

# IMPLICATIONS OF INCREASING WORLD OIL SCARCITY FOR NATIONAL FOOD SECURITY IN SOUTH AFRICA

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## ABSTRACT

Economic and social stability depend on a healthy, functioning and affordable system of agricultural production and food distribution. In recent years, however, international and domestic food prices have risen considerably, partly as a result of rising oil prices. A growing body of literature indicates that world oil supplies will become increasingly scarce and expensive in the coming years, due to the depletion of easily extractable reserves. This poses a significant threat to agricultural production in South Africa, which is overwhelmingly derived from oil-intensive commercial farming. To mitigate the risk of serious disruptions to food production and distribution, the agriculture sector may require government support in the form of temporary fuel subsidies and, possibly, prioritised fuel access in order to cope with oil price shocks and potential fuel scarcity. Furthermore, to boost resilience and improve sustainability for the longer term, the agriculture sector should embark on a programme aimed at gradually reducing the reliance on petroleum products by adopting practices such as conservation agriculture and agro-ecological farming methods. In addition, since the current food distribution system is heavily reliant on road transport, and thus exposed to fuel price and supply shocks, the mitigation strategy should aim at a partial localisation of agricultural production and consumption, for example, by developing urban agriculture.

**Keywords:** national food security, oil dependence, oil shocks, sustainable agriculture, localisation

## JEL CLASSIFICATION

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## 1 INTRODUCTION

Economic and social stability both depend on a healthy, functioning system of agricultural production and food distribution, together with affordable and

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accessible supplies of food and adequate nutrition for households. In recent years, however, international food prices have risen dramatically, prompting governments in many countries to give increased priority to national food security (FAO 2011). One of the major drivers of rising food prices has been the steep increase in international oil prices since 2004 (Baffes and Haniotis 2010; Brown 2009). International oil and food prices have become increasingly tightly connected in the past few years, partly because oil is a crucial input in industrial agriculture, both for diesel fuel and for petrochemical products such as pesticides and packaging materials. Another reason is because liquid biofuels such as ethanol and biodiesel manufactured from food crops have linked the oil and agriculture markets (Brown 2012).

The International Energy Agency (2012) has forecast that the global demand for oil could grow by 14 percent by 2035, driven mainly by rising incomes and growing transport needs in the emerging market economies. However, data from the United States Energy Information Administration (2014) show that conventional crude oil production – oil derived using typical extraction and refining techniques – has been essentially flat at around 74 million barrels per day (mbpd) since 2005. Although there has been an increase in the production of unconventional oil (eg ‘tight oil’ from shale deposits in the United States and oil sands in Canada), natural gas plant liquids, gas-to-liquids (GTLs) and biofuels, the average annual supply increase for all liquid fuels of 0.4 mbpd between 2005 and 2012 was substantially below the trend increase of 1.2 mbpd recorded between 1983 and 2005 (Kumhof and Muir 2012). Rising unconventional oil production has come with substantially higher economic and environmental costs. According to several analysts, it is unlikely to offset the depletion of conventional oil production for more than a few years so that the global production of all liquid fuels might reach a peak and enter a terminal decline this decade, or soon thereafter (see, for example, Robelius 2007; Aleklett et al 2010; Sorrell, Miller, Bentley, and Speirs 2010a; Sorrell et al 2010b; UKITPOES 2010; Hirsch, Bezdek and Wendling 2010; Miller and Sorrell 2014).

Of even greater importance to net oil-importing countries – such as South Africa – and for international oil prices, is the fact that net world oil exports have stagnated since 2005 as they are being eroded by rising domestic consumption and stagnating production in many oil-exporting countries (see figure 1). Moreover, the quality of available oil – as measured, for example, in the energy return on (energy) investment for world oil – is declining (Gagnon, Hall and Brinker 2009; Guilford, Hall, Connor and Cleveland 2011; Murphy and Hall 2010). This is happening because conventional oil fields, which are easier to access, are rapidly being depleted. The frontier for new oil production has moved into more remote areas such as deep offshore wells, polar regions and unconventional oil sources, which are economically more costly and technically more difficult to access and process. Recent modelling conducted by researchers at the International Monetary

Fund has shown that oil supply constraints in the face of growing demand could, by 2020, result in the international price of oil rising to US\$200 per barrel in real terms in the more optimistic scenarios. The oil price can reach even more devastating levels if it proves to be difficult to find adequate substitutes for oil (Benes et al 2012; Kumhof and Muir 2012).

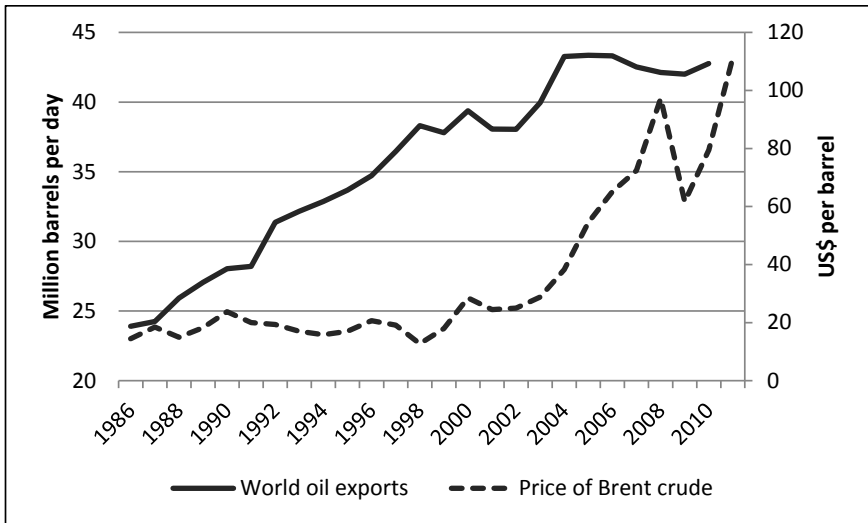


Figure 1: World oil exports and crude oil price, 1986–2011

Source: EIA (2014) and BP (2014)

The issue of food security has garnered a reasonable amount of attention in the academic literature and government policy documents in South Africa in recent years (eg Aliber and Hart 2009; Baiphethi and Jacobs 2009; Hendriks 2005; Leroy, Van Rooyen, D’Haese and De Winter 2001; Pauw 2007; Economic Development Department 2010), with the focus mainly on poverty-related aspects of household food security and the threat to national food security posed by climate change (eg Wlokas 2008). However, the critical role played in agriculture by energy in general and by oil in particular has largely been missing from the local discourse. This article aims to address this gap by exploring the potential consequences of the growing world oil scarcity and rising oil prices for national food security in South Africa. The focus is on the national rather than the household level, which involves some overlapping, but distinct issues such as the impact of rising oil prices on poverty. The analysis of the oil dependency of agriculture is based on data provided by the Department of Agriculture, Forestry and Fishing (2014a)

and the International Energy Agency (2014), amongst other sources, while the recommendations for bolstering national food security in the face of potential oil price and supply shocks draw on existing international and South African literature.

The remainder of the article is organised as follows. Section 2 provides a brief overview of the agriculture sector in South Africa. Section 3 details the extent to which South Africa's agricultural system and national food security depend on oil-based fuels and petrochemical products. Section 4 explores the strengths and vulnerabilities of agriculture in relation to oil shocks, with special emphasis on the implications for national food security. Section 5 discusses the likely consequences of rising world oil prices and increasing oil scarcity for agricultural output and food security, assuming 'business-as-usual' agricultural practices and policies. Section 6 puts forward a range of mitigation strategies and policies which could strengthen the agriculture sector's resilience to future oil shocks and scarcity. In the concluding section, it is argued that the mitigation of global oil depletion is a crucial part of transitioning South Africa's agriculture and food system toward enhanced sustainability and resilience.

