CHAPTER 8

Agriculture

CHAPTER 8: AGRICULTURE

Integrating Author:	Noel Oettle[1]
Contributing Authors:	Lehman Lindeque[2], Justin du Toit[2], Igshaan Samuels[3]
Corresponding Authors:	Antony Osler[4], Susi Vetter[5], Emma Archer Van Garderen[6]

[1] Environmental Monitoring Group Trust, Nieuwoudtville, 8180

[2] Department of Agriculture, Forestry and Fisheries (DAFF), Pretoria, 0001

[3] Agricultural Research Council, Pretoria, 0001

[4] University of the Free State (UFS), Bloemfontein, 9301

[5] Rhodes University, Grahamstown, 6140

[6] Council for Scientific and Industrial Research, Pretoria, 0184

Recommended citation: Oettle, N., Lindeque, L., du Toit, J., Samuels, I., Osler, A., Vetter, S. and van Garderen, E.A. 2016. Impacts on Agriculture. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7, Pretoria: CSIR. Available at http://seasgd.csir.co.za/scientific-assessment-chapters/

CONTENTS

Tables

Figures

Executive Summary

Agriculture is an important contributor to the regional economy. The total Gross Farm Income (GFI) of the region is just over five billion rand (R 5006 million). The agricultural sector in the study area provides a direct source of income for about 38 000 people. Considering the average size of families in the study area of approximately 4.5 persons, this translates to supporting the livelihoods of around 133 000 people.

The biggest risk of shale gas development (SGD) to agricultural production in the study area relates to the use, availability and quality of water resources. In the Central Karoo, groundwater is essential for human and livestock consumption, and surface water is also utilised for livestock and irrigation purposes. In the dryer central and western parts of the study area, farming communities rely exclusively on boreholes for the provisioning of water for humans and livestock consumption. This is due to the unreliable and limited rainfall in the area and high evapotranspiration rates, resulting in limited quantities of available surface water. SGD poses a risk to groundwater aquifers and surface water resources in the region which will affect agricultural production and land-based livelihoods. Opportunities also do however exist to utilise treated water from SGD operations, or that sourced from saline deep aquifers for productive purposes, should it be either of an acceptable quality or amenable to purification (see Hobbs et al., 2016).

Although the risks of SGD on agriculture can be reduced if sensitive areas are avoided and the threat to groundwater is adequately mitigated, the likelihood of negative impacts of SGD on agricultural productivity remains. The central and western parts of the study area are areas of low potential productivity in a national context, yet have made a relatively constant contribution to regional Gross Domestic Product (GDP), and sustained local livelihoods. Due to low and variable rainfall and inadequate access to water resources, the area offers limited options and opportunities for intensive farming operations. The area is thus typified by large, extensive farms and low levels of population. There is a trend amongst land users to move towards alternative sources of land-based incomes such as eco-tourism and hunting. Local land users draw on profound local knowledge to sustainably use these vulnerable land-based resources. Farming has proven to be a sustainable land use for centuries and most farmers live in equilibrium with scarce natural resources. The potential short-term benefits of SGD pose a threat to that equilibrium of this relationship (Section 8.2.1).

The resilience of both the area and its land users will be put at risk by any activity that destroys current land-based livelihoods. This risk can be reduced by careful planning to reduce fragmentation of the landscape. In the light of the North American experience, disturbance of agricultural landscapes can be expected to effect on average 2.7 ha of land per wellpad (Drohan and

Brittingham, 2012). Rehabilitation of soil surrounding wellpads post production may not restore the full soil functionality; which will limit the success of revegetation. Some land will be taken out of production while SGD is underway (leased or purchased) which would potentially have a positive impact on the incomes of agricultural land users. On the other hand, if farmers lease their farms in entirety this would have a negative impact on the continuity of the farming practices in the area, especially if farmers take up alternative employment for the period of the lease.

Local economic development associated with the SGD will provide some stimulus for local markets for agricultural products. Significant numbers of locally-based staff of SGD companies will increase demand for agricultural products to a limited extent. SGD operations are likely to attract non-employees in service enterprises who will also contribute to the local economy and consume agricultural products.

SGD will put the protection of the privacy and security of land users at risk. Currently land users enjoy high levels of control over the farm-based resources resulting in minimal losses of livestock and other property, and good levels of overall safety and security of rural communities, including land users, farm workers and their families. This is in part a result of minimal through-traffic on most farms, and relatively stable local populations. The anticipated influx of work seekers and staff of shale gas companies and the situating of exploration and extraction operations on farm land will expose farm property, for example livestock, to theft and increase vulnerability of local communities to farm attacks and violence. The international experience also indicates that influxes of work seekers and broader social disruption are likely to increase alcohol, drug and domestic abuse in SGD areas (see Atkinson et al., 2016).

SGD may put the agricultural landscape at risk if undertaken in sensitive areas or in a careless fashion. The current trend of investment in agricultural land in the study area is associated with multiple perceived benefits including deriving incomes from eco-tourism and agricultural-based tourism or lifestyle farming (see Toerien et al., 2016). SGD could pose a risk to these growing industries and perceived benefits of land ownership by eroding the aesthetic integrity of the area (see Oberholzer et al., 2016), impinging on privacy and undermining lifestyle choices based on appreciation of pristine environments.

Sufficient policy, legislation and regulation exist to protect agricultural resources; however, enforcement of these instruments and institutional capacity remains inadequate. Current legislative and policy instruments include the Conservation of Agricultural Resources Act (CARA), Act 70 of 1970 (Subdivision of Agricultural Land), the Spatial Planning and Land Use Management Act (SPLUMA), and the National Policy on Food and Nutrition Security. However, the institutional capacity, skills and knowledge to implement or enforce these measures are limited, especially at local implementation level. It is recommended that SGD operators be obliged to enter into binding contractual agreements that guarantee the protection of the natural resource base and oblige them to finance any necessary rehabilitation and provide adequate compensation to affected land users for environmental damage. In addition, government must invest sufficient resources to build the capacities of responsible institutions to address these deficiencies in order to ensure the sustainable utilisation of natural resources and to protect rural livelihoods.

Long-term monitoring and evaluation is essential to measure the effectiveness and efficiency of mitigation measures applicable to all SGD scenarios, and thus to ensure continuous improvement through immediate corrective actions and positive impact of these measures on the sustainable use of agricultural resources. The effective implementation of mitigation and rehabilitation measures is important to limit the negative impacts of SGD. In order to measure effective implementation and maintenance of infrastructure, monitoring and evaluation of key variables (as described in Section 8.8.2) is necessary. The effective implementation of such a long-term monitoring programme depends on the availability of adequate resources, especially at the level of local implementation. Sufficient capacity and skills must be developed within the appropriate institutions to ensure the effective implementation thereof over the necessary time-scales. It is further recommended that monitoring outcomes and evaluation processes be fed back to relevant stakeholders to ensure continuous improvement.

CHAPTER 8: AGRICULTURE

8.1 Introduction and scope

8.1.1 Relevance of the agriculture for the region

Agriculture has been identified as the dominant land use in the Karoo region of South Africa, which covers virtually the entire study area. The value of agricultural production in South Africa was R 218 045 million in 2014, while its contribution to the Gross Domestic Product (GDP) was approximately R 69 423 million. The primary agricultural sector has grown by an average of approximately 11.8% per annum since 1970, while the total economy grew by 14.9% per annum over the same period, resulting in a decline in agriculture's share of the GDP from 7.1% in 1970 to 2.0% in 2013. Wool sales from South Africa realised R 3 749 million in 2015 (Wool SA, 2016), with the majority of this coming from the Eastern, Western and Northern Cape Provinces.

Agriculture's prominent, indirect role in the economy is a function of backward and forward linkages to other sectors. Purchases of goods such as fertilisers, chemicals and implements form backward linkages with the manufacturing sector, while forward linkages are established through supplying raw materials to the manufacturing industry. About 70% of agricultural output is utilised in other industries as intermediate products, thus contributing far more to overall GDP than is apparent from the statistic above. Agriculture is therefore a crucial sector and an important engine of growth for the rest of the economy (Department of Agriculture, Forestry and Fisheries (DAFF), 2014).

8.1.2 International and national context

While the impacts of shale gas development (SGD) on agricultural production have been a concern in Queensland, Australia (Thomas, 2015), the most thorough research on the impact of these activities on small to medium scale farms was conducted in Pennsylvania (Malin and DeMaster, 2015) and Wyoming (Haggerty and McBride, 2016). Bamberger and Oswald (Bamberger, 2012, 2014) report serious adverse effects of the chemicals used for hydraulic fracturing ("fracking") in the USA on livestock, including respiratory, reproductive, and growth-related problems in animals with major implications for farming and the food system. All of these studies point to the double-edged sword of unconventional gas projects providing an alternative income to those farmers who are burdened with high debt loads while compromising their natural resources and leading to conflict and often termination of farming.

Since the possibility of SGD is very new in South Africa, it is met with the expected fears and suspicion. Even though the larger study area is not known for large areas of productive crop fields, it supports a vast area dominated by meat production and smaller niche areas of high-value irrigated crops. There are currently no policies in South Africa for the assessment and management of shale gas impacts on agriculture. Therefore it is important that lessons learned from the international agricultural communities impacted by these activities be used to inform policies and legislation that will prevent these impacts as far as possible from occurring in the study area and the rest of the country.

8.2 Scope of the study

8.2.1 Agricultural parameters

Land, according to Gwartney (Wessels & Willemse, 2013), is defined as "*everything outside of people themselves or the products they make. It includes all natural resources, air, soil, minerals and water is included in the definition of land*". In other words, everything that is freely supplied by nature, and not by man, is categorised as land. Land is important and plays a pivotal role in social, political, environmental, economic and agricultural disciplines.

In contrast to this, agriculture as a study field can be defined as *"the cultivation of plants, animals, fungi and other life forms for food, fibre, biofuel, medicinal and other products used to sustain and enhance human life" (*International Labour Organisation, *1999).* For the purpose of this Chapter agriculture will therefore entail food and fibre production from natural resources to support the livelihoods of land users (and their employees), both within the cash economy and for subsistence and cultural purposes. It is considered to be the effective management of the synergies between climate, soil, vegetation, water and livestock that sustains the livelihoods of most people in the Karoo.

Agriculture also functions on different levels or scales, including both a social subsystem and an ecological subsystem. Decision-making within agriculture needs to consider both these subsystems, the agroecosystems agriculture depends on, as well as the governance systems organising and regulating agriculture in the study area, for example. According to Rivera-Ferre et al. (2013), agriculture can therefore be seen as a complex socio-ecological system and both these aspects need to be considered in decision-making related to agriculture (Figure 8.1). The complexity of agriculture and the importance to focus on both the social and ecological aspects related to decision-making within the agricultural field is further illustrated by the linkage between the Agriculture Chapter and other Chapters of this study.

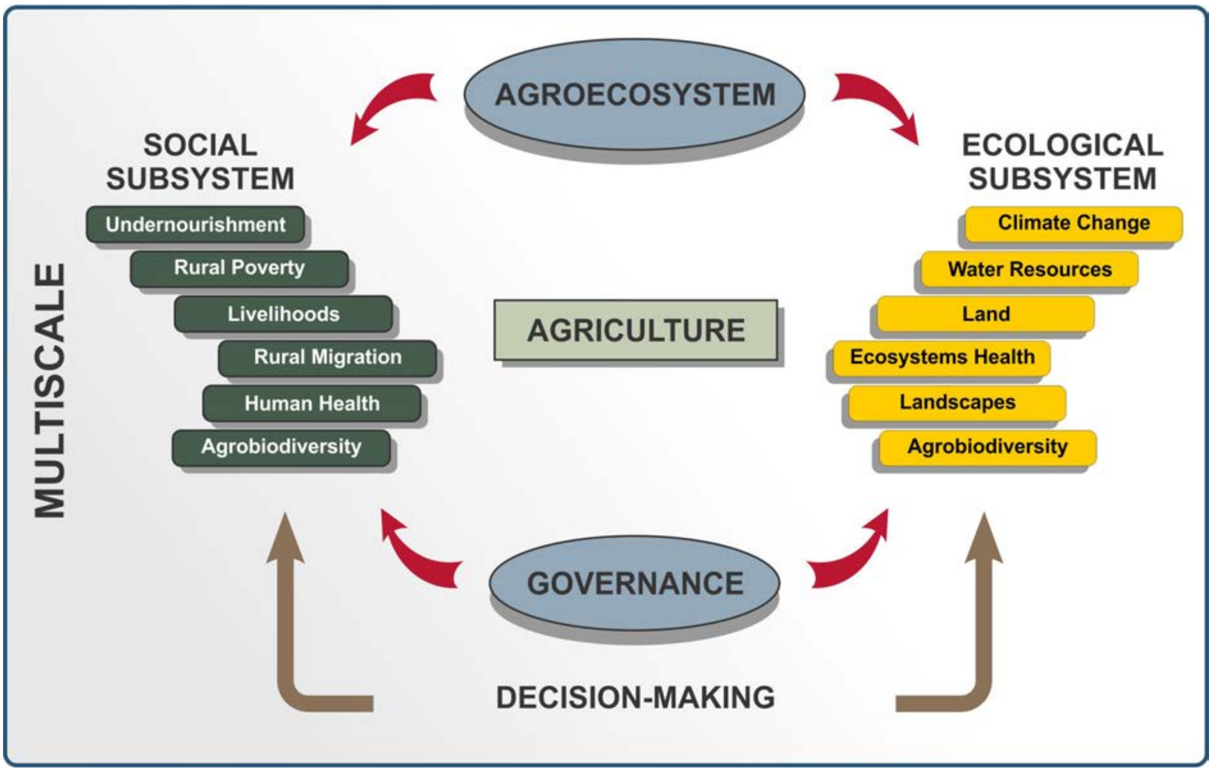

Figure 8.1: Agriculture as a complex socio-ecological system (Rivera-Ferre et al., 2013)

8.2.2 Links to other strategic issues

Considering the definition of land, the direct dependency of agriculture on land, but also the important role land plays in other disciplines like social, political, environmental and economical disciplines; one could expect the agricultural chapter to have linkages with other study fields. Figure 8.1 indicates the relative strength of the linkages between the agricultural field and other study fields' that are part of this scientific assessment.

The strong dependency of agriculture in the study area to the basic natural resources, terrestrial biodiversity and water, is clearly indicated in Figure 8.1. The anticipated impacts described in the scientific assessment should thus be kept in mind when reading the Agriculture Chapter. In the South African context, agriculture is primarily about people utilising natural resources to sustainably produce food and fibre to ensure food security for a growing South African population whilst generating sustainable incomes and creating employment of significant numbers of rural dwellers. Farmers are part of a bigger community, and rely on each other, farm workers, townspeople and other users of agricultural produce to make a living and provide them with a sound raison d'être. This relationship, secondary to their dependency on natural agricultural resources, is demonstrated in the relative strength of the linkages between this chapter and those addressing spatial planning and infrastructure (van Hussteen et al., 2016), tourism (Toerien et al., 2016), sense of place (Seeliger et al., 2016) and social fabric (Atkinson et al., 2016).

8.3 Legislation applicable

The National Environmental Management Act (Act 107 of 1998) (NEMA) (South Africa, 1998a) creates a legislative framework within which degradation of the environment regulated and sanctioned. In addition, the following South African legislation specifically applies to the conservation of agricultural resources:

The Conservation of Agricultural Resources (Act 43 of 1983) (CARA) (South Africa, 1983) states that the degradation of the agricultural potential of soil is illegal, and requires the protection of land against soil erosion and the prevention of waterlogging and salinisation of soils by means of the construction and maintenance of suitable soil conservation works. The sustainable utilisation of marshes, water sponges and watercourses on agricultural land is also regulated in terms of the Act.

The National Water Act (Act 36 of 1998) (NWA) (South Africa, 1998b) is concerned with the quality and quantity of water used, including for agriculture. Any impacts caused by shale gas activities on the volume and quality of water available for authorised agricultural water use, will be an infringement of this Act.

