# The economics of spatial reallocation of maize production in South Africa

by

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A dissertation submitted in partial fulfilment of the requirements for the degree

M.Com (Agricultural Economics)

in the

Faculty of Economic and Management Sciences

UNIVERSITY OF PRETORIA

SOUTH AFRICA

February 2016

# DECLARATION

I, Gerhard van der Burgh, declare that the dissertation, which I hereby submit for the Degree, M.Com Agricultural Economics, at the University of Pretoria, is my own work and has not been submitted for a degree at any other tertiary institution.

SIGNATURE: ……………………….……….. DATE: February 2016

# ACKNOWLEDGEMENTS

Without knowing that in my own capacity, I am nothing, this piece of work would not have happened. For He has granted me the power to do all things through Christ, and to Him be the praise.

To Phil, Michelle, Jason and the rest of the INSTEPP team from the University of Minnesota, thank you for hosting Nanet and myself for four months; this time is imprinted in our memories. Particular thanks go to Phil Pardey, as my co-supervisor, for making time to assist.

A special word of appreciation to Ferdi Meyer, my supervisor, director and mentor. Thank you for being a leader to many and for all the time you invest in us as BFAP employees, it is highly valued and appreciated. To my colleagues at the Bureau for Food and Agricultural Policy, I owe a great deal of gratitude for always being willing to assist and provide guidance into new thinking.

To my family – without your backing and support I would not have been here today. Your support and understanding was invaluable and I am ever grateful for your involvement in my life. To every one of my friends who provided me with advice, guidance and motivation, thank you.

Then, my wife Nanet. The many long nights, endless sitting down to type instead of going for a trail run or going out with our friends, thank you! Your commitment towards my work, studies, farm and sense of thinking is one of a kind. Thank you for making my journey worth all the effort.

Gerhard van der Burgh

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February 2016

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## ABSTRACT

The economics of production and market fundamentals, which drive the competition for arable land, create the expectation of a continuous decline in the South African maize production area. Besides the economic factors affecting maize production, the granting of mining permits in the Mpumalanga province, coupled with the policy objectives spurring agricultural development in South Africa's former homelands, induces a substantial shift in the location of maize production. Furthermore, The Former Homeland Region of the Eastern Cape were identified as being capable of effecting the potential reallocation of land suitable for growing maize.

Geographic Information System (GIS) analysis is typically utilised to spatially identify biophysically suitable areas for crop production. However, economic viability or suitability is seldom the focus of multi-criteria spatial analysis. Refinement was therefore necessary to evaluate a field of study where the economics of land use inform the spatial allocation of production.

Informed by the South African government's maize reallocation initiatives, this study undertook a spatially explicit assessment of the likely shifts in the location of maize production, analysing biophysical and economic factors in play.

Spatial criteria informing production allocation was reviewed based on existing spatial analytical methodologies, of which the Spatial Production Allocation Model (SPAM) is an example of such as production allocation model. The most applicable criteria to determine the economics of spatial allocation were identified as: a) modelling the location of production, b) biophysical cropland suitability, c) modelling land use change, and d) spatial allocation modelling concerned with resource optimisation and profit maximisation. This existing methodology was combined and altered to a South African-based application in the Former Homeland Region of the Eastern Cape. The reviewed outcome informed which criteria to incorporate into spatial economic analysis. The criteria was further adapted to an Economically Suitable Spatial Allocation (ESSA) framework utilising existing South African spatial data and models. It was found that the ESSA framework could provide an additional approach to multi-criteria GIS modelling applied in the field of agricultural land use allocation. This framework addresses the incongruity between the outcomes of land capability, crop suitability and the economic factors determining production in the Former Homeland Region of the Eastern Cape.

The key findings indicate that a total area of 298 367 hectares for potential dryland maize could be allocated in the Former Homeland Region of the Eastern Cape, with the production potential estimated at 971 750 tons of maize. However, since local un-milled maize consumption was derived at approximately 260 000 tons, it implies that under a scenario where close to one million tons of maize is produced in the Former Homeland Region of the Eastern Cape, surplus maize will have to be transported out of the region, which will bring new dynamics into the regional markets and the economic realities of smallholder farmers. The farm gate prices will typically decline by a margin linked to the transportation and transaction costs to move the maize. Surplus availability of maize will on the other hand stimulate trade and further downstream activities in the value chain.

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# KEY CONCEPTS

**GIS:** Geographic Information System

**Layer:** The data from geo-referenced maps are in the form of shapefiles/rasterized data with latitude and longitude coordinated, as used in the Geographic Information System (GIS) profession. These maps are also referred to as layers, which can indicate, amongst others, land capability, rainfall, soil depth and average temperature.

**Arable Land:** The FAO has defined arable land as land that could be used for growing crops. It includes all land under temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market, and kitchen gardens, as well as land temporarily fallow (for less than five years) (FAOSTAT, 2011b).

**Land Capability:** According to Rossiter (1995:1), “Land capability classification rates land from class 1 (best) to 8 (worst) according to the intensity of land use it can support and the degree of management that would be necessary to support that intensity.” Schoeman, van der Walt, Monnik, Thackrah, Malherbe and le Roux (2002:vi) concurred that these classifications were based on “the extent to which land could meet the needs of one or more uses under defined conditions of management.” For instance, Land in Class II had some limitations that reduced the choice of plants or required moderate conservation practices; it may be used for cultivated crops, but with less latitude in the choice of crops or management practices than Class I; the limitations were few and the practices were easily applied (Schoeman et al., 2002:8).

**Land Suitability:** Land suitability evaluation is mostly based on the requirements and tolerances of individual uses of soils or a specific land utilisation category (Laker, 2004:358). Characteristics typically evaluated in land suitability analysis include, but are not limited to: (a) individual crop requirements, (b) management requirements (which include infrastructure and markets) and (c) environmental requirements (including soil conservation) (Laker, 2004:358).

**Former homelands:** The 1913 and 1936 Land Acts discriminated against black South Africans and regulated their access to land. The restriction of black South Africans to acquire land anywhere outside of the boundaries stipulated by these Acts, made farming possible only in the allocated reserve areas, now described as the "former homelands" (Lahiff, 2000, as cited in Pienaar & von Fintel, 2014:43). The former homeland areas consist of approximately 14 per cent or 17 million hectares of the total surface area of South Africa (DBSA, 1991, in DAFF, 2011). The Eastern Cape's former Transkei-Ciskei is the largest, with an area of approximately 5 million hectares.

**Smallholder producer:** The definition of smallholders varies in different contexts, which explains the frequent and interchangeable usage of the term "smallholder" with "small-scale", "subsistence", "resource poor", "small", "low income", "low-input" (Nagayets, 2005; Machingura, 2007, in Pienaar, 2014:9). As Pienaar (2014:9) rightly concludes, there seems to be no universally accepted definition for smallholder farmers. In South Africa, "smallholder producers" often refer to black smallholder farmers, characterised by non-commercial and subsistence producers (Kirsten & van Zyl, 1998, in Pienaar, 2014:11). Although there is considerable variation in the sizes of land for smallholder cultivation, for the purpose of this study, a range of 1 – 2 hectares per producer provided the frame of reference.

**Table 1: List of abbreviations used**

| Abbreviation | Meaning |
|---|---|
| AGIS | Agricultural Geo-Information System |
| ARC-ISCW | Agricultural Research Council – Institute for Soil, Climate and Water |
| BFAP | Bureau for Food and Agricultural Policy |
| DAFF | Department of Agriculture, Forestry and Fisheries |
| DRDLR | Department of Rural Development and Land Reform |
| FAO | Food and Agricultural Organisation |
| FCB | Field Crop Boundary |
| FHREC | Former Homeland Region of the Eastern Cape |
| ECDARD | Eastern Cape Department of Agriculture and Rural Development |
| GIS | Geographical Information System |
| GRAIN SA | Grain South Africa |
| IFNSI | Integrated Food Nutrition Security Initiative |
| MP | Mpumalanga Province |
| NAMC | National Agricultural Marketing Council |
| PAC | Potentially Available Cropland |
| SAFEX | South African Futures Exchange |
| SAGIS | South African Grain Information Services |

# CHAPTER 1

# RESOURCE UTILISATION IN SOUTH AFRICA

## 1.1 INTRODUCTION

Arable land is a scarce resource and its management has been central to human society from the earliest times. In addition to its function for agricultural and forestry production, it can be used for many other purposes which includes conservation, mining, storage, human settlements and others which creates competition in the usage of land (Young, 1998:1, 48). Land use change receives enormous societal interests as land use both reflects and governs where economic activity takes place, it influences how communities develop and it affects the natural environment (Goetz, Shortle and Bergstrom, 2005: 1).Competition of different uses of land in South Africa remains high as the country has a limited set of resource. For instance, of the total land area of 122.3 million hectares only 15.8 million hectares (12.4 percent) is considered to be potential arable land for farming, and only 1.8 percent of the arable land is considered as high-potential arable land. The Mpumalanga province accounts for a large share (46 percent) of the country's high-potential arable land, and most of that is currently used to produce maize, one of the major staple food crops in South Africa. Unfortunately, the vast majority of this high-potential arable land is embedded within South Africa's richest coal mineral seams giving rise to competing uses between the two sectors.

Coal production and sales makes a sizeable contribution to the South African economy and is expected to grow (BFAP, 2015a:21). On the other hand, there is a need for land to support agricultural production, which is vital to maintain and improve South Africa's food security status. If maize production in Mpumalanga alone is replaced by mineral mining, long-term average maize prices and therefore maize meal prices are expected to increase.

The amount of surplus maize that South Africa produces will shrink and cause the local market to ease away from trading mainly at export parity prices towards a market that trades more frequently in an autarkic manner, when the outlook for the South African maize industry is simulated stochastically (BFAP, 2012:5). Maize porridge (made from maize meal) has been identified as one of the five most widely consumed food items in South Africa (Nel & Steyn, 2002). Therefore, it is of critical importance to maintain an affordable and continuous supply of this commodity to remain food secure, as a nation. Although South African farmers have been able to meet the growing demand for maize in most of the years through the rapid increase in yields, the cropping areas in South Africa have faced increasing competition from mining activities (BFAP, 2013:29, 39). Apart from gross margins per commodity driving the competition for arable land, the rapid expansion in mining activities, particularly in high-potential agricultural areas, has increased the pressure on the availability of maize production area (BFAP, 2012:8).

With a food security objective, the South African Government's Integrated Food Nutrition Security Initiative ("Fetsa Tlala") has set a target of bringing 1 million hectares of additional area into cash crop production in the former homeland regions of South Africa. It was emphasised that empirical evidence was needed to assess the potential, capability, suitability and state of the natural resources, with special reference to the soil resource (AGIS, 2013:2). A need existed to evaluate a field of study in which the economics of land use would define the spatial allocation of production, instead of only combining land classifications and biophysical models, as in the case of most spatial allocation models (Chakir, 2007:3).

Therefore, this study uses spatially disaggregated data to access the economic and agro-ecological feasibility of reallocating maize production from Mpumalanga to the Eastern Cape Former Homeland region.

## 1.2 CONTEXTUALISING THE COMMODITY-DRIVEN COMPETITION FOR LAND USE IN SOUTH AFRICA

### 1.2.1 The importance of agriculture for food security

Since 2006 there has been a steady increase in the price of agricultural commodities, which has reignited concerns about the ability of the world to feed itself in the future (FAO, 2011a:13). In addition to the concerns of increasing agricultural commodity prices, is the fear over the amount of land and water available to supply global demand for food and agricultural production, as it continues being placed under pressure (FAO, 2011a:13). The United Nations Food and Agricultural Organization (FAO) (2011a:13) stated that: “the buffering capacity of global agricultural markets to absorb supply shocks and stabilize agricultural commodity prices is tied to the continued functioning of land and water systems.”

In line with the evaluations of South African food price inflation, the FAO found that the social impacts of rapid food price inflation have hit the poorest the hardest. In their responsive resolution to the effects of low production, high prices and poverty, the FAO (2011a:4) argued that investing in agriculture was regarded as being one of the most effective strategies for reducing poverty and hunger, and thereby promoting sustainability in the access to food. It was found that epicentres of poverty and hunger in the world are prevalent today in regions where agricultural capital per worker and public agricultural spending per worker have either deteriorated or stagnated over the past thirty years (FAO, 2011a:4).

South Africa is faced with a growing competition for arable land between different cereal crops. For example, the hectares of white maize is projected to decrease by approximately 400 000 hectares to roughly 1 100 000 hectares by the year 2024 (BFAP, 2013:39). This decrease in hectares under white maize production is mainly attributable to the relative shift into yellow maize production, following the rapid rise in the demand for yellow maize in the feed market and the expansion of soybean production (BFAP, 2013:39).

Average yields for dry land white and yellow maize production have increased from 2.7t/ha in the early 2000s to just over 4.5t/ha over the past three seasons (BFAP, 2015).

### 1.2.2 Competitors for arable land

The continuous loss of high-yielding cropland, as experienced in Mpumalanga, can be attributed, in part, to the expansion in coal mining (BFAP, 2013:39). With the current granting of mining licenses, more and more agricultural production may be lost, especially through reduced areas of land for the production of maize. This is especially evident in the Mpumalanga province, which holds a large percentage of the country's wealth derived from land of high-potential for the production of crops. Unfortunately, the vast majority of this high-potential arable land is also embedded within South Africa's richest coal mineral seams. The high-potential arable land is currently utilised for producing maize – one of the primary consumed food products in South Africa. If maize production in Mpumalanga alone is replaced by mineral mining, drastic price increases in maize meal can be expected (BFAP, 2012:5).

As this rapid shift and competition for land continues in the Mpumalanga province, possible implications relating to food security were evaluated. A study done by BFAP (2012:5) found that over the long run (2012 to 2022), the reduction of 447 581 tons of maize (from this region) per year from the market would result in an average annual price increase of R300/ton, over and above a long-run projected average maize price of R2 090/ton. In other words, average white maize prices are projected to increase by approximately 14 per cent, which in turn would cause maize meal prices to rise by approximately 5 per cent. Maize porridge (made from maize meal) has been identified as one of the five most widely consumed food items in South Africa (Nel & Steyn, 2002).

Options to mitigate the effects of reduced supply of maize includes the reallocation of production, import the required grains if a deficit were to arise, or increase production efficiencies even more. However, keeping in mind that food security is based not only on food accessibility but also on affordability, importing maize implies that maize would be traded at import parity levels. Import parity levels will typically be around 30 per cent more expensive than maize trading at export parity prices in a scenario where South Africa has a surplus of maize (BFAP, 2015). Therefore, there is a requirement for more empirical evidence to support spatial land use allocation to selected industries in certain locations, as well as the quantification of economic constraints associated with those reallocations.

### 1.2.3 A proposed mitigation strategy

Due to the finite amount of arable resources available in South Africa, increasing focus falls on utilising currently unproductive arable land for additional agricultural production, while at the same time advancing rural development initiatives in the production expansion process. Within the context of expanding production, it has been said that vast amounts of arable land lie fallow in the former homeland regions of South Africa. According to the Department of Minerals and Energy (2006:10), more than 3 000 000 hectares of under-utilised, high-potential arable land can be utilised in the former homeland regions of the country. This is a significant area, given that the total arable land in current commercial farming amounts to approximately 15 000 000 hectares (AGIS, 2008).

With the objectives to eliminate hunger and poverty, the South African Integrated Food Nutrition Security Initiative ("Fetsa Tlala") has the target of bringing 1 million hectares into cash crop production in the former homeland regions of South Africa. Grain SA (NDA, 2014:1) has also coherently proposed the reallocation of maize production from Mpumalanga's current productive land that may potentially be transformed due to mining, to land with similar potential in the Eastern Cape and other former homeland regions in South Africa, where there are said to be significant areas that are either underutilised or unutilised.

There are three factors motivating the notion that the former homeland regions should be considered for the reallocation of maize production. Firstly, based on a modelled crop suitability assessment, these regions have the potential to grow maize successfully. Secondly, from a rural development perspective, these regions could benefit from expanding primary agricultural production. Finally, it is claimed that the Eastern Cape contains the most untapped and currently underutilised land resources which are available for enhancing agricultural production in South Africa.

The rationales presented above were partly developed and substantiated based on multi-criteria spatial analysis, which will be presented in Chapter 2. Even though spatial analyses take biophysical attributes, such as soil characteristics, land cover, rainfall and elevation, into account, one still needs to consider the economic viability of the proposed reallocation of maize production from Mpumalanga to the Former Homeland Region of the Eastern Cape.

### 1.2.4 Current approach in spatial allocation

Multi-criteria spatial analysis is one approach for assessing the bio-economic feasibility of prospective land use decisions (Shattri, Saied, Ahmad-Rodzi & Saied, 2012:231). The analytical techniques applied to spatially identify or allocate crop production are mostly evaluated based on the existing crop production or remote-sensed data. The base-layers for some of these crop allocation models would in most cases be land type or land capability classification layers, for which the approach was developed by Klingebiel and Montgomery (1961). However, it is argued that most of these land classification models, underpinning crop allocation models, lack economic suitability measures, as explained by Rossiter (1995:1).

Spatial economic analyses requires a comprehensive understanding of the geographic competition of land use, as well as the spatial location of production (Duranton, 2004:2). Consequently the need was identified to evaluate a field of study in which the economics of land use define the spatial allocation of production, instead of generally combining land classifications, biophysical models and a mathematical cross-entropy approach, as is the case in most spatial allocation analyses (Chakir, 2007:3).

## 1.3 RATIONALE AND PROBLEM STATEMENT

Besides the supply and demand factors driving the competition for land is specific land which is classified as unique or scarce (Laker, 2004:357). It is argued that value of land also depends on the scarcity of its qualities in a specified area or region, this according to the FAO (1976:21), as cited in Collett (2008:227). This scarcity of quality often results in the land being rare, and in most cases requires protection against uses that may lead to expropriation or non-agricultural uses which may nevertheless be highly profitable. Apart from the commodity based agricultural returns per hectare driving the competition for arable land, rapid expansions in mining activities are increasing the pressure on the availability of arable farmland. Policymakers in South Africa are currently trying to assess whether or not a particular region of the country should be awarded mining permits, and whether or not these mining activities might generate economic revenue for the country that exceeds the revenue streams of the agricultural activities they would displace. One challenge, however, is that the typical lifespan of a mine is only 15 to 20 years, whereas sustainable agricultural practices can, in principle at least, generate a permanent income stream and can boost the food security status of the country by expanding local production sufficiently to reduce food prices (BFAP, 2015).

One area reflecting this debate is the Mpumalanga area. In a recent study, undertaken by BFAP (2012:8), it was estimated that if the current field crop boundaries were overlaid with prospective areas designated for mining activity in the Mpumalanga province, a total of 326 022 hectares of cultivated farmland would be lost due to existing mining activities. A further 439 577 hectares are at risk, too, if the prospected mining areas are to proceed (BFAP, 2012:8).

In conducting this analysis, the dryland crop production layer of the Integrated Food Nutrition and Security Initiative (IFNSI) primarily used Land Capability Classes (I to IV) to conduct a spatial maize suitability analysis for South Africa.

## 1.4 RESEARCH GOAL AND OBJECTIVES

The specific objectives of this study, are:

- To review existing spatial land use models available and assess their ability to successfully incorporate the economic dimensions needed for the reallocation of maize area from Mpumalanga to the Eastern Cape.

- To illustrate the impact of economic fundamentals (prices) on regional maize production and consumption in the Former Homeland Region of the Eastern Cape.