## 2 OVERVIEW OF AGRICULTURE IN SOUTH AFRICA

South Africa's total agricultural land area amounts to 122 million hectares, of which just over 100 million hectares is classified as farmland (DAFF 2014a:5). The vast majority of this farmland (84 million hectares) is suitable for grazing only. Approximately 16.7 million hectares receive sufficient rainfall to be potentially arable, although only about a fifth of this arable land is of high quality (GCIS 2012:36). Irrigation uses approximately 50 percent of the country's run-off water. Water scarcity is a major limiting factor for agriculture (GCIS 2012:36).

South Africa's agricultural economy is made up of two parts: an industrialised commercial sector and a largely rural subsistence or smallholder sector (GCIS 2012). Commercial farmers account for at least 95 percent of the total marketed agricultural produce (FAO 2005:2). The commercial agriculture sector produces a wide range of commodities, including field crops (grains such as maize, wheat and sorghum; sugar; oil seeds and cotton), horticultural produce (fruits and vegetables), and livestock products (meat and dairy products). These three major categories contributed R51.8 billion (28.3%), R46.5 billion (25.4%) and R84.6 billion (46.3%), respectively, to the total value of commercial agricultural production of R182.9 billion in 2012/13 (DAFF 2014a). Maize, the most important food crop by volume of output and the staple food of the majority of South Africans, occupies about half of all the land under crops (DAFF 2014b). In 2013, the agriculture, forestry and fishing sector contributed 2.4% of the gross domestic product (GDP) but, owing to extensive backward and forward linkages, it is estimated that the agro-industrial sector contributes about 12% of GDP (GCIS 2012:36).

Subsistence farming occurs predominantly in the former ‘homeland’ areas of South Africa (Pauw 2007:196) and contributes less than 5 percent of the total agricultural output (FAO 2005:2) and approximately 5 percent of national maize production (DAFF 2014b:11). Subsistence farming involves approximately four million South Africans, mostly to secure an ‘extra source of food’ (Aliber and Hart 2009:439). For various historical reasons, the subsistence sector represents a small share of the South African population relative to other sub-Saharan African countries (Baiphethi and Jacobs 2009:462; [Vink 2012](#)).

The production of most agricultural products is geographically restricted according to favourable growing conditions such as rainfall, temperatures and soil types. For the most part, the western half of the country is arid, with average annual rainfall of less than 500 millimetres. It is therefore used mainly as rangeland for extensive livestock production (O’Farrell, Anderson, Milton and Dean 2009). The major exception is the south-western Cape, where the winter rainfall supports the production of wheat, while irrigation is used for horticultural production during the summer months. The eastern half of the country has a higher average annual rainfall, generally above 500 millimetres, and supports a greater diversity of agricultural commodities. The majority of the country’s maize is grown in the Highveld ‘maize quadrangle’ in the North West, Free State and Mpumalanga provinces, while some wheat is cultivated in the eastern Free State (DAFF 2014b). Sugar cane production is concentrated along the coast in KwaZulu-Natal. The geographical location of agricultural production has also been partly shaped by agricultural marketing legislation over many decades (Vink 2012).

### 3 OIL DEPENDENCE OF AGRICULTURE

The agriculture, forestry and fishing sector accounted for 2.7% of the total final energy consumption in 2011 (IEA 2014), which was commensurate with its contribution to the GDP (2.5%). As seen in figure 2, the relative contributions of coal, petroleum and electricity to the total energy consumption in agriculture have not changed substantially over the past two decades. In the period 2001 to 2011, on average 68 percent of the energy used by the agriculture sector was in the form of liquid petroleum fuels, whilst electricity contributed 29 percent and coal 3 percent (IEA 2014). Approximately 70 percent of South Africa’s national petroleum demand is met by imported crude oil and refined fuels, the balance (30%) of which is supplied in the form of coal-to-liquid (CTL) and GTL synthetic fuels by Sasol and PetroSA, respectively (Wakeford 2012). Energy and oil intensity varies according to the type of farming practiced, namely industrialised commercial, organic or subsistence farming.

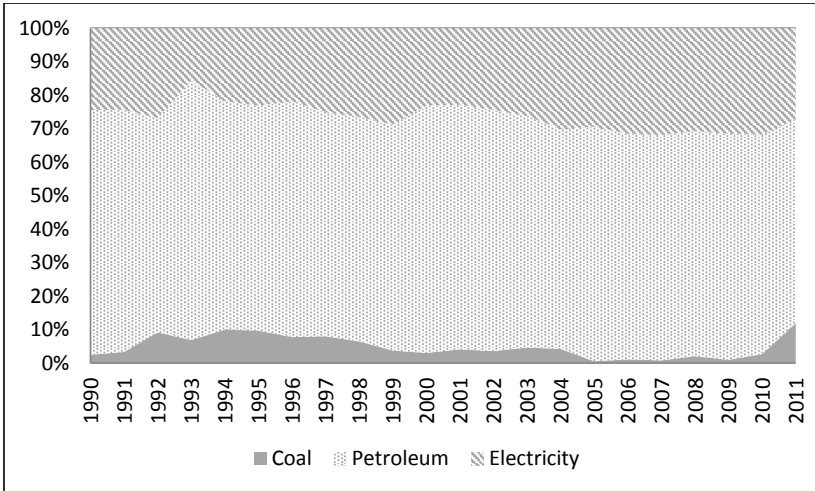


Figure 2: Energy consumption in the agriculture sector, 1990–2011  
Source: IEA (2014)

### 3.1 Commercial agriculture

The industrialised, commercial agriculture system in South Africa is highly dependent on fossil fuel energy at every stage of the value chain, including primary production on farms, refrigeration, processing in factories, and wholesale and retail distribution. At the production stage, this energy intensity results primarily from the extensive use of liquid petroleum fuels – especially diesel – to power farm vehicles and machinery such as tractors, planters and harvesters. Electricity, and to some extent diesel, is also consumed by power irrigation systems and other machinery. The relative capital intensity of commercial agriculture has increased considerably over the past several decades as farmers have progressively replaced human labour with machinery and materials, including fuel and fertilisers (Townsend, Van Zyl and Thirtle 1997; Sparrow, Ortmann, Lyne and Darroch 2008; Liebenberg and Pardey 2012). The level of farm employment fell from 1.67 million in the 1960s to under 900 000 in the 2000s (Liebenberg and Pardey 2012:19).

The volume of petroleum products (eg, diesel, petrol and lubricating oils) purchased by commercial farmers has been following a slightly declining trend since the early 1990s (see figure 3). This decline may reflect the declining planted land area of the major field crops over the same period, which resulted from the deregulation of the agriculture sector and the withdrawal of state subsidies

(FAO 2005). Another contributing factor is likely to have been the adoption of conservation agriculture practices, including reduced tillage, particularly in maize-producing areas. It has been estimated that a third of South Africa's cultivable area has been subject to reduced tillage farming practices (Du Toit 2007:2). In addition to the direct use of petroleum fuels, commercial agriculture consumes significant quantities of energy, indirectly in the form of fertilisers and pesticides, the manufacturing of which involves the use of natural gas (or gasified coal) and oil, respectively. The consumption of fertilisers used to plant a hectare of the major field crops has been following a slightly rising trend since the late 1980s (FSSA 2014). Organic fertilisers (derived from manures) contribute just three to four per cent of fertilisers consumed (FAO 2005:21).

