total number of employees in MAIN TYPE OF LIVESTOCK produced (number)

- Employees 2011:…………………………………
- Employees 2016:…………………………………

Section B: Other information

<u>Instructions:</u> The questions to follow for the YEAR 2016 (**the most recent drought year**) are about livestock sales, livestock slaughter and livestock deaths. Please answer these questions **if it is your assessment** that these actions occurred in response to the DROUGHT. **The questions for the year 2011 are not related to drought**.

3.1 Total number of livestock SOLD (number)

- Number sold in 2011:……………………………………………………………
- Number sold in **2016 as a result of the drought**:…………………………………

3.2 Total number of livestock SLAUGHTRED (number)

- Number slaughtered in 2011:……………………………………………………
- Number slaughtered in **2016 as a result of the drought**:…………………………

3.3 Total number of livestock RECORDED DEAD (number)

- Number recorded dead in 2011:…………………………………………………
- Number recorded dead in **2016 as a result of the drought**:…………………………

Section C: IMMEDIATE responses by farmer to the impact of the worsening drought conditions on livestock

4.1 Did the farmer take any management actions/decisions **in response to impact that the worsening drought condition was having on livestock** in 2016, YES or NO?

4.2 If YES to Q4.1, please specify the management actions that were taken. **Be specific about the expenditures incurred as a result of taking these management actions**.

Response management action 1

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Response management action 2

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Response management action 3

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Section D: Long-run responses by farmer to FUTURE impact that the worsening drought conditions will have on livestock

5.1 Does the farmer plan to take any management actions/decisions **in anticipation of FUTURE drought conditions**, YES or NO?

5.2 If YES to Q5.1, please specify the management actions that were taken. **Be specific about the expenditures incurred as a result of taking these management actions**.

Response management action 1

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Response management action 2

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Response management action 3

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THANK YOU VERY MUCH FOR PARTICIPATING IN THIS INTERVIEW

Appendix 4: Questionnaire on impact of drought on mining sector

No structured interviews were used

Appendix 5: Questionnaire on impact of drought on tourism sector

Data requirements for tourism at Kruger National Park (KNP) in the most recent normal year (2011) and in the most recent drought year (2015)

THE STUDY: The Pegasys Institute is conducting a study for the Water Research Commission on the economic impact of the recent drought on different sectors of the economy in South Africa.

AIM OF THE STUDY: South Africa's current drought has resulted in significant economic losses to the economy, most notably to the agricultural sector, which is highly dependent on water. However, a wide range of sectors are impacted on by droughts, and droughts typically have a range of direct, indirect and induced impacts. These include impacts on production, employment, downstream and upstream industries, prices, inflation, exports and imports, and long-term investment. The aim of this project is to highlight the economic impacts of the recent/current drought on 8 South African sectors to highlight the economic risks associated with droughts to businesses and the economy. The sectors are as follows: irrigated agriculture; livestock farming; mining; agro-processing; tourism; industries in small towns; small businesses; and water quality. The study will culminate in the publishing of Fact Sheets for each of the 8 sectors, which will provide compelling arguments for early action.

Following our telephone conversation, we kindly request for the data enumerated below.

Section A: Data on water pumping costs for 2011 and 2015

1.1 Volume of water pumped from rivers (if available) (volume units)

- Volume 2011:…………………………………
- Volume 2015:…………………………………

1.2 Expenditure on pumping water from rivers (Rands)

- Expenditure 2011:…………………………………
- Expenditure 2015:…………………………………

1.3 Volume of water pumped from wells (if available) (volume units)

- Volume 2011:…………………………………
- Volume 2015:…………………………………

1.4 Expenditure on pumping water from wells (Rands)

- Expenditure 2011:…………………………………
- Expenditure 2015:…………………………………

NB: if available data aggregates rivers and wells, it would also be sufficient.

Section B: Data on water treatment costs for 2011 and 2015

2.1 Treatment costs for water drawn from rivers (Rands)

- Treatment 2011:…………………………………
- Treatment 2015:…………………………………

2.2 Treatment costs for water drawn from wells (Rands)

- Treatment 2011:…………………………………
- Treatment 2015:…………………………………

NB: if available data aggregates rivers and wells, it would also be sufficient.

Section C: Operating and maintenance costs for boreholes in 2011 and 2015

3.1 Costs of opening, servicing, operating, monitoring and maintaining boreholes (Rands)

- Borehole costs 2011:………………………………….
- Borehole costs 2015:………………………………….

Section D: Off-take programme for hippo and buffalo in 2011 and 2015

4.1 Number of hippopotamus culled for onward human consumption (number)

- Culled hippopotamus 2011:………………………………….
- Culled hippopotamus 2015:………………………………….

4.2 Cost of processing hippopotamus meat before offering it for consumption (Rands)

- Processing costs 2011:………………………………….
- Processing costs 2015:………………………………….

4.3 Number of buffaloes culled for onward human consumption (number)

- Culled buffaloes 2011:………………………………….
- Culled buffaloes 2015:………………………………….

4.4 Cost of processing buffaloes meat before offering it for consumption (Rands)

- Processing costs 2011:………………………………….
- Processing costs 2015:………………………………….

THANK YOU VERY MUCH FOR PARTICIPATING IN THIS INTERVIEW

Appendix 6: Questionnaire on impact of drought on agro-processing sector

No structured interviews were used

Appendix 7: Questionnaire on impact of drought on small-business sector

Data requirements for Small & Medium Businesses in the most recent drought year (2015)

THE STUDY: The Pegasys Institute is conducting a study for the Water Research Commission on the economic impact of the recent drought on different sectors of the economy in South Africa.

AIM OF THE STUDY: South Africa's current drought has resulted in significant economic losses to the economy, most notably to the agricultural sector, which is highly dependent on water. However, a wide range of sectors are impacted on by droughts, and droughts typically have a range of direct, indirect and induced impacts. These include impacts on production, employment, downstream and upstream industries, prices, inflation, exports and imports, and long-term investment. The aim of this project is to highlight the economic impacts of the recent/current drought on 8 South African sectors to highlight the economic risks associated with droughts to businesses and the economy. The sectors are as follows: irrigated agriculture; livestock farming; mining; agro-processing; tourism; industries in small towns; small businesses; and water quality. The study will culminate in the publishing of Fact Sheets for each of the 8 sectors, which will provide compelling arguments for early action.

Following our telephone conversation, we kindly request for the data enumerated below.

Section A: Current situation regarding the impact of drought on your business

1. Type of business

……………………………………………………………………………………………………

2. Explain how drought impacted on your business

Impact 1

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Impact 2

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Impact 3

……………………………………………………………………………………………………

……………………………………………………………………………………………………

3. Explain the decisions you took to minimise the impact of drought on your business

Decision 1

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………

Decision 2

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………

Decision 3

………

………

4. In your view, approximately how much expenditure did your business incur as a result of the actions you took to minimise the impacts of the drought (in Rands)?

………

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THANK YOU VERY MUCH FOR PARTICIPATING IN THIS INTERVIEW

Appendix 8: Questionnaire on impact of drought on large-business sector

No structured interviews were used

Appendix 9: Questionnaire on impact of drought on water quality

No structured interviews were used