- To undertake a spatially explicit gross margin analysis to compare Mpumalanga's maize production area to that of the Former Homeland Region of the Eastern Cape, focusing on a spatial gross margin analysis as a selected economic attribute.

## 1.5 DELIMITATIONS

As several issues fall beyond the scope of this study, a few caveats concerning the analysis were identified:

- It is important to note that, owing to data constraints concerning the former homeland areas of the Eastern Cape, the study is limited to more detailed evaluations for the Mpumalanga province.
- The study is focused on a single commodity, white maize, and also ignores the economic trade-offs involved between livestock and cash crop production.
- Factors pertaining to land tenure have an important influence on patterns of land use, but these land tenure issues are set aside in the context of this study.
- The size and structure of farms can have a significant influence on the economics of maize production. Although this study is undertaken with spatially disaggregated data, the nature and structure of the farming unit is not explicitly considered.
- Relatedly, whole farm planning, as a means for spatial economic comparisons, is not included in this study. Whole farm planning can calculate net profit margins, which provides more insight than gross profit margins as an output for analysis.
- This study does not consider broader social and historical aspects as a possible factor of influence on spatial reallocation.
- The purpose of this study is not to explain relocation of maize production, as that would require evaluating the relocation of the same intensity, practice and farmer typology. The reallocation evaluation implies that new or unused land would need to be placed into production in the Eastern Cape.

# CHAPTER 2

# CONTEXTUALISING SOUTH AFRICA'S SPATIAL DATA

## 2.1 INTRODUCTION

The Agricultural Research Council – Institute for Soil, Climate and Water (ARC-ISCW), has estimated that South Africa has a surface area of 122 000 000 hectares (ARC-ISCW, 2004:2). From that total surface area, between 94 543 292 hectares (AGIS, 2008) and 100 665 792 hectares (DBSA, 1991, in DAFF, 2011) have been designated as agricultural land. However, only 15 887 725 hectares were considered arable, which constituted approximately 12.4 per cent of the total surface (AGIS, 2008).

South Africa has distinctive sets of resource limitations when viewed from a refined natural resource base (ARC-ISCW, 2004:2). These limitations include vast amounts of semi-arid areas not suitable to dryland crop production and regions which receive high rainfall, but the soils are susceptive to erosion, such as the Eastern Cape. Apart from these resource limitations, the country does have areas with very high suitability for arable crop production. Integrated spatial approaches, which allocate or identify proposed production areas, comprise an important concept to consider and appreciate in the current and future utilisation of agricultural resources (Samranpong & Pollino, 2009:1).

The report on natural agricultural resources compiled by the ARC-ISCW (2004) mapped some of the most relevant natural resource layers and presented the main constraints on, as well as the most suited layers to be used in evaluating, the potential for agricultural production. The purpose of this chapter is therefore to show how these spatial layers are typically applied in multi-criteria GIS analyses and to further argue towards their relative importance and inclusion in the related approach of this study.
Furthermore, the past and present cultivated areas of South Africa, with a specific focus on maize, will be quantified. The projected shifts of grain and oilseed production in the coming decade will be measured in order to introduce the market drivers in crop selection and future allocation.

## 2.2 AN OVERVIEW OF THE NATURAL AGRICULTURAL RESOURCES

The ARC-ISCW compiled a report, the "Overview of the Agricultural Natural Resources of South Africa", in which extensive analyses were done to provide a data catalogue of available information on the natural resource base for agricultural in South Africa (ARC-ISCW, 2004:1). The report was conducted on a national scale by implementing the use of spatial information, with the aim to provide baseline information for identifying threats and opportunities related to land use and land management (ARC-ISCW, 2004:1). Approximately seventy-five maps of different compilations were used in the report, of which only a few will be discussed in this study.

This section explains the integrated application procedures and the accuracy of layers used in spatial resource analysis or resource modelling using GIS. To analyse climate, terrain and soil criteria layers, different factors or variables were considered. Those factors included the consideration of slopes, natural acidity levels, soil structure, susceptibility of soils to erode, land forms, predicted soil loss, degraded soils and natural soil carbon (ARC-ISCW, 2004). All of those layers were developed, modelled or re-calibrated to a national scale and verified with field observations or by the Land Type database (ARC-ISCW, 2004).

### 2.2.1 Introduction to the natural resource database

Within the evaluation of agriculture and its contribution to food security, it should be kept in mind that a resource limitation is not necessarily a production limitation when best agricultural practices and intensive management is implemented (Schoeman et al., 2002:viii).

Apart from resource limitations identified in the ARC-ISCW report, the country does have areas with very high suitability to arable crop production, which in reality should have a much broader focus than grain crop production, where return per hectare could be higher with high-value commodities. Those areas were identified as certain coastal districts with limited land, but the land identified was of very high arable potential, such as the Western and Eastern Cape. As explained by Schoeman et al. (2002:viii), the land in the former Transkei (Eastern Cape) can also be regarded as “irreplaceable” agricultural land. This land should most probably be seen as comparable to the Western Cape, with the production potential for high-valued commodities such as grapes, apples, pears and stone fruit. However, that could only be achieved if best agricultural practices were to be followed. Semi-permanent agricultural commodities have lower limitations as to slopes and difficult terrain than grain crops do. Therefore, in this particular case, climate or rainfall can represent a higher weight in the process of modelling the capability of land.

Sectional overviews were extracted from the ARC-ISCW report, which were used as a benchmark to draw comparative overviews between related production regions or provinces. The sectional overviews, namely climate, terrain and soil, described the basis of criteria that were used in the analysis of the agricultural land capability layer, as presented by Schoeman et al. (2002:vi).

#### *2.2.1.1 Climate*

The ARC-ISCW (2004:124) identified average monthly rainfall as the main determinant of a resource status. It was explained that 90 per cent of South Africa belongs to the drylands of the world (ARC-ISCW, 2004:124). Drylands are internationally recognised as being inclined to degradation, and in advancing cases, desertification if not well managed (ARC-ISCW, 2004:124).

#### *2.2.1.2 Terrain*

The ARC-ISCW (2004:124) emphasised that level land seldom corresponded with high rainfall and good soils, except in the Mpumalanga Highveld and adjacent Gauteng, the KwaZulu-Natal midlands, and the Eastern Free State. Those identified areas were found to have some of the best arable land, classified as land capability Class II and III (ARC-ISCW, 2004:124).

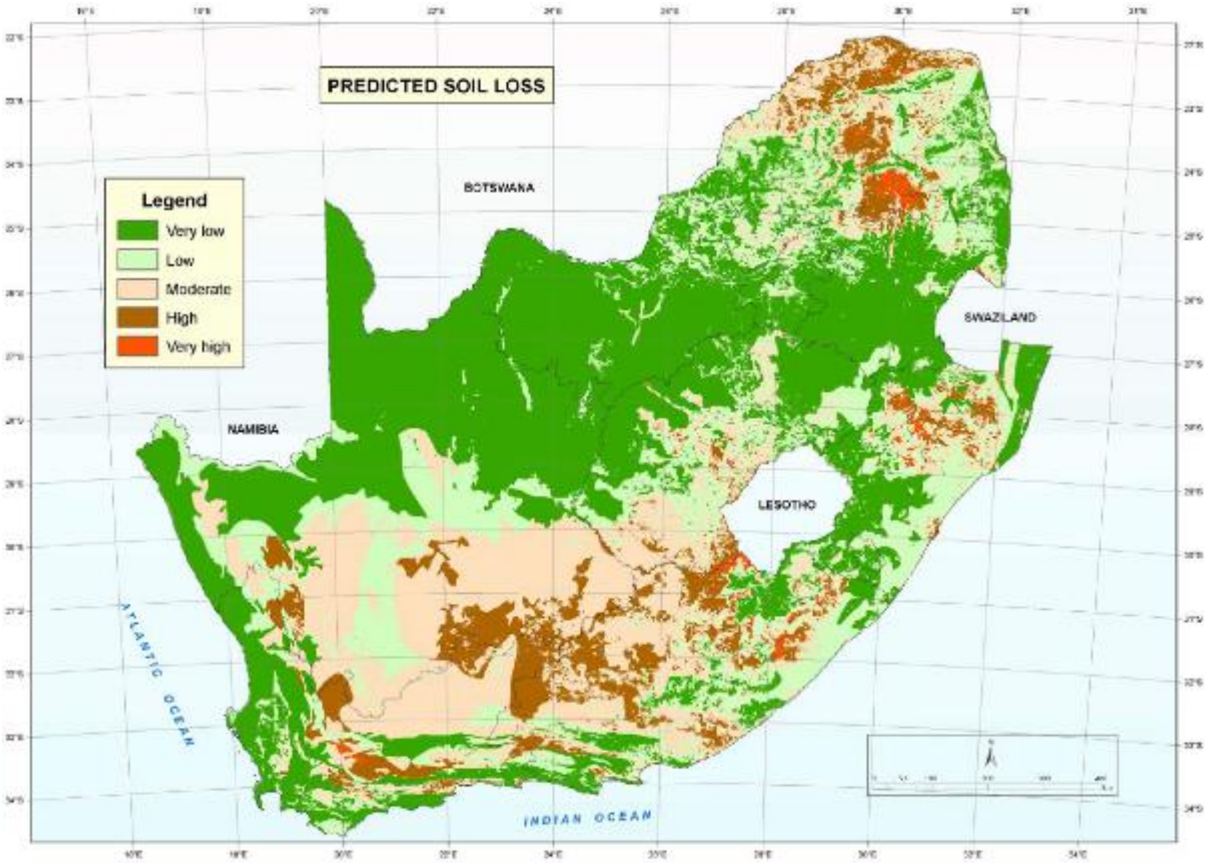
*2.2.1.3 Soil*

In the land capability models, higher weights are given to rainfall as a function of arability, but soil properties and the level of land use can in many instances be a stronger determinant in determining land use allocation (ARC-ISCW, 2004:124).

Mills and Fey (2004:394) stated that soil was regarded as the foundation for sustainable crop production and further argued that:

> “The pedoderm or first few centimetres of undisturbed topsoil hold disproportionately more humus, nutrients and salts than the underlying layers. Consequently even a small loss of surface soil can initiate a decline in soil quality that becomes self-sustaining. It is this very thin layer of organic-rich surface soil, evident in uncultivated land, as well as minimally tilled cropland and pasture, on which future soil quality research should concentrate.”

Pretorius (1998), as cited in ARC-ISCW (2004:104), conducted a modelling exercise for predicting soil erosion using the Revised Universal Soil Loss Equation (RUSLE), which considered soil management, climate, terrain, and soil profiles. This output, as shown in Map 2.1 below, provides a spatial illustration of the integrated layers and represents the importance of assigning key representative variables in the allocation of land use for the purposes of sustainable agricultural production.




**Map 2.1: Modelled predicted soil loss**

*Source: Pretorius (1998), in ARC-ISCW (2004:105)*

Among the current models for predicting erosion of soils, Map 2.1 may be the most useful as it is closest to taking all the key variables into account (ARC-ISCW, 2004:104). This erodibility model calculates average soil loss by means of the following factors:

A (Average annual soil loss) = R x K x L x S x C x P, where:

R = Rainfall erosivity

S = Slope gradient

C = Cover and management factor

P = Support practice factor

K = Soil erodibility factor

L = Slope length

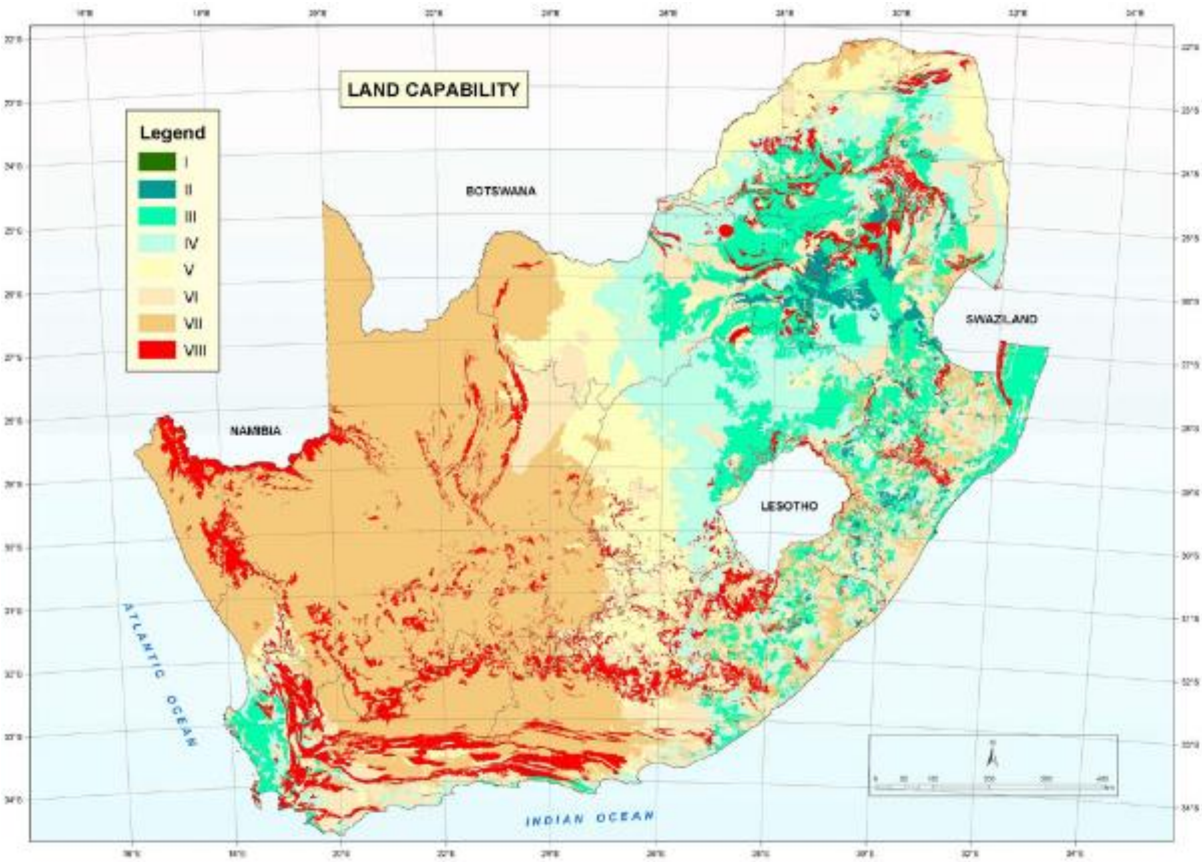
The final coverage was confirmed by means of 106 observation points along predetermined transects and it was determined that the accuracy between the modelled or predicted erosion and the field observed erosion was 74 % for the high classes and 69 % for the low classes (ARC-ISCW, 2004:104).

The outputs as provided through the RUSLE model, presented in Map 2.1 above, indicate that most areas in South Africa have some risk of soil loss. Losing topsoil, where a large percentage of the carbon or organic nutrients is found, can be regarded as one of the main risk factors in maintaining high levels of grain production (Mills & Fey, 2004:394). The loss in topsoil may consequently result in heavily degraded land, which is currently the case within most of the former homeland areas of South Africa (ARC-ISCW, 2004:100).

### 2.2.2 South Africa`s agricultural land – land capability data

According to AGIS (2013:2), the National Department of Agriculture (NDA) appointed the ARC-ISCW in the year 2000 to evaluate the existing scientific spatial database on terrain, soil and climate parameters. This was captured and reclassified from the Land Type Inventory, climate, soil and terrain databases, and presented in the ARC-ISCW report (ARC-ISCW, 2004:94). That analysis was undertaken to compile a national Land Capability (LC) database to create a geo-referenced map for the country (Map 2.2 below).

The land capabilities were identified as having cropping potential or being suitable for cultivation according to the same criteria used by Klingebiel and Montgomery (1961) for the USDA land capability classifications. Those criteria were applied to the South African natural resource database using multi-criteria GIS analyses. According to Schoeman et al. (2002:1), those classifications were based on “the extent to which land can meet the needs of one or more uses under defined conditions of management.” It was further explained that land capability can be regarded as the classification of a group of land units with similar potential, limitations or hazards for rain-fed agricultural production (Schoeman et al., 2002:viii).




**Map 2.2: South Africa's Land Capability**

*Source: Schoeman et al. (2002), in ARC-ISCW (2004:95)*

Locally available data was used and analysed into criteria at all levels of scale to produce outputs related to climate, soil and terrain (Schoeman et al., 2002:vi). Those criteria were then future analysed and compiled within the same framework as set out by Klingebiel and Montgomery (1961) in their land capability classification. Table A.1 (Appendix B) provides an explanation of the relevant land classifications and their concepts of identification, including climate, terrain and soil criteria. The layers presented in Table 2.1 below were utilised for the spatial analyses and classification (Schoeman et al., 2002:vi). A comprehensive evaluation of the available land capability datasets and methods concluded that all of them since 1974 to 2002 were mostly based on the USDA's land classification system (Laker, 2004:363). The broader classification structure of the USDA, underlying South Africa's land capability database, was designed for production systems which are virtually fixed for "large scale mechanized farming; high management levels; good infra-structure; a small number of field crops dominating" and regrettably these assumptions are potentially not entirely valid for small-scale farmers in South Africa's former homelands (Laker, 2004:358). In one of the most recent reports on land capability, Schoeman et al. (2002:7) explained that "land capability is determined mainly by the collective effects of soil or terrain features and climate." However, it was also acknowledged that within certain conditions, land use planners would first make an effort to rate soil capability, before considering the influence of climate on the use of the land (Schoeman et al., 2002:7).

**Table 2.1: Layers used in South Africa`s Land Capability Classification**

| Section or criteria | Layers used |
|---|---|
| **Climate** | Moisture availability, length of moisture season, length of temperature season, frost hazard, wind hazard, hail. |
| **Terrain** | Flood hazard, erosion hazard. |
| **Soil** | Depth, texture, erodibility, internal drainage, mechanical limitations, acidity. |

*Source: Schoeman et al. (2002:vi)*

With regard to the recommended resource utilisation of South Africa's available land, reports claim that between 94 543 292 hectares (AGIS, 2008) and 100 665 792 hectares (DBSA, 1991, in DAFF, 2011) are found to be agricultural land. In the effort to understand the dryland cropping potential of the country, AGIS (2008) identified[1] 15 887 725 hectares as having the potential to be cultivated or land in capability classes I-III, whereas the data gathered from Schoeman et al. (2002) presented in Table 2.2 below, is recalculated at 15 881 944 hectares.

Arable land would therefore constitute approximately 12.4 per cent of the total surface area of South Africa that is capable for the cultivation of rain-fed crops without much limitation. From the total surface area of South Africa, a mere 1.8 per cent might be regarded as high-potential agricultural land (land in capability class II), while only 0.002 per cent might regarded as very high-potential agricultural land (land in capability class I) (ARC-ISCW, 2004:94).