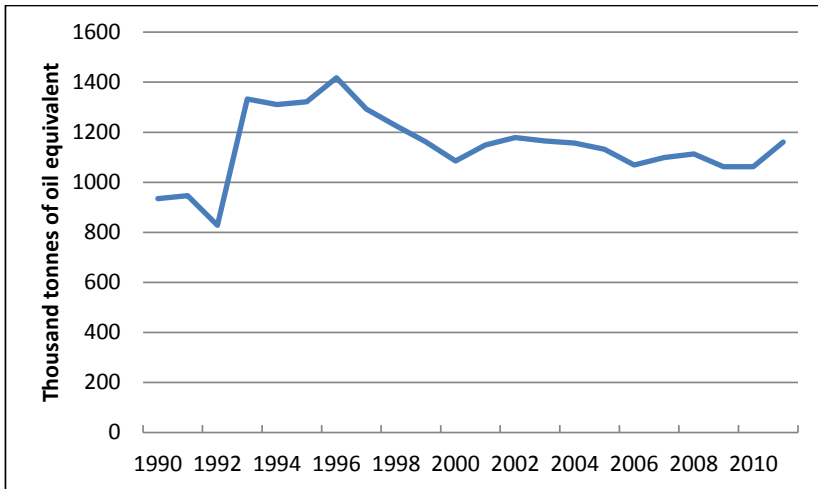


Figure 3: Petroleum fuel consumption in the agriculture sector, 1990–2011

Source: IEA (2014)

Intermediate input costs, as a proportion of gross income in the agriculture sector, have generally risen since the 1970s, with the exception of fertiliser costs (see figure 4). Most noticeable is the rising trend in the proportionate cost of fuel, from a low of 4.3 percent in 1987 to a high of 9.8 percent in 2008, driven mainly by the rising international price of crude oil. Total input costs rose from an average of 33 percent of gross income in the 1970s to 55 percent in the 2000s (DAFF 2014a).

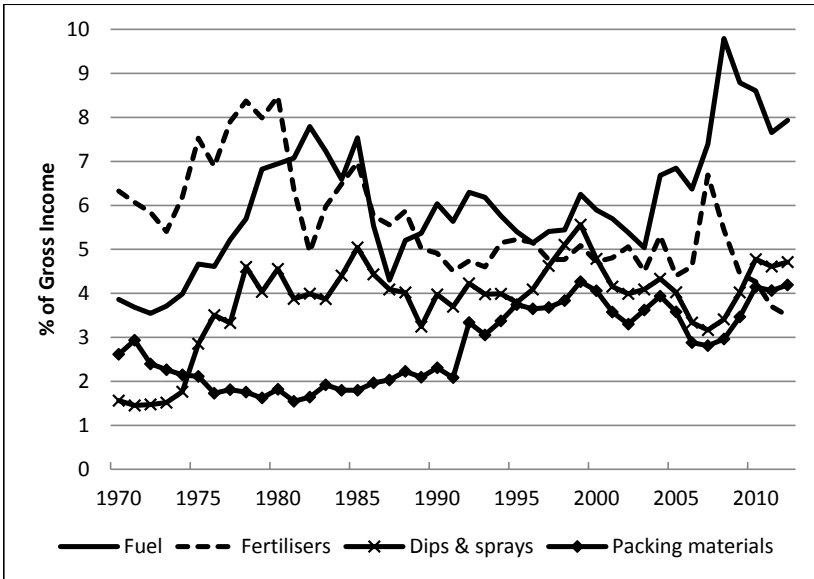


Figure 4: Selected input costs as a percentage of gross income in agriculture, 1970–2012  
 Source: Authors' calculations based on DAFF (2014a)

Beyond the production stage, energy is also consumed for the transportation, (cold) storage, processing and distribution of agricultural commodities and food products. First, agricultural produce has to be transported from farms to industrial centres for processing and/or packaging. Owing to the geographical dispersal of farms, the predominant mode of freight transport from farms to urban centres is by road, which necessitates petroleum fuels (mostly diesel). Secondly, electricity (derived mainly from coal) is required for the short or long-term refrigeration of fresh produce. Indeed, this source of energy demand has shown an increasing trend as the volume of goods in the cold chain has grown. Thirdly, the processing of raw agricultural commodities into food products in factories requires energy, mostly in the form of electricity. Much of the packaging used for food products consists of plastics that are derived from oil or coal (the latter is produced in South Africa by the diversified petrochemical company Sasol). Fourthly, processed food products are transported to distribution centres and thence to retail outlets, primarily the large supermarket chain stores. In the final stage, many consumers (especially those living in urban areas) rely on motorised transport to shops to purchase their food. As a result of the geographical specificity of agricultural production mentioned earlier, some food products travel great distances within the country to arrive on supermarket shelves and dinner plates.



Although energy intensity figures for commercial agriculture in South Africa are not readily available, comparative figures for the United States, whose commercial agriculture is also heavily mechanised, may serve as an example. It is estimated that ten calories of fossil energy inputs are required to produce one calorie of food in the United States (Pfeiffer 2006:21). In South Africa, it appears as if the intensive use of fossil fuels has enabled a substitution of capital for labour and helped to increase yields for field crops since the 1970s. The commercial agriculture sector has therefore become increasingly reliant on petroleum products (and other fossil fuels) over time.

### 3.2 Organic and subsistence farming

By reducing or avoiding the use of chemical fertilisers and pesticides that are derived from fossil fuels, organic farming is up to 50 percent less energy-intensive than conventional agriculture (Pfeiffer 2006:68). Organic farming has grown fairly rapidly in recent years, but this has been from a very small base and the sector comprises a miniscule proportion of commercial farms in South Africa (Niemeyer and Lombard 2003:1). It has been estimated that there are approximately 250 organic farms occupying about 45 000 hectares of certified land in South Africa (GCIS 2012:43). Organic farms, most of which are horticultural, also tend to be smaller than conventional farms (Niemeyer and Lombard 2003:5). Conventional farms become more energy-efficient than organic farms at larger scales (Pfeiffer 2006:68). Small organic farms may be less reliant on fossil-fuel powered machinery than larger scale farms, however, commercial organic farming, like conventional farming, currently depends on oil-based transport to deliver produce to factories and markets. Given their large emphasis on horticultural products, organic farmers may rely even more on the cold chain (and the electricity and diesel this requires) than their non-organic counterparts.

Traditional subsistence farming is generally much less dependent on oil than commercial farming, for several reasons. First, subsistence production is small-scale and labour-intensive rather than large-scale and capital-intensive (mechanised) and therefore uses little or no petroleum fuel directly. Secondly, traditional farming has at least until recently been mostly organic, ie farmers do not use chemical fertilisers and pesticides derived from fossil fuels (Modi 2003:676). Nevertheless, some subsistence farmers may, to an extent, rely on the purchase of fertilisers, seeds and other inputs, the cost of which may be affected by oil prices. Thirdly, most smallholder produce is consumed locally rather than being transported to distant markets via roads.

In summary, the commercial sector dominates the output of agricultural products in South Africa and is highly reliant on petroleum-based inputs. While organic and traditional farming are considerably less oil intensive, they contribute only a very small share to agricultural production.

## 4 STRENGTHS AND VULNERABILITIES OF AGRICULTURE: NATIONAL FOOD SECURITY

The dependence of agriculture on oil has significant implications for food security. According to the Food and Agricultural Organisation (1996 in Hendriks and Msaki 2009:184), '[f]ood security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'. Food security can be analysed on different scales of aggregation. This section considers food security at the national level, while household-level food security is left for further research. At national level, food security has two main determinants: (1) the capacity of a country to be self-sufficient in food production and (2) the ability of a country to afford food imports where necessary or desirable.