CARA was promulgated more than three decades ago, and did not anticipate all of the current potential impacts of new developments on agricultural resources. To ensure more sufficient protection of agricultural resources, it is recommended that the International Finance Corporation (IFC) Performance Standards on Environmental and Social Sustainability that became effective on 1 January, 2012 also be considered. With regards to the impacts on agricultural resources, the following standards and guidelines are of most relevance:

- IFC Performance Standard 3: Resource Efficiency and Pollution Prevention provides guidelines on project-level approach to resource efficiency and pollution prevention, in this case specifically for land management.
- IFC Guidelines for Mining which recommend practices for sustainable land use and topsoil management.
- IFC General Environmental, Health and Safety Guidelines: Contaminated Land for the detection, remediation and monitoring of contaminated land.

8.4 Purpose of the Chapter

The main purpose of this chapter is to identify the potential risks and impacts of SGD on agriculture, the vulnerability of the area to these operations and making strategic policy recommendations towards the sustainable management of these risks, impacts and vulnerabilities. To enable the authors to describe the potential impacts, risk and vulnerabilities, agriculture within the study area needs to be put into context, different agricultural systems in the Karoo need to be described, as well as their relative importance and some recent trends. As previously explained, agriculture within the study area is not only complex, but depends largely on a very limited supply of natural resources making it a very vulnerable system when considering the potential impact of climate change over the long-term and climate variability in the short and medium-term. The authors have thus developed a vulnerability map of the study area to provide an index value (on a quaternary catchment scale) indicating the relative vulnerability of agriculture to fracking within specific catchments.

8.5 Agriculture in the study area

8.5.1 General overview

Agriculture in the study area is heavily dependent on water, especially from aquifers since surface water resources are very limited. First introduced in 1874; wind pumps raising groundwater made permanent farms and towns in the Karoo possible. Underpinning the Karoo's economy are its 7 million sheep, divided between three million hardy Dorpers and 4.3 million wool-bearing sheep like Merinos, according to Cape Wools SA and National Wool Growers Association. There are also approximately a million goats. The Karoo has long been a good producer of fibre, contributing 13 million kg of South Africa's annual 44 million kg of wool. It also produces all of South Africa's 2.4 million kg of mohair annually – around than 60% of the world's production – from some 670 000 Angora goats. Most of the wool and mohair is exported and brings in billions in foreign revenue for South Africa.

Primary types of farming in the area comprise:

- Livestock, both extensive and intensive, for commercial and subsistence purposes;
- Dryland cultivation, including subsistence, small-scale and commercial;
- Cultivated irrigated land, both small scale and commercial;
- Game farming; and
- Tourism-related production, including both eco-tourism and farm-stays.

8.5.2 Main farming types

Almost the entire extent of the study area is used for extensive commercial livestock and/or wildlife production. Municipal commonage adjacent to all towns within the study area is utilised for communal farming by small livestock producers. A small section of the study area east of Queenstown (historically part of the Transkei) is farmed communally. Some commercial farms (both extensive and intensive) within the study area have been purchased by the national government in the context of its Land Reform Programme for the benefit of aspirant farmers. Where water is available, pastures or crops (including horticultural crops) are cultivated. Where livestock is produced, farms are invariably divided into multiple paddocks to contain animals (with different rotational systems), allowing for better animal control and veld management. Below follows a generic description of the most widely used animal production systems with the study area.

8.5.2.1 Commercial sheep production in the arid west

The arid western region of the study area (approximately west of 24°E) is predominantly Karoo vegetation. Vegetation is described as ‘sweetveld’, meaning that the quality of forage is high enough throughout the year to allow animals to increase or at least maintain body weight (‘sourveld’ in contrast has a low forage value during winter meaning that animals require supplementary feeding to avoid losing weight). Carrying capacity of the veld is low, ranging from 17-90 ha/AU (ca. 3-15 ha/SSU). Veld provides most forage for animals, though during droughts supplementary licks, pelletised feed or hay may be provided. Where available, irrigated pastures (lucerne in particular) provide additional feed for animals, and may be used during the lambing season for improved management and protection from predators. The carrying capacities of irrigated areas are orders of magnitude higher than those of rain fed areas of the study area.

8.5.2.2 Commercial sheep and/or cattle production in the east

The eastern section of the study area (approximately east of 24°E) experiences sufficient rainfall to allow perennial grasses to contribute significantly to available forage for livestock, thereby allowing for cattle to be farmed. Sheep and cattle are often produced together, though sheep-only and cattle-only farms do occur. Veld here is a mixture of sweetveld (lower lying, lower rainfall areas) and sourveld (higher lying, higher rainfall), often with both types of veld occurring on single farming units, in which case they would be separately fenced into different paddocks. On farms with sweetveld and sourveld, animals typically utilise the sourveld during the summer months when the quality of grazing is good, and move to the sweetveld when forage quality decreases and the weather turns cold. On farms with a significant proportion of sourveld, animals are supplemented with nitrogen licks and sometimes fed additional forage during the winter. Forage is usually produced on arable lands on the farm.

8.5.2.3 Commercial goat production in the south-east

Goat production, either for meat or for mohair, takes place primarily in the savannah or thicket biomes where trees and shrubs provide forage, with some production in the grassland and Nama-Karoo biomes. Sheep and cattle may also be present depending on the vegetation type. Angora goats can easily die in wet and cold conditions, particularly if they have recently been shorn. Herd management must thus be of a high standard, and ensure that Angoras are generally not farmed in areas that regularly experience cold, wet weather. Boer goats are hardier animals.

8.5.2.4 Wildlife farming

Wildlife is present on most freehold farms across the study area. Dedicated 'game-farms' usually have a tall perimeter fence (a 'game-fence') to prevent animals from foraging beyond the boundaries of the farm. Within the farm boundary, animal movement is often unrestricted; though some wildlife species are contained by normal livestock fencing (there are arguments for rotation of certain wildlife species types at certain densities). In some areas several farms are combined to form conservancies. Here, the movement of some wildlife species is unrestricted within the conservancy. In the case of farms where lions are produced, two tall, parallel, electrified boundary fences are required for containment.

8.5.2.5 Commercial ostrich farming

Ostrich production is centred in the arid south-western portions of the study area, but ostrich farms also occur as far south as Grahamstown. Ostrich production is semi-intensive to intensive, with animals relying on natural veld for only a small proportion of their dietary requirements. The remainder of their feed is either bought or from irrigated pastures.

8.5.2.6 Communal sheep, goat, and sheep production in the far eastern section

In the far eastern section of the study area livestock is produced under communal farming tenure. Wool production has been steadily increasing over the past approximately two decades and provides a highly significant source of income for some farmers. The communal areas occur primarily in sourveld, though some patches of sweetveld do occur. Animals are often not constrained within fenced paddocks but are kraaled at night for protection against predators. Animal movement is controlled by herders. Animals graze veld throughout the year, though in winter often rely on crop residues (e.g. maize stover) and riverine areas for nutrition.

8.5.2.7 Small-scale and subsistence farming

Around hamlets, villages, and towns, small-scale farming or production is common. Production enterprises range from ‘kitchen gardens’ through to small-holdings. Vegetable, fruit, pork and poultry production are common, but are seldom the sole source of income. Small-holdings are usually confined to riverine areas close to towns (e.g. Graaff-Reinet and Cradock). In towns without rivers (e.g. Middelburg) there are very few (if any) small-holdings. On many small-holdings near towns, arable lands have been invaded by the exotic alien plant *Solanum elaeagnifolium* (satansbos/ silver nightshade), which is highly persistent, very difficult to eradicate, and which greatly reduces agricultural potential.

8.5.3 Current agricultural trends in the study area

8.5.3.1 Agricultural employment in the study area

Recent and reliable employment figures for the agricultural sector are not readily available. AGRI-SA estimate the Karoo Region supports around 100 000 permanent and seasonal jobs (see http://karoospace.co.za/fracking-vs-farming-karoo/)

However, the 2002 Agricultural Census data provided to the team by AGRI-SA offer more reliable employment data for the agricultural sector in the study area. The employment figures for the district municipalities within the study area are summarised in Table 8.1. Where districts fall only partly within the study area, the figures have been proportionally adjusted.

Table 8.1*:* 2002 Agricultural employment figures for the SGD study area

Owners who farm themselves and part-time farmers	Family members involved in farming operations	[A] Total full time paid employees	[B] Total Casual and seasonal workers	Total paid employees [A+B]
2 950	823	15 015	19 764	34 779

When looking at the employment figures for 2002, it is clear that for each full-time or part-time farmer who farms themselves, at least five full-time employees were in full-time service on farms in the study area. These figures differ substantially between the high productive fruit growing areas of the Western Cape to the more communal farming areas of the Eastern Cape Province and the drier livestock producing areas of the Northern Cape. For example, in Ceres there were 89 owner-farmers and part-time farmers in the study area alone (and not the whole district) who employed in total 5732 full-time employees. On the other hand, in Sterkstroom in the Eastern Cape 52 owner- and part-time farmers employed only 17 full-time employees. Sutherland in the Northern Cape had 135 owner- and part-time farmers who employed only 59 full-time employees.

Considering the types of farming operations in the study area (ranging from horticulture, fodder production and livestock farming) and the seasonality of these operations, the relatively high number of casual and seasonal workers employment (19 764 for study area in 2002) is not surprising. Seasonal and casual workers are mainly employed for fruit and vegetable picking, working in pack houses, undertaking sheep and angora goat shearing and for general farm maintenance.

In summary, in 2002 the agricultural sector within the study employed about 35 000 people. Including the 2 950 owners and part-time farmers who farm themselves, the agricultural sector in the study area provides a direct source of income for about 38 000 people. Considering the average size of families in the study area of approximately 4.5 persons, this translates to a sustainable livelihood for 133 000 people. The figures may currently be higher than this, but considering the very substantial increase in minimum wages since 2002, low profit margins within the agricultural sector in general, and the mechanization of farming enterprises, it may be expected that these figures will currently be more or less the same.

8.5.3.2 Economic trends

The Census of Commercial Agriculture 2008 reflected a 31% decline in the number of farmers since 1993, resulting in the industry being left with fewer than 40 000 farms. The maize, wheat and dairy sectors have been the hardest hit. Although the number of farming units has dropped during this time, gross farm income (GFI) has increased by more than 300%. With expenses growing by a relatively low 285%, net farm income (NFI) grew by a staggering 410% over this period. Because of this growth, the net farm income per farm unit has increased significantly to five times more than what it was in 1993. This may in part be ascribed to economies of scale resulting from operations taking place within fewer, but larger units.

Agricultural land values have increased throughout the study area in the past two decades. For example, land values in the Graaff-Reinet area have increased from between R 170 – R 325 per hectare in 1995 to between R 2 700 – R 5 900 per hectare in 2016. (Derek Light Attorneys and Conveyancers 2016: Deeds Registry, Cape Town).

Local and national markets for agricultural products from the study area have shown steady growth. International markets for fibre are both stable and lucrative. Returns from game farming industry show a strong positive tendency, reflecting the success of this industry in marketing its products and services nationally and internationally.

In contrast to this, many smaller and more marginal farmers had to quit their farming enterprises as a result of rising input costs and shrinking profits. These farmers had frequently been reliant on subsidies and soft funding from institutions such as the Land Bank, and faced a situation where government support was phased out at the same time as the markets opened to allow competition from cheap imports.

8.5.3.3 Agricultural activities and their economic importance in the study area

To our knowledge, there is no single, comprehensive, methodologically consistent report that details the economic contribution from agriculture in the study area. Rather, a picture must be developed from several sources. The most comprehensive description derives from the 2007 census of commercial agriculture. When values are adjusted for inflation, this provides a robust background overview of the economic contribution of agriculture to the economy of the study area. However, the economic contribution of hunting was further scrutinised as much of the income for this activity is not associated with the sale of produce, which is what the census results detail.

Census results from 2007

To quantify the primary agricultural activities and their economic importance, data provided by Statistics South Africa (StatSA, 2007a, 2007b, 2007c) were used. This is the most recent comprehensive survey available. In these reports, agricultural data are provided per province on a per-district basis. For the purposes of this report, data were included if the town used to describe the district fell inside the study area.

Economic data are presented in the form of Gross Farming Income (GFI) which reflects income from the sale of agricultural products. Values were multiplied by a factor of 1.693 to account for inflation from 2007 to 2016 based on the ZACPI Index (FXTOP, 2016).

Thirty-one districts across the three provinces, including 30 agricultural practices, were described (Table 8.2). Agriculture is primarily livestock-orientated, with wool and sheep present in all districts, cattle in 29 districts, and milk and cream in 27 districts.

Table 8.2: Important agricultural activities in 30 districts in the study area.

Province	District	Animal products				Animal sales							Field crops				Horticulture														
		Eggs	Milk and cream	Mohair	Wool	Cattle	Chickens	Game	Goats	Ostriches	Pigs	Sheep	Barley	Lucerne	Maize grain	Wheat	Cabbages	Lemons	Naartjies	Onions	Oranges	Peaches	Pears	Pineapples	Potatoes	Table grapes	Tomatoes	Wine grapes	Pumpkins	Carrots	Apples
Eastern Cape	Aberdeen	1	1	1	1	1		1	1	1	1	1		1	1	1		1	1		1				1		1				
	Adelaide		1	1	1	1		1	1			1		1	1				1		1										
	Albany		1	1	1	1		1	1	1		1		1	1						1			1	1		1				
	Bedford		1	1	1	1		1	1	1	1	1		1	1																
	Cradock		1	1	1	1		1	1	1	1	1		1	1	1			1		1				1						
	Fort Beaufort	1	1	1	1	1	1	1	1			1		1		1		1	1		1										
	Graaff-Reinet		1	1	1	1		1	1	1	1	1		1	1						1			1							
	Hofmeyr		1	1	1	1		1	1			1		1	1						1										
	Jansenville		1	1	1	1		1	1	1		1		1																	
	Middelburg		1	1	1	1		1	1		1	1		1	1	1									1						
	Molteno		1		1	1						1			1																
	Pearston			1	1	1		1	1	1		1		1																	
	Queenstown	1	1	1	1	1	1	1	1		1	1		1	1										1						
	Somerset East		1	1	1	1	1	1	1	1		1		1	1	1									1						
	Sterkstroom	1	1	1	1	1	1		1			1		1																	
	Steynsburg		1	1	1	1		1			1	1		1	1																
	Tarka[stad]		1	1	1	1		1	1			1		1	1																
	Venterstad				1	1		1	1			1		1																	
	Victoria East		1	1	1	1						1		1	1	1									1		1				
Northern Cape	Carnarvon		1		1	1		1	1			1			1																
	Colesberg		1		1	1	1	1	1			1			1																
	Fraserberg		1		1	1			1			1			1	1															
	Noupoort		1		1	1						1																			
	Richmond		1		1	1		1	1			1																			
	Sutherland		1		1				1			1	1																		
	Victoria West		1		1	1		1	1			1			1					1											
	Williston				1	1			1			1																			
Western Cape	Beaufort West		1		1	1				1	1	1													1						
	Ceres	1	1		1		1			1		1	1			1	1			1	1	1	1		1	1	1	1	1	1	1
	Laingsburg		1		1	1	1			1		1	1			1	1					1				1		1			
	Prince Albert		1		1	1	1			1	1	1			1	1				1		1	1		1			1			

The total GFI of the region is just over five billion rand (R 5006 million), of which 48% is from the Eastern Cape, 10% from the Northern Cape, and 41% from the Western Cape. The sale of animals accounts for 39% of GFI, animal products 19%, field crops 4%, and horticultural crops 38%. These rankings are relatively consistent across the three provinces (Figure 8.2), except for Horticultural production in the Western Cape. The GFI of districts varies considerably, with the Ceres district being the highest and Victoria West the lowest (Table 8.2).