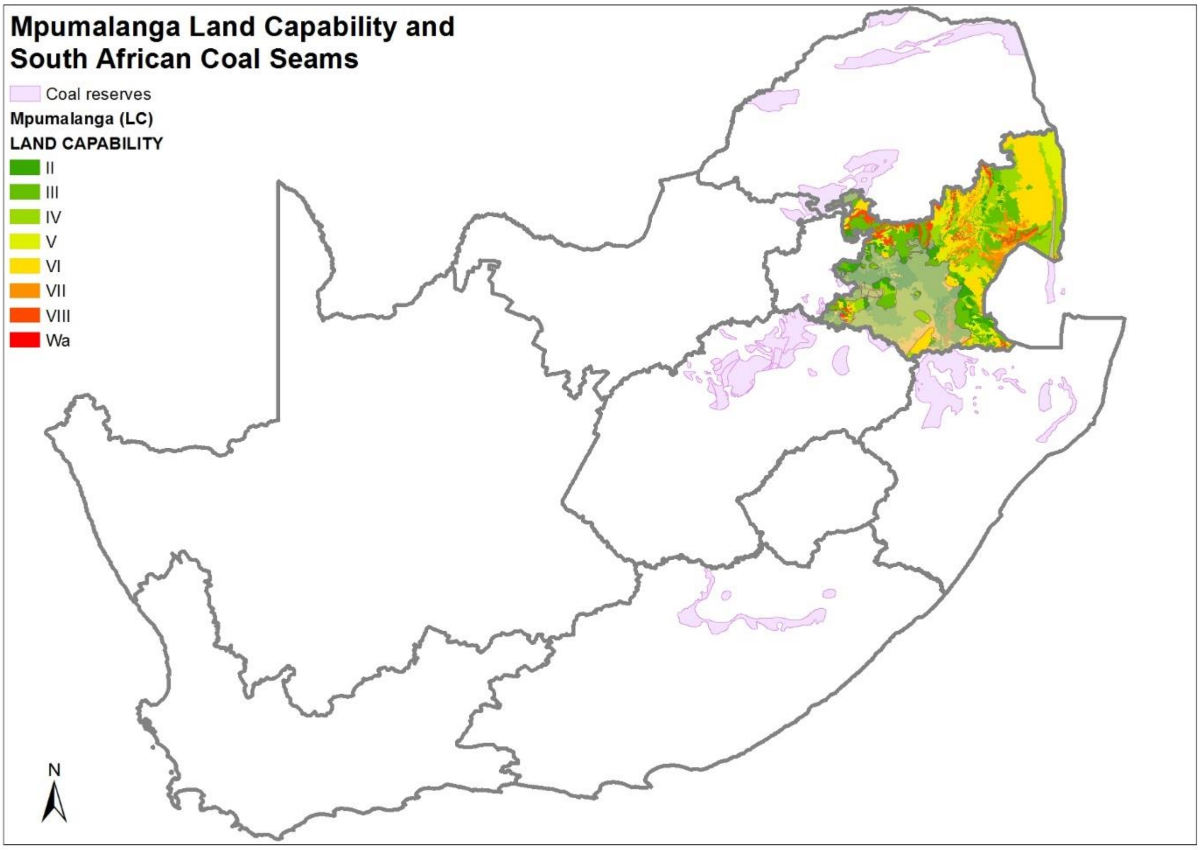
[1] AGIS calculated this figure from the land capability layer as presented by Schoeman et al. (2002). AGIS further went on to exclude the permanently transformed or built-up areas. They further excluded the land that falls outside agriculture according to Act 70 of 1970 (AGIS, 2008).

**Table 2.2: Land capability per province**

| | High (II) capability arable land | % of Class | Moderate (III) capability arable land | % of Class | Combined (II & III) | % of Class |
|---|---|---|---|---|---|---|
| | Hectares | | Hectares | | Hectares | |
| **Eastern Cape** | 78 787 | 4 % | 1 191 729 | 9 % | 1 270 517 | 8 % |
| **Free State** | 12 701 | 1 % | 2 241 476 | 16 % | 2 254 177 | 14 % |
| **Gauteng** | 389 310 | 21 % | 704 595 | 5 % | 1 093 905 | 7 % |
| **KwaZulu-Natal** | 406 932 | 22 % | 2 690 674 | 19 % | 3 097 606 | 20 % |
| **Limpopo** | 96 921 | 5 % | 2 437 993 | 17 % | 2 534 915 | 16 % |
| **Mpumalanga** | 872 008 | 46 % | 2 085 727 | 15 % | 2 957 735 | 19 % |
| **North West** | 21 941 | 1 % | 1 755 342 | 13 % | 1 777 283 | 11 % |
| **Western Cape** | | | 895 808 | 6 % | 895 808 | 6 % |
| **Northern Cape** | | | | | | |
| **Total** | 1 878 600 | | 14 003 344 | | 15 881 944 | |

*Source: Own compilation based on Schoeman et al. (2002)*

It was previously mentioned that the scarcity of resource qualities often results in arable land being rare, and in many cases require protection against uses that may lead to expropriation or non-agricultural uses (Collett, 2008:227). For example, Chapter 1 referred to South Africa's vast mineral resource base, which results in an increasing competition for arable land. Furthermore relating to the rareness or value of land, Map 3 below presents the vast amounts of mineral wealth in the province of Mpumalanga situated underneath land that also provides high levels of profitability from the production of crops that contribute to the wealth South Africa. In Map 2.3, Mpumalanga Province is highlighted in green and is embedded within South Africa's largest coal mineral seams that are highlighted in pink. At the same time, 48 per cent of the country's highest potential arable land is found in this region, with dryland maize yielding between 5 t/ha to 9 t/ha.




**Map 2.3: South Africa's coal seams overlaid with Mpumalanga's (MP) maize suitability**

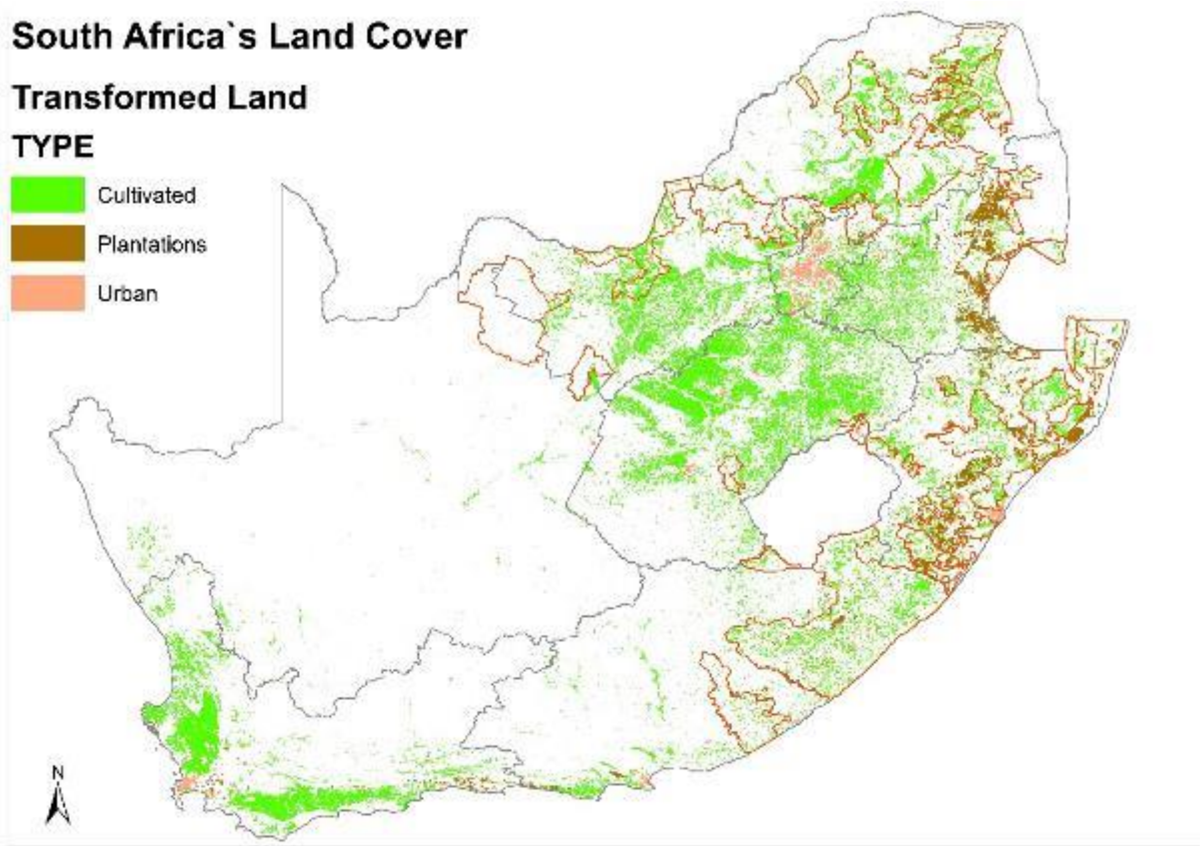
*Source: Own compilation based on Council of Geo-Science (2013) and AGIS (2013)*

From a land capability or soil suitability potential perspective, South Africa's limitations are unavoidable. However, the province of Mpumalanga poses an exception, with 46 per cent of the total high-potential agricultural soils (land in capability class II) being located in this province (BFAP, 2012:9). In addition to the Mpumalanga province's high-potential agricultural soils, it was further stated that "extremely valuable land in the seaboard areas of the former Transkei with moderately steep slopes and shallow soils can, in a sense, also be regarded as unique farmland. Its value has to be unlocked by best practice technologies" (Schoeman et al., 2002:viii). More in-depth analyses on the land capability data, as well as its applications, will follow in Chapters 3 and 4.

## 2.3 SOUTH AFRICA'S CROPPED AREAS – PAST, PRESENT AND LIKELY FUTURE

Section 2.2 gave a spatial overview of agricultural land and associated "suitability" attributes. In this section we explore shifts in the past and present cultivated areas of South Africa over the past several decades, as well as the projected shifts of maize production in the coming decade.

### 2.3.1 Land cover at a national scale (2000)




**Map 2.4: Total national land cover**

*Source: Own compilation based on ARC-ISCW (2004:96)*

According to Fairbanks, Thompson, Vink, Newby, van den Berg, and Everard (2000), cited in ARC-ISCW (2004:96), human-impacted classes of South African land cover were originally mapped by the National Land Cover project. A further analysis was done by AGIS (2011) which estimated the agricultural cultivated areas per province, as shown in Table 2.3 below. According to AGIS (2011), at least 13.1 million hectares of land was under some form of cultivation, or was cultivated, during each of the years 2007–2009.

**Table 2.3: Total hectares cultivated per province**

| Year | 2007 | 2008 | 2009 | 2007 | 2007 | 2007 | 2007 | 2009 | 2007 |
|---|---|---|---|---|---|---|---|---|---|
| **Cultivation Type** | Province (viewed in hectares) | | | | | | | | |
| | **EC** | **FS** | **GP** | **KZN** | **LP** | **MP** | **NC** | **NW** | **WC** |
| **High cultivation** | 19 274 | 1 064 183 | 26 995 | 0 | 141 252 | 159 773 | 27 274 | 936 800 | 214 147 |
| **Medium cultivation** | 160 696 | 1 738 863 | 165 619 | 159 133 | 199 424 | 579 197 | 2 996 | 641 205 | 87 927 |
| **Low cultivation** | 318 076 | 652 712 | 81 953 | 131 414 | 255 540 | 204 736 | 156 722 | 384 404 | 50 889 |
| **Old Fields** | 18 554 | 170 744 | 1 934 | 3 291 | 21 369 | 0 | 2 180 | 69 218 | 7 415 |
| **Pivot Irrigation** | 22 627 | 121 540 | 18 650 | 40 110 | 125 183 | 33 298 | 72 546 | 67 865 | 149 878 |
| **Small-scale farming** | 1 080 332 | 23 919 | 1 940 | 255 963 | 524 540 | 16 297 | 282 | 184 244 | 1 475 442 |
| **Smallholding** | 0 | 0 | 3 913 | 0 | 0 | 0 | 0 | 0 | |
| **Smallholding < 5ha** | 0 | 0 | 13 932 | 0 | 0 | 0 | 0 | 0 | |
| **Total** | 1 619 559 | 3 771 961 | 314 936 | 589 911 | 1 267 308 | 993 301 | 262 000 | 2 283 736 | 1 985 698 |

*Source: AGIS (2011)*

Of the 13.2 million hectares of cultivated land, approximately 3.1 million hectares was planted to cereal or oilseed crops during the 2013/2014 production season, well down from its peak of 8 million hectares during the 1985/1986 production season (Figure 2.1 below).

### 2.3.2 Historical shifts in grain and oilseed area

The total area planted to maize in the 2014 production season decreased by 1 966 800 hectares or 39 per cent from the record area planted in 1986, while the tonnage of maize produced over the same period increased by 90 per cent (SAGIS, 2014). Similar decreases in area planted can be observed in other cash crop commodities, such as wheat and groundnuts. However, the area planted to soybeans and canola oilseed crops increased in response to higher global demand, while new production technologies also increased output per hectare. The South African reduction in maize and wheat area sown was larger than the increase in oilseed area (BFAP, 2014a:38).

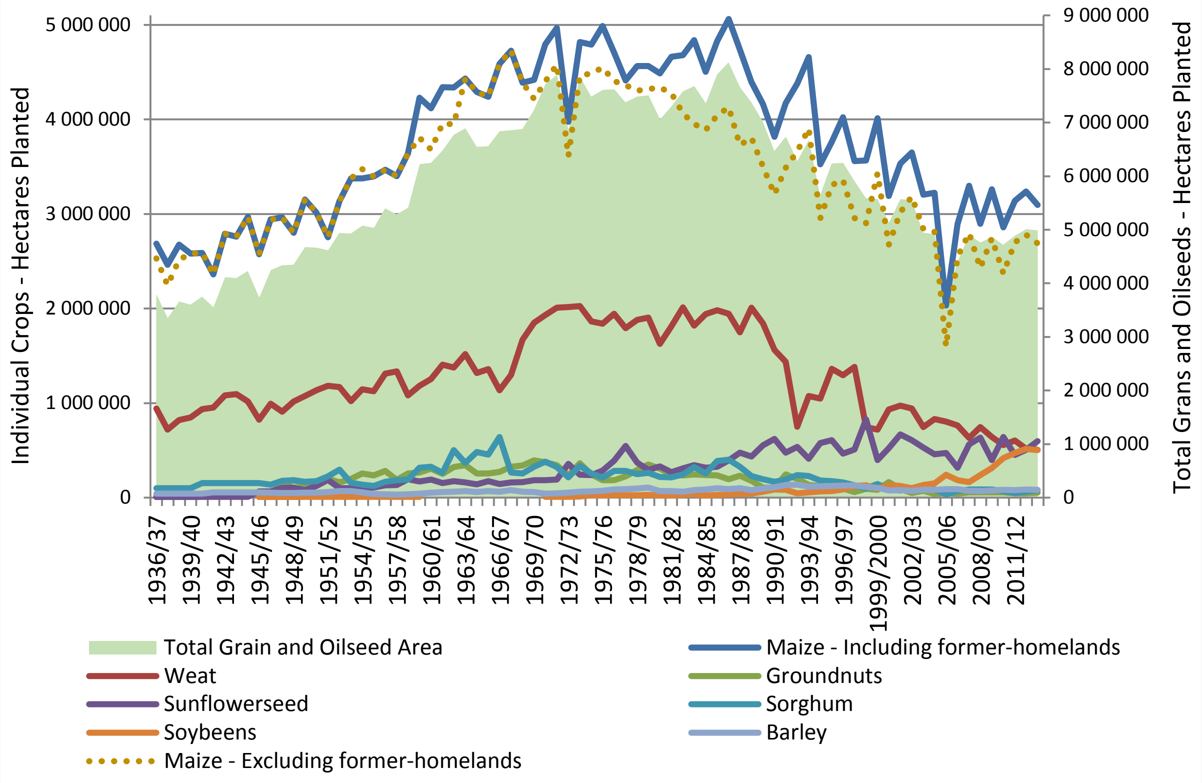



**Figure 2.1: Historical area change in grains and oilseeds planted**

*Source: SAGIS (2014)*

The increase in maize output, accompanied by the reduction in area planted, can broadly be attributed to efficiency gains due to higher yielding varieties of seeds, increased area under irrigation and the optimal utilisation of higher potential soils using adopted technologies (BFAP, 2015). The overall reduction in cash cropped hectares can further be explained by the deregulation of the South African marketing boards in May 1997. This new marketing regime meant that producers were fully exposed to market driven prices, contrary to the price determination made under the Marketing Boards where prices were set prior to the onset of the production seasons. According to the NAMC (2003:8), grain producers had to operate in a deregulated market with volatile and fluctuating prices, and a large gap in local market information existed. The NAMC further explained that there was an extensive decrease, as well as regional shifts, in the area planted to maize (mainly yellow maize) (NAMC, 2003:8).

In addition to the reduction in areas for the commercial production of maize, there was a collapse of the “betterment schemes” in the former self-governing regions in South Africa (Laker, 2004:363). The betterment schemes were first implemented in South Africa in the late 1930s, with the aim to “rehabilitate” agriculture and land use in the “native reserves” (ECDARD, 2008:4). Dispersed family landholdings were merged into village settlements and land was divided into residential, crop production and grazing usage (ECDARD, 2008:13). It was considered that the failure of the betterment schemes might also be attributed to soil erosion and related soil degradation (Laker, 2004:363). According to Laker (2004:363), differences in soil quality and the susceptibility to erosion were not considered when particular parcels of land were designated for the production of particular crops. The result was that by the mid-1970s, large tracts of the Transkei and Ciskei production areas were abandoned by farmers. In the South African maize sector, there has been a steady decline since 1968 in the area sown to (commercial) maize, especially the areas sown to white maize. Over the past five years, the total area under maize has fluctuated at around 2.6 mil hectares, as shown in Figure 2.2 below. In the 2013/2014 production season, a total of 14.17 million tons of maize was produced on an area of 2.78 million hectares. The domestic use for the same period was 9.65 million tons, which can be further divided into two main categories, being for stock feed (5.04 million tons, in the form of yellow maize) and human consumption (4.61 million tons, in the form of white maize). South Africa is a net exporter of (mainly yellow) maize, and during 2013 a total amount of 2.23 million tons was exported (BFAP, 2014a:29).

Together, the Free State, North West and Mpumalanga provinces accounted for nearly 83 per cent of the total annual maize crop produced in South Africa in 2014 (SAGIS, 2014). The largest producer was the Free State province, which alone delivered an average of 4.2 million tons of maize, which is 37 per cent of total national deliveries from over a million hectares, or 42 per cent of the total area planted to maize in 2013/14 (SAGIS, 2014). The Free State’s total grain and oilseed hectares combined is roughly 1.7 million hectares and had been as high as 2.3 million hectares in the late 1990s, as calculated from SAGIS (2014). The second largest producing province, the North West, has had a sharp decline in the area planted to maize of roughly 57 per cent since 1988 (Figure 2.2 below), which accounts in part for the overall national reduction in hectares planted to maize. Finally, the Mpumalanga province continued to produce a steady supply of maize as this province has since 1988 to date remained to produce on between 18 and 20 per cent of the total area planted to maize and further managed to produce an average of 23 per cent or 2 134 000 tons of maize total maize crop over the same period.