### 4.1 Self-sufficiency in food production

South Africa has the capacity to be self-sufficient in most agricultural products (GCIS 2012). In most years, South Africa produces a surplus over the domestic consumption of the main staple crop, maize (DAFF 2014a); historical exceptions to this have largely been the result of droughts. However, South Africa does rely on imports for some significant agricultural products, including rice, wheat, poultry and vegetable oils (DAFF 2014b:9). Approximately one third to one half of the country's wheat requirement is imported, although this is partly because imports are cheaper than domestic production on marginal lands in the absence of import tariff protection. All of the rice consumed domestically is imported, but rice is generally consumed by the wealthier minority and does not represent a broad staple food. The primary agricultural export products are wine, a large variety of fruits and fruit juices, maize, sugar and wool (DAFF 2014a). These products have a relatively high weight to value ratio, which means that export volumes are vulnerable to rising transport costs. Over the past decade, the value of South Africa's agricultural exports has consistently exceeded the value of agricultural imports, with a surplus of some R2 billion in 2012 (DAFF 2014a). The balance between exports and imports is influenced by a variety of factors, including the rand exchange rate, international commodity prices, comparative production costs, and global and local weather conditions.

Continued national food self-sufficiency clearly depends on access to affordable, quality inputs for agricultural production. Key inputs include fertilisers, pesticides, machinery, farming skills, water and soil. South Africa has vulnerabilities in each of these areas, as elaborated upon in this section.

Following the abolishment of fertiliser subsidies and tariff protection after 1994, the domestic fertiliser industry was severely rationalised (FAO 2005).

Consequently, after being a net exporter until the late 1990s, South Africa became a net importer of fertilisers in the 2000s (FAO 2005:19). South Africa currently imports all of its potassium salts (potash), the majority of its nitrogen fertilisers and some phosphates (Mostert 2013). Domestic fertiliser prices are influenced heavily by prevailing international prices, the rand-dollar exchange rate and freight costs (FAO 2005:28). Therefore, the prices are susceptible to rising oil prices, both directly through higher transport costs and indirectly through the impact of oil prices on the exchange rate and international fertiliser prices. Fertilisers are mostly delivered to farms by road (FAO 2005:30), which further entrenches dependence on oil.

The second key agricultural input category is machinery and equipment. The majority of farming equipment, such as tractors and harvesters, is imported; Fofana, Mabugu and Chitiga (2008:63) report that the import penetration ratio for agricultural machinery was 56 percent in 2000. Therefore, farmers face the risk of rising equipment costs as a result of rising international prices and/or a depreciating exchange rate.

The third major agricultural input, namely farming skills, has suffered from substantial attrition in recent years. According to the Department of Agriculture, Forestry and Fishing (2014a), agricultural employment levels declined between 2006 and 2013 from over one million to 740 000, while the number of skilled agricultural workers declined from 432 000 to 67 000. The decline of farming employment and skills has partly been driven by the consolidation of commercial farms and the mechanisation of farming (Liebenberg and Pardey 2012). In addition, there has been a loss of knowledge of traditional, organic African farming techniques as a consequence of the so-called 'Green Revolution' (Thamaga-Chitja and Hendriks 2008:320) as well as the process of urbanisation.

The scarcity of water resources is potentially a major threat to future agricultural production. Large areas of the country, especially the western half, are arid to begin with and, moreover, prone to drought (O'Farrell et al 2009:34). According to Laker (2005:1), '[i]t is estimated that a maximum of 1.5 million ha [of arable land] can be irrigated'. Climate change is expected to exacerbate the water scarcity situation, with more erratic rainfall patterns in the eastern half of the country, a general drying in the west, and an increase in the prevalence of droughts overall (O'Farrell et al 2009:34). In addition, higher average temperatures may reduce the yields of certain crops – notably maize – especially in the drier western parts of the Highveld (Walker and Schulze 2008:114).

A further vulnerability is the poor quality of South Africa's soils, which are generally shallow and sandy (Laker 2005) and mostly low in organic content and essential minerals (FAO 2005:5–6). Further problems include a high degree of vulnerability to various types of soil degradation, including water and wind

erosion, soil compaction and crusting, acidification (partly the result of coal mining), nutrient leaching and pollution (mainly from mines and industry) (Laker 2005; FAO 2005; GCIS 2012). The intensive use of chemical fertilisers and pesticides has degraded the fertility of arable land over time (Kelly 2009:103). Another form of land degradation, which is largely irreversible, derives from the conversion of arable land to industrial, residential and mining uses (Laker 2005).

## 4.2 Capacity to import food products

The second important determinant of national food security is South Africa's capacity to import food products. This depends on international food prices as well as the strength of the domestic economy, in particular the balance of payments and the level of the exchange rate. These aspects of the macro-economy are likely to come under pressure from any future oil price shocks (Wakeford 2012). At the same time, the prices of agricultural commodities on international markets are related to oil prices, both directly because of rising input and transport costs and also indirectly because of the incentives to produce biofuels from food crops or using arable land that could have supported food production (FAO 2008:10). Because of these linkages, the oil price spike between 2006 and 2008 was accompanied by spikes in the prices of many basic agricultural commodities such as maize, wheat and rice (FAO 2011). These price spikes were exacerbated by steps taken by governments in some countries to lower domestic food prices and to safeguard food security by imposing limitations or outright bans on the export of certain staple commodities (FAO 2008:11; Brown 2012). A repeated confluence of these factors in future could constrain South Africa's ability to import agricultural products and make it increasingly important for the country to be able to feed its own population and thereby maintain social wellbeing and stability.

## 5 POTENTIAL IMPACT OF OIL SCARCITY ON AGRICULTURE AND FOOD SECURITY

As demonstrated above, energy – especially in the form of liquid fuels derived from oil – is used intensively in all stages of the commercial agricultural production and food distribution system. This system is therefore vulnerable to oil price rises and supply constraints. The potential impact of oil scarcity may have serious implications for South Africa's national food security in the medium to long term.

Rising fuel prices will raise direct input costs for fuel as well as chemical products that use oil (and substitutes like natural gas) in their manufacture, including pesticides, fertilisers and petrochemical-based packaging materials. Price indices for these inputs have indeed grown rapidly in recent years (figure 5). In addition, rising transport costs will push up the prices of chemical inputs

and raise the costs of transporting produce to food processors, wholesalers and markets. On the other hand, as mentioned earlier, oil prices have, in recent years, become increasingly tightly correlated with international prices of major agricultural commodities. International commodity prices largely determine local prices for most agricultural products via import and export-parity pricing regimes. Thus, farmers' revenues may increase when oil prices rise. The net impact of oil price shocks on farming profitability will depend on the relative increases in production costs and sales prices as well as the impact of higher prices on market demand for agricultural products (for an analysis of prospects for these factors in the medium term, see BFAP 2014). Households facing higher fuel costs and related price increases might respond by altering the composition (and possibly the size) of their consumption baskets. For example, they may on average reduce their consumption of animal products, which comprised over half of the gross income from agriculture in 2013 (BFAP 2014:14).