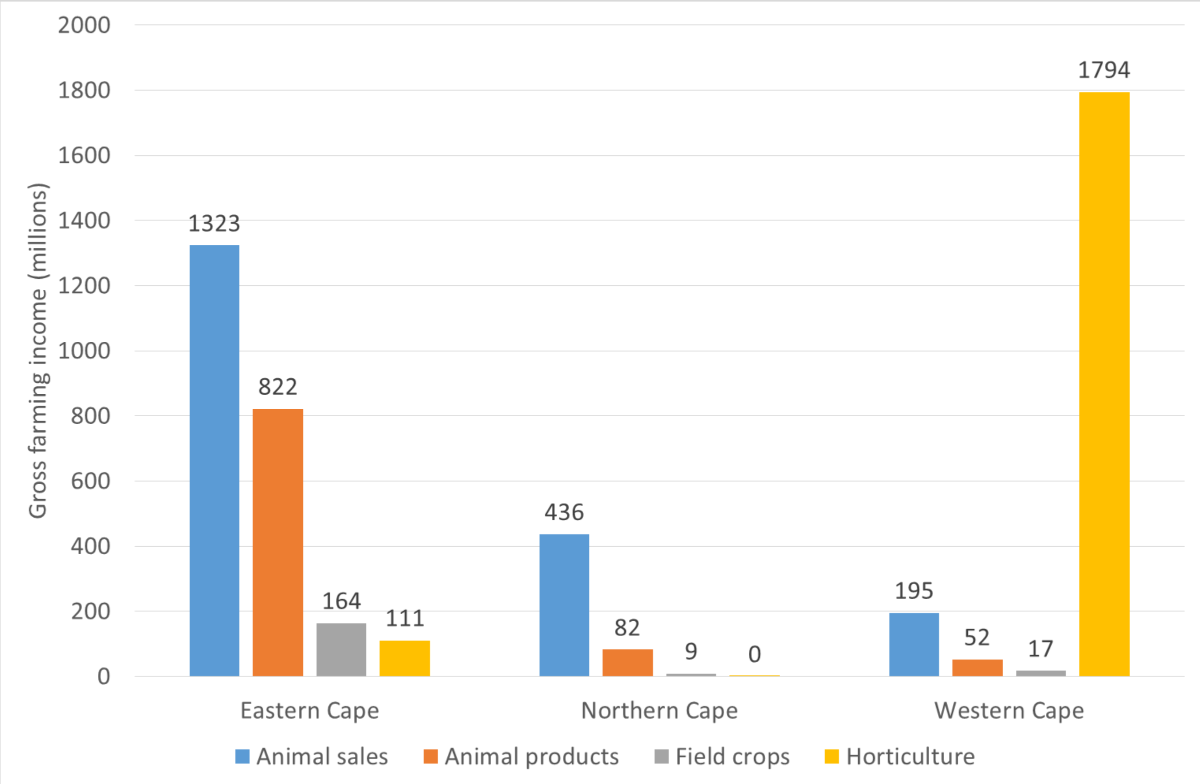

Figure 8.2: Gross farming income (2007 values adjusted to 2016 values) in millions of Rands of major agricultural products in the three provinces in the study area (StatSA, 2007a, 2007b, 2007c).

Table 8.3: Gross farming income (millions of Rands) of four main classes of agricultural products for all districts within the study area (StatSA, 2007a, 2007b, 2007c).

District	Animal sales	Animal products	Field crops	Horticulture	Grand Total
Ceres	21.4	24.3	14.5	1774.8	1834.9
Cradock	209.9	169.0	69.6	15.4	464.0
Queenstown	166.8	94.1	18.0	8.0	286.9
Aberdeen	112.5	75.2	8.2	31.5	227.4
Somerset East	116.8	93.7	7.0	0.3	217.8
Albany	85.7	67.3	1.4	21.5	175.9
Graaff-Reinet	112.3	47.9	6.2	2.5	169.0
Middelburg	106.7	28.6	20.3	0.8	156.5
Jansenville	61.6	80.7	0.9		143.1
Carnarvon	124.1	8.3	1.4		133.9
Bedford	59.4	67.8	5.8		133.0
Beaufort West	87.7	17.7		9.2	114.7
Victoria West	81.3	25.4	0.2	0.2	107.1
Adelaide	59.1	32.4	0.6	0.9	93.0
Tarka[stad]	58.0	16.4	2.2		76.6
Colesberg	58.5	12.0	3.7		74.3
Prince Albert	47.7	6.6	0.8	7.6	62.8
Williston	55.5	3.9			59.4
Fraserberg	41.1	9.2	3.7		54.0
Laingsburg	38.4	3.6	1.8	2.9	46.7
Richmond	31.8	13.2			45.0
Fort Beaufort	16.4	5.4	1.1	20.8	43.7
Steynsburg	32.4	8.2	1.8		42.5
Molteno	34.1	6.8	0.3		41.2
Hofmeyr	18.0	7.8	10.0	0.8	36.6
Sterkstroom	27.0	8.5	0.9		36.4
Sutherland	30.2	3.9	0.0		34.1
Pearston	23.7	8.9	1.3		33.9
Venterstad	20.4	2.3	1.2		23.9
Noupoort	13.8	5.9			19.7
Victoria East	2.4	0.8	7.0	8.2	18.4
Grand Total	**1955.0**	**955.9**	**189.8**	**1905.5**	**5006.1**

Forty-five percent of all income derives from extensive animal production (Table 8.4). Of this, 46% is from the sale of sheep, 26% from the sale of cattle, 16% from the sale of wool, and the remaining 12% from mohair, goats, and game.

Fifty-five percent of all income derives from intensive agricultural activities (Table 8.5). Of this, 24% is from apple sales, which occurs exclusively in the Western Cape. Other important contributors (between 10 and 20%) are pears, milk and cream, and onions.

Table 8.4: Gross farming income (in millions of Rands) from extensive livestock production activities across the three provinces within the study area (StatSA, 2007a, 2007b, 2007c).

Product	Eastern Cape	Northern Cape	Western Cape	Grand Total
Sheep	480.7	389.5	163.9	1034.0
Cattle	525.9	32.1	10.6	568.6
Wool	256.9	76.8	26.9	360.6
Mohair	126.2			126.2
Goats	82.7	9.0		91.8
Game	79.7	5.6		85.3
Grand Total	**1552.0**	**513.0**	**201.4**	**2266.4**

Table 8.5: Gross farming income (in millions of Rands) from intensive agricultural production activities across the three provinces in the study area.

Product	Eastern Cape	Northern Cape	Western Cape	Grand Total
Apples			647.2	647.2
Pears			468.0	468.0
Milk and cream	417.0	5.0	20.0	442.1
Onions		0.2	372.0	372.2
Peaches			146.6	146.6
Potatoes	21.0		98.3	119.3
Lucerne	91.7			91.7
Ostriches	71.3		16.4	87.7
Pigs	80.2		0.2	80.4
Maize grain	63.2	7.4	0.7	71.2
Oranges	34.9		0.5	35.4
Eggs	21.7		5.3	27.1
Wheat	8.9	1.6	15.3	25.8
Tomatoes	23.0		0.4	23.5
Table grapes			21.8	21.8
Pineapples	19.2			19.2
Carrots			16.2	16.2
Wine grapes			14.4	14.4
Lemons	9.3			9.3
Cabbages			8.0	8.0
Chickens	2.8	0.2	4.1	7.2
Naartjies	3.4			3.4
Pumpkins			1.1	1.1
Barley		0.0	1.1	1.1
Grand Total	**867.7**	**14.4**	**1857.7**	**2739.8**

The Hunting Industry

The economic contribution from the hunting industry (R 85 million in 2016 prices) in the study area is probably underestimated in the data from the 2007 census because: a) there has been a significant increase in the hunting industry since 2007; and b) the census reports only on the number of animals sold, and does not consider on-farm income directly associated with hunting, notably accommodation.

To calculate the contribution of hunting to the economy of the study area, an estimate of the economic contribution of hunting (accommodation and animals) to the economy of South Africa was sourced, and the proportional contribution of each of the three provinces in the study area was calculated based on data from Department of Environmental Affairs (DEA, 2014), and the contribution of each of the three provinces for the portions within the study area were calculated by scaling linearly with area (Table 8.6).

The contribution of hunting (animals and accommodation) to the South African economy was R 1.5 billion in 2014 (DEA, 2014), which corrected for inflation is R 1.7 billion (FXTOP, 2016). As a comparison, the contribution of the entire value chain (including food, transport, crafts and curios, additional sight-seeing activities, permits, licensing fees, clothing, ammunition, hunting accessories, taxidermy and trophy shipping fees), has been estimated at R 6.2 billion (Kings, 2013) which corrected for inflation is R 7.25 billion.

In summary, the contribution of hunting is likely higher (R 189 million) than was estimated using the census data (R 85 million).

Table 8.6: Contribution of hunting to economies of the three provinces in the study area (DEA, 2014).

	Eastern Cape	**Northern Cape**	**Western Cape**	**Total**
Proportional contribution to hunting economy in SA (DEA, 2014)	21%	8%	0.4%	
Proportion of province within study area	41%	31%	17%	
Contribution of activities directly associated with hunting to economy within the study area	R 1.7 billion x 0.21 x 0.41 = R 146 million	R 1.7 billion x 0.08 x 0.31 = R 42 million	R 1.7 billion x 0.004 x 0.17 = R 1.1 million	R 189.1 million

8.5.3.4 Land use changes

Following the main agricultural trends in North America, Europe and Australia, land use changes are also taking place in South Africa. To some extent land use change is being driven by investors purchasing farmland as a financial investment without necessarily intending to farm it productively. Research by Wessels and Willemse (2013) in the South-Eastern Nama Karoo confirmed that purchasers do indeed buy farmland at prices much higher than the actual productive value of land, primarily as an investment. Motivated by the sheer beauty and natural magnificence of the land, which they believe will increase in value as natural land becomes scarcer; they believe that purchasing land is a sound investment for the future.

The perception that the deeply rural 'platteland' areas such as the study area are economically dwindling and under pressure, may be somewhat misplaced considering the on-going investment by relatively wealthy urban people buying land for investment purposes. According to Wessels and Willemse (2013), although life is still rewarding in these areas, the economic value of production is exported to the cities and sold at a relatively low cost, whereas services are imported at a premium, creating relative impoverishment in rural areas. The scarcity of farmland and the desire of many city dwellers for a more relaxed rural lifestyle that is closer to nature combine to produce the significant and steady increases in farm prices seen in recent years.

The significance of natural beauty as a motive for investment in buying farms in remote rural areas is very important when considering the impact of SGD on agriculture. Although not directly linked to agricultural production, it highlights the important link to other Chapters of this assessment, namely Atkinson et al. (2016), Seeliger et al. (2016) and Oberholzer et al. (2016).

8.5.3.5 Farm management practices

Farm management practices in the study area reflect resilience in the face of an increasingly globalised market for agricultural products. Since the withdrawal of market protection and extensive subsidies to the commercial agricultural sector prior to 1994, the majority of farmers in the study area have adapted their practices and re-aligned their enterprises in response to emerging realities and new opportunities. As a result of a combination of low product income, high input costs and interest rates as well as the present disaster drought, some farmers in the study area are currently facing the problem that their farms cannot produce enough net income to allow their enterprises to thrive, or even survive. Many farmers have adapted or switched their enterprises in recent decades in response to new market opportunities. These changes have included incorporating or switching to game farming (see next section for a discussion in this regard), adding on-farm value to livestock products, or diversifying in other ways such as poultry or eco-tourism.

8.5.3.6 Game farming

Right of ownership lays the foundation for wild animals to become a financially viable alternative land use option in South Africa. However, sweeping structural changes in the rest of the agricultural sector also made a notable contribution towards the development of the local wildlife industry. South Africa and especially the study area, is resource poor compared with major agriculture producing regions such as Europe and the Americas.

As explained above, many commercial farmers whose operations focussed on conventional agricultural enterprises face severe financial challenges. Since 1995 South African farmers have been obliged to compete in a global market for agricultural products, despite having access to poorer resources than their counterparts in other parts of Africa and on other continents. This resulted in lower prices for agricultural produce whilst at the same time being exposed to the subsidised dumping of agricultural surpluses from other, better endowed countries. Simultaneously, other structural and environmental changes also forced farmers to re-assess their land use practices. These included deregulation of the agricultural sector immediately prior to 1994, followed by a subsequent decline in political power of farmers and (associated with this) the successive weakening of financial support from government, the extension of labour legislation to the agricultural sector, and the land reform process. Broader structural changes in the economy also increased the cost of doing business. Furthermore, on-going loss of productivity and climate change have had negative effects on the agricultural sector.

As a result, in the early 1990s, the pioneers of private game ranching started to explore alternative land use options in the form of wildlife ranching. Game ranching – initially primarily valued as a means of satisfying the personal needs of landowners, their families and acquaintances – rapidly changed when conservation, profit and sustainability of wildlife production become the main drivers of transformation. The result is what is regarded by many as one of the greatest agricultural transformations in history. Most land utilised for game production is also farmed with domestic livestock. Today South Africa boasts the largest privately owned wildlife industry in the world (Cloete et al., 2015).

The wildlife ranching industry has four pillars: breeding, hunting, ecotourism and game products (Cloete et al., 2015). International tourism to South Africa has grown strongly since 1994, and has a strong focus on nature-related tourism. This includes wildlife and ecotourism activities, 4x4 and hiking trails, nature photography and corporate team building. Hunting tourism, especially biltong and trophy hunting has experienced exponential growth. All of these factors have driven transformation from traditional livestock farming to wildlife ranching, and make it an attractive option for farmers.

Table 8.7 below reflects the methods by which individuals have become game farm owners. It is notable that over 50% of the respondents confirmed they had converted a farm (either bought or inherited) from livestock or crops to game farming.

Table 8.7: Methods of acquiring a game farm (Cloete et al., 2015)

Category	**%**
Bought a livestock or crop farm and converted it into game farm	46
Bought an existing game farm	23
Bought a livestock or crop farm already partially converted to game farm	9
Inherit livestock and crop farm and converted it into game farm	6
Inherit livestock and crop farm already partially converted into game farm	8
Other	8

Although the Karoo has seen a sizeable increase in game ranching activities over the past decade, the region is not especially known for wildlife production and it is the least profitable of the game ranching regions in South Africa. Despite this, game ranching in the Karoo provides farmers there with a financially superior option to traditional livestock practices, especially cattle. A small game ranch in the Karoo (3 000 ha) has the ability to generate an estimated R 371/ha worth of economic output compared to an average of R 165 for conventional livestock farming. Return on Investment (ROI) will range from 2% to 2.8% depending on the size of the ranch.

8.6 Agricultural sensitivity evaluation

8.6.1 Agricultural characteristics of the study area

As previously described, all forms of agricultural production and agriculture-related activities like agricultural or farm tourism depend largely on the natural agricultural resources, including soil, vegetation, water, climate and the topography of the area. A negative impact on any of these resources will result in the loss of the agricultural production potential of the area.

8.6.2 The Impact System

SGD on agricultural production systems will primarily impact upon the rangeland veld resource and surface- and groundwater, upon which sustained production of livestock production depends (see Section 8.6).

Use of heavy prospecting equipment is anticipated to cause long-term damage to veld (and in some cases, to soils) where it moves over the landscape. Natural landscapes can be damaged when vehicles drive over them, and in arid areas the damage may take decades or longer to repair unless effective remedial action is taken. The degree of damage depends on various factors, including the type of vehicle, whether the vehicle is travelling straight or turning, the nature of the vegetation, and the number of times the vehicle drives over the same place (Redi, 2005; Schlacher, 2008). While the effect of vehicle tracks on system degradation appears not to have received adequate attention in the Karoo, it has been recognised as a problem in other arid ecosystems as it is recognised that vehicles can destabilise and compact soils, and increase water and wind erosion (Webb & Wilshire, 1983). In the Karoo biome it has been demonstrated that various types of physical impact, including ploughing, trampling by animals, and overgrazing, can lead to degradation (Keay-Bright, 2007). If such disturbances take place on highly erodible soils, the effect can be the formation of ‘badlands’, which are landscapes with deep, eroded gullies (Boardman, 2008). A lesser effect, but nevertheless of aesthetic and ecological significance, is the formation of semi-permanent tracks in the veld. The cumulative effect of these impacts will be a degree of fragmentation of the landscape (Drohan, et al., 2012).