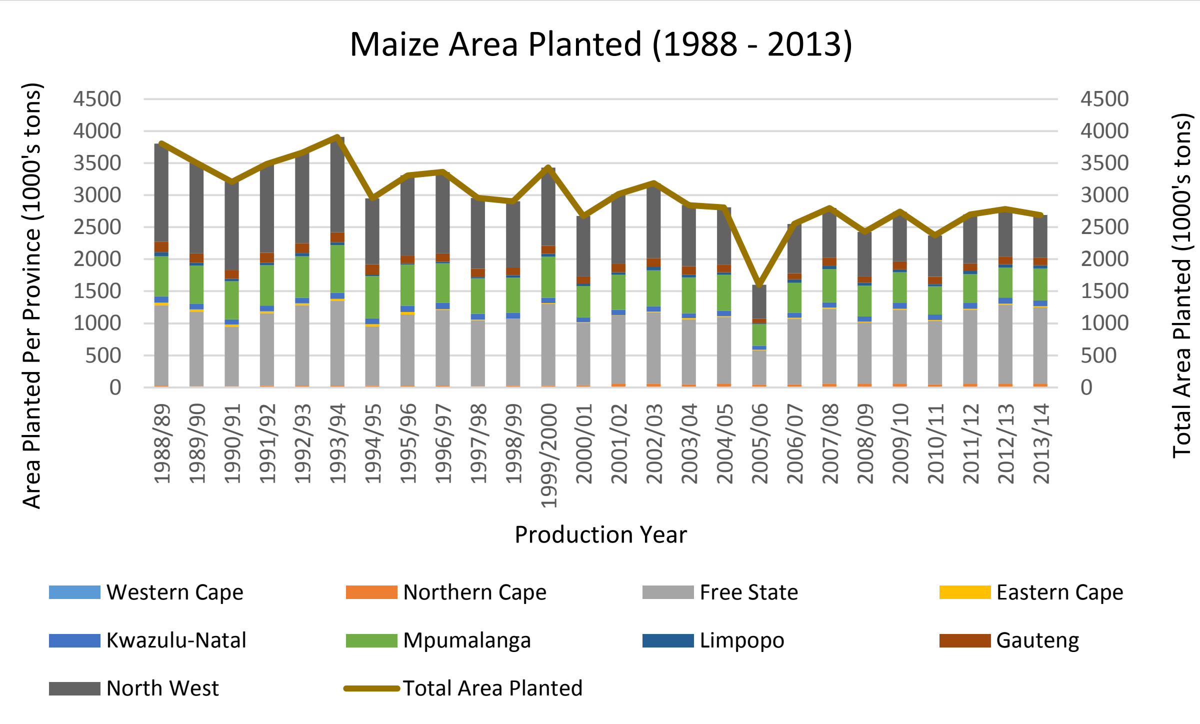



**Figure 2.2: Maize area planted per province (White & Yellow Maize)**

*Source: SAGIS (2014)*

Although Chapter 2 has covered South African maize production in general, Chapter 4 will more specifically cover the Former Homeland Region of the Eastern Cape and the Mpumalanga province in more detail.

### 2.3.3 Projected shifts in maize production

Various approaches and methodologies are typically applied to generate a projected outlook for an industry (BFAP, 2015). In its annual baseline projections, BFAP makes use of a partial equilibrium approach. The baseline projections include a 10-year outlook of key fundamental variables for various industries. According to BFAP (2014a) (Figure 2.3 below), a decreasing trend in grain area planted can still be expected. The area planted to maize is projected to decline, while the area for oilseeds might gain or take over some of the hectares sown to maize. The prospective shift in hectares under production was generated within the partial equilibrium framework of the BFAP sector model. It is a recursive partial equilibrium model and does not take all the spatially explicit attributes into consideration when generating the outlook. The competition for arable hectares is mainly driven by farm-level profitability (Van der Westhuizen, 2013:214) and this competition is expected to favour the oilseed expansion, while total arable land usage is not expected to increase, but rather to remain flat, as shown in Figure 2.3 below.

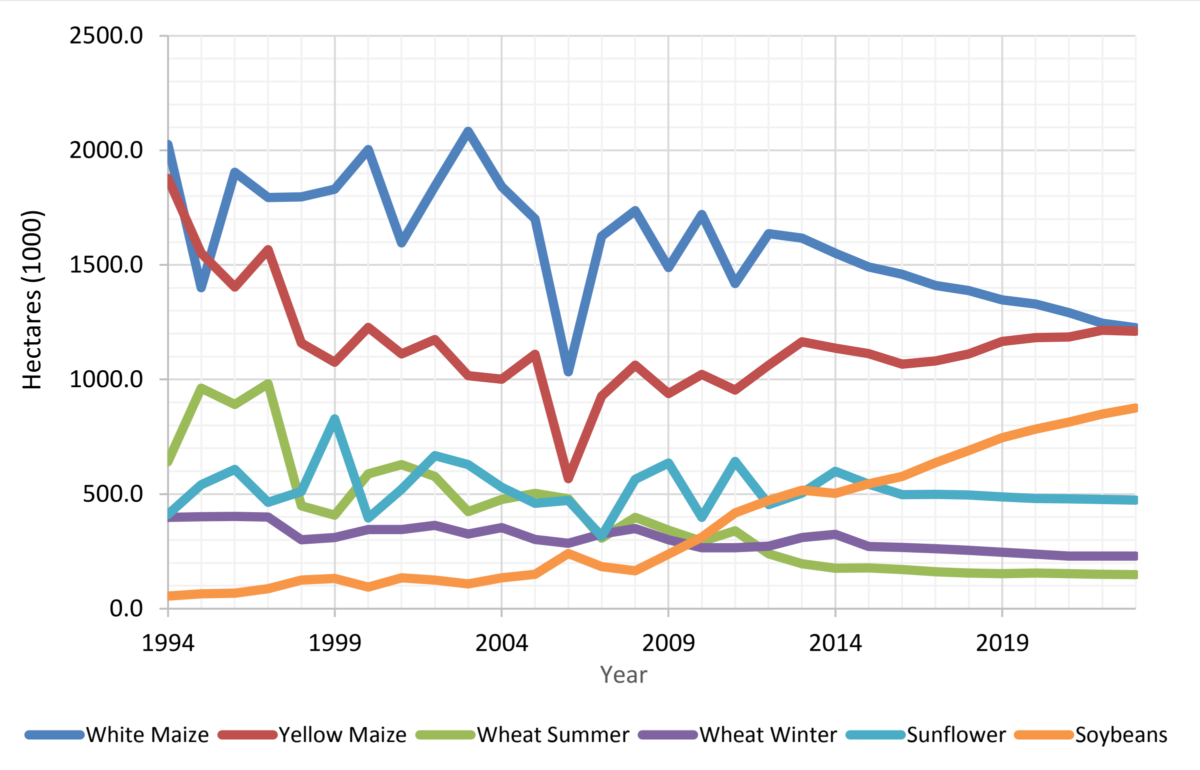



**Figure 2.3: Projected grain and oilseed hectare competition**

*Source: BFAP (2014a)*

## 2.4 CONCLUSION

This chapter provided insight to the spatial-varying biophysical, economic and policy properties of current and future maize production. The Natural Resource Atlas (ARC-ISCW, 2004) provided some of the main contributions to this knowledge base. Understanding the past policy regimes and their impact on land use is vital in the reallocation of production, given the defined and restricted resource endowments of South Africa, as presented in Section 2.2 above. In the next chapter, a more detailed analysis of certain processes followed in spatial analysis is presented, with specific emphasis being placed on spatial allocation analysis.

# CHAPTER 3

# SPATIAL ANALYSES

In this chapter, various methodologies used in spatial analysis provide insight into the possible application of spatial analysis in the field of agricultural economics. These methodologies can inform the selection process of the most applicable spatial allocation criteria to use to determine the economics of spatial reallocation. Spatial data was defined as data that vary over space (Bell & Irwin, 2002:2). Based on a simple rule of thumb, considering whether to use spatial data is to ask the question: does location matter? According to Bell and Irwin (2002:2), "when values are measured at specific locations and relative location matters, data are inherently spatial."

According to You, Wood and Wood-Sichra (2006:2), "Spatial data (or geo-referenced data), which are data that include the coordinates (either by latitude/longitude or by other addressing methods) on the surface of the earth, are essential for any meaningful development strategies." As the objectives and implementation of rural development policies are essential to fuel economic growth and alleviate poverty, researchers recognised the importance of conserving natural resources in order to sustain long-term growth (You, et al., 2006:1). It is not surprising that an increasing number of agricultural economists value and argue for the importance of spatial data and have used spatial analysis in their research (Nelson, 2002, in You et al., 2006:2). It has been emphasised that since the location of agricultural production matters, influences on developmental strategies would to a large extent depend upon a better understanding of spatial determinants of agricultural development (Wood, Sebastian, Nachtergaele, Nielsen & Dai, 1999:1-4, in You et al., 2006:1).

The criteria or spatial determinants identified within this chapter will be included in the spatial analysis process to evaluate the land use consequences of selected economic variables in Chapter 4. The outcomes will enable an assessment to be made of the relative importance of different data layers within a spatial economic analysis.

## 3.1 SPATIAL ALLOCATION

The decision process referred to as spatial allocation assigns subsets of relevant criteria relating to activities of interest explained in spatial units, such as grid cells or land parcels (Shirabe, 2005:269). Different spatially explicit approaches to assessing land use options exist and only some of the models make explicit use of economic attributes (Lambin, Rounsevell & Geist, 2000:321; Malczewski, 2004:31; Nguyen, Verdoodt, Van Y, Delbecque, Chi Tran & Van Ranst, 2015:1). In one of the recent studies evaluating the interaction between economic and biophysical models, Chakir (2007:2) explained that it was required to take biophysical variables (soil characteristics, climate and altitude) into account when applying economic modelling. Considering biophysical variables may enhance the analyses of farmer behaviour and establish the effects of public policies with much more rigour (Chakir, 2007:2). Similarly, various authors (Dorosh, Wang, You & Schmidt, 2009:12; Benke, Wyatt & Sposito, 2011:1) provide frameworks of economic suitability analyses aimed to maximise net revenue. This form of spatial analysis offers yet another measure in land use allocation.

The following four categories of spatial allocation approaches are discussed: 1) allocating disaggregated production data; 2) multi-criteria analysis; 3) land use determination and 4) resource optimisation. These approaches have differing, but aligned, fields of application. Within GIS analysis it is not necessarily required that the complete methodology of the mentioned approach needs to be applied to produce spatial allocation results (Malczewski, 2004:27). Instead, key variables or components of the spatial allocation process can be selectively identified to use combinations of spatial criteria applicable to a specific study (Shirabe, 2005:269). Thus, such criteria can often be based on the expert knowledge of the researcher.

An illustrative explanation of the procedure to spatially disaggregate agricultural production data in the study by Xavier, Martins and Fragoso (2011:3) is presented in Diagram 3.1 below. Various authors regard the spatial disaggregation of production data as being a requirement for spatial allocation modelling.

### 3.1.1 Modelling the location of production

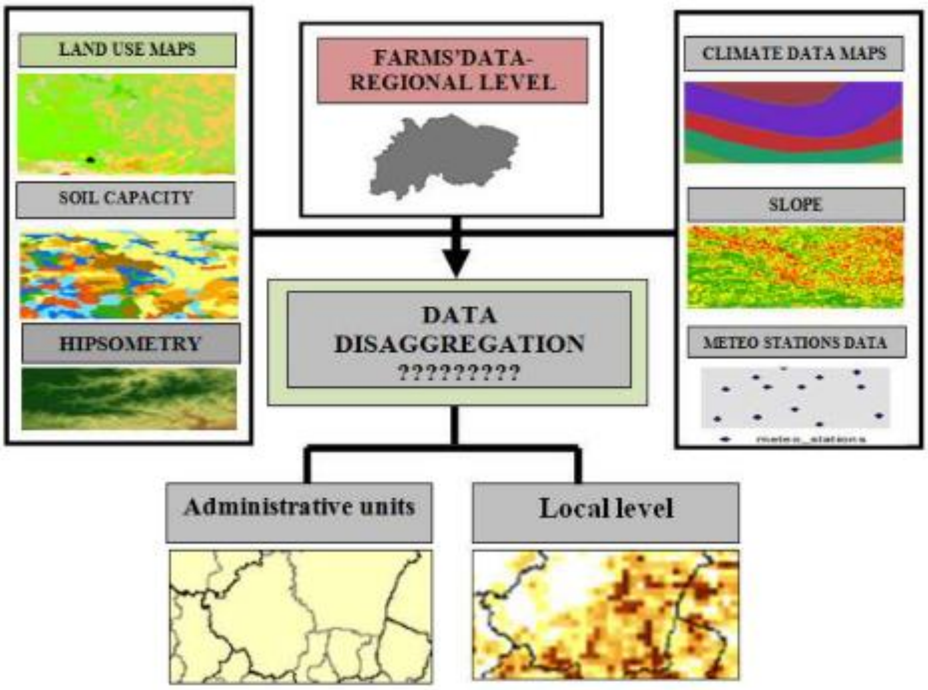



**Diagram 3.1: The description of the disaggregation problem**

*Source: Xavier, Martins and Fragoso (2011:3)*

The empirical analysis utilises a maximum entropy approach to disaggregate agricultural data reported in vector (or geopolitical) units to raster (or pixilated) units (see, for example, Anderson, You, Wood, Wood-Sichra & Wu, 2014:1; Chakir 2007:1; Xavier, Martins & Fragoso, 2011:3 You & Wood, 2006:2). In a recent study relating to the spatial allocation of global crop production, it was argued that remote-sensing products could also offer spatially disaggregated information (Anderson et al., 2014:1). However, it was found that remote-sensed data (on a global scale) are currently ill-suited for a variety of applications owing to their limitations in separating crop types within areas classified as cropland (Anderson et al., 2014:1). Furthermore, verifying the accuracy of land-cover classifications(as an output of remote-sensing) with ground truth data is necessary before it can be used in scientific investigations and decision-making policies (Jensen, 2005, in Shattri et al., 2012:231).

It can be summarised that the disaggregation process described in Diagram 3.1 is usually conducted in three steps. Firstly, an information input (prior) at disaggregated level is calculated based on various aspects. Expert opinions, land cover or land use, crop production statistics, farming system characterisation, biophysical crop suitability assessments and, in some cases, population density, are considered. In the second step, a minimum cross-entropy process is used to manage these information inputs (or priors), to secure a solution compatible with all the different restrictions. Thirdly, all the data previously acquired are spatially analysed and represented graphically. It was explained that land cover, land use and crop production statistics could in most cases be collected with remote-sensed data. However, some biophysical crop suitability assessments use a different approach to spatial analysis, called multi-criteria analysis.

### 3.1.2 Multi-criteria analysis - Biophysical Cropland Suitability

Multi-criteria analysis can be regarded as a spatially structured analytical approach which some GIS practitioners apply to identify, locate or analyse fields of interest by means of over-laying spatial information referred to as shapefiles (Malczewski, 2004:34). Land suitability analysis has been regarded as a prerequisite to achieving optimal land resource utilisation (Kihoro, Bosco & Murage, 2013:1). An example is shown in Diagram 3.2 below as a generalised model of cropland suitability, used as a prior in modelling the location of production.

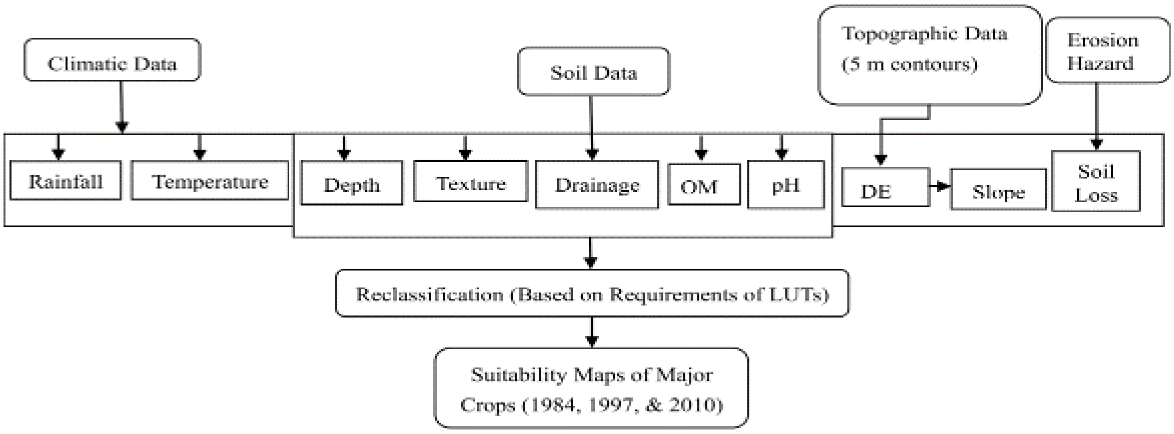



**Diagram 3.2: Generalised model of cropland suitability**

*Source: Woubet, Tadele, Birru, Yihenew, Wolfgramm & Hurni (2013:103)*

The suitability of land is usually developed or structured to homogenous suitability classes with the aim to enhance decision-making processes. These classes have been utilised by various authors over many years to distinguish between highly suitable, moderately suitable, marginally suitable and unsuitable land for a given land utilisation type or crop production allocation (Woubet et al., 2013:96). The classification of suitable land uses, informed by production conditions, assists primary producers and institutes to implement sustainable land use decision-making processes and informs future agricultural production (Woubet et al., 2013:96).

Woubet et al. (2013:96) explained some of the main contributing factors to sustainable production as: "Evaluating land capacity, adopting appropriate land use and employing farming systems that realize the potential of the land." An ever increasing need exists to match land and land uses in the most coherent way to capitalise on agricultural production and to ultimately fulfil the diverse needs of people (Woubet et al., 2013:96). Within the framework of land use, land suitability is therefore regarded as "how well different land areas match the requirements of a particular land use" (Benke et al., 2011:90).

### 3.1.3 Modelling land use change

It is one thing to develop a quantitative assessment of, say, the location of maize production at a point in time; it is altogether another procedure to model the prospective changes in the location of maize (and other crops) over time. During the past ten years, various studies have sought to integrate economic models with land use change (LUC) models (van Delden & McDonald, 2010:1). Van Delden and McDonald (2010:2) compared several of what they call "Integrated Spatial Decision Support Systems (ISDSS)" which integrate economic and spatially explicit land use change (LUC) models with the aim to influence the policy-making environment. These examples of ISDSS include various models used for spatial land use allocation and are listed in Table 3.1 below, with their respective sources.

**Table 3.1: Systems used for spatial land use allocation**

| Model | Source |
|---|---|
| **1 – LUMOCAP** | Van Delden, Stuczynski, Ciaian, Paracchini, Hurkens, Lopatka, Gomez, Calvo, Shi, and Vanhout (2007), cited in van Delden and McDonald (2010:1) |
| **2 – WISE** | Rutledge, Cameron, Elliott, Fenton, Huser, McBride, McDonald, O'Connor, Phyn, Poot, Price, Scrimgeour, Small, Tait, van Delden, Wedderburn and Woods (2008), cited in van Delden and McDonald (2010:1) |
| **3 – Eururalis** | Verburg, Eickhout and van Meijl (2008), cited in van Delden and McDonald (2010:1) |
| **4 – MedAction** | Van Delden, Stuczynski, Ciaian, Paracchini, Hurkens, Lopatka, Gomez, Calvo, Shi, and Vanhout (2007), cited in van Delden and McDonald (2010:1) |

*Source: van Delden and McDonald (2010:1)*

In the first three systems shown in Table 3.1, macro-economic models are linked to land use change (LUC) models, whereas in the fourth model, macro-economic behaviour is not taken into consideration (van Delden & McDonald, 2010:1). These systems largely succeeded in linking economic and land use change processes. Unfortunately, none of the approaches found a procedure that was fully satisfactory. The non-satisfactory issues are mainly due to clashes in the underlying theories such as: "static equilibrium versus dynamic simulation, macro-economic approaches on short-term predictions based on an extrapolation of historic trends, instead of a dynamic approach that captures cause-effect relationships and transitions" (van Delden & McDonald, 2010:6).