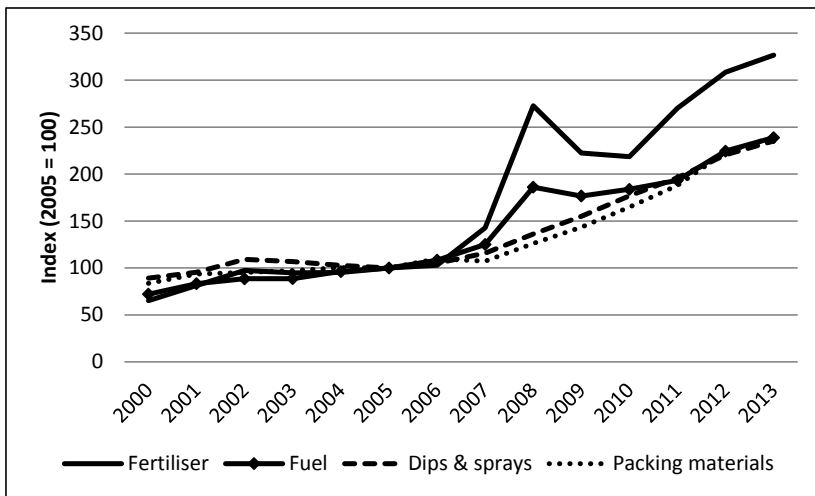


Figure 5: Price indices of intermediate goods in agriculture, 2000–2013  
Source: DAFF (2014a)

The impact of oil price shocks on farming profitability and production levels is therefore likely to vary considerably; farmers whose product prices are determined in local markets, but who rely heavily on oil-based inputs are likely to suffer the most from oil price hikes. In the case of some products, individual farmers are not able to pass on all cost increases to consumers, especially given the highly concentrated

nature of the food processing and retail sectors in South Africa (Mather 2005). In this case, and if costs rise too much while sales prices are inflexible and/or market demand declines, some farmers could potentially be exposed to bankruptcy. The profitability of agricultural exporters, by contrast, would depend considerably on exchange rate movements. The rand could become more volatile but, on balance, is expected to weaken following oil price shocks (Wakeford 2012; Fofana et al 2008). The anticipated volatility in oil prices and the exchange rate will create a great deal of uncertainty for farmers who will face difficult decisions regarding planting and investment.

Periodic physical shortages of liquid fuels arising in rural areas as a result of global oil supply constraints (and associated market and geopolitical turmoil) would likely have a much more serious impact on agricultural production in South Africa than higher oil prices. Since key farming operations such as planting and harvesting are highly time-dependent, fuel shortages at such critical times could be devastating to output. Fuel shortages would also curtail the distribution of farming products to processing facilities and markets in towns and cities. The likelihood of fuel shortages emerging in rural areas is greater than that in urban areas, due to the location of South Africa's oil refineries in or near to major urban centres (Cape Town, Durban, Mossel Bay and Secunda near Johannesburg).

In the longer term, when world oil production is in its declining phase, higher oil prices and physical oil shortages may force many farmers to revert to more labour-intensive and organic methods of production that rely less on petroleum-based fuels, pesticides and synthetic fertilisers. Conceivably, this may also lead to a reversal of the historical trend of consolidating farms into larger units, which was made possible by the mechanisation of farming. Rising and volatile input costs and fuel shortages, combined with the impact of other factors such as soil degradation, rising water scarcity and cost, and climate-related variability and extremes of weather conditions, could lead to a decrease in agricultural output and possibly an increasing rate of bankruptcy amongst farmers. Decreasing agricultural production volumes would erode self-sufficiency in certain products, thereby compromising national food security. Any further loss of farming knowledge and skills, in addition to what has occurred over the past two decades, would exacerbate this risk. Higher international food prices, in combination with a weakening exchange rate (resulting from pressure on the balance of payments exerted by rising oil import costs and capital flight), would reduce the affordability of food imports. Finally, growing demand for biofuels to replace scarce and expensive crude oil would place additional pressure on arable land and water resources, and could further compromise food security, despite a government prohibition on the use of maize as a feedstock for bioethanol (DME 2007).

## 6 MITIGATING THE IMPACT OF WORLD OIL SCARCITY ON SOUTH AFRICAN AGRICULTURE

The previous sections have argued that increasing world oil scarcity poses a threat to South Africa's food sovereignty, which has been defined as 'the right of each nation to maintain and develop their own capacity to produce foods that are crucial to national and community food security, respecting cultural diversity and diversity of production methods' (Pimbert 2008:43). Consequently, there is a need for mitigation and adaptation strategies and policies to develop the resilience of agriculture to oil price and supply shocks in both the short and the long term.

In the short term (less than a year), farmers could be protected from severe oil price shocks by way of temporary fuel subsidies, so that they can maintain production and avoid possible bankruptcy (if there are substantial time lags between rises in input costs and output prices, perhaps in combination with weakening consumer demand in response to food price increases). In the event of physical fuel supply disruptions and shortages, there is a strong case to be made for a strategic prioritisation of fuel supplies for agricultural production and the distribution of food products to markets. From a practical point of view this should be feasible, considering that the agriculture sector consumes only about 5 percent of the country's petroleum fuels (IEA 2014). The main obstacles to both of these short-term mitigation responses are likely to be of a political nature, but the authorities should recognise that maintaining national food security is in the country's vital interest.

One possible longer term strategy to mitigate the impact of global crude oil price and supply shocks would be for South Africa to develop indigenous sources of liquid fuels in order to reduce the reliance on imported oil (see Wakeford, 2013 and Wakeford and Swilling, forthcoming for more detailed analysis of the alternatives). The first option would be to find and develop domestic crude oil resources. Although plenty of offshore oil exploration activity is taking place along much of South Africa's coastline, as of this writing, no oil field discoveries have been announced (see PASA 2014). Even if fields of significant size were to be found, it would probably take between five and ten years for oil to be brought to the market. A second possibility would be to expand production of CTL fuels, which currently meet about a quarter of South Africa's demand. However, Sasol has shelved its investigations into a new CTL plant, citing high costs and risks associated with the need to curb greenhouse gas emissions (Njobeni 2012). The prospect for growing GTL fuel production will depend either on new domestic gas discoveries (offshore conventional gas or shale gas in the Karoo basin) or imports of gas either via pipeline from neighbouring Mozambique or in the form of liquefied natural gas. All of these potential GTL feedstock options are uncertain and would require massive capital expenditure by the state and/or

private investors. In the best case, it would probably take five to ten years to start delivering meaningful quantities of fuel. The fourth alternative is biofuels, but these are likely to be severely limited by water and arable land constraints, as well as the generally low energy return on investment (or net energy) yield of ethanol and biodiesel fuels (Murphy and Hall 2010). A final consideration is that, while an expansion of domestic liquid fuel production capacity would alleviate physical oil supply constraints, it would not shield farmers from high fuel prices as long as South African fuel prices continue to be regulated according to an import parity pricing formula.

In light of the uncertainties and limitations surrounding the further development of domestic fuel supplies, an alternative strategy would be to address the demand side of the equation, by aiming to systematically reduce oil dependency in the agricultural and food systems. Two core strategies for achieving this are considered below. Section 6.1 explores ways in which the use of petroleum fuels can be reduced in the food production system, together with specific policy measures and likely constraints. Section 6.2 considers the efficiency of food distribution systems and advocates a general reduction of distances between food producers and consumers, ie a relocalisation of the food system.

## 6.1 Reducing oil use in agricultural production

The main use of oil in agriculture in South Africa is in the form of diesel fuel for tractors, harvesters and other farm machinery. However, a wide range of other inputs are derived from crude or synthetic oil, including irrigation piping and fittings, pesticides, and packaging materials. In addition, rising crude oil prices will put upward pressure on the price of natural gas, which globally is the primary feedstock for synthetic nitrogen fertilisers. More sustainable farming practices, such as conservation agriculture and agro-ecological farming, offer ways to reduce the dependence on oil and other fossil fuel inputs.