In the absence of previous studies on the effects of vehicles on Karoo vegetation, it is difficult to recommend best-management practices. Nevertheless, impacts of SGD on agricultural landscapes have been well-researched elsewhere (Drohan, et al., 2012; Fink, 2015), and on the basis thereof, best-practice recommendations have been compiled for SGD in agricultural lands (Eshleman, 2013). This literature would suggest that an important mitigation would be to reduce the amount of traffic over the veld to a minimum. Additionally, wide tyres and light vehicles reduce the pressure on the ground and thus damage to vegetation and compaction of topsoil. Track formation (and hence erosion potential) can be reduced by avoiding repeated driving over the same ground.

During initial exploration phases (Scenario 1 – Exploration Only) there will be opportunity to monitor the effect of vehicles on Karoo soils and vegetation. Monitoring should take the form of describing traversed and non-traversed vegetation over time. Key factors that should be monitored are vegetation composition and the proportion of bare ground, and these should preferably take place in permanent quadrats with backup photographic monitoring. Invasive alien plants tend to thrive in disturbed areas, and as vehicle tyres provide an effective vector, monitoring should include assessing the spread and density of alien plant populations.

Construction of roads for the installation of other infrastructure for gas extraction and transportation of inputs, outputs and waste will fragment the agricultural landscape, remove significant amounts of land from production and render even larger areas unproductive through other effects, advance soil erosion and create opportunities for invasive species to colonise disturbed areas. Eshleman and Elmore (2013) recommend “minimising the amount and impact of new road and pipeline construction as much as practicable by (1) limiting the linear distance of new roads through strategic siting of operations; and (2) co-locating project infrastructure with current roads, power lines, and pipelines".

Water will be required for the fracking process, and will have to be transported to the sites from source (which may well be outside the Karoo, because the Karoo is generally water stressed). Large volumes of water will thus have to be transported by road.

The zones in which fracking will take place are likely to be so far down in the rock strata as to render the danger of pollution of groundwater used for agriculture of lesser significance. Nevertheless, leaking encasements could cause pollution of aquifers (see Hobbs et al., 2016). A proportion of the water that is used in the fracking process will be permanently lost, but what is returned or delivered to the surface will comprise both flowback (injected water contaminated with toxic fracking fluids ejected from the well in the days immediately following fracking) and produced water (a mixture of the originally injected water contaminated with toxic fracking fluids and so-called formation water, which is brackish water from the targeted shale). Indications from international experience are that between 15-80% of the water will be returned to the surface, where it will have to be contained before disposal or re-use, and leakages and pollution of surface and shallow groundwater by flowback and produced water will be a threat to agricultural production (Vengosh, 2014; Warner, 2013). Radioactivity of produced water is a serious threat to the agricultural environment (Vengosh, 2014). If ingredients similar to those that have been used elsewhere are utilised, the sites of containment dams may be rendered permanently contaminated by toxins, carcinogens and salts (Bamberger, 2012, 2014), with serious health implications for humans and animals.

Veld fires are relatively unusual in the Karoo because a) it is not a standard veld management practice and b) fuel loads are usually too low to allow it. However, veld fires do occasionally burn in the Karoo, particularly in the grassier eastern parts of the study area, and during periods of high rainfall, and are most frequently caused by lightning or accidentally by humans (du Toit, O'Connor, & van den Berg 2015). Fires pose a risk to human and animal life, and to infrastructure such as buildings and fences. Additionally, fires can destroy vegetation that would otherwise have been available as grazing. Longer-term effects include changes in species composition (notably the eradication of fire-intolerant shrub species), often resulting in a temporary change in vegetation structure from dwarf-shrubland to arid sparse grassland (du Toit et al., 2014). This effect is strongly exacerbated by grazing by livestock following the fire (du Toit et al., 2015), and veld should accordingly be rested for several years (probably between three and five) following a fire.

Usually, a naked flame is needed to ignite a veld fire. However, if the fuel is suitably dry then sparks or embers will suffice (Cheney & Sullivan, 2008). Sparks and embers may be emitted by machinery, tools, vehicles, cooking fires, and cigarettes, and there are recorded examples of these having caused veld fires in the Karoo (Cheney & Sullivan, 2008; du Toit et al., 2015; du Toit et al., 2014).

It is anticipated that the increased activity of people and machinery in the event of prospecting or drilling for gas will lead to an increased likelihood of fires in the Karoo, particularly during dry weather and if fuel loads are high. Although fracking poses a risk of increased incidence of fire in the Karoo, appropriate mitigation measures, including training on how to avoid igniting fires and how to extinguish fires, and the provision of equipment to immediately extinguish fires should one ignite, should reduce the risk of fire significantly. Should a fire be ignited during the process of SGD, farmers or landowners should be compensated for the destruction of property, including grazing resources and the loss of production from rested veld, which will typically require a decade to recover its productivity and stability.

The influx of skilled workers during the exploration and production phases will create limited market opportunities for agricultural products. Security considerations could oblige farmers to remove livestock from the areas surrounding wellpads, although these areas will only occupy a very small percentage of existing agricultural land. SGD will probably create limited employment opportunities for local people (see van Zyl et al., 2016) meaning that local farm labour availability should not be affected to a great degree.

8.6.3 Agricultural Sensitivity

Natural agricultural resources consist of soil, climate, natural vegetation and water. Agricultural production in the study area strongly relies on these resources for continued and sustained agricultural production. A negative impact on any of these natural agricultural resources will result in the loss of the agricultural production potential of the area. To obtain an indication on the vulnerability of the study area to the potential impact of the SGD on agricultural production, a combined agricultural sensitivity index was developed which takes into consideration the vulnerability of the basic natural agricultural resources, including climate. To determine the sensitivity of agriculture within the study area to the potential impacts of SGD, an agricultural sensitivity index was developed by DAFF (Lindeque, 2016).

As a result of the authors being limited to using only existing data sources, and the absence of resources to undertake further research relating to the relevant topics; accessing reliable available data sources at national level to be integrated into an Agricultural Sensitivity Map presented something of a challenge. As the study area covers three provinces, it was necessary to use national datasets to ensure data availability for all the quaternary catchments of the study area. In some cases, detailed data was available for the Western Cape part of the study area, but not for the Eastern Cape areas. In order to ensure uniformity of the data presented, this more detailed data could not be used for developing the sensitivity maps. Furthermore, in the light of comments received by reviewers of this assessment, it was decided to not make use of certain data sources (for example the borehole dataset) due to the incompleteness of the data.

The Agricultural Sensitivity Index aimed to demarcate a four tier approach pertaining to the sensitivity for the study area in relation to agricultural production potential and to include both cultivation and rangeland related aspects. The four tiers are defined as Very High Sensitivity; High Sensitivity; Moderate Sensitivity; Low Sensitivity. The sensitivity index rating was based per quaternary catchment located within the study area. The following input data sets were used to calculate the sensitivity index:

- Land capability 2016;
- Grazing capacity 2016;
- Cultivated Fields 2015;
- Irrigated Areas 2016;
- Surface water
    - Rivers
    - Dams.

Each of the Agricultural Sensitivity Index Input factors (see Table 8.8) was mapped on a quaternary catchment scale and data sets were classified using sensitivity values between 1 and 4 (4 being the most sensitive to potential impacts by SGD) (Figure 8.8). These values were equally weighted when added to a single agricultural sensitivity rating.

Table 8.8: Description of factors contributing towards agricultural sensitivity index.

Agricultural Sensitivity Index Input factors	Description
Soil, Climate & Terrain (combination of factors provides Land Capability Classes)	The newly 2016 refined national land capability data set was used. This data set was derived on a 1:50 000 scale and based on an evaluation of the land capability for the area concerned for possible agricultural production. It does not take any crop suitability into consideration but focusses on the capability of the area concerned pertaining to soil, climate and terrain capability. The national land capability evaluation is classified into 15 land capability classes with 15 being the highest (Very High land capability evaluation rating) and 1 being the lowest (Very Low land capability evaluation rating). The study area's highest land capability classification is 10. The sensitivity index was therefore based on an evaluation of the range of applicable land capability evaluation classes (1 – 10) and not on the complete national land capability evaluation classification range of values. The dominant (majority value) per quaternary catchment was used to determine

Agricultural Sensitivity Index Input factors	Description
	the applicable Land Capability Evaluation Sensitivity Index value for the catchment (Figure 8.3). Four-Tier classification: Land Capability Evaluation Sensitivity Index: Very High Land capability evaluation classes 8 - 10 High Land capability evaluation classes 6 - 7 Moderate Land capability evaluation classes 3 - 5 Low Land capability evaluation classes 1 - 2
Natural vegetation (referred to as Grazing Land)	The newly derived grazing capacity potential for South Africa was used as input data set to determine the potential for the study area pertaining to grazing. This data set is to replace the 1993 Grazing Capacity Regulation under the Conservation of Agricultural Resources Act, 43 of 1983. The range of Grazing capacity potential values for the study area ranges from 2.5 Ha/LSU[1] – 140 Ha/LSU. The dominant (majority value) per quaternary catchment was used to determine the applicable Grazing Capacity Sensitivity Index value for the catchment (Figure 8.4). 4-Tier classification: Grazing Land Sensitivity Index Value (Ha/LSU): Very High 2.5 – 10 Ha/LSU High 11 – 30 Ha/LSU Moderate 31 – 60 Ha/LSU Low 61 – 140 Ha/LSU
Surface water (River Sensitivity Index as well as Dams Sensitivity Index)	Surface water is represented by the occurrence of the water source within the quaternary catchment that includes rivers, streams and open water (dams). The latest available river data set obtained from the Department of Water and Sanitation (DWS) was used as the input data set. The total length of the river, in kilometre, within the quaternary catchment was used as the basis for the calculation of the range within the complete study area, which was again then further reclassified into the 4-tier River Sensitivity Index. The more surface water present in a catchment, the more sensitive the area towards SGD impacts. As is the case with boreholes, data relating to the actual yield of water for agricultural purposes extracted from the river concerned (as well as the volume of available water and data relating to the sustainability of the river for the supply of water) would have greatly assisted in conducting a more accurate and in-depth evaluation of the availability of water as well as use within the study area per quaternary catchment.
Irrigated land	The study area in question mostly resides in areas with a limited annual rainfall, resulting in the conclusion that areas under irrigation, due to the availability of water should be assessed against these areas' agricultural sensitivity. An assessment was therefore made pertaining areas under irrigation per quaternary catchment. There is currently no data layer indicating areas under irrigation and the approach followed was based on an analysis of available data layers as well as indigenous knowledge of the area. Use was made of the Land cover 2000 data layer where in irrigated areas were included in the legend. This layer was however complemented by the 2015 cultivation data layer where pivot irrigated areas are specifically classified. This was further supported by the presence of a water source as well as the intensity of cultivated areas. The total irrigated area, in hectares, were calculated per quaternary catchment, to determine the range (min / maximum areas) within the study area, where after these areas were reclassified into the four-tier Irrigation Sensitivity Index using a Geometrical Interval approach (Figure 8.7).

[1] LSU: Large Stock Unit, equivalent to one adult cow.

Agricultural Sensitivity Index Input factors	Description
	Four-Tier classification: Irrigation Sensitivity Index Values (ha). Very High 803 – 4077 ha High 154 – 802 ha Moderate 25 – 153 ha Low 0 – 24 ha
Cultivated Fields	The 2015 release of the national Field Crop Boundary data set per province was used as input data set. This data set demarcate all cultivated areas in South Africa and is done on a 1:10 000 or finer scale using SPOT satellite imagery as well as the latest available aerial photography. The total area, in hectares, used for cultivation (irrespective whether it is rain-fed or irrigated, commercial or subsistence) were calculated per quaternary catchment, to determine the range (min/maximum areas) within the study area, where after these areas were reclassified into the four-tier Agricultural Cultivation Sensitivity Index using a Geometrical Interval approach (Figure 8.6). 4-Tier classification: Agricultural Cultivation Sensitivity Index Value (ha): Very High 1075 – 4077 ha High 1074 – 272 ha Moderate 271 – 58 ha Low 0 – 57 ha
Surface water, rivers	The latest available river data set obtained from the DWS was used as input data set. The total length of the river, in kilometre, within the quaternary catchment was used as basis for the calculation of the range within the complete study area which was again then further reclassified into the four-tier River Sensitivity Index (Figure 8.5). As is the case with the boreholes the actual yield/available of water for agricultural purposes extracted from the river concerned (as well as the sustainability of the river for the supply of water) would have greatly assisted in conducting a more accurate and in-depth evaluation of the availability of water as well as use within the study area per quaternary catchment. Four-Tier classification: River Sensitivity Index Values (km): Very High >201 High 101 - 200 Moderate 51 - 100 Low 0 - 50
Surface water, dams	The latest available dam data set obtained from the DWS was used as input data set. The area, in hectare taken up by the dam, as a percentage of the quaternary catchment, was calculated to determine the range within the study area, which was then reclassified into the four-tier index determining the Dam Sensitivity Index. As is the case with boreholes and rivers the availability and use of the water for agricultural purposes and extraction from the dam would have given a more accurate evaluation but this information is not available. Four- Tier classification: Dams Sensitivity Index Values (%): Very High 14 – 29% (there were no values between 4.1 – 13.9%) High 2 – 4% Moderate 1 - 1.9% Low <1%

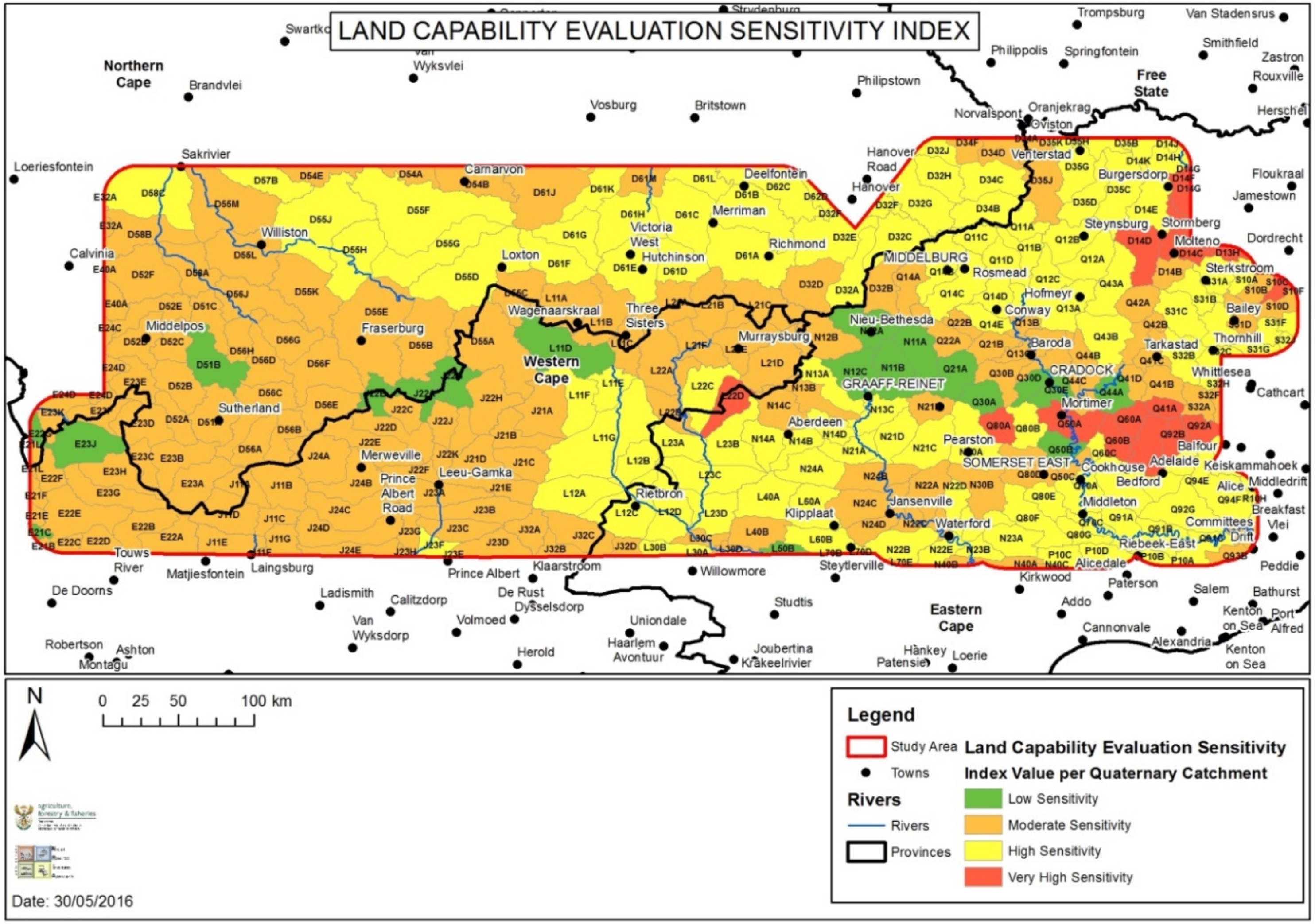

Figure 8.3: Land capability sensitivity index value per quaternary catchment (Collett, 2016d).