Within the Eururalis system identified in Table 3.1, a spatially explicit land use change (LUC) model (the Conversion of Land Use and its Effects (CLUE-s) model) allocated land use change based on competition between different land uses. It furthermore utilised spatial allocation rules while including various environmental and spatial policies (Verburg et al., 2008, in van Delden & McDonald, 2010:1). The CLUE-s model, displayed in Diagram 3.3 below, "uses a spatial statistical analysis to define the suitability of locations for different land use types. The suitability of a location is a function of a number of case-study specific location factors, such as soil quality, accessibility, socio economic conditions etcetera" (Verburg, 2010:2). This model is therefore able to run statistical analysis in order to relate location factors, such as distance to markets, distance to roads, soil capability and population density. Using then a logistic regression (logit) model the suitability of the different land use types (Verburg, 2010:7).

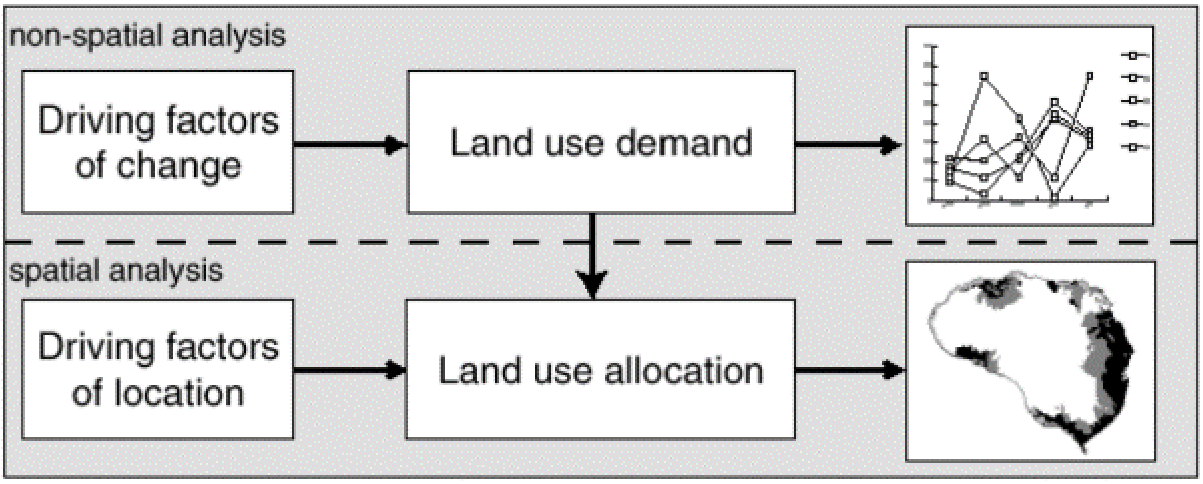



**Diagram 3.3: The CLUE-s Model Integration**

*Source: Verburg (2010:3)*

The ISDSS approaches focused on allocating new production areas based on a hierarchy of criteria differing in land use and policy relevance. The integration of spatially explicit models, such as the ISDSS process, is vital to reallocating any form of land use, whether agricultural or industrial, as the drivers to land use have a strong social science element to it.

### 3.1.4 Spatial allocation – Resource optimisation and profit maximisation

The resource optimisation and revenue maximisation model is an application of a multi-criteria analysis for spatial allocation, applied by You et al. (2006:9), using the Spatial Production Allocation Model (SPAM). Benke et al. (2011:89) further provided an economic application for spatial land use allocation. This process combines the methods of multi-criteria analyses to produce a final output which is land use allocation based on the maximisation of total revenue. According to Benke et al. (2011:90), land suitability alone may not be an adequate measure for production output when a variety of crops can be produced in a given region. Production economic variables can therefore be identified as a possible limiting factor within a defined geographic region. More specifically, market prices and cost of production having an impact on crop selection. Benke et al. (2011:90) in this regard stated that “a small quantity of a particular crop sold at a high market price may produce more revenue than other high volume crops.”

The relative allocations of crops to an area need to be based on the valuation of pre-defined figures of merit, such as the total revenue from a production region. Producers want to maximize profits and profits are limited to certain constraints imposed by the prevailing resources, technologies and policies. This concept was further developed as an optimisation problem (Benke et al., 2011:90). An optimisation model may also include constraining environmental and economic factors, including transportation costs and market demand. The aim of the study conducted by Benke et al. (2011:90) was to:

> (a) investigate the possible increase in the revenue for the South West Region of Victoria due to optimizing the spatial allocation of crops, to (b) develop a general modelling framework for the spatial allocation of commodity production over a region, subject to the modelling constraints mentioned above, and to (c) use a methodology suitable for use with planned future risk and uncertainty analysis in model predictions.

It can be concluded that the modelled output, named “CropOptimizor 2”, created “the optimum amount of each commodity produced, the maximum revenue for the entire region, and the geographic location and spatial extent of each agricultural crop produced” (Benke et al., 2011:90). It should be noted that within their model, livestock and other agricultural industries were not accounted for. The model was limited to cash crops suitable for this specific production region (Benke et al., 2011:90).

## 3.2 IDENTIFYING POTENTIALLY AVAILABLE CROPLAND

Potentially Available Cropland (PAC) was identified as moderate to highly productive land which could be utilised in future for rain-fed farming, with low to moderate financial investment, which is not legally protected or already intensively managed (Lambin, Gibbs, Ferreira, Grau, Mayaux, Meyfroidt, Morton, Rudel, Gasparri & Munger, 2013:892).

Lambin et al. (2013:893) identified physical, social, political and economic constraints in land conversion for agricultural usage. If the constraints, listed in Table 3.2 below, were to be ignored, possible upwardly biased estimates of the amount of PAC might follow. Lambin et al. (2013:893) emphasised that economic constraints created disincentives for transforming or intensifying potential cropland.

**Table 3.2: Land conversion constraints in identifying PAC**

| Social | Administrative, political – Land access | Economic | Physical |
|---|---|---|---|
| Labour quantity and qualifications | Security of land tenure | Lack of capital for conversion and investment | Climate variability |
| Cultural attitudes | Conflicts and political instability -Weak institutions and corruption | Domestic and international market access | Soil susceptibility to erosion |
| Indigenous reserves | Land zoning | Transportation infrastructure | Landscape fragmentation |
| Relied on for sustenance by local communities | Nationalistic policies restricting access to foreign capital or owners | Industry supply chain | Presence of mineral deposits, mining concessions |
| Small, fragmented land holdings | | Narrow local markets | Topography |
| | | Access to credit | Wetland |
| | | Transaction costs for land titling | |

*Source: Lambin et al. (2013:863)*

By advancing to economical estimates in PAC, additional guidance can be given to policy makers concerning future land allocation. Furthermore, in establishing the threshold levels of PAC, guidance can be given as to allocating underutilised land among competing interest groups (Chamberlin, Jayne & Headey, 2014:52). In addition to the PAC constraints developed by Lambin et al. (2013:892), Chamberlin et al. (2014:56) identified alternative or additional estimates of PAC that, among other criteria, included the economic profitability per hectare. The PAC approached followed by Chamberlin et al. (2014:54) made use of the Global Agro-Ecological Zoning 3.0 (GAEZ) Database (IIASA/FAO, 2012) which uses crop-specific land suitability and potential yield data as underlying model drivers.

The application of a spatially explicit profitability framework allowed Chamberlin et al. (2014:56) to address key policy questions related land-use allocation. Instead of depending on biophysical suitability variables as a threshold to land-use, Chamberlin et al. (2014:56) imposed a minimum profitability criterion that "reflects different levels of crop-specific production potential as well as the spatially varying costs and returns to production."

Within their analytical approach, Chamberlin et al. (2014:53) estimated the economic returns to expansion by calculating the potential net revenue. This was estimated by a gross margin analysis where the gross margin was calculated as gross revenue less the directly allocated variable costs per hectare.

> Gross margin = Gross Revenue − Variable Production Costs
> Such that:
> Gross margin = [Yield (MT/ha) * Output Price] − Variable Production Costs per hectare

The approach followed by Chamberlin et al. (2014:53) combined two important spatial varying elements for the profitability of production, namely (1) land productivity (i.e. the biophysical production endowment), and (2) the values of inputs costs and output prices. As these fundamentals of production economics vary in space, they jointly govern the profitability of agricultural production under most sets of production assumptions concerning the usage of technology in primary agricultural production (Chamberlin et al., 2014:53).

A basic cost assumption implies that when market distance increases, the cost of production inputs will increase and potential net revenue will vary as a function of both the biophysical potential (via yields) and economic remoteness (via prices and costs) (Chamberlin et al., 2014:55). It can therefore be expected that in very isolated locations, areas identified as "relatively productive" may be able to generate positive net revenue if they were to be expanded (Chamberlin et al., 2014:55).

One of the more recent applications of a multi-criteria analysis in South Africa was undertaken by AGIS (2013) to identify land suitable for the production of maize. This project was initially referred to as the Integrated Food Nutrition Security Initiative (IFNSI) and later renamed as “Fetsa Tlala”. The approach followed by Fetsa Tlala will be dealt with in more detail in the following section. The approach of Fetsa Tlala was however related to PAC’s multi-criteria spatial analysis process. The outcome from the Fetsa Tlala study sets the baseline for more elaborative analysis of models involved with the suitability of maize production in certain locations in South Africa (Collett, 2015).

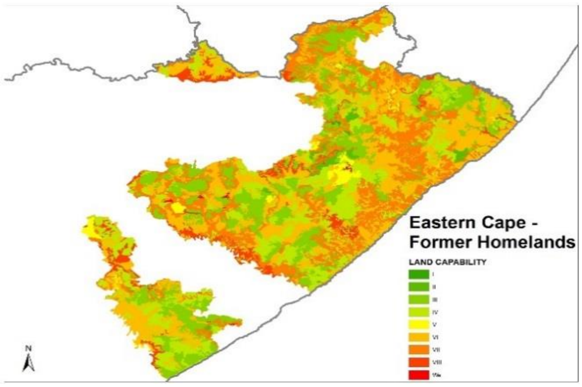
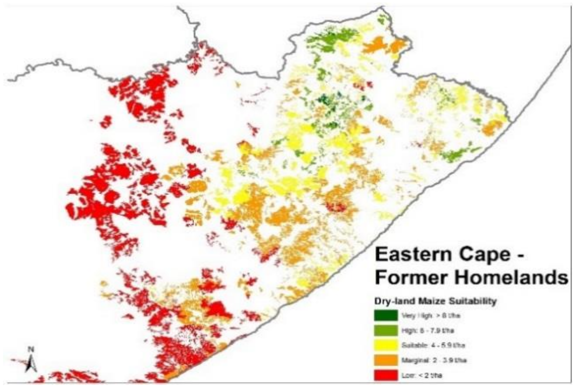
## 3.3 THE FETSA TLALA INITIATIVE – “INTEGRATED FOOD AND NUTRITION SECURITY INITIATIVE”

### 3.3.1 Context of the Fetsa Tlala

Within the national government’s objective to eliminate hunger and poverty, the South African Integrated Food Nutrition Security Initiative (IFNSI) has the target of allocating 1 million hectares of agricultural land suitable for dryland crop production in the former homelands to bring into crop production. That objective was explained as being a part of former homeland development and existing land reform projects (AGIS, 2013:2). In the middle of 2014, that initiative was renamed as “Fetsa Tlala”, a Sotho concept meaning “end hunger” (Makenete, 2014:6). For the purposes of this study, the initiative will be referred to as Fetsa Tlala.

### 3.3.2 Outputs

From the available agricultural resource data which was compiled by the ARC-ISCW’s natural resource database, a dryland crop production layer was developed for the IFNSI (Fetsa Tlala). The Land Capability Classes (I to IV) were refined to develop a maize-crop-suitability layer for South Africa (AGIS, 2013:2). The results of this layer indicated that 1 289 205 hectares can regarded as suitable for dryland maize production in the various local municipalities of the Former Homeland Region of the Eastern Cape (AGIS, 2013:2) (Table 3.3 below the map). AGIS (2013:2) provided the context in which the data should be used: “the identification of areas suitable for a specific agricultural enterprise and related investment decisions in agricultural capital must be based on the potential, capability, suitability and current state of these resources.” Agricultural potential, capability and suitability at farm level should not be defined by the Land Type data (AGIS, 2013:2). An example of Land capability versus Crop suitability in the Former Homeland Region of the Eastern Cape is displayed in Map 3.1 below.

| **Land Capability** | **Maize Crop Suitability** |
| --- | --- |
|   |   |

**Map 3.1: An example of Land capability versus Crop suitability**

*Source: Compiled from AGIS (2013) and ARC-ISCW (2004)*

If the data were to be used at a fine spatial scale, a specific farm or cultivated land would most probably be found within a Land Type with a predominantly low, moderate or high agricultural potential within the suitability classes for the production of dryland maize. The five suitability classes for dryland maize production were defined and each of the selected crop suitability polygons was rated according to that classification (AGIS, 2013:3). In Table 3.3 below, the probable outputs of what the maize suitability layer will provide is shown.

**Table 3.3: Maize suitability classification for the Eastern Cape**

| Maize Suitability Class | Potential Yield | Total cropland available in maize suitability class |
| --- | --- | --- |
| Very High | > 8 tons/ha | 14 822 |
| High | 6 – 7.9 tons/ha | 138 309 |
| Suitable | 4 – 5.9 tons/ha | 253 682 |
| Marginal | 2 – 3.9 tons/ha | 518 656 |
| Low | < 2 tons/ha | 363 736 |
| Total | | 1 289 205 |

*Source: AGIS (2013:3)*

Further refinement of the maize-crop suitability layer was proposed by AGIS, ARC and the Department of Rural Development and Land Reform (DRDLR) as the biophysically developed (GIS) layer had its limitations. It was recommended that a survey could increase the accuracy of the spatially developed maize-crop layer to verify whether areas listed as suitable for maize production by the GIS model was indeed physically or practically suitable for production.

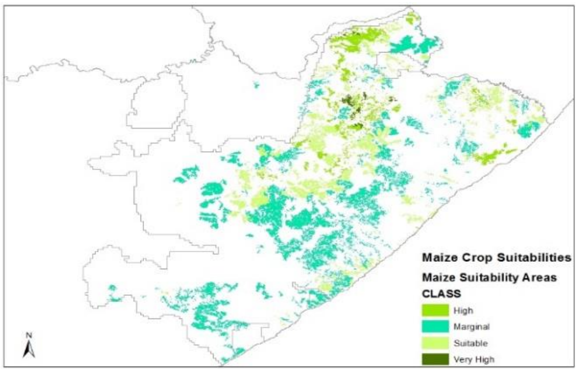
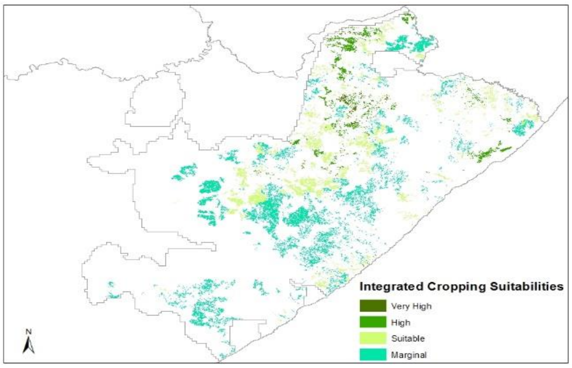
Aerial surveyors, in collaboration with DRDLR and the ARC, created a refined and re-modelled suitability layer for maize which was based on the integration of different criteria to be presented in a geo-statistical database. The final output was therefore a modelled GIS maize crop suitability layer, which was further aerially surveyed to present a final model which had the criteria shown in Table 3.4 below.

**Table 3.4: Criteria of maize suitability model for the Former Homelands Region of the Eastern Cape**

| **Background layer - Land suitability for maize production** |
|---|
| Suitability – very high |
| Suitability – high |
| Suitability – suitable |
| Suitability – marginal |
| Suitability – low |
| |
| **Criteria used in model** |
| Existing crops planted |
| Existing fields present |
| Dispersion / fragmentation of crop area |
| Tractor and equipment |
| Equipment capacity matches capacity for crop area |
| Fencing |
| Contours |
| Roads and bridges are present and working – serviceable for specified tonnage truck |
| Distance from tarred road or equivalent |
| Existing storage facilities |
| Storage (for input supplies) |
| Irrigation infrastructure (on farm) |
| Irrigation infrastructure (off-farm) |
| Previous irrigation (some infrastructure still there) |
| Slopes |
| Bush clumps |
| Surface rocks |

*Source: DRDLR (2013) and DAFF (2013)*

The result of the DRDLR and ARC model was captured in a geo-statistical database, from which 2 km by 2 km grid cells assigned a maize suitability weight to each grid. This would imply that very high to suitable grids should probably be targeted first for the expansion or revitalisation of maize crop production in the former homelands, as they identified attributes that had a higher numerical weight for the most relevant criteria. It was noticed that a much higher weight was placed on crop suitability than on any other criteria of analyses. With prior knowledge from the natural resource sections, it was considered that crop suitability, which was mostly derived from land capability, had a very high climatic (rainfall) weight to it.

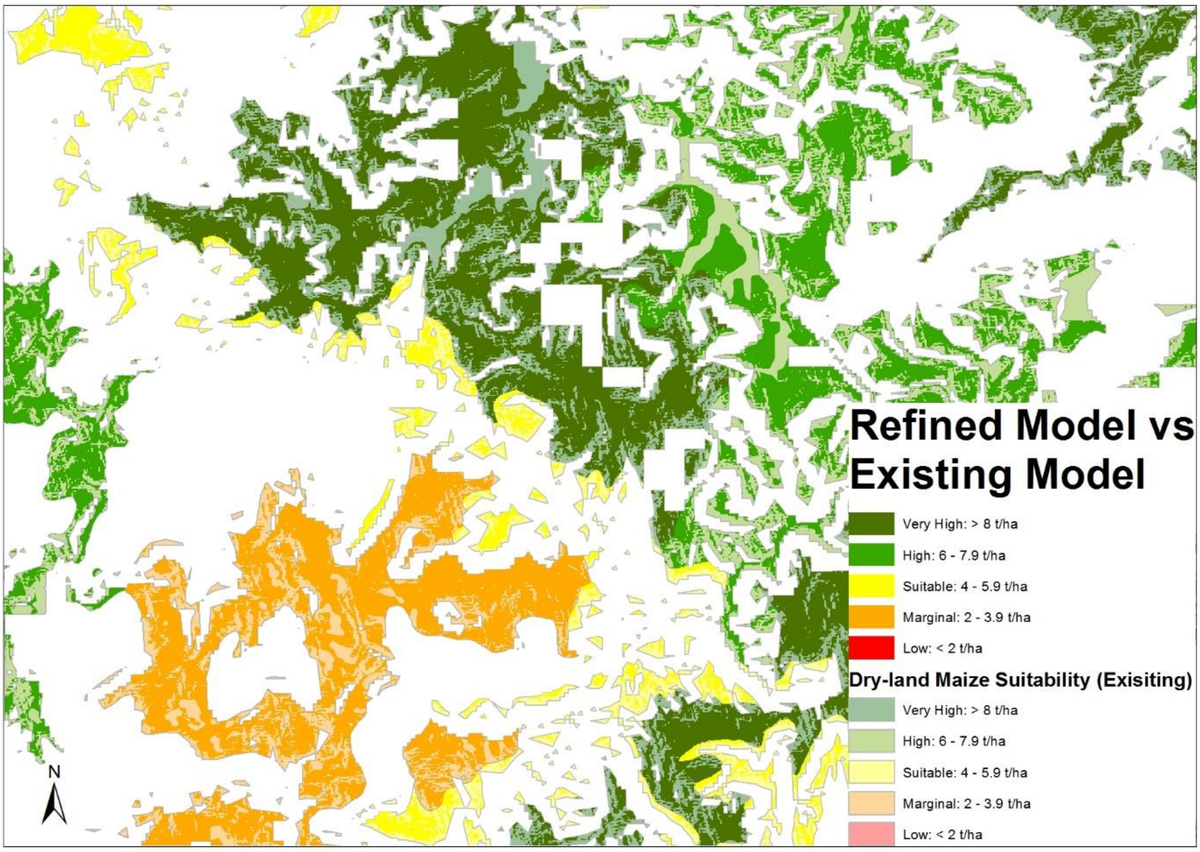
| **Maize crop suitability layer (Existing)**<br>**Part 1** | **Survey suitability layer (Refined)**<br>**Part 2** |
|---|---|
|  |  |

**Map 3.2: A comparison for crop suitability of maize in the Eastern Cape**

*Source: Own compilation based on AGIS (2013) – Maize crop suitability layer and DRDLR (2013) – Survey modelled suitability layer*

It was evident that the above-mentioned GIS developed databases or spatial analysis did not necessarily combine the required economic criteria or economic suitability classifications. It was highlighted that “The Land Type data can thus not be used to determine the agricultural potential, capability and suitability at farm level” (AGIS, 2013).