Conservation agriculture involves three key principles, namely minimal soil tillage, the use of organic soil covering, and crop rotation (Du Toit 2007). The low-till aspect of conservation agriculture reduces the need for tractor use and therefore diesel fuel (FAO 2010). By improving soil moisture retention, conservation agriculture may also reduce the need for energy-intensive irrigation. However, weed management becomes more challenging, implying a greater need for petroleum-based herbicides or increased demand for labour (Giller, Witter, Corbeels and Tittonell 2009).

Agro-ecological farming, which applies ecological principles to the management of agricultural systems (Pfeiffer 2006:59; Altieri 2009), is also compatible with reducing the reliance on oil and other fossil fuels. Emphasising the use of locally available, natural inputs that minimise the adverse ecological impact has much



in common with organic agriculture (Hine, Pretty and Twarog 2008). The use of inorganic fertilisers can be reduced through the adoption of appropriate crop rotation practices, incorporating nitrogen-fixing crops and the recycling of critical nutrients (including phosphorus) through the use of composting, animal manures, green manures and even 'humanure' (Pfeiffer 2006:58; Greer 2009; Heinberg and Bomford 2009:22). However, using animal manure implies allocating more arable land to grazing and therefore less to growing food crops. Oil-based pesticides and herbicides can, in theory, be replaced with integrated pest management, utilising biopesticides, microbes and natural pest control, intercropping to reduce losses to pests, and cover-cropping to counteract weeds (Pfeiffer 2006; Heinberg and Bomford 2009:11). A shift to agro-ecological farming methods could bring additional sustainability benefits beyond reduced oil dependency and lower production costs, including environmental benefits such as reduced pollution and enhanced soil fertility, water quality and biodiversity (Hine et al 2008).

A transition to less oil dependent and more sustainable forms of agriculture will involve several challenges. First, good quality land and water are both scarce in South Africa. Secondly, the current dearth of farming skills implies that considerable time would be needed to train new farmers in agro-ecological methods. Thirdly, the agro-ecological model of farming requires more land than conventional industrial farming as part of the land has to be set aside for animals to produce manure for fertilising (Pfeiffer 2006:63). Agro-ecological farming also has greater labour requirements, although this can be seen as an opportunity to alleviate high unemployment levels. Fourthly, farmers who convert from conventional to organic farming will face transition costs in the form of initially reduced output and revenues (to some extent offset by reduced input costs) and human capital investment costs (Hine et al 2008:34). Nevertheless, Hine et al (2008:11) state that, while farms that convert from industrial to organic methods generally experience a decrease in yield initially, yields increase notably once the agro-ecosystem recovers. On the other hand, large-scale mechanised farms are able to reap the benefits of economies of scale and thus produce at lower prices, although some costs are externalised to the environment. In addition, fertilisers and pesticides have allowed the cultivation of more marginal soils, which might not be suitable for organic production. Thus, total output could decline significantly as it did in the early 1980s after fertiliser subsidies were reduced (FAO 2005).

The successful diffusion of conservation agriculture and agro-ecological innovations requires specific policy support and institutions, partly because of their knowledge-intensive nature (Du Toit 2007; Altieri 2009; Hine et al 2008). Support could come in the form of increased research funding; strengthening of networks involving scientists; agricultural extension providers and farmers; and the facilitation of connections between farmers, civil society organisations

and government departments. Furthermore, if the viability of large-scale, oil-intensive industrial farming is gradually undermined by oil scarcity and needs to be progressively replaced by organic agriculture requiring an increase in the number of farmers and farm workers, then a carefully managed and effective land reform process will be necessary. An essential requirement for effective land reform is adequate training and skill acquisition programmes for emerging farmers (INR 2008). Moreover, emerging small-scale farmers are likely to need financial support, for example, in the form of subsidies or low-interest credit. Any subsidies provided to farmers should be targeted at those who are progressively implementing more sustainable agricultural methods, otherwise petrochemical dependency will be perpetuated. Farming subsidies would reflect the national priority of agriculture and food security in ensuring social welfare and cohesion.

## 6.2 Distributional efficiency and localisation

The vulnerabilities of the food distribution system to rising oil prices and fuel shortages can be addressed in two main ways. In the first instance, targeted interventions should be made to enhance logistical efficiencies of supply chains operating between input suppliers and farms, and between farms and consumers (Vink and Van Rooyen 2009:37). Resilience to fuel supply shortages can be increased by building in redundancies and increasing inventories (Heinberg and Bomford 2009:33). Secondly, given the overwhelming dependence of the current distribution systems on road-based transport infrastructure, a fundamentally new orientation may be required for the longer term, namely a relocalisation and decentralisation of food economies that reduces distances between producers and consumers. Relocalisation implies that the production of a greater proportion of necessary foodstuffs should occur locally, while longer distance trade should be reserved mainly for luxury items (Heinberg and Bomford 2009:15). In addition, it may mean consumers would be more restricted to seasonal produce. In order to promote food security, each area should produce regionally adapted staple crops as far as possible. For food processing, relocalisation would involve the establishment of smaller scale facilities rather than large, centralised processing plants. Local food economies may have additional benefits such as fostering community networks (Feenstra 1997) and encouraging greater sustainability (Schulschenk 2010). However, they may be limited in their capacity to meet the diverse nutritional needs of some communities and be constrained by environmental conditions such as extreme climates or degraded ecosystems (Schulschenk 2010:59–61).

Localisation would require a major redirection of national agricultural policy that currently favours an export-led growth path. At the micro level, government can help to establish localised agricultural markets and promote farmers' markets by, for example, making public spaces available in urban areas and rural towns.

Such local markets may help to reduce the market power of giant wholesalers and retailers (Pfeiffer 2006). Government can also support ‘buy local’ campaigns and insist that government institutions source a minimum portion of their food needs locally (Heinberg and Bomford 2009:17). Building local food economies may initially depend on civil society participation in order to be competitive with the current food system, although, over time, rising oil prices will assist the process (Schulschenk 2010:122).

The development of urban agriculture represents a specific form of localisation with significant opportunities to foster the resilience of urban communities (Hopkins 2000). Local governments can promote urban food production by allocating underutilised land for food gardens and leasing allotments to residents. Local by-laws can foster rooftop and backyard food gardens, and laws could be enacted to compel urban farmers to employ organic production methods, as in Cuba (Pfeiffer 2006:61). Municipalities can either organise their waste systems to process food waste into compost or biogas (Heinberg and Bomford 2009:17) or incentivise residents to do so themselves. Thornton (2008) recommends that the Department of Agriculture widen its extension services to cover urban townships and informal settlements. Yields from bio-intensive urban agriculture proved to be higher than those of conventional farming in the United States (Hopkins 2000:206). Nevertheless, it is acknowledged that the development of urban agriculture would face significant challenges and constraints in the South African context such as the availability of suitable land, water and organic materials for composting as well as for security. Evidence suggests that cultural attitudes about the ‘backwardness’ of food production and the availability of social welfare grants can also hinder the growth of urban agriculture ([Thornton 2008](#)).

## 7 CONCLUSION

Agriculture in South Africa depends on petroleum for nearly two thirds of its energy inputs. The vast majority of agricultural produce comes from highly oil-intensive commercial farming, which is exposed to rising input costs for fuel, fertilisers, pesticides and packaging, all of which are affected by international oil prices. Fuel shortages are potentially catastrophic at critical times such as during planting and harvesting periods. Organic and subsistence farming are much less oil intensive than conventional commercial agriculture, but currently contribute tiny shares to the total agricultural output. The knowledge and skills required for agro-ecological farming are very limited in South Africa. Subsistence farming is limited to a small percentage of the country’s population, and most subsistence farmers have access to low quality land and water, suffer from poverty and rely on supplementary sources of income and food. Moreover, the distribution of food products to consumers relies heavily on road-based transport and therefore on

liquid petroleum fuels. Continued national self-sufficiency in the production of most agricultural commodities is by no means certain in a future context of rising oil prices and increasing fuel scarcity.