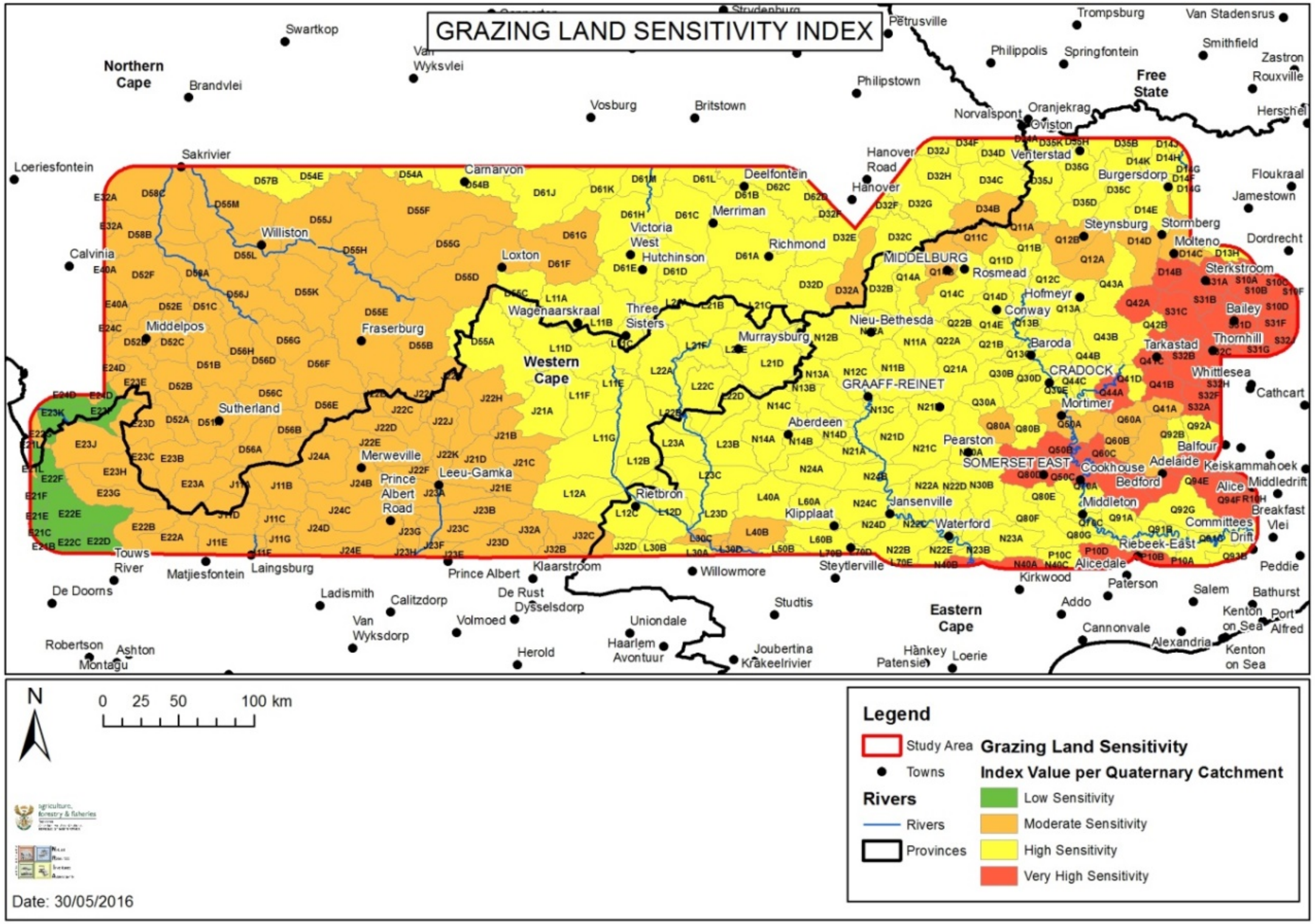

Figure 8.4: Grazing land sensitivity index (Collett, 2016c).

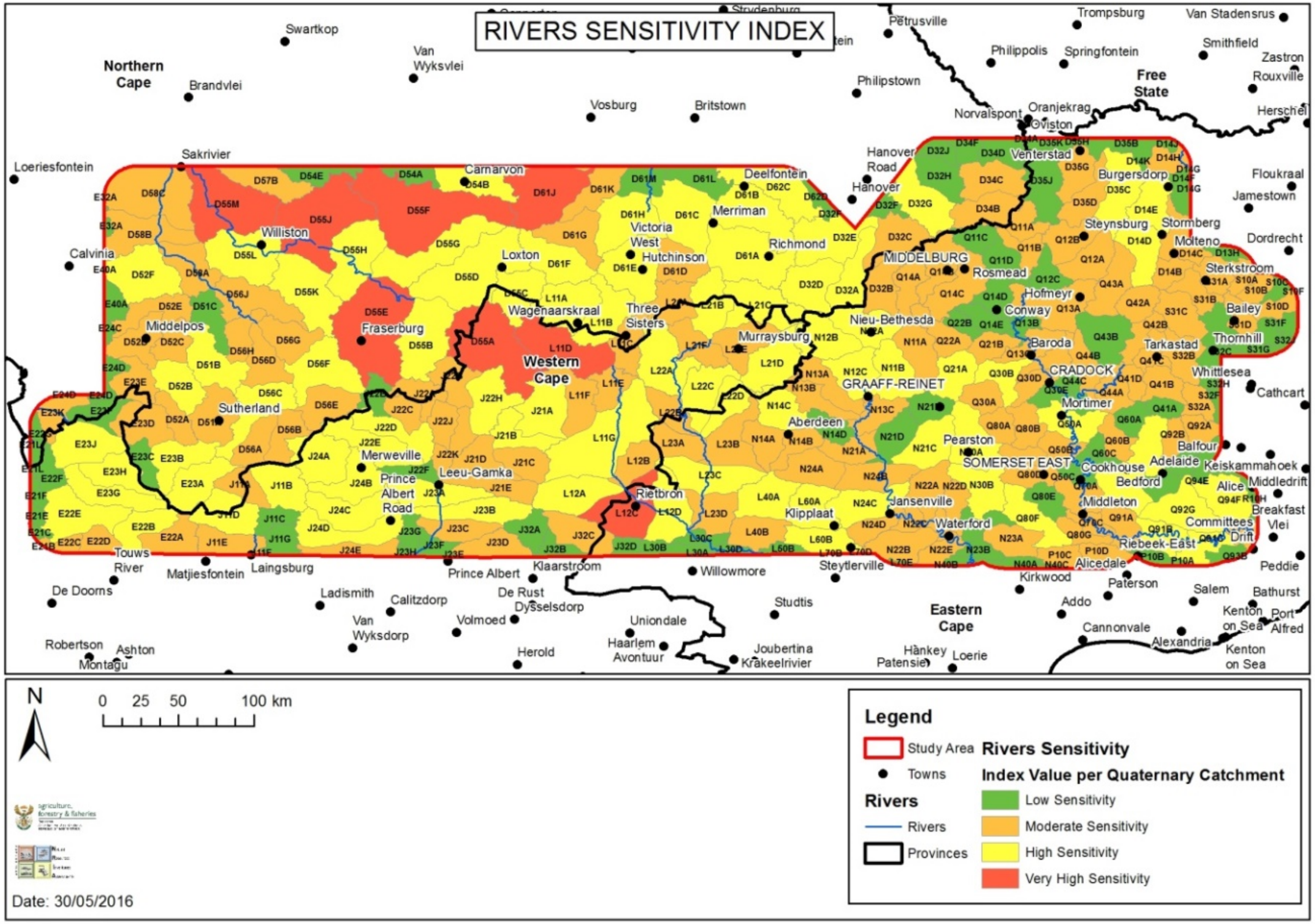

Figure 8.5: River sensitivity index per quaternary catchment (Collett, 2016f).

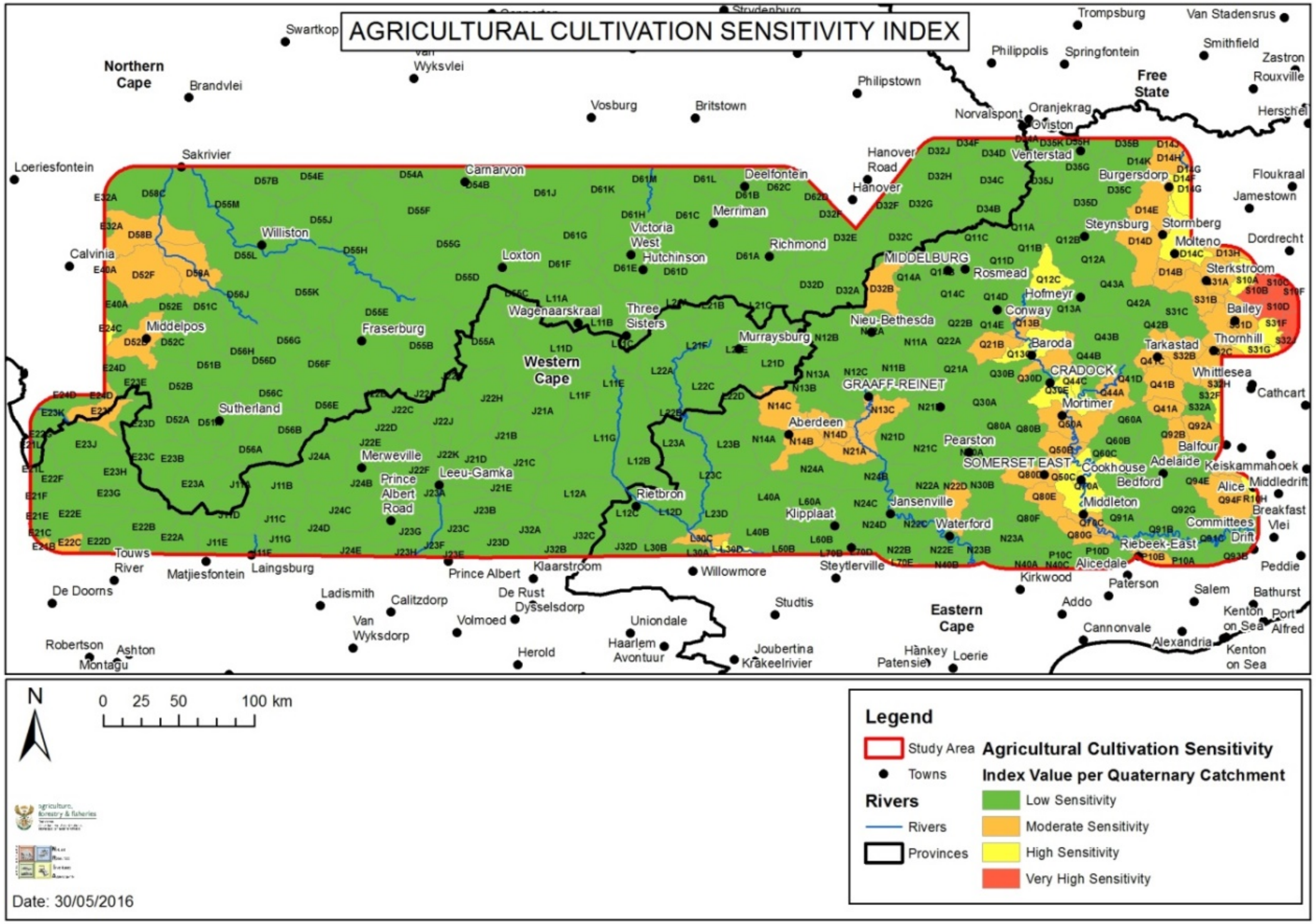

Figure 8.6: Agricultural cultivation sensitivity index value per quaternary catchment.

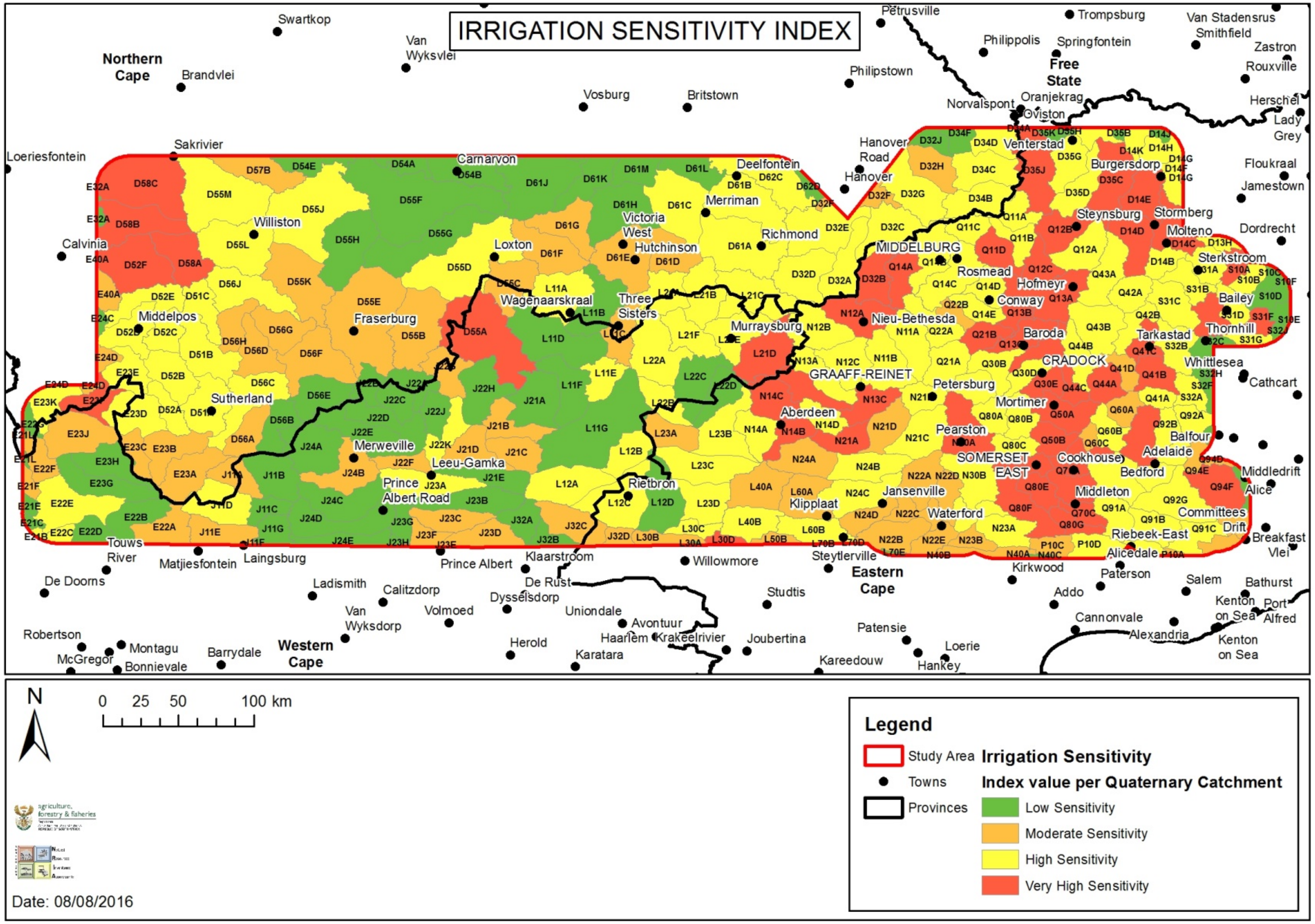

Figure 8.7: Agricultural Irrigation Sensitivity (Collett, 2016b, 2016e, 2016g).