The closest to identifying economic variables was the crop suitability index presented by DRDLR (2013), which was the final output of the aerial survey work. However, it was found that the datasets from DRDLR (2013) (Map 3.2, Part 2), described in the section above, are similar to the AGIS (2013) (Map 3.2, Part 1) output. The only difference was the weight placed on the terrain, as a variable in the model. A higher resolution digital elevation model (DEM) was used to extract more pixels or land area with unfavourable slopes (Map 3.3 below). The output still needs a clearer approach to the economic parameters, as the DRDLR (2013) model simulated the highest weight to climate as did AGIS (2013) in determining suitability parameters for the output.




**Map 3.3: Maize suitability – DRDLR layer overlaid with AGIS layer**

*Source: Own compilation based on AGIS (2013) and DRDLR (2013)*

## 3.4 CONCLUSION

The purpose of this chapter was to illustrate some of the more relevant models found to date in the environment of spatial analyses. At the same time, knowledge was extracted from what those approaches had to offer in order to apply some form of a static approach to multi-variable spatial analysis with the view to comparing outputs determined by them. Even though there are some concerns with regard to databases utilised for land capability and crop suitability modelling, this study still depends on these datasets, as no other source of this type of data exists in South Africa. Besides the constraint of lack of suitable data, the aim of this research was to verify the importance of acquiring more accurate data for the modelling of resource potential for future allocation of crops.

Spatial analyses that relate to spatial allocation can have different meanings and applications, as explained in Section 3.1 above. More importantly, applications of spatial analyses can seldom be used in isolation if general assumptions in the raw databases are not accompanied by descriptive meta-data, or are based on detailed, fine-scale observations which combine expert knowledge in the field of resource analysis (Lambin et al., 2013:893).

From the existing spatial analytical approaches discussed in Chapter 3, it was evident that spatial hierarchy approaches can be utilised to structure selected criteria in the process of multi-criteria spatial analysis. It was furthermore established that the existing procedures from various spatial allocation approaches would need to be adapted for evaluating the impact of introducing economic perspectives into the reallocation of parts of the maize sector in South Africa. In order to achieve this, the following applicable sets of spatial analytical criteria were identified and these criteria will be applied further in the economically suitable spatial allocation framework that will follow in Chapter 4. The criteria identified are:

- The utilisation of the South African Natural Resource Atlas database to identify resource limitations with production implications and apply the aerial survey outputs to evaluate the level of agricultural land use in the Former Homeland Region of the Eastern Cape.

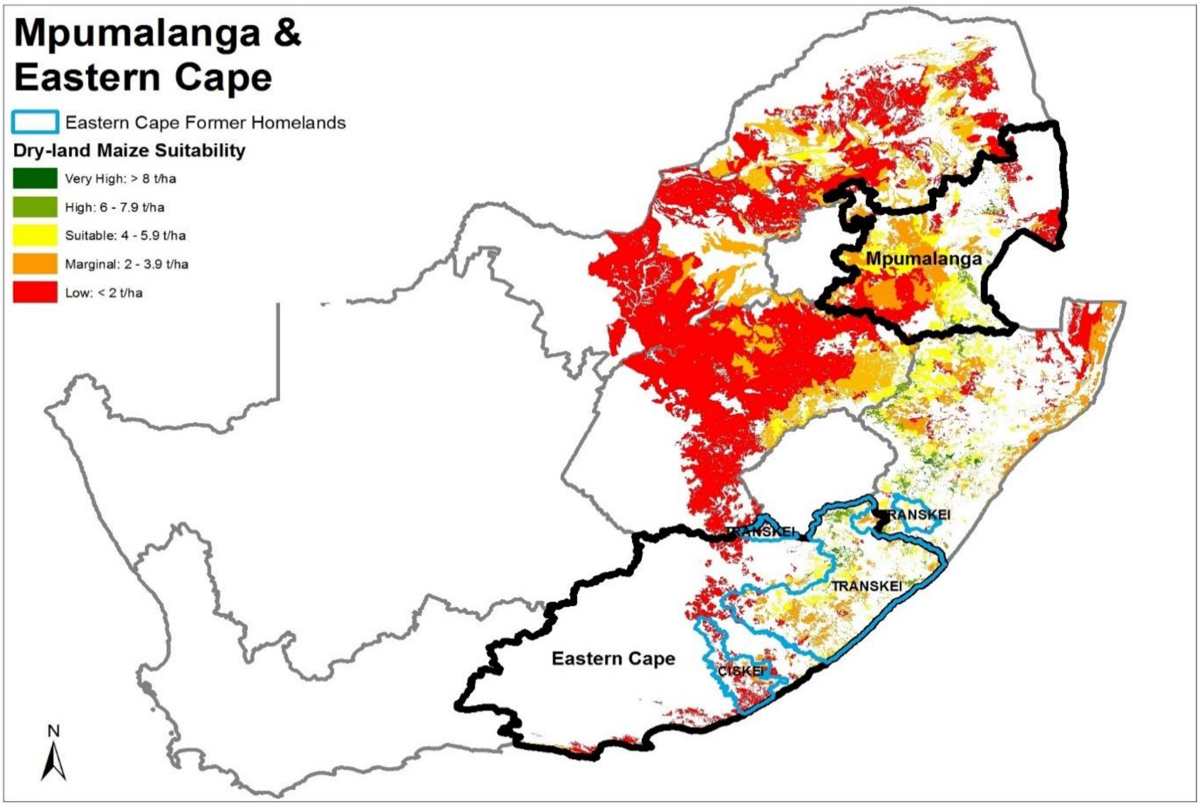
- The application of remote-sensed data as an actual production verification technique and use adjusted spatial outputs which represent crop suitability layers specifically for maize production.

- The use of economic analysis with the objective of achieving positive gross margins, given the various sets of resource and economic constraints. This will lead to the consideration of potential reallocations of cropland which incorporates the variable of economic profitability.

# CHAPTER 4

# ECONOMICALLY SUITABLE SPATIAL ALLOCATION: REALLOCATING MAIZE PRODUCTION

This chapter presents key criteria applied to the reallocation of future crop production and, more specifically, economically suitable maize production. It further evaluates the economics of agricultural land use allocation by applying the criteria identified in the last section of Chapter 3 to Mpumalanga and the Former Homeland Region of the Eastern Cape, being the two regions highlighted in Map 4.1 below. The criteria identified in Chapters 2 and 3 stressed that in order to apply biophysical variables in land use allocation, further refinements were made in land capability and crop suitability analysis. This chapter accounts for additional economically driven variables, which were excluded from some prior spatial allocation approaches.




**Map 4.1: Mpumalanga, the Former Homeland Region of the Eastern Cape and maize crop suitability**

*Source: Own compilation based on AGIS (2013)*

Within the framework of Potentially Available Cropland (PAC) analysis discussed in Chapter 3, Lambin et al. (2013:893) listed important factors to consider in agricultural land conversion. These constraints should be recognised when evaluating possibilities for the reallocation of maize production in South Africa. The constraints mentioned by Lambin et al. (2013:893) included climate variability, land susceptible to soil erosion or salinisation, history of land occupation, densely populated places, lack of infrastructure, limited access to markets, labour availability, rural to urban migration and insecure land tenure, to mention but a few. However, the past PAC analysis (Lambin et al., 2013) mostly focused on biophysical production potential and under-emphasised economic profitability as a variable to cropland expansion (Chamberlin et al., 2014:51). It is argued that in the short- to medium-term, potential profitable smallholder-based cropland expansion, in most African countries, is likely to be much more limited than it is typically perceived to be due to economic profitability (Chamberlin et al., 2014:51).

Descriptive spatial analysis would illustrate the importance of integrating and comparing economic rationale to the natural resource layers identified in Chapter 2 and Chapter 3. Besides analysis of descriptive data, spatial gross margin analysis will integrate spatial market factors, such as demand and supply, which drive local prices and therefore the economics of production within the Former Homeland Region of the Eastern Cape.

## 4.1 IDENTIFIED FRAMEWORK FOR AN ECONOMICALLY SUITABLE SPATIAL ALLOCATION ANALYSIS

The selected criteria for this research is illustrated in Diagram 4.1 below, representing the main criteria identified to analyse potential economic attributes associated with allocating economically suitable maize production.

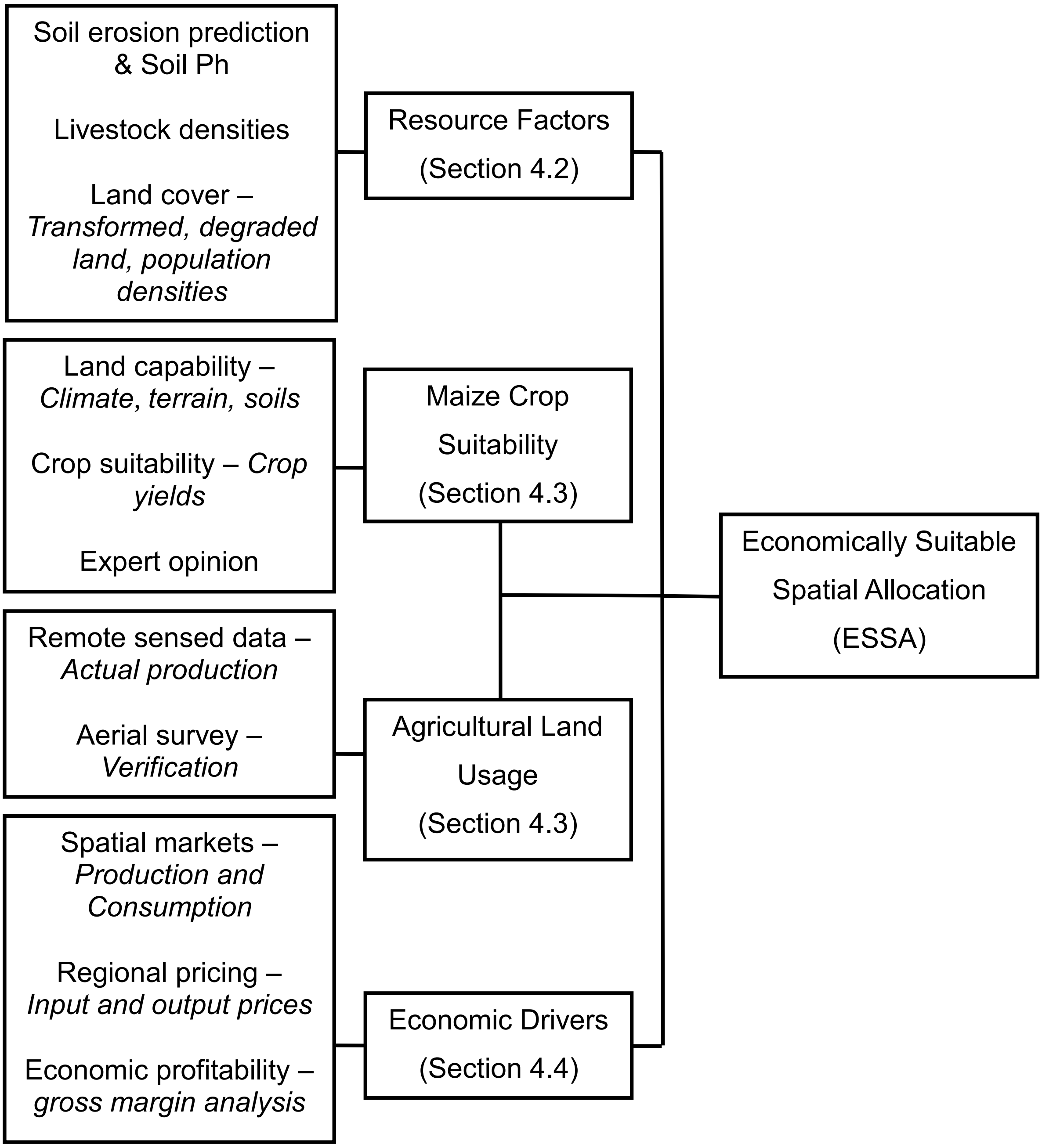



**Diagram 4.1: Selected criteria for spatial allocation analysis**

*Source: Own compilation*

The framework in Diagram 4.1 was designed according to the objectives of Shattri et al. (2012:229) who studied dominant crops for a selected region and followed a crop selection process incorporating an "economic suitability evaluation" of the land. Another consideration was that of Pilehforooshha, Karimi and Taleai (2014:116) who determined the highest suitability of crops for a given area, based on selected objectives that included "maximizing net income and minimizing production cost."

By applying the framework represented in Diagram 4.1, the remaining sections of Chapter 4 will present a widened scope of reallocating land for maize production in the Former Homeland Region of the Eastern Cape. The four categories of criteria for spatial allocation analysis, as outlined in Diagram 4.1, are discussed in the subsequent sections and will be evaluated separately.

### 4.1.1 Mpumalanga (MP) and the Former Homeland Region of the Eastern Cape (FHREC)

This study had the objective to analyse some of the economic implications of spatially reallocating maize production from Mpumalanga (MP) to the Eastern Cape former homeland (FHREC) regions. To understand the status quo of production for these regions, cultivated land statistics from AGIS (2011) and AGIS (2013) were used. It was calculated that in the year 2007, Mpumalanga's total cultivation equaled a total of 993 301 hectares (AGIS, 2011), whereas the Eastern Cape's former homeland region had a total cultivated area of approximately 490 000 hectares (AGIS, 2013). Between 1986 and 2013, the Mpumalanga province planted 570 000 hectares of maize, making it the third-largest maize producing province in the country, contributing to roughly 22 per cent of the total maize production in South Africa (SAGIS, 2013). Currently, limited formal and informal production data is available for the former homeland regions of the Eastern Cape, as these production districts were not captured separately by the crop estimates committee. It should be observed, too, that the field crop boundary layer for the total area cultivated in the FHREC automatically joins smaller fields or paddocks. These smaller fields are the norm for cultivation of field crops in the former homelands, which implies a probable over-estimation of field cropped area.

## 4.2 RESOURCE LIMITATIONS WITH PRODUCTION IMPLICATIONS

Resource limitations that can affect crop production, such as soil erosion, soil pH and land degradation (ARC-ISCW, 2004:124), were identified in Chapter 2 and some of these limitations have spatially varying economic attributes. Typical cost layers can be prepared to calculate the costs of erosion, for instance (Shattri et al., 2012:223). However, such analysis would direct the study into the field of environmental economics, which is not the focus of this study. This research will take recognition of this factor, as numerous land use "disasters" have probably occurred over the past 25 years because of poor land suitability evaluations and land use planning in South Africa (Laker, 2004:363).

It is necessary to model the combination of environmental factors, thereby informing a more accurate and sustainable allocation of agricultural land use (Pilehforooshha et al., 2014:119). In addition to the study of Pilehforooshha et al. (2014:116), other authors, such as Lambin et al. (2013:893) and Chamberlain et al. (2014:51), have concurred that climate variability has affected crop production in dryland areas and that the susceptibility of land to soil erosion or salinisation has reduced the potential of land, making it ‘marginal’ for crop production.

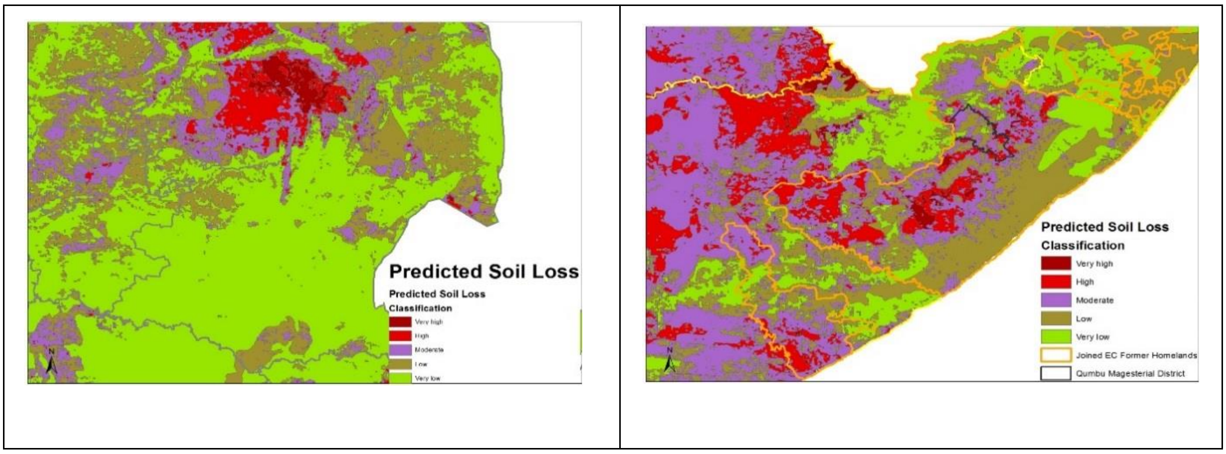
Poor knowledge of soil qualities and/or lack of attention to soil factors have been regarded as being one of the main causes of unsustainable cropland use (Laker, 2004:363). Another factor in addition to cropland allocation is livestock production which, as a criterion in agricultural land usage analysis, is seldom given the required research in allocation modelling. Lambin et al. (2013:897) mentioned some implications of livestock densities in future (PAC) analysis and explained that high capital costs would need to be incurred if livestock needs were to be relocated to convert grazing land to crop production. Applied descriptive spatial analysis will be used in this section to illustrate and quantify the importance of the factors mentioned above in the economics of spatial reallocation.

The purpose of this section is therefore to illustrate and evaluate resource impacts for possible reallocation processes. Initiatives like Fetsa Tlala may need to consider economic implications attributable to resource limitations. This further addresses the key challenges defined in Chapters 1 and 2 that speak to the potential of applying Land Capability analysis to support possible cropland allocation.

### 4.2.1 Descriptive spatial analysis

Spatial comparisons related to resource limitations will be discussed by utilising descriptive spatial statistics or visual analysis based on GIS outputs represented by the maps below. Map 4.2, Map 4.3 and Map 4.4 each represent Mpumalanga (MP) on the left, and a higher resolution view of the Former Homeland Region of the Eastern Cape (FHREC) on the right.