Given the commercial agriculture sector's extensive dependence on diesel and other petroleum-based inputs, and its vital role in national food security, it may in the short term require government support to cope with severe oil price shocks and potential fuel scarcity. This support could be in the form of subsidies and priority fuel allocations in times of shortage. However, financial support should arguably be linked to a programme aimed at gradually phasing out the use of petroleum products and undertaking a gradual transition to more sustainable farming practices. Agro-ecological farming methods will probably involve smaller scale farms and higher labour intensity of production, which would assist in the creation of sustainable livelihoods. A transition to sustainable agriculture will require institutions that support both existing and emerging farmers with appropriate knowledge and skill acquisition. Farmers may need to invest in renewable energy and adopt farming practices that rely less on mechanisation, such as conservation tillage. Finally, to mitigate the vulnerabilities inherent in the heavy reliance on road transport in the current food distribution system, a gradual relocalisation of agricultural production and consumption may be called for over the longer term, although this will face biophysical constraints.

It is imperative to view the agriculture and food distribution system holistically. In efforts to mitigate declining oil availability, cognisance needs to be taken of various additional vulnerabilities of the agriculture system such as low and declining soil quality, water scarcity and droughts, climate change and an attrition of farming skills and knowledge. Thus, reducing oil dependency should form part of an overall transition to sustainable agriculture. Such a transition will take time as soils will need to be rebuilt after years or decades of intensive chemical use. Mitigation efforts should thus begin sooner rather than later. The scale of the challenge is immense, given the current dominance of oil-intensive industrialised agriculture. Government should recognise the strategic importance of the agriculture sector in maintaining social welfare and cohesion, and allocate sufficient funds accordingly to support a transition to sustainable and resilient agricultural systems.

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## REFERENCES

- Aleklett, K., Hook, M., Jakobsson, K., Lardelli, M., Snowden, S. and Soderbergh, B. 2010. The peak of the oil age – analyzing the world oil production reference scenario in world energy outlook 2008. *Energy Policy*, 38(3):1398–1414.
- Aliber, M. and Hart, TG. 2009. Should subsistence agriculture be supported as a strategy to address rural food insecurity? *Agrekon*, 48(4):434–458.
- Altieri, MA. 2009. Agroecology, small farms and food sovereignty. *Monthly Review: An Independent Socialist Magazine*, 61(3):102–113.
- Baffes, J. and Haniotis, T. 2010. Placing the 2006/08 commodity price boom into perspective. Policy research working paper 5371, World Bank. Washington, DC: World Bank.
- Baiphethi, MN. and Jacobs, PT. 2009. The contribution of subsistence farming to food security in South Africa. *Agrekon*, 48(4):459–482.
- Benes, J., Chauvet, M., Kamenik, O., Kumhof, M., Laxton, D., Mursula, S. and Selody, J. 2012. The future of oil: geology versus technology. Working paper WP12/109, International Monetary Fund. Washington, DC: International Monetary Fund.
- BFAP *see* Bureau for Food and Agricultural Policy.
- BP *see* British Petroleum.
- British Petroleum. 2014. *Statistical review of world energy 2013*. London: British Petroleum.
- Brown, LR. 2009. *Plan B 4.0: mobilising to save civilization*. New York, NY: Norton.
- Brown, LR. 2012. *Full planet, empty plates: the new geopolitics of food security*. New York, NY: Norton.
- Bureau for Food and Agricultural Policy. 2014. BFAP baseline agricultural outlook 2014–2023. [http://www.bfap.co.za/images/documents/baseline/bfap\\_baseline\\_2014.pdf](http://www.bfap.co.za/images/documents/baseline/bfap_baseline_2014.pdf) (Accessed 6 August 2014).
- DAFF *see* Department of Agriculture, Forestry and Fishing.
- Department of Agriculture, Forestry and Fishing. 2014a. *Abstract of agricultural statistics 2014*. Pretoria: Department of Agriculture, Forestry and Fisheries, Directorate Statistics and Economic Analysis.
- Department of Agriculture, Forestry and Fishing. 2014b. *Trends in the agricultural sector 2013*. Pretoria: Department of Agriculture, Forestry and Fishing.
- Department of Minerals and Energy. 2007. *Biofuels industrial strategy*. Pretoria: Department of Minerals and Energy.
- DME *see* Department of Minerals and Energy.
- Du Toit, G. 2007. Promoting conservation agriculture in South Africa: a case study among commercial grain producers in the North West province. Policy report 2007–04, Bureau for Food and Agriculture, University of Pretoria.
- Economic Development Department. 2010. *New growth path: framework*. Pretoria: Economic Development Department.
- EIA *see* Energy Information Administration.
- Energy Information Administration. 2014. International energy statistics. <http://www.eia.doe.gov/emeu/international/contents.html> (Accessed 4 August 2014).
- FAO *see* Food and Agriculture Organisation.

- Feenstra, G. 1997. Local food systems and sustainable communities. *American Journal of Alternative Agriculture*, 1291:28–36.
- Fertiliser Society of South Africa. 2014. Consumption of fertilizers in South Africa. [http://www.fssa.org.za/Statistics/Fertilizer\\_Consumption\\_in\\_South\\_Africa\\_1955-2018.pdf](http://www.fssa.org.za/Statistics/Fertilizer_Consumption_in_South_Africa_1955-2018.pdf) (Accessed 5 August 2014).
- Fofana, I., Mabugu, R. and Chitiga, M. 2008. Analysing impacts of alternative policy responses to high oil prices using an energy-focused macro-micro model for South Africa. Report prepared for the Financial and Fiscal Commission. Pretoria: Financial and Fiscal Commission.
- Food and Agriculture Organisation. 2005. *Fertilizer use by crop in South Africa*. Rome: Food and Agriculture Organisation.
- Food and Agriculture Organisation. 2008. *The state of food insecurity in the world 2008*. Rome: Food and Agriculture Organisation.
- Food and Agriculture Organisation. 2010. *Conservation agriculture*. Rome: United Nations Food and Agriculture Organisation.
- Food and Agriculture Organisation. 2011. *The state of food insecurity in the world 2011*. Rome: Food and Agriculture Organisation.
- FSSA *see* Fertiliser Society of South Africa.
- Gagnon, N., Hall, CAS. and Brinker, L. 2009. A preliminary investigation of energy return on energy investment for global oil and gas production. *Energies*, 2:490–503.
- GCIS *see* Government Communication and Information System.
- Giller, KE., Witter, E., Corbeels, M. and Tittonell, P. 2009. Conservation agriculture and smallholder farming in Africa: the heretics' view. *Field Crops Research*, 114(1):23–34.
- Government Communication and Information System. 2012. *South Africa yearbook 2011/12*. Pretoria: Government Communication and Information System.
- Greer, JM. 2009. *The ecotechnic future*. Gabriola Island: New Society Publishers.
- Guilford, MC., Hall, CA., Connor, PO. and Cleveland, CJ. 2011. A new long term assessment of Energy Return on Investment (EROI) for US oil and gas discovery and production. *Sustainability*, 3(10):1866–1887.
- Heinberg, R. and Bomford, M. 2009. *The food and farming transition: toward a post carbon food system*. Santa Rosa, CA: Post Carbon Institute.
- Hendriks, SL. 2005. The challenges facing empirical estimation of household food (in)security in South Africa. *Development Southern Africa*, 22(1):103–123.
- Hendriks, SL. and Msaki, MM. 2009. The impact of smallholder commercialisation of organic crops on food consumption patterns, dietary diversity and consumption elasticities. *Agrekon*, 48(2):184–199.
- Hine, R., Pretty, J. and Twarog, S. 2008. *Organic agriculture and food security in Africa 2007/15*. New York, NY: UNEP-UNCTAD Capacity-building Task Force on Trade, Environment and Development.
- Hirsch, RL., Bezdek, RH. and Wendling, RM. 2010. *The impending world energy mess: what it is and what it means to you*. Burlington: Apogee Prime.
- Hopkins, R. 2000. The food producing neighbourhood. In H. Barton (ed), *Sustainable communities*. London: Earthscan, 199–215.
- IEA *see* International Energy Agency.