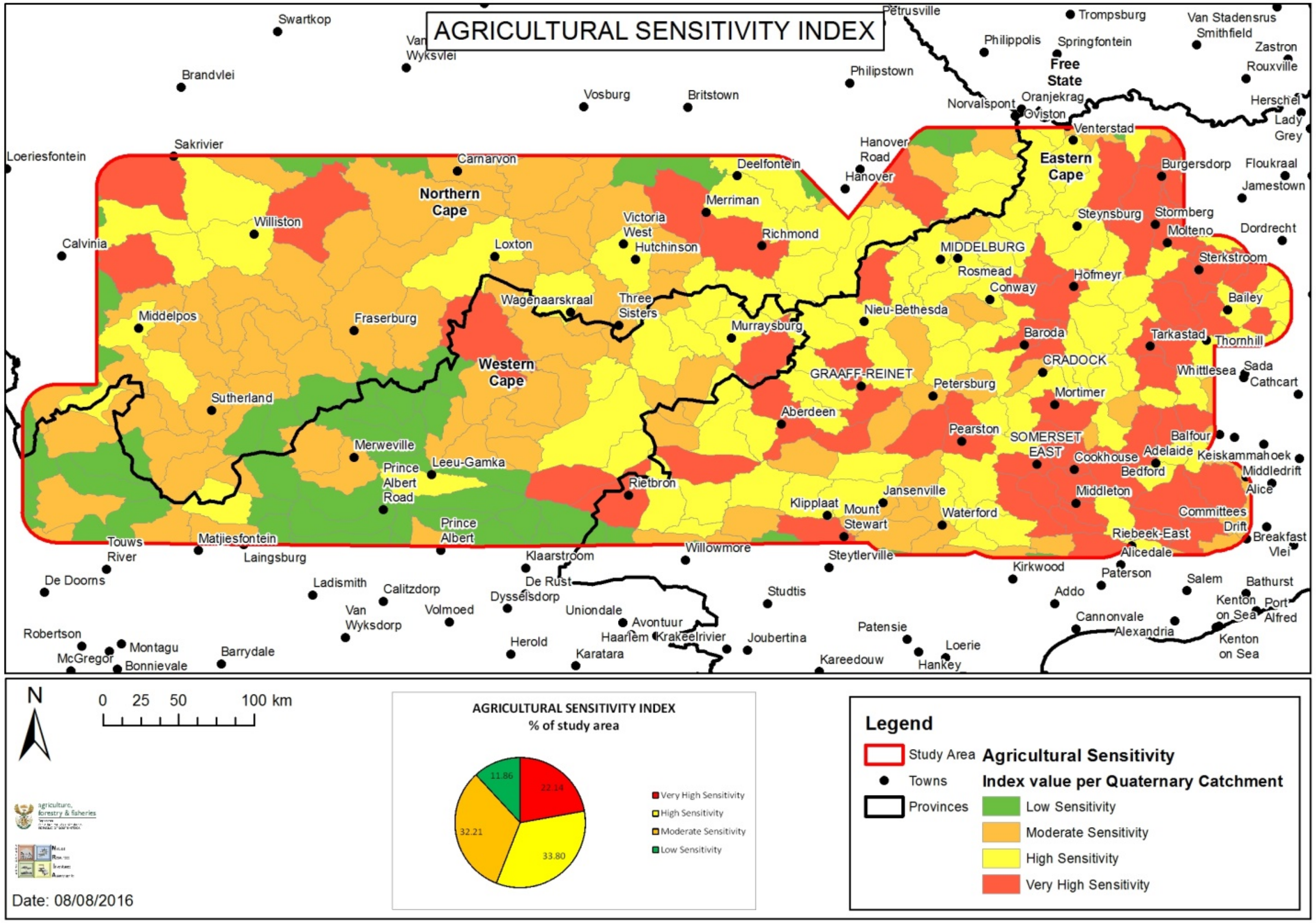

Figure 8.8: Agricultural Sensitivity Map for the study area per quaternary catchment (Collett, 2016a).

The potential maximum value for the agricultural sensitivity index is 24 (4 X 6 input datasets). However the range obtained for the agricultural sensitivity was from 6 – 19. Due to the fact that the land capability evaluation values as well as the grazing capacity values were classified according to the range within the study area, it was decided to reclassify the agricultural sensitivity range based on the values obtained (6 – 19) to the four-tier classification of agricultural sensitivity classes based on a natural interval approach (see Table 8.9 and Table 8.10, and Figure 8.9).

Table 8.9: Four-tier classification of Agricultural Sensitivity Index values

4-Tier classification:	Agricultural Sensitivity Index values:
Very High	16 - 19
High	14 – 15
Moderate	11 – 13
Low	6 - 10

Table 8.10: Percentage (%) land coverage per each Agricultural Sensitivity Classification.

Agric Sensitivity class	Total ha	% per catchment
Very High Sensitivity	3 800 904.94	22.14
High Sensitivity	5 803 508.82	33.80
Moderate Sensitivity	5 530 762.60	32.21
Low Sensitivity	2 035 981.18	11.86
Total	**17 171 157.54**	**100**

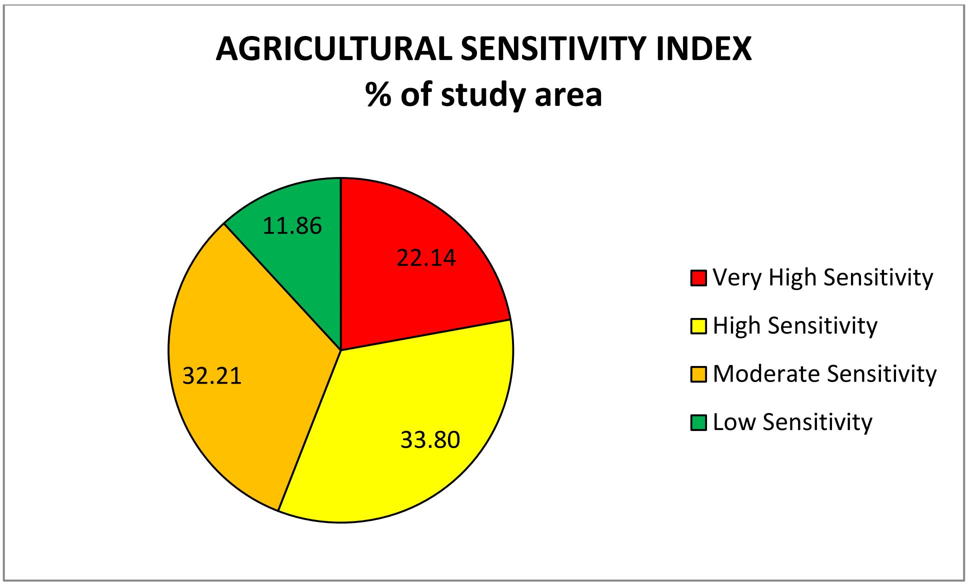

Figure 8.9: Agricultural Sensitivity Index reflecting percentages of the study area.

8.6.3.1 Potential negative impacts

Table 8.11 below describes the potential degree of agricultural impacts in relation to their location, extent, time scale and overall intensity for the four scenarios.

The main agricultural impact of SGD on agriculture will be the intrusion of industrial and mining type of activities and facilities into the study area, altering the rural and agricultural dominated character of the Karoo and affecting the natural agricultural resources base the agricultural sector depend upon for future sustainable production of agricultural goods and fibre.

Table 8.11: Potential agricultural impacts

Agricultural impact (Detail risk assessment in Table 8.12**)**	**Agricultural Sensitivity Index Zone**	**Scenario**	**Extent**	**Timescale**	**Intensity**
The intrusion of industrial and mining type activities and facilities into the study area, altering the rural and agriculturally dominated character of the Karoo and affecting the natural agricultural resources base that the agricultural sector depends upon for future sustainable production of agricultural goods and fibre.	Very High Sensitivity Zone	**Scenario 0:** Reference Case	None	None	None
		Scenario 1: Exploration Only	Local	Long term	Severe
		Scenario 2: Small Gas	Local	Long term	Severe
		Scenario 3: Big Gas	Regional	Long term	Extreme
	High Sensitivity Zone	**Scenario 0:** Reference Case	None	None	None
		Scenario 1: Exploration Only	Local	Long term	Substantial
		Scenario 2: Small Gas	Local	Long term	Severe
		Scenario 3: Big Gas	Regional	Long term	Extreme
	Moderate Sensitivity Zone	**Scenario 0:** Reference Case	None	None	None
		Scenario 1: Exploration Only	Local	Long term	Substantial
		Scenario 2: Small Gas	Local	Long term	Substantial
		Scenario 3: Big Gas	Regional	Long term	Severe
	Low Sensitivity Zone	**Scenario 0:** Reference Case	None	None	None
		Scenario 1: Exploration Only	Local	Long term	Substantial
		Scenario 2: Small Gas	Local	Long term	Substantial
		Scenario 3: Big Gas	Regional	Long term	Substantial

8.7 Risk assessment

The risks to agricultural production in the study area are assessed in the context of four anticipated scenarios:

Scenario 0: Reference Case

Agricultural production systems in the Karoo are relatively stable, and demand for agricultural products from the region will continue to grow under virtually all future economic development scenarios. The productive capacity of the rangeland has not been affected to a great degree by degradation, and most rangeland is managed sustainably. A significant number of farmers have adopted, or are moving to less environmentally damaging production systems.

With the exception of an area surrounding Beaufort West, water resources are adequate for sustained livestock production and the associated low-density farm population.

The study area is affected by cyclical changes to weather patterns, resulting in a relatively high level of climate variability and afflicting agricultural production with severe cyclical droughts associated with the El- Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). Climate change projections for the area show an increase peak and average temperatures, with some impact upon livestock production. In the winter rainfall area in the far west of the designated area winters are likely to become shorter and drier as a result of the predicted pole-wards shift of the rain-bearing cyclonic systems. There would also be an increase in extreme events such as droughts and floods. However, most of the designated area receives the majority of its rainfall in the summer and late summer. Future rainfall predictions for these areas are characterised by a greater degree of uncertainty, with some models indicating significant increases in overall precipitation.

Scenario 1: Exploration Only

In addition to the anticipated impacts of the Reference Case, the movement of heavy prospecting equipment through the landscape will impact on the soil and vegetation. Seismic exploration would entail traversing watercourses and other ephemeral water bodies. This will result in physical disturbance such as compaction and surface disturbance within watercourses and catchments areas, which is likely to diminish infiltration and increase runoff. It is likely that this will result in higher rates of runoff, soil erosion and sedimentation. Impacts of this nature have been described as associated with wellpad and pipeline construction in shale and coal seam gas exploration and production in the USA and Australia (Brantley, 2014; Cavaye et al., 2016).

Scenario 2: Small Gas

In addition to the cumulative effects from the previous two scenarios, the Small Gas scenario will include more extensive prospecting and the construction and installation of infrastructure within designated areas. Within these areas this will necessitate removal of natural vegetation and disturbance of drainage and infiltration systems in the course of construction of roads, wellpads, water storage facilities, accommodation and other facilities. The mitigation measures required will be similar to those described in the Exploration Only scenario, albeit on a wider scale and over a longer period of time.

Land users will incur higher management costs to maintain optimal use of their grazing resources and to minimise losses from wandering of flocks, injury, contamination or theft with the presence of contaminated waste water reservoirs on their land and in the face of on-going movement of people and equipment through the landscape (Cavaye et al., 2016).

Scenario 3: Big Gas

Should the reserves of shale gas prove to be bounteous and should the market price provide sufficient economic motivation and justification, very extensive prospecting (with more extensive impact upon the veld) will be followed by construction and installation of infrastructure over large areas of the Karoo. The cumulative effects described for the Small Gas scenario will occur on landscape scale. Construction roads will be more heavily used and the dangers of waste water spillages and leakages into groundwater resources will increase exponentially.

A risk assessment matrix is provided in Table 8.12 below, including risk levels ‘without’ mitigation and ‘with’ mitigation. The table is based on the description of the four scenarios and the identification of agricultural sensitive zones in the previous section. These are combined with the potential intensity of the agricultural impacts (derived from Table 8.11), and the likelihood (probability) of the impact occurring, to provide an overall risk evaluation.

Table 8.12: Risk assessment matrix.

Impact	Agricultural sensitivity zone	Scenario	*Without mitigation*			*With mitigation*		
			Consequence	**Likelihood**	**Risk**	**Consequence**	**Likelihood**	**Risk**
The intrusion of industrial and mining type of activities and facilities into the study area, altering the rural and agricultural dominated character of the Karoo and affecting the natural agricultural resources base the agricultural sector depend upon for future sustainable production of agricultural goods and fibre.	Very high agricultural sensitivity	Reference Case	Moderate	Not likely	Low	Slight	Extremely unlikely	Very low
		Exploration Only	Substantial	Likely	Moderate	Moderate	Very unlikely	Low
		Small Gas	Severe	Likely	High	Substantial	Not likely	Moderate
		Big Gas	Severe	Very likely	Very high	Severe	Likely	High
	High agricultural sensitivity	Reference Case	Moderate	Not likely	Low	Slight	Extremely unlikely	Very low
		Exploration Only	Moderate	Likely	Moderate	Moderate	Very unlikely	Low
		Small Gas	Moderate	Likely	Moderate	Substantial	Not likely	Low
		Big Gas	Severe	Likely	High	Substantial	Likely	Moderate
	Moderate agricultural sensitivity	Reference Case	Slight	Very unlikely	Very low	Slight	Extremely unlikely	Very low
		Exploration Only	Moderate	Not likely	Low	Slight	Extremely unlikely	Very low
		Small Gas	Substantial	Likely	Moderate	Moderate	Not likely	Low
		Big Gas	Severe	Likely	High	Severe	Likely	Moderate
	Low agricultural sensitivity	Reference Case	Slight	Extremely unlikely	Very low	Slight	Extremely unlikely	Very low
		Exploration Only	Moderate	Not likely	Low	Slight	Extremely unlikely	Very low
		Small Gas	Substantial	Likely	Moderate	Moderate	Not likely	Low
		Big Gas	Substantial	Likely	High	Moderate	Likely	Moderate

Figure 8.10 presents a risk map of impacts on the natural agricultural resources base across four SGD scenarios, with- and without mitigation.

8.8 Management of potential agricultural impacts

8.8.1 Potential Positive Impacts

SGD offers a number of potential positive impacts on the agricultural sector:

Increased local demand for agricultural outputs: The anticipated influx of staff employed by SGD operators and the attendant increase in local economic activity can be expected to stimulate limited demand for agricultural produce. It is also anticipated that demand for farm-stay Bed and Breakfast accommodation in the area will increase in response to the need for skilled technicians, management personnel and specialist service providers to have access to suitable overnight accommodation in the vicinity of shale gas operations.