*4.2.1.1 Predicted soil loss*

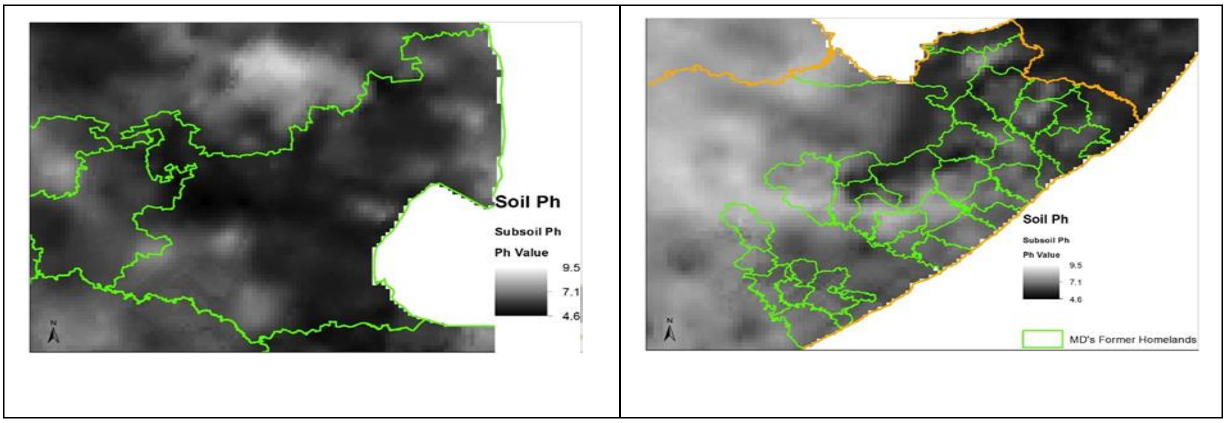



**Map 4.2: Predicted soil loss comparison**

*Source: Own compilation based Pretorius (1998) in ARC-ISCW (2004:105)*

Considering the findings of Mills and Fey (2004:394), Map 4.2 shown above illustrates that very low to low levels of predicted soil loss areas are found in MP. Contrary to MP, the FHREC has 30 per cent of the identified field crop boundaries covered with very high to high levels of predicted soil loss, and more importantly, in the areas classified as having high suitability for maize crop production.

*4.2.1.2 Soil Ph*




**Map 4.3: Soil Ph comparison**

*Source: Own compilation based on ARC-ISCW (2004:65)*

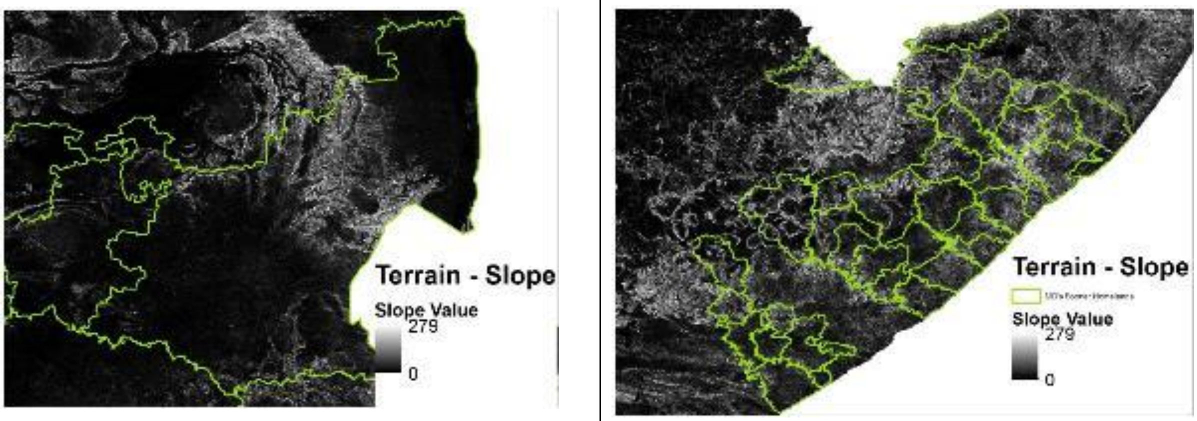
Soil acidity was found to be a harmful chemical condition of the soil, which ultimately reduces crop growth and production output (ARC-ISCW, 2004:64). Soil acidity is mostly measured in pH scale, with strongly acid soils considered to have pH (H2O) values below 5.5. As low pH conditions lead to poor nutrient status, root growth may be restricted. Where low levels of soil pH levels were found, the ARC-ISCW (2004:124) explained that:

> "In the higher rainfall areas, soils tend to be low in base status, acidic and P fixing. The carbon status, on the other hand, is relatively high and the physical properties favourable. Although crop yield potentials may be high, they are difficult to realize under resource poor agriculture due to the need for liming and fertilization."

In relation to other producing regions, such as the Free State, higher levels of lime application are currently required in MP due to low soil pH, which is represented by a darker colour in Map 4.3 above. This could also be case in the FHREC shown on the right, as 8 per cent of the identified field crop boundaries (DRDLR, 2013) fall within a pH level below 5.5, and a further 18 per cent with pH levels between 5.5 – 6.0. Levels of pH (H2O) greater than 5.5 are considered to be more optimal for maize production (Laker, 2015), depending on the remaining soil properties. A further 56 per cent of the identified field crop boundaries fall within pH 6.0 – 7.2 class, and the remaining 18 per cent has a pH > 7.2.

Soil pH corrections are one of the main yield maximisation considerations as the optimal uptake of mineral fertilisers is required to increase technical efficiencies and ultimately maximise profit. However, it can be noted that soil corrections with lime application has varying economic implications depending on the acidity levels of the soil.

#### 4.2.1.3 *Slopes*




**Map 4.4: Slope comparison**

*Source: Own compilation based on ARC-ISCW (2014:33)*

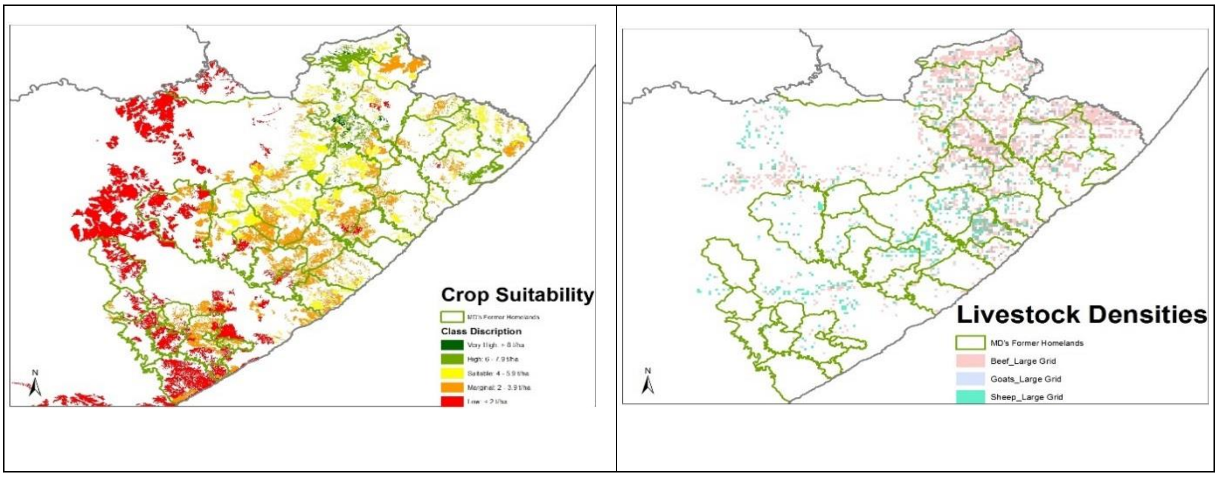
According to the Conservation of Agricultural Resources (CARA) Act, Act 43 of 1983, all cultivated areas with a slope of more than 2 per cent are subjected to suitable conservation measures and practices to prevent excessive soil erosion (AGIS, 2013:4).

Besides the CARA Act (1983) restrictions, producers may be confronted with practical production factors attributable to steep slopes. It is possible that continuous contour management will need to be applied to prevent additional soil erosion, which may have economic implications, given that most FHREC production areas, shown in Map 4.4 above, were identified as “high soil loss” areas. Relatively flatter slopes can be observed in MP, which has additional cost saving attached to it, such as reduced transportation costs if tractor–trailer combinations can be avoided to move maize harvested. This transportation constraint will apply in the high-sloped areas of production which are evident in the FHREC.

#### 4.2.1.4 *Livestock densities and degraded land*

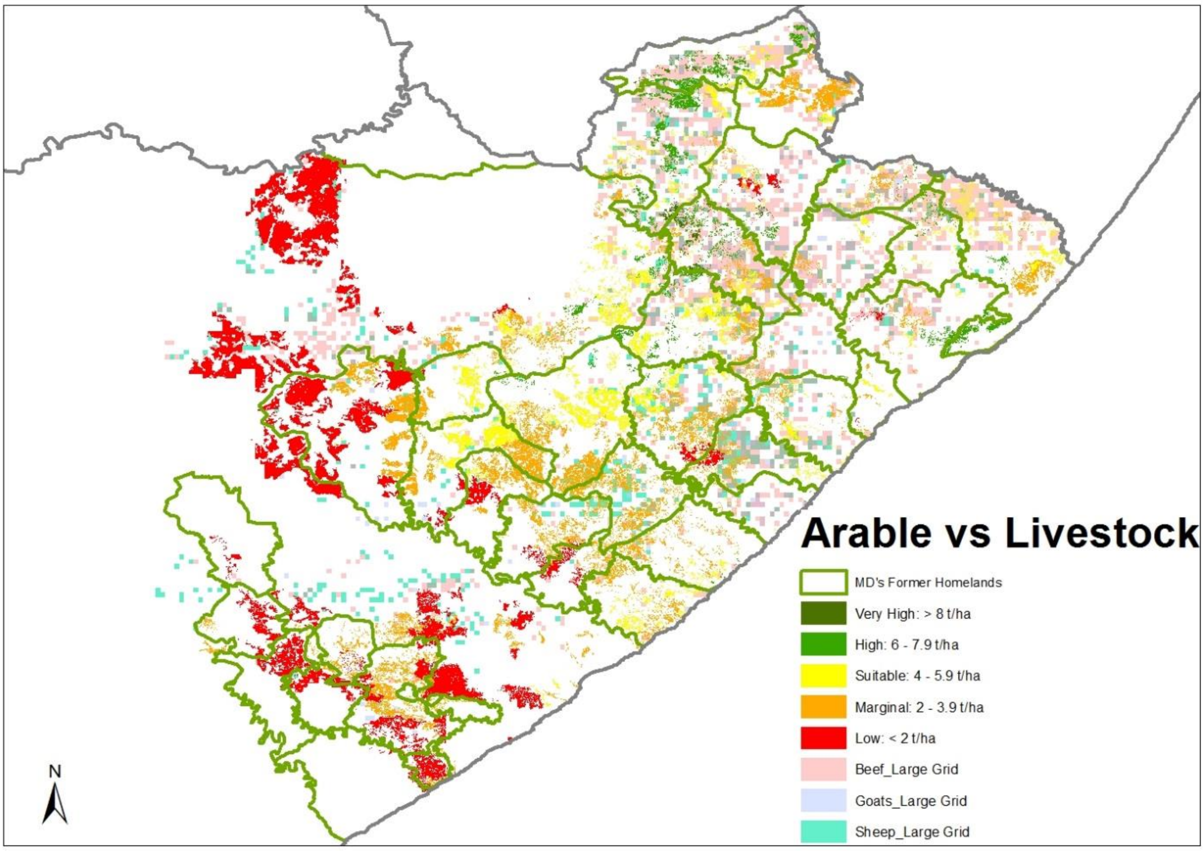
In addition to the resource limitations evaluated in cropland allocations, there are competing agricultural enterprises such as livestock production. This additional variable can be researched in the form of livestock densities, which is similar to a field crop boundary allocation, except that livestock production is a moving form of land use. In this particular study, livestock density data was limited to the aerial surveyed area in the FHREC. Approximated livestock densities were therefore identified and recalculated as an additional economic impact variable to consider in the reallocation of maize production.

Potentially, utilising grazing land for arable cropland expansion in the FHREC would need to adjust for the fact that a conversion or reallocation of arable land to maize production could also have negative consequences for the area available to livestock (Aliber, Baiphethi & Jacobs, 2009:151). With a finite amount of land available in the FHREC, opportunity costs of land use constitutes a production variable to consider. Stocking densities were calculated to be as high as 1:1, which is one livestock unit per hectare (Table 4.1). Due to these high stocking densities, cropped area directly competes with grazing land, if unproductive land (covered in grass) were to be reallocated to maize crop production.




**Map 4.5: FHREC Crop suitability and livestock densities**

*Source: Own compilation based on AGIS (2013) and DRDLR (2013)*

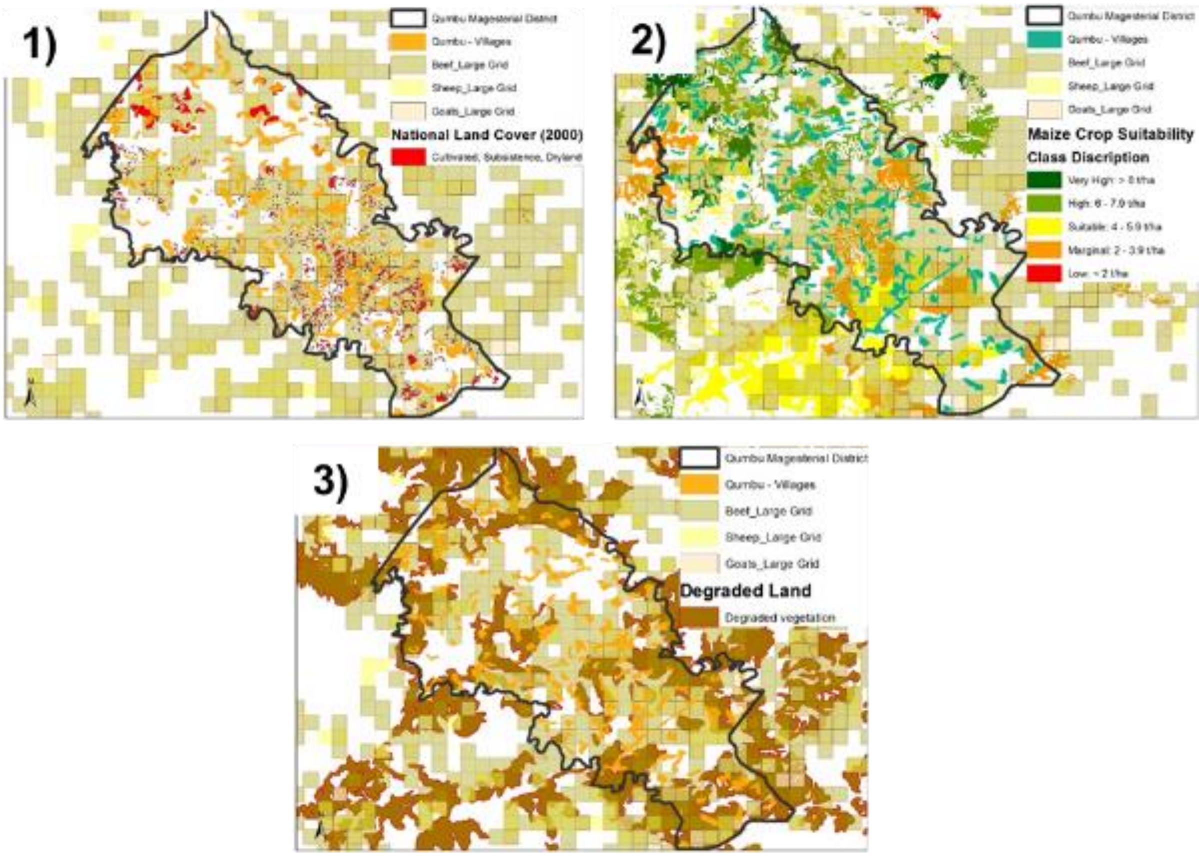



**Map 4.6: Overlay of crop suitability and livestock densities**

*Source: Own Compilation based on AGIS (2013) and DRDLR (2013)*

Based on the visual representation (Map 4.5 & Map 4.6 above) and further analyses of the underlying surveyed data, presented in Table 4.1 below, it was found that an average 300 000 head of cattle and 120 000 head of sheep could be identified within the Former Homeland Region of the Eastern Cape's aerial survey, which is a very conservative estimate. Other animals, such as goats, donkeys, horses and pigs, were also surveyed but not included in the analysis. In a study conducted in the former Transkei, Maura and Fox (2004:698) found that one of the leading causes of a decline in larger areas of crop cultivation was the continued damage caused by livestock entering planted fields owing to un-fenced fields. From the Former Homeland Region of the Eastern Cape's aerial survey data, it was calculated that roughly 18 per cent, or 121 000 hectares, of the field crop boundaries found in the maize suitability areas had some form of fencing. This is contrary to anecdotal evidence from Mpumalanga's maize production region, which is found to be highly fenced and livestock is restrained from entering cultivated fields.

The widespread failure of the “betterment schemes” has been partly attributed to an outflow of irreversible soil erosion and land degradation (Laker, 2004:363). Even though cropland allocations were selectively chosen by “planners” and were well-contoured for production, those production areas were still destroyed by soil erosion, more specifically by gully erosion (Laker, 2004:363). To avoid the past failures of land allocation in the FHREC, cognisance should be taken of the properties of soil and the biophysical attributes when considering cropland allocation.




**Map 4.7: (1, 2 & 3) Density analysis on a selected district – illustrating land degradation**

*Source: Own compilation based on DRDLR (2013)*

When considering the high population densities, high livestock densities, and the combination of un-fenced arable fields, sustainable maize cultivation would seem to be at high risk in some areas. Map 4.7 above, representing the FHREC’s Qumbu Magisterial District, was selected to visually illustrate the impact of high population density (Qumbu Villages Part 1 – Orange), high cultivation (Cultivated subsistence dryland Part 2 – Red), and high stocking densities (Livestock Grids –Part 1 & 2). High density land use seems to be correlated with land degradation, shown as brown in Part 3 of Map 4.7.

Land identified as having high suitability for maize production would be in direct competition with those three land cover criteria, and factoring for future land degradation might be costly if land rehabilitation is a foreseeable outcome.

**Table 4.1: Livestock density evaluation**

| | | | | | |
|---|---|---|---|---|---|
| **Livestock Observation Scale** | | Number of livestock units (LSU) identified per grid block | | | |
| | Livestock Observation Scale (LSU's per grid block) | 0-10 | 11-50 | 50+ | |
| | Grid Classification | **Small** | **Medium** | **Large** | |
| | Average number of LSU per grid block | 5 | 30 | 75 | |
| **Number of Grids** | | Number of identified (2 * 2 km) grid blocks in survey area | | | |
| | | **Small** | **Medium** | **Large** | |
| | **Beef** | 1011 | 4000 | 2418 | |
| | **Sheep** | 179 | 1412 | 1025 | |
| **Average LSU's** | Total average LSU's per grid block classification | Grids * Average number of LSU`s per grid block | | | Total number of livestock |
| | | **Small** | **Medium** | **Large** | **LSU** |
| | **Beef** | 5 055 | 120 000 | 181 350 | 306 405 |
| | **Sheep** | 895 | 42 360 | 76 875 | 120 130 |
| **Total Area** | Total livestock gridded area (hectares) | Area per grid classification: 1 grid block = 40 ha | | | Total gridded livestock area |
| | | **Small** | **Medium** | **Large** | **Hectares** |
| | **Beef** | 40 440 | 160 000 | 96 720 | 297 160 |
| | **Sheep** | 7 160 | 56 480 | 41 000 | 104 640 |
| **Average Stocking Density** | | Average stocking density per hectare – LSU/Ha | | | Average stocking density LSU/ha |
| | | **Small** | **Medium** | **Large** | |
| | **Beef** | 8.0 | 1.3 | 0.5 | **1.0** |
| | **Sheep** | 8.0 | 1.3 | 0.5 | **0.9** |

*Source: Own compilation based on DRDLR (2013).*

## 4.3 SPATIAL VERIFICATION: LAND CAPABILITY, CROP SUITABILITY AND ACTUAL CROP PRODUCTION

A critical part of spatial analysis is verifying the accuracy of land-cover classifications with ground truth data before it is used in scientific investigations and decision-making policies (Jensen, 2005, in Shattri et al., 2012:231). The aim of this section is to verify the current land capability and crop suitability layers with actual crop production per field crop boundary. This is done by spatial analyses, using existing remote-sensing data where available. From the discussions in Section 3.3, emphasis was placed on using the maize crop suitability outputs in the initial high-level allocation process for the government's Fetsa Tlala project. The approaches used to create the inputs of the maize crop suitability layer will be discussed and verified with commercial production data for Mpumalanga, the Free State and the Former Homeland Region of the Eastern Cape (FHREC), with the aim being to inform possible future reallocation of maize production into the FHREC.