INR *see* Institute of Natural Resources.

Institute of Natural Resources. 2008. Study to develop a value chain strategy for sustainable development and growth of organic agriculture. Investigational report IR285. Scottsville: Institute of Natural Resources.

International Energy Agency. 2012. *World energy outlook 2012*. Paris: International Energy Agency.

International Energy Agency. 2014. Energy statistics. <http://www.iea.org/stats/index.asp> (Accessed 4 August 2014).

Kelly, C. 2009. Lower external input farming methods as a more sustainable solution for small-scale farmers. Unpublished MPhil thesis. Stellenbosch University, South Africa.

Kumhof, M. and Muir, D. 2012. Oil and the world economy: some possible futures. Working paper WP/12/256, International Monetary Fund. Washington, DC: International Monetary Fund.

Laker, MC. 2005. South Africa's soil resources and sustainable development. Unpublished paper commissioned by the Department of Environmental Affairs and Tourism.

Leroy, JLP., Van Rooyen, J., D'Haese, L. and De Winter, A. 2001. A quantitative determination of the food security status of rural farming households in the Northern province of South Africa. *Development Southern Africa*, 18(1):5–17.

Liebenberg, F. and Pardey, PG. 2012. A long-run view of South African agricultural production and productivity. *African Journal of Agricultural and Resource Economics*, 7(1):14–38.

Mather, C. 2005. The growth challenges of small and medium enterprises (SMEs) in South Africa's food processing complex. *Development Southern Africa*, 22(5):607–622.

Miller, RG. and Sorrell, SR. 2014. The future of oil supply. *Philosophical Transactions of the Royal Society*, 372:1–27.

Modi, AT. 2003. What do subsistence farmers know about indigenous crops and organic farming? Preliminary experience in KwaZulu-Natal. *Development Southern Africa*, 20(5):675–684.

Mostert, A. 2013. South African fertilizer imports and exports. Fertiliser Society of South Africa. [http://www.fssa.org.za/Statistics/South\\_Africa\\_fertiliser\\_imports\\_and\\_exports.pdf](http://www.fssa.org.za/Statistics/South_Africa_fertiliser_imports_and_exports.pdf) (Accessed 5 August 2014).

Murphy, D. and Hall, CAS. 2010. Year in review – EROI Or Energy Return on (Energy) Invested. *Annals of the New York Academy of Sciences*, 1185:102–118.

Niemeyer, K. and Lombard, J. 2003. Identifying problems and potential of the conversion to organic farming in South Africa. Unpublished paper. Paper presented at the 41st Annual Conference of the Agricultural Economic Association of South Africa, 2-3 October 2003, Pretoria.

Njobeni, S. 2012. Sasol mulls Limpopo coal opportunities. *Business Day*, 24 October. <http://www.bdlive.co.za/business/energy/2012/10/15/sasol-mulls-limpopo-coal-opportunities> (Accessed 15 August 2014).

O'Farrell, PJ., Anderson, PML., Milton, SJ. and Dean, WRJ. 2009. Human response and adaptation to drought in the arid zone: lessons from southern Africa. *South African Journal of Science*, 105:34–39.

PASA *see* Petroleum Agency of South Africa.

Pauw, KW. 2007. Agriculture and poverty: farming for food or farming for money? *Agrekon*, 46(2):195–218.

- Petroleum Agency of South Africa. 2014. Exploration maps. <http://www.petroleumagencyrsa.com/index.php/maps> (Accessed 15 August 2014).
- Pfeiffer, DA. 2006. *Eating fossil fuels*. Gabriola Island: New Society.
- Pimbert, M. 2008. *Towards food sovereignty: reclaiming autonomous food systems*. London: IIED.
- Robelius, F. 2007. Giant oilfields – the highway to oil: giant oil fields and their importance for future oil production. Unpublished PhD thesis. Uppsala University, Sweden.
- Schulschenk, J. 2010. Benefits and limitations of local food economies to promote sustainability: a Stellenbosch case study. Unpublished MPhil thesis. Stellenbosch University, South Africa.
- Sorrell, S., Miller, R., Bentley, R. and Speirs, J. 2010a. Oil futures: a comparison of global supply forecasts. *Energy Policy*, 38(9):4990–5003.
- Sorrell, S., Speirs, J., Bentley, R., Brandt, A. and Miller, R. 2010b. Global oil depletion: a review of the evidence. *Energy Policy*, 38(9):5290–5295.
- Sparrow, GN., Ortmann, GF., Lyne, MC. and Darroch, MAG. 2008. Determinants of the demand for regular farm labour in South Africa, 1960–2002. *Agrekon*, 47(1):52–75.
- Thamaga-Chitja, J. and Hendriks, SL. 2008. Emerging issues in smallholder organic production and marketing in South Africa. *Development Southern Africa*, 25(3):317–326.
- Thornton, A. 2008. Beyond the metropolis: small town case studies of urban and peri-urban agriculture in South Africa. *Urban Forum*, 19:243–262.
- Townsend, RF., Van Zyl, J. and Thirtle, C. 1997. Machinery and labour biases of technical change in South African agriculture: a cost function approach. *Agrekon*, 36(4):492–500.
- UKITPOES see United Kingdom Industry Task Force on Peak Oil and Energy Security.
- United Kingdom Industry Task Force on Peak Oil and Energy Security. 2010. The oil crunch: a wake-up call for the UK economy. London: Industry Task Force on Peak Oil and Energy Security.
- Vink, N. 2012. The long-term economic consequences of agricultural marketing legislation in South Africa. *South African Journal of Economics*, 80(4):553–566.
- Vink, N. and Van Rooyen, J. 2009. The economic performance of agriculture in South Africa since 1994: implications for food security. Working paper series 17, Development Planning Division. Midrand: Development Bank of Southern Africa.
- Wakeford, JJ. 2012. Implications of global oil depletion for South Africa: vulnerabilities, impacts and transition to sustainability. PhD dissertation. Stellenbosch University, South Africa.
- Wakeford, JJ. 2013. *Preparing for peak oil in South Africa: an integrated case study*. New York, NY: Springer.
- Wakeford, JJ. and Swilling, M. 2014. Peak oil as a stimulus for a green economy transition in South Africa: alternative liquid fuel and transport options. *International Journal of African Renaissance Studies*, 9(2):133-153
- Walker, NJ. and Schulze, RE. 2008. Climate change impacts on agro-ecosystem sustainability across three climate regions in the maize belt of South Africa. *Agriculture, Ecosystems and Environment*, 124(1):114–124.
- Wlokas, HL. 2008. The impacts of climate change on food security and health in southern Africa. *Journal of Energy in Southern Africa*, 19(4):12–20.