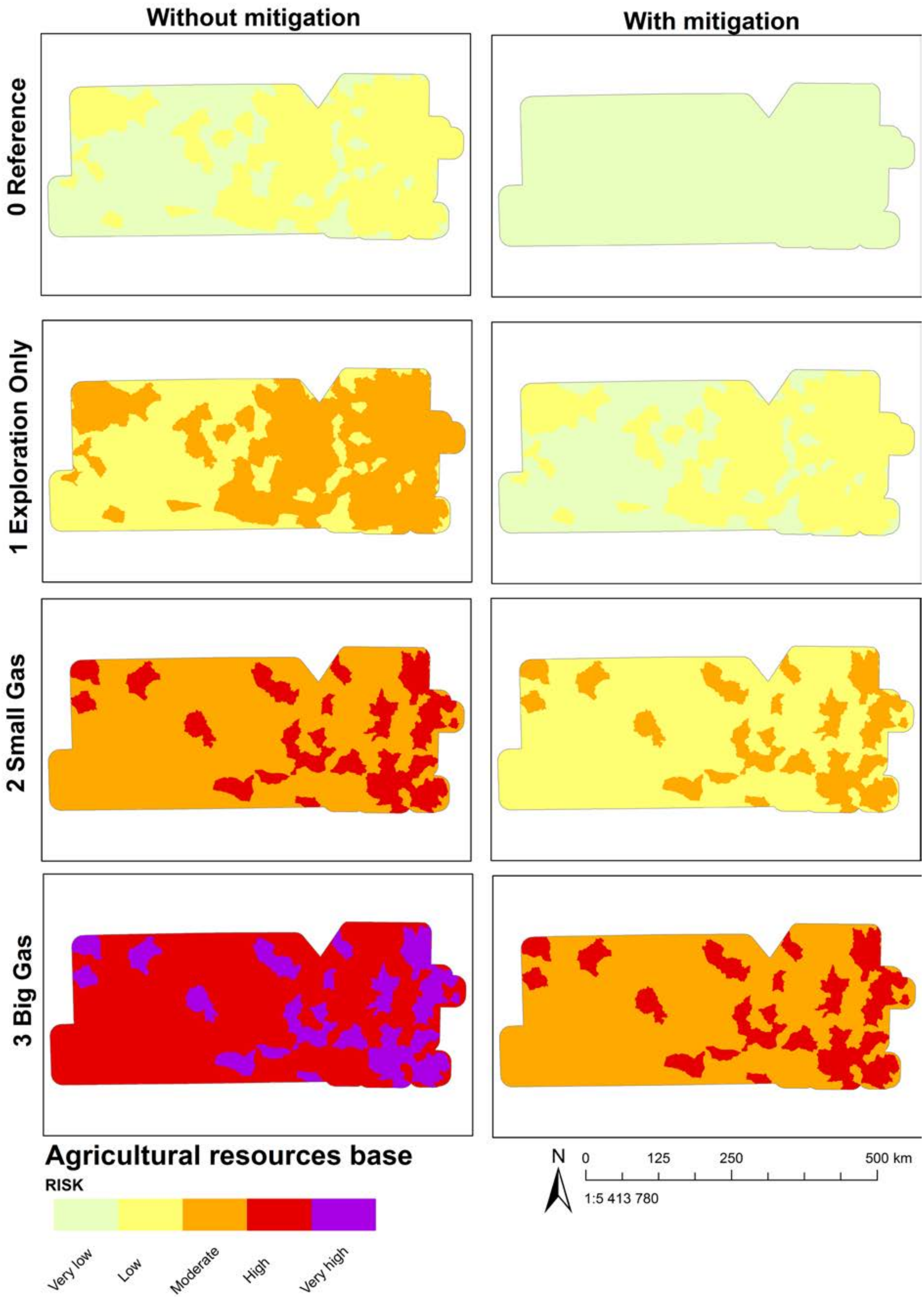

Figure 8.10: Map indicating the risk to the natural agricultural resources base across four SGD scenarios, with- and without mitigation.

Improved infrastructure: SGD will require the construction of improved road access to otherwise remote areas of the study area. This will potentially improve access to these areas for land users, and reduce wear and tear of their vehicles. It will be important that contractual provision is made to maintain and improve such infrastructure over time. On the other hand, increased vehicular travel on existing road infrastructure will impact negatively on its condition and necessitate more frequent maintenance or even upgrading. Increased short-term demand for telecommunication services will stimulate mobile network operators to improve coverage in the longer term by investing in improved hardware or construction of additional transmission stations.

Job creation potential and employment opportunities: Although likely to be limited in terms of scope and duration, it is anticipated that SGD activities will create some spin-off employment opportunities in service industries, which could benefit agricultural communities and their dependents.

Supplementary sources of on-farm income: Farmers will have a range of opportunities to enhance their incomes by leasing parts of their land or land-based resources (water, gravel for roads, etc.) to SGD operations.

Veld improvement through extended resting periods: Should shale gas operators seek to lease land on which extractive operations are to take place; opportunity will be created for veld improvement through extended resting periods.

8.8.2 Management strategies

Strategies for the management of potential negative impacts can be divided into mitigation, avoidance and offsets.

- *Mitigation*

Mitigation will involve reducing the effects of the shale gas activities on agricultural receptors through all project phases. These receptors include the farming community, the economic viability of farming operations as well as the biophysical components of agriculture such as soil and water.

- *Avoidance*

This is a preventative approach relying on the planning phase to identify areas of high sensitivity to agricultural impacts and to avoid it. In the case of SGD, the siting of wells is determined by geological and economic considerations, limiting the potential for avoidance. Avoidance is possible at the project scale where measures can be taken to avoid quaternary catchments with very high and high agricultural sensitive index values.

- *Offsets*

Offsets is a strategy of acknowledging and quantifying irreparable damage to natural resources and/or loss of livelihood and to replacing it with areas or projects of similar or better value elsewhere.

8.8.2.1 Mitigation measures

In the absence of SGD: Sustainable management of the agricultural resources of the study area requires on-going management interventions on the part of the land user. Without such interventions, even in the absence of SGD, the agricultural landscape will continue to degrade and its productivity will diminish. This section is included to draw attention to the necessity to promote on-going improvement in land management and effective planning to enable farmers, other residents and itinerant visitors to cope with anticipated impacts. Mitigation of anticipated climatic change in the study area should include interventions to ensure that vegetation in catchment areas and stream- and riverbeds is conserved so as to increase infiltration capacity of the soil and slow runoff waters. Compacted soil surfaces should be rehabilitated to restore vegetative cover. The construction standards for roads, railroads, pipelines, telephone and transmission lines should be revised to accommodate higher levels of peak run-off and associated sedimentation. Biodiversity loss and veld degradation from long-term selective grazing on farms should be addressed via increased investment in supporting biodiversity stewardship, including in situ conservation of biodiversity and the introduction and large-scale adoption of rangeland 'best management practices' suitable for this area.

During exploration: Mitigation would require that heavy prospecting equipment should not transgress main watercourses and pans, and be excluded from areas subject to hydrological extremes in the case of floods and droughts. Mitigation will also require active rehabilitation of compacted or otherwise disturbed surfaces of watercourses, pans and catchment areas that have been affected by the movement of prospecting equipment. Without active rehabilitation, disturbed surfaces in catchment areas that have lost their vegetative cover and become compacted might not recover. Because Karoo veld is very slow to regenerate after disturbance and some species do not easily recruit or recolonise, it may be necessary to re-seed disturbed areas (Esler, Milton, & Dean, 2006). Australian research shows the timing of remediation (minimising delays, especially during drought) is critical as it can lead to surrounding areas also remaining out of production (Cavaye et al., 2016).

The movement of heavy prospecting equipment across the landscape is likely to distribute the seeds of undesirable plants between and within agricultural properties. Similar impacts will be experienced in the course of regular maintenance operations. Seeds may be collected on the moving parts of the machinery that are in contact with the soil surface either en-route to the prospecting site or during the traversing process. The areas that will be at most risk of alien plant invasion are the roads to the wellpads, and the disturbed areas around the wellpads. Without mitigation there is a high likelihood of the spread of invasive plants. Mitigation would need to include cleaning and sanitisation of the parts of prospecting machinery before it enters a property, and after it has been thorough an area infested with invasive plants. Aftercare would require that prospecting sites were monitored and managed to control new infestations of invasive plants for a period of approximately five years after prospecting.

During operations: Mitigation of these threats could include rental of the farmers' land by the gas operator at a rate linked to, but higher than the current livestock-based financial returns, thus allowing farmers to destock those areas. Providing farmers with the resources to increase their on-farm security and strengthen their existing farmer security networks would also mitigate this problem. Farm workers displaced by rental of the farms on which they have worked and resided should be guaranteed employment in the agricultural sector, or provided with settlement packages that will enable them to receive training, accommodation and social services support to facilitate any necessary adjustment to life in communities that are new to them. The groundwater resources upon which agriculture in the Karoo is entirely dependent is vulnerable to pollution by leakage of toxic fracking fluids (Davenport, 2012; Pichtel, 2016; Sneegas, 2016). Furthermore, such leakage will release toxic chemicals into the environment that will undoubtedly have a negative impact on the health of livestock that have access to these areas (Bamberger, 2012, 2014). Surface water resources within the extraction zone will be at risk from disturbances of catchment areas and pollution for leakage of toxic fluids used for fracking (Atangana & van Tonder, 2014; Davenport, 2012; Perry, 2012). Ground-to-surface water contamination may take place as a result of the degradation of well seals and liners over relatively long periods of time (Hobbs et al., 2016). Mitigation should include avoidance of areas where surface-groundwater linkages are likely, and enforced long-term and on-going monitoring and maintenance of wells and easements (Hobbs et al., 2016; Pichtel, 2016).

Despite assurances from prospecting companies such as Shell™ that they do not intend to utilise groundwater resources for fracking, the increased populations that will enter the area to undertake the prospecting and gas production will undoubtedly add to water use for personal consumption, sanitation and other purposes. This may well lead to over-exploitation of scarce groundwater resources in some areas. Mitigation should include assessment of available resources for agricultural purposes before allowing use of these resources for other purposes, trucking in water if need be and also employing minimum water usage technologies on site. If farming land is rented by gas companies for the duration of the production period, this would be an effective mitigation of this potential problem. In the Australian experience, a major impact of gas personnel on farms has been time required by farmers to meet and communicate with staff and manage gas impacts on their farms (Cavaye et al., 2016).

During rehabilitation and post closure: Mitigation measures along the lines described above will be required on a landscape level, and over the entire lifecycle of the gas extraction process, including closure and subsequent rehabilitation of wellpad areas.

Table 8.13 below discusses the agricultural impacts in more detail and provides options for mitigation of these impacts.

8.8.2.2 Offsets

A possible offset for SGD in the Karoo would be the extension of existing game farms and the incorporation of these farms into wilderness or scenic rural corridors, linking with existing protected areas. The involvement of the Stewardship program could be of great benefit to manage agricultural resources in a sustainable way, while protecting the unique biodiversity of the study area.

Another possible offset could be to protect important catchments, especially rivers and streams of importance for water supply for humans, animals and also important agricultural industries. Typical these catchments will have large storage dams or reservoirs and these areas have also a fair amount of irrigation areas. These values have all been considered in the sensitivity map developed for the purposes of this assessment.

8.8.3 Limits of acceptable change

Natural agricultural resources in South Africa are protected by the CARA, Act 43 of 1983. The objective of this legislation is to protect and control the use of natural agricultural resources through regulations controlling the use of natural veld, water sources, wetlands and the use and protection of cultivated fields and irrigated areas. Other, related legislation control water pollution, air pollution or noise. Another important piece of legislation is the Subdivision of Agricultural land (SALA), Act 70 of 1970 (South Africa, 1970). This legislation will have a direct impact on the fragmentation of agricultural land.

The tipping point for the limit of acceptable change would be related to adhering to CARA legislation and other related legislation discussed earlier in this chapter, such as the NEMASALA, and NWA. Setbacks and exclusion zones would to some degree define levels of acceptable change. A number of these are listed in Table 8.14.

Table 8.13: Possible agricultural impacts and options for mitigation.

Scenario	Possible agricultural impact	Options for mitigation of impacts
Reference Case	Status quo	Not applicable
Exploration Only	Localised soil degradation in the form of compaction, soil pollution and soil erosion.	• Introduce soil conservation measures and structures as soon as possible. • Revegetation with adapted local species.
	Localised vegetation degradation in the form of cleared vegetation strips, the loss of productive potential and the possibility of soil erosion and the introduction of weeds and invasive species.	• Retain scrubs and trees where possible. • Revegetation with adapted local species. • Control weeds and invader plants, mechanical, herbicides and biological control, depended on sensitivity of area. • Careful planning of access roads and infrastructure. Rather improve existing roads than build new ones.
	Localised and limited degradation of surface water resources, mainly due to obstacles to water flow and possible point source pollution (mostly accidental events).	• Planning to avoid activities near water bodies. • Cleaning up operations immediately after a spill or pollution event.
	Visual pollution having an impact on game ranching and eco-tourism activities, littering from construction sites and accommodation camps.	• Include litter control and education in the Environmental Management Programme (EMPr).
	Limited influx of people (outsiders) into the area will decrease safety and security on farms (farm attacks and livestock theft).	• Implement a farm visit protocol. • Improve security in area, both formally through police service and private security firms and informally through community policing and patrols.
Small Gas	Increased soil degradation in the form of compaction, soil pollution and soil erosion.	• Implement soil conservation measures and structures. Re-shaping and revegetation with adapted local species.
	Increased vegetation degradation in the form of cleared vegetation strips, the loss of productive potential of land and the possibility of soil erosion and the introduction of weeds and invasive species.	• Retain scrubs and trees where possible. • Revegetation with adapted local species. • Control weeds and invader plants, mechanical, herbicides and biological control, depended on sensitivity of area. • Careful planning of access roads and infrastructure.

Scenario	Possible agricultural impact	Options for mitigation of impacts
		Rather improve existing roads than building new ones.
	Increased possibility of degradation of surface and groundwater quality due to waste water from the fracking process (flowback) and pollution through spills, leakages and accidents.	• Planning to avoid activities near water bodies. • Cleaning up operations immediately after a spill or pollution event.
	Increased demand on available water sources leading to a decrease in water quantity (availability) from both surface and groundwater sources for agricultural activities.	• Water harvesting measures. • Re-use of waste water. • Import water from outside study area.
	Increased traffic, noise and dust during the construction phase.	• Cluster target areas where possible, upgrade existing roads, law enforcement on roads to avoid speeding and limit likelihood of accidents.
	Fragmentation and industrialisation of the landscape, wilderness and rural areas. Fragmentation of farms and land management units/sections on specific farms.	• Confine wellpads to carefully selected areas with low agricultural sensitivity.
	Effect on the rural agricultural character of the study area by shale gas activities.	• Minimise footprint of wellpads as far as possible within the production block.
	Localised effect of wellpads on views from farmsteads, possibly affecting property values.	• Consider setbacks from farmsteads. • Create shelterbelts for visual screening.
	Loss of productive land (localised) through changes in land use and fragmentation of the landscape.	• Confine wellpads to carefully selected areas with low agricultural sensitivity.
	Changes in social fabric of community, community values and the possibility of conflict between those farmers for and those farmers against fracking (or those benefiting from SGD and those not benefiting at all).	• Consider alternative, renewable energy sources like wind and solar. • Consider a more representative compensation system. • Consider payment for use and loss of ecosystem services by fracking companies.
	Farmers unhappy with impacts of SGD sell their land - loss of traditional knowledge and experience.	• Consider alternative, more environmental friendly "green" energy sources.
	Loss of privacy and control over property with an increase in crime, damage to property, stock theft and possible farm attacks.	• Implement a farm visit protocol. • Improve security in area, both formally through police service and private security firms and informally through community policing and patrol.

Scenario	Possible agricultural impact	Options for mitigation of impacts
Big Gas	Increased soil degradation in the form of compaction, soil pollution and soil erosion.	• Implement soil conservation measures and structures. Re-shaping and revegetation with adapted local species.
	Increased vegetation degradation in the form of cleared vegetation strips, the loss of productive potential of land and the possibility of soil erosion and the introduction of weeds and invasive species.	• Retain scrubs and trees where possible. • Revegetation with adapted local species. • Control weeds and invader plants, mechanical, herbicides and biological control, depended on sensitivity of area. • Careful planning of access roads and infrastructure. Rather improve existing roads than building new ones.
	Increased possibility of degradation of surface and groundwater quality due to waste water from the fracking process (flowback) and pollution through spills, leakages and accidents. Increased demand on available water sources leading to a decrease in water quantity (availability) from both surface and groundwater sources for agricultural activities.	• Planning to avoid activities near water bodies. • Deep well injection. • Cleaning up operations immediately after a spill or pollution event. • Water harvesting measures. • Re-use of waste water. • Import water from outside study area.
	Increased traffic, noise and dust during the construction phase.	• Cluster target areas where possible, upgrade existing roads, law enforcement on roads to avoid speeding and accidents.
	Widespread fragmentation and industrialisation of the landscape, wilderness and rural areas. Fragmentation of farms and land management units/sections on specific farms by wellpads, pipelines and access roads.	• Confine wellpads and production blocks to carefully selected areas with low agricultural sensitivity. • Minimise footprint of wellpads as far as possible within the production block.
	District-wide or regional effect on the rural agricultural character of the study area by SGD.	• Consider setbacks from farmsteads. • Create shelterbelts for visual screening. • Wildlife and rural corridors as possible offset.
	Diminished recreation amenity and agri- and eco-tourism attraction, including the environments of private game farms and lodges.	• Confine wellpads to carefully selected areas with low agricultural sensitivity. • Shelterbelts for visual screening.

Scenario	Possible agricultural impact	Options for mitigation of impacts
	General effect of wellpads on views from farmsteads, possibly affecting property values.	• Avoid areas with very high and high agricultural sensitivity index score.
	Loss of productive land (localised) through changes in land use and fragmentation of the landscape, especially within production blocks.	• Consider a more representative compensation system. • Consider payment for use and loss of ecosystem services by fracking companies.
	Changes in social fabric of community, community values and the possibility of conflict between those farmers for and those farmers against fracking (or those benefiting from SGD and those not benefiting at all).	• Consider alternative, more environmental friendly “green” energy sources.
	More farmers unhappy with SGD sell their land, loss of traditional knowledge and experience, impact on property values.	• Consider alternative, renewable energy sources like wind and solar.
	Loss of privacy and control over property with an increase in crime, damage to property, stock theft and possible farm attacks.	• Implement a farm visit protocol. • Improve security in area, both formally through police service and private security firms and informally through community policing and patrol.

Table 8.14: Potential exclusion zones for shale gas activity.

Agricultural resource	Exclusion zone
Terrain	Restricting development on steep slopes (NEMA) (South Africa 1998a) l).
Major rivers and water bodies	Restrictions within 500 m of water courses and 1 km of wetlands (Regulation for Petroleum Exploration and Production) (South Africa, 2015).
Human settlements	Provisions included in local authority planning documents (Integrated Development Plans, Municipal Zoning Schemes and Overlay Schemes).

8.9 Conclusion and recommendations

We conclude that SGD is likely to have a wide range of potential impacts on the agricultural production systems of the study area. Although many of these are likely to be of a negative nature, opportunities do exist for the activities and impacts of these processes to contribute to the improvement of the lives of some the people of the area. These anticipated benefits must be weighed carefully against the likelihood that a currently resilient agricultural resource will be degraded as a result of pollution of water resources and rangeland. In a water scarce country that has limited agricultural resources to support an ever-growing population, any permanent loss of agricultural productivity should be avoided, despite the allure of short- to medium-term financial gain.

This study has been undertaken in the context of the requirements of the NEMA. Chapter 5 of NEMA addresses integrated environmental management so as to give effect to the general objectives of the Act relating to the potential impact on the environment, socio-economic conditions and the cultural heritage. Section 24 (7) (b) of the Act outlines how the precautionary principle must be applied in assessing the potential impact and cumulative effects of proposed activities on the environment, socio-economic conditions and cultural heritage. These must be outlined and an assessment made of the significance of that potential impact. Mitigation measures must be investigated to “keep adverse impacts to a minimum”, and the option of not implementing the activity must also be considered. Agriculture is an enterprise that both depends and impacts upon all three of these elements: the environment, socio-economic conditions and cultural heritage. The linkages between them are inextricable, and should one be compromised by SGD, so too will the others.

Realising net positive benefits for at least some members of the farming communities of the area will require careful planning, strict regulation and skilful mediation of the interactions between land-based communities and gas exploitation companies. The international experience demonstrates that the interventions of petro-chemical companies in landscapes have frequently caused environmental and social damage and disruption, and set in train events that have had negative impacts that are of a lasting nature. Financial contributions by the relevant companies to mitigate these costs have likewise frequently been inadequate. If such costs are externalised and must be borne by local populations, governments and their citizens, the future of communities and nations will be ransomed for relatively short-term benefit.

The farming communities of the study area have learned over many generations how to live in a water-scarce environment, and to sustainably produce unique and highly valued agricultural outputs. This production is entirely reliant on groundwater resources, and it is therefore indisputable that if groundwater resources are polluted or abnormally depleted, the entire agricultural system in this semi-arid area will collapse.

Many of the physical impacts of SGD can be mitigated with a combination of careful planning to meet stringent environmental and social standards, vigilant management of operations, active enforcement of laws, regulations and standards and engagement of local stakeholders in seeking appropriate solutions to perceived challenges and threats. Nevertheless, SGD will change the nature and quality of many of the physical and social conditions upon which the agricultural productivity and the livelihoods of agriculturally-dependent communities are grounded. Environmental pollution from leakage or spillage of water containing toxic chemicals is likely, and the United States experience indicates that it will have a long term, negative impact on the people, livestock and wildlife of the study area that will outlast any short-term economic benefits.

Globally, agricultural resources are recognised as a finite resource that is rapidly shrinking due to land transformation and degradation. As this resource is crucial to meeting the needs of an exponentially expanding human population, its conservation should be regarded as a priority higher than that of short-term energy benefits of SGD.

Investment in land in the study area is coupled with the unspoiled natural beauty of the region, and its demonstrated potential to attract nature, farm and game tourists. Intimately linked to this is the farming lifestyle of the region, which motivates urban-based investors to envisage a higher quality of life for themselves and their families should they relocate there and to transfer wealth back from urban centres of accumulation to these rural landscapes. Sustaining the value of such investment, and ensuring that it is able to continue to generate further returns and create benefits for the people of the study area is dependent on retaining the natural beauty of the environment. If SGD is perceived as degrading or destroying this natural beauty, the fast-growing game farming sector and the associated agri-tourism and eco-tourism sectors will all be negatively impacted. Should this happen, local populations will inevitably be disrupted, and agricultural skills will probably be eroded or permanently lost.

In conclusion, notwithstanding the short-term gains that may be realised from SGD in the study area, it will be of crucial economic and social importance to ensure that the long-term future of the region and its peoples is firmly grounded upon diverse and sustainable agricultural land use.

8.10 References

Atangana, A., & van Tonder, G. 2014. Stochastic Risk and Uncertainty Analysis for Shale Gas Extraction in the Karoo Basin of South Africa. *Abstract and Applied Analysis*, 2014, 10. doi:10.1155/2014/342893.

Atkinson, D., Schenk, R., Matebesi, Z., Badenhorst, K., Umejesi, I. and Pretorius, L. 2016. Impacts on Social Fabric. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7

Bamberger, M. O., Robert E. 2012. Impacts of Gas Drilling on Human and Animal Health New Solution, 22(1), 51-77. doi:doi: http://dx.doi.org/10.2190/NS.22.1.e.

Bamberger, M. O., Robert E. 2014. The Real Cost of Fracking. Boston: Beacon Press.

Boardman, J. F., I. D. L. 2008. Badland and gully erosion in the Karoo, South Africa. *Journal of Soil and Water Conservation*, 63(4), 121–125.

Brantley, S. L., Yoxtheimer, D.A., Arjmand, S., Grieve, P., Vidic, R.D., Pollak, J., Llewellyn, G.T., Abad, J.D. & Simon, C. 2014). Water resource impacts during unconventional shale gas development: The Pennsylvania Experience. *International Journal of Coal Geology*, 126, 140 - 156. doi:DOI: 10.1016/j.coal.2013.12.017.

Cavaye, J., Kelly, L., Martin, M., Cameron, D., Muriuki, G., Rillorta-Goloran, T., & Baldwin, S. 2016. The Impacts of Coal Seam Gas Development on Agricultural Production and Productivity in Southern Queensland and Understandings of Co-existence. *In prep.*

Cheney, P. & SullivanA. 2008. Grassfires: fuel, weather and fire behaviour. Collingwood, CSIRO.

Cloete, P. C., Van der Merwe, P., & Saayman, M. 2015. Game ranch profitability in South Africa. Cape Town: ABSA, CTP Printers.

Collett, A. A. P. (Cartographer). 2016a. Agricultural Sensitivity Map.

Collett, A. A. P. (Cartographer). 2016b. Eastern Cape Irrigated Areas Boundary data layer, 2011.

Collett, A. A. P. (Cartographer). 2016c. Grazing Capacity 2016: Grazing capacity data layer.

Collett, A. A. P. (Cartographer). 2016d. Land capability 2016: Land capability evaluation data layer.

Collett, A. A. P. (Cartographer). 2016e. Northern Cape Irrigated Areas Boundary data layer, 2013.

Collett, A. A. P. (Cartographer). 2016f. Rivers data layer, 2013.

Collett, A. A. P. (Cartographer). 2016g. Western Cape Irrigated Areas Boundary data layer, 2013.

Davenport, J. P. 2012. Unconventional Shale Gas Development: Conventional Risks to Surface Water from Deforestation, Erosion and Sedimentation, and Stormwater Runoff. 30th Annual Water Law Conference, San Diego.

Department of Agriculture, F. A. F. 2014. Quarterly Economic Overview of Agriculture, Forestry and Fisheries sector. Pretoria.

Department of Environmental Affairs (DEA).2014. Hunting statistics for 2014. Retrieved from https://www.environment.gov.za/sites/default/files/docs/hunting_statistics2014.pdf

Drohan, P. J. & Brittingham, M. 2012. Topographic and soil constraints to shale-gas development in the northcentral Appalachians. *Soil Science Society of America Journal*, 76(5), 1696-1706.

Drohan, P. J., Brittingham, M., Bishop, J. & Yoder, K. 2012. Early Trends in Landcover Change and Forest Fragmentation Due to Shale-Gas Development in Pennsylvania: A Potential Outcome for the

Northcentral Appalachians. *Environmental Management*, 49(5), 1061–1075. doi:10.1007/s00267-012-9841-6

du Toit, J. C. O., O'Connor, T.G. & van den Berg, L. 2015. Photographic evidence of fire-induced shifts from dwarf-shrub-to grass-dominated vegetation in Nama-Karoo. *South African Journal of Botany*. 101, 148–152.

du Toit, J. C. O., van den Berg, L. & O'Connor, T.G. 2014. Fire effects on vegetation in a grassy dwarf shrubland at a site in the eastern Karoo, South Africa. *African Journal of Range and Forage Science*, 32(1), 13–20.

Eshleman, K. N. E., A. 2013. Recommended Best Mangement Practices for Marcellus Shale Gas Development in Maryland. Baltimore, Maryland, USA: Appalachian Laboratory, University of Maryland Center for Environmental Science.

Esler, K. J., Milton, S. J., & Dean, W. R. J. 2006. Karoo Veld: Ecology and Management. Pretoria: Briza Publications.

Fink, C. M., & Drohan, P.J. . 2015. Dynamic Soil Property Change in Response to Reclamation following Northern Appalachian Natural Gas Infrastructure Development. Soil Science Society of America Journal, 79(1), 146-154. doi:10.2136

FXTOP. 2016. Inflation calculator and change of price between 2 dates. Retrieved from http://fxtop.com/en/inflation-calculator.php

Hobbs, P., Day, E., Rosewarne, P., Esterhuyse, S., Schulze, R., Day, J., Ewart-Smith, J., Kemp, M., Rivers-Moore, N., Coetzee, H., Hohne, D., Maherry, A. and Mosetsho, M. 2016. Water Resources. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7

Keay-Bright, J. B., J. 2007. The influence of land management on soil erosion in the Sneeuberg Mountains, Central Karoo, South Africa. *Land Degradation & Development*, 18(4), 423–439.

Kings, S. 2013. Hunting industry earns SA R6.2-billion. Retrieved from http://mg.co.za/article/2013-05-28-hunting-industry-earns-sa-r62-billion

Lindeque, L., Collett, A. & Avenant, P. 2016. Towards an Agricultural Sensitivity Map for the Karoo Shale Gas study area. Pretoria: Department of Agriculture, Forestry and Fisheries, Natural Resource Inventories and Assessments.

Oberholzer, B., Lawson, Q., Klapwijk, M., Young, G., Anderson, M. and Orton, J. 2016. Visual, Aesthetic and Scenic Resources. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7

Perry, S. L. 2012. Development, Land Use, and Collective Trauma: The Marcellus Shale Gas Boom in Rural Pennsylvania. *Culture, Agriculture, Food and Environment*, 34(1), 81–92. doi:10.1111/j.2153-9561.2012.01066.x

Pichtel, J. 2016. Oil and Gas Production Waste water: Soil Contamination and Pollution Prevention. *Applied and Environmental Soil Science*, 2016, 24. doi:10.1155/2016/2707989

Redi, B. H., Van Aarde, R.J. & Wassenaar, T.D. 2005. Coastal dune forest development and the regeneration of millipede communities. *Restoration Ecology*, 13(2), 284–291.

Rivera-Ferre, M., Ortega-Cerdà, M., & Baumgärtner, J. 2013. Rethinking Study and Management of Agricultural Systems for Policy Design. *Sustainability*, 5(9), 3858-3875. doi:10.3390/su5093858

Schlacher, T. A. T., L.M.C. 2008. Physical damage to coastal dunes and ecological impacts caused by vehicle tracks associated with beach camping on sandy shores: a case study from Fraser Island, Australia. *Journal of Coastal Conservation*, 12(2), 67–82.

Seeliger, L., de Jongh, M., Morris, D., Atkinson, D., du Toit, K. and Minnaar, J. 2016. Impacts on Sense of Place. In Scholes, R., Lochner, P., Schreiner, G., Snyman- Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7

Sneegas, G. 2016. Media representations of hydraulic fracturing and agriculture: A New York case study. The Extractive Industries and Society, 3(1), 95-102. doi:http://dx.doi.org/10.1016/j.exis.2015.11.011

South Africa. 1970. Subdivision of Agricultural Land Act (Act 70 of 1970). Government Gazette No. 2867, 5pp.

South Africa. 1983. Conservation of Agricultural Resources Act (Act 43 of 1983). Government Gazette No. 8673. 24pp.

South Africa. 1998a. National Environmental Management Act (Act 107 of 1998). Government Gazette No. 19519. 96pp.

South Africa. 1998b. National Water Act (Act 36 of 1998). Government Gazette No. 19182. 201 pp.

South Africa. 2006. Census of Agriculture Provincial Statistics 2002 Western Cape: Financial and Production Statistics," Report 11-02-02 (2002), Statistics South Africa, Department of Agriculture.

South Africa. 2006. Census of Agriculture Provincial Statistics 2002- Eastern Cape Province: Financial and Production Statistics," Report 11-02-03 (2002), Statistics South Africa, Department of Agriculture.

South Africa. 2006. Census of Agriculture Provincial Statistics 2002- Western Cape: Financial and Production Statistics," Report 11-02-04 (2002), Statistics South Africa, Department of Agriculture.

Statistics South Africa (StatSA), S. A. 2007b. Census of commercial agriculture, 2007 Northern Cape: Production statistics for selected products (11-02-04). Retrieved from http://www.statssa.gov.za/

Statistics South Africa (StatSA), S. A. 2007c. Census of commercial agriculture, 2007 Western Cape: Production statistics for selected products. Retrieved from http://www.statssa.gov.za/

Statistics, S. A South Africa (StatSA). 2007a. Census of commercial agriculture, 2007 Eastern Cape: (11-02-03). Retrieved from http://www.statssa.gov.za/

Toerien, D., du Rand, G., Gelderblom, C. & Saayman, M. 2016. Impacts on Tourism in the Karoo. In Scholes, R., Lochner, P., Schreiner, G., Snyman- Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7

Van Huyssteen, E., Green, C., Paige-Green, P., Oranje, M., Berrisford, S., McKelly, D. 2016. Impacts on Integrated Spatial and Infrastructure Planning. In Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7

Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., & Kondash, A. 2014. A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States. *Environmental Science & Technology*, 48(15), 8334-8348. doi:10.1021/es405118y

Warner, N. R., Christie, C. A., Jackson, R. B., & Vengosh, A. 2013. Impacts of shale gas waste water disposal on water quality in western Pennsylvania. *Environmental Science & Technology*, 47(20), 11849-11857. doi:10.1021/es402165b

Webb, R. H., & Wilshire, H. G. 1983. Environmental Effects of Off-Road Vehicles. Impacts and Management in Arid Regions. New York: Springer.

Wessels, J., & Willemse, B. 2013. The impact of changed land use on farmland values and farmland valuations – an example from the South-Eastern Nama Karoo. Agrekon: Agricultural Economics Research, Policy and Practice in Southern Africa, 52 (Supplement 1). doi:10.1080/03031853.2013.770958