In chapter 2 the Global Agro-Ecological Zoning (GAEZ) database which is typically used in models such as the Potentially Available Cropland (PAC) model and the Spatial Production Allocation Model (SPAM) was discussed. Since the existing South African maize crop suitability data, used in Fetsa Tlala, can be compared with agro-ecological crop suitability database from the GAEZ, additional maize production estimates can be applied or verified for South Africa. The GAEZ's maize crop suitability database will therefore be evaluated as an additional crop model to provide supplementary yield estimates to evaluate the potential for maize production in the FHREC. The GAEZ's agro-ecological maize crop suitability model was chosen as a complementary model since the GAEZ's yield parameters can be adjusted for different production input regimes. These input regimes provides a useful tool to highlight the range of potential yields that can be achieved in an area and specifically in the FHREC where production is directed at own consumption and commercial markets.

The choice of provinces or production areas selected for the verification process can firstly be attributed to crop production characteristics pointed out by Laker (2015), such that soil moisture management for production within in low rainfall areas is the deciding factor, whereas in high rainfall areas, soil fertility is the other over-riding factor. The

Free State is therefore characterised with lower rainfall and larger fields, whereas Mpumalanga is typically classified as a higher rainfall province, with smaller fields and some form of contour management. Secondly, since it was previously stated that the Free State accounts for nearly 40 per cent of the total maize production and Mpumalanga for 20 per cent, land which is cropped to maize in these provinces can be characterised to inform future allocations. This verification process aims to inform future land use allocation for maize production in the FHREC, since the FHREC has similar biophysical production potentials to both Mpumalanga and the Free State, but leans more towards Mpumalanga's characteristics. It is also perceived that the FHREC has vast amounts of underutilised land, suitable for maize production, and more importantly, suitable for maize reallocation from Mpumalanga.

### 4.3.1 Land capability and actual cultivation

Due to the unavailability of data for actual field crop production in the FHREC and the use of the above-mentioned technical criteria (Laker, 2004:358) for land capability modelling, current spatial verifications may render land capability and actual crop production per field crop boundary arbitrary for most parts of the FHREC. A refined verification process is currently not possible for the Former Homeland Region of the Eastern Cape. Outputs from the Mpumalanga and Free State land capability verifications would rather serve as a guide for future analysis required for the FHREC and may further inform future research required for South Africa's former homeland regions.

To verify the actual production with modelled land capabilities in commercial agriculture, land capability outputs were selected for the respective provinces mentioned, with the Free State having 14 per cent of the national area in capability classes I–III. These capability classes are considered a practical limit for arable rain-fed grain production (Schoeman et al., 2002). Mpumalanga has 19 per cent of the South African class I to III land, and the Eastern Cape province has a total of 8 per cent, of which 83 per cent is found in the Former Homeland Region of the Eastern Cape.

Farmers in the Free State have mostly utilised marginal land for crop production, such that close to 60 per cent of all grain and oilseed production takes place on land in capability class IV (marginal land), as set out in Table 10 below (Map A.2, Appendix A). The data derived for the "Hectares Cropped" column, show in Table 10 (Map A.1 and Map A.2, Appendix A), was evaluated using remote-sensed data statistics per field crop boundary, per selected crop (DAFF, 2014). Within Mpumalanga, production seems to be more evenly spread between the land capability classes, but most of the production still takes place in land capability classes II and III, which according to definition is more suitable for crop production (Map A.1, Appendix A). Table 10 indicates that 35 % of the total grain and oilseed crop production in Mpumalanga takes place on high capability soils. Actual grain and oilseeds production per field crop boundary is unfortunately not available for the Eastern Cape or the FHREC.

**Table 4.2: Total actual cultivation of grains and oilseeds per land capability type – 2013/2014 production season**

| Land Capability (LC) Class | Mpumalanga | | | Free State | | | Eastern Cape | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total (LC) Hectares | Hectares Cropped | % of hectares cropped | Total (LC) Hectares | Hectares Cropped | % of hectares cropped | Total (LC) Hectares | Hectares Cropped | % of hectares cropped |
| **High (II)** | 872 008 | 265 012 | 35 % | 12 701 | 2 565 | 0.2 % | 78 787 | N.a. | |
| **Moderate (III)** | 2 085 727 | 296 728 | 39 % | 2 241 476 | 571 351 | 34 % | 1 191 729 | N.a. | |
| **Marginal (IV)** | 1 596 610 | 187 652 | 25 % | 5 345 077 | 974 826 | 58 % | 1 830 878 | N.a. | |
| **Non-arable (V)** | 383 457 | 12 709 | 2 % | 3 526 138 | 142 953 | 8 % | 1 728 574 | N.a. | |
| **Total** | | **762 100** | | | **1 691 694** | | | **N.a.** | |

*Source: Own compilation based on Schoeman et al. (2002), BFAP (2014b) and DAFF (2014)*

From the comparisons with remote-sensed crop production statistics per field crop boundary, land capability alone seems to be too broad to make general assumptions on agricultural arable resource endowments, since 60 per cent of the Free State's grain and oilseed production is on marginal land. The national Land Capability (LC) database refers to land as having a certain cropping potential or as Schoeman et al. (2002:7) explained “the extent to which land can meet the needs of one or more uses under defined conditions of management.” This LC database was used to extract LC rated classes of I, II, III and IV, which were used as a base layer for the national maize crop suitability analysis discussed in the section to follow (AGIS, 2013). Additional limitations in land capability modelling would need to be considered to truly unlock the potential of arable land in the EC, and more specifically, the FHREC.

### 4.3.2 Maize crop suitability and actual cultivation

In Section 3.3, emphasis was placed on using the maize crop suitability outputs from the initial high-level allocation process undertaken for the Fetsa Tlala governmental initiative. Similarly, Chamberlin et al. (2014:54) used the crop-specific land suitability and potential yield data from the GAEZ database (IIASA/FAO, 2012) for their Potentially Available Cropland (PAC) analysis.

Here the researcher evaluate how actual crop production relates to these maize suitability layers, given that land capability (LC) is the base layer in maize crop suitability analysis in South Africa. The South African maize crop suitability analysis is in accordance with the international GAEZ agro-ecological maize crop suitability model, which will be applied as an additional proxy for potential maize production analysis in the FHREC.

A South African maize crop suitability layer was created using the national Land Capability database as an initial base layer to extract Land Capability (LC) classes I, II, III and IV. Permanently transformed areas such as cities, towns, parks, rivers and servitudes, which cannot be used for arable agricultural were derived from the national land cover database and these areas were removed after the LC allocations were made. The national land cover database, which also calculated the national cultivated area for South Africa, was referenced in Chapter 2 above. Finally, outputs from three maize suitability models were used to create one final maize suitability map, incorporating all the above-mentioned processes (AGIS, 2013:2).

As land capability was discussed in the previous section, and the national land cover in Chapter 2, more detail will be given to the processing of the maize crop models used to create the yield parameters for the suitability layer. The crop models, as explained by AGIS (2013:3), were reconstructed using:

> the maize yield outputs of the Sustainable Land Use Model as compiled by the ARC (Beukes); the highly suitable and suitable maize areas outputs of the bio-fuels model as compiled by the ARC (Schoeman); and the short, medium, long-term and high yield maize areas outputs as compiled by R.E. Schulze.

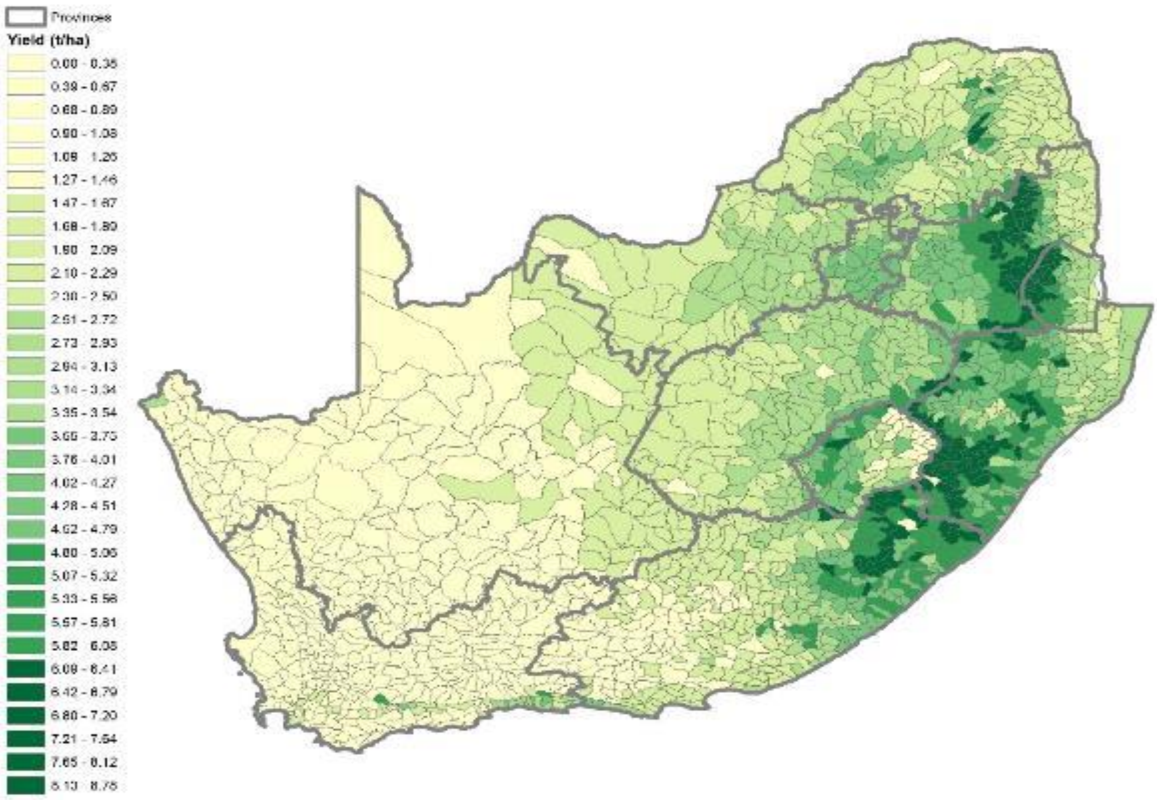
An example of such a crop model will now be discussed in order to follow the interconnectedness of these models to crop suitability modelling.

#### *4.3.2.1 A crop model to identify high yielding maize areas*

Crop yield models can vary in their degree of complexity, such that certain simpler models are primarily driven by rule-based climate criteria, and they apply modified variations in soil properties and production management levels to produce yield outputs as developed by Smith (1994; 1998, in Schulze & Walker 2007:3). Other more complex models are physiology- and genetics-based growth models, such as the CERES-maize model developed by Jones and Kiniri (1986) and Jones et al. (1998). The CERES-Cereal model is known as a crop model option within the Decision Support System for Agro-technology Transfer (DSSAT) model. It mainly simulates the following (Wu et al., 1989, in Schulze & Walker, 2007:3):

- Respiration,
- Photosynthesis,
- Accumulation and partitioning of biomass,
- Phenology,
- Extension growth of leaves, stems and roots,
- Soil water extraction,
- Evapotranspiration, and
- Nitrogen transformation processes.

Numerous studies since the late 1980s have been undertaken within the CERES-maize model, specifically for South African conditions, and local improvements have been made to continuously adapt the model according to these alternations (Schulze & Walker, 2007:7). An example of the CERES-maize crop model is illustrated in Map 4.8 below, which was further improved to be represented by the South African Quaternary Catchments Database, as presented by Schulze, Hallowes, Horan, Lumsden, Pike, Thornton-Dibb and Warburton (2007:2).




**Map 4.8: High yielding dryland maize areas – CERES-maize model output**

*Source: Own compilation based on Schulze et al. (2007)*

The output map, showing high yielding maize areas, indicates that most of the high yielding areas lie to the east of the country, which is also correlated with the areas of highest rainfall. The areas are displayed in Map A.3 of Appendix A. By using the combination of land capability, national land cover and crop models, a final maize crop suitability dataset was developed by AGIS (2013). Crucial to the understanding and application of such a crop suitability map, is a verification process. This verification process might also inform future reallocation and provide a greater confidence in actual and potential maize production evaluations.

#### *4.3.2.2 Accessing actual production and maize crop suitability*

Within the concluding arguments of Chapter 3 above, it was stated that remote-sensed data, as an actual production verification technique, can used be to calculate the amount of maize hectares planted. In addition to saying something about actual hectares planted, future potential cropland needs to be verified and identified to inform spatial reallocation initiatives. In order to achieve this, maize crop suitability data derived from the preceding section was overlaid with two sets of remote-sensed production data for Mpumalanga and the Free State. Given that limited or no individual field crop production data currently exist for the Former Homeland Region of the Eastern Cape, this section will serve as a prior for the next section, which will evaluate how maize suitability analysis might potentially be used in future allocations of land use in the FHREC.

The remote-sensing crop type classification data for Mpumalanga were available for the 2006/2007 and 2013/2014 production years, delineated according to actual field crop boundaries (DAFF, 2014). Similar data were also available for the 2013/2014 production year for the Free State. Within both provinces, dryland field crop boundaries were used to exclude a confounding analysis with yields associated with irrigated areas. Irrigation accounts for 20 per cent of South African maize production, with only 3 per cent of all irrigated production being from the Eastern Cape Province and 8 per cent from Mpumalanga. Irrigated areas were therefore set aside for the purposes of this analysis.

From the 2013/2014 maize production data for Mpumalanga, compiled in Table 4.3 below, it was shown that only 0.4 per cent of the maize crop was cultivated on land classified as high maize suitability, while the majority, or 52 per cent, was cultivated within the marginal and low maize suitability classes. Applying the same methodology to the Free State, it was found that in the 2013/2014 production season, 59 per cent was cultivated within the low maize suitability class and a further 23 per cent on land without any suitability class assigned to it, ostensibly rendered unsuitable in the maize suitability classification schema (Table 4.4). An additional analysis of the 2006/2007 Mpumalanga production season confirmed that only 1 per cent of that season’s maize crop was cultivated on land classified as high maize suitability, with an even higher share, 65 per cent, cultivated within the marginal and low suitability classes.

**Table 4.3: Mpumalanga's dryland maize crop suitability and the 2013/2014 dryland maize crop**

| | | (A) | (B) | (A) * (B) | (D) | (A) * (D) |
|---|---|---|---|---|---|---|
| **Maize Suitability Class** | | Actual Maize Hectares Cropped (2013/2014) | Potential average maize yield (t/ha) - Upper yield | Average Calculated Production (tons) | Average maize yield (t/ha) Re-estimated Yield | Average Calculated Production (tons) |
| VH | Very High | 52 | 9 | 467 | 9 | 467 |
| H | High | 2 242 | 8 | 17 933 | 8 | 17 933 |
| S | Suitable | 123 474 | 6 | 740 842 | 6.5 | 802 579 |
| M | Marginal | 182 070 | 4 | 728 280 | 4.5 | 819 315 |
| L | Low | 80 501 | 2 | 161 001 | 4.5 | 362 253 |
| N-C | Non-Classified | 121 599 | 2 | 243 198 | 4 | 486 395 |
| **Dryland Production** | | | | 1 891 720 | | 2 488 941 |
| **Irrigated Production** | | | | 213 200 | | 213 200 |
| Total | | **509 937** | **5.2** | **2 104 920** | **6.1** | **2 702 141** |
| Actual Reported Figures (2013/2014) | | 500 000 | 2 799 600 | | | |

*Source: Own compilations based on BFAP (2014b), DAFF (2014), AGIS (2013) and Grain SA (2014b)*

**Table 4.4: Free State's dryland maize crop suitability and the 2013/2014 dryland maize crop**

| | | (A) | (B) | (A) * (B) | (D) | (A) * (D) |
|---|---|---|---|---|---|---|
| **Maize Suitability Class** | | Actual Maize Hectares Cropped (2013/2014) | Potential average modelled maize yield (t/ha) - Upper yield | Average Calculated Production (tons) | Average maize yield (t/ha) Re-estimated Yield | Average Calculated Production (tons) |
| VH | Very High | 0 | 9 | 0 | 9 | 0 |
| H | High | 3 | 8 | 20 | 8 | 20 |
| S | Suitable | 12 766 | 6 | 76 597 | 6.5 | 82 980 |
| M | Marginal | 179 161 | 4 | 716 642 | 4.5 | 806 223 |
| L | Low | 652 540 | 2 | 1 305 080 | 4.5 | 2 936 430 |
| N-C | Non-Classified | 253 359 | 2 | 506 718 | 4 | 1 013 436 |
| **Dryland Production** | | | | 2 605 058 | | 4 839 089 |
| **Irrigated Production** | | | | 550 000 | | 550 000 |
| Total | | **1 097 828** | **5.2** | **3 155 058** | **6.1** | **5 389 089** |
| Actual Reported Figures (2013/2014) | | 1 195 000 | 6 270 500 | | | |

*Source: Own compilations based on BFAP (2014b), DAFF (2014), AGIS (2013) and Grain SA (2014b)*

Multiplying Mpumalanga's actual maize field crop boundaries with the potential upper maize yields derived from the maize crop suitability layer, as presented in Table 4.3, shows that the crop suitability layer's total estimated production reflects an underestimated production output, when compared to Grain SA's (2014b) actual recorded production. For the 2013/2014 production season in Mpumalanga, actual provincial production (including 213 200 tons of irrigated production) was recorded to be 2 799 600 tons, whereas the potential production was underestimated in Table 4.3 as 2 104 920 tons. Similarly, the Free State's total maize production in the 2013/2014 season was 6 270 500 tons (Grain SA, 2014b), (roughly 550 000 tons accounted for as irrigation deliveries), compared with the modelled production of 3 155 058 tons. The maize crop suitability layer's upper yield estimates would therefore have underestimated 3 810 122 tons of the production in these two provinces. Most of the underestimation is derived from the marginal and lower classified production regions, the yield estimates of which are probably too low, considering technology adoption by producers.

The yield estimates of the maize crop suitability layer were further re-estimated within Mpumalanga and Free State according to the calculated yields per magisterial district, derived from the Crop Estimates Committee (DAFF, 2014). This adjustment realised 2 702 141 tons and 5 389 089 tons, respectively, as the estimates came closer to the actual dryland deliveries shown in Table 4.3 and Table 4.4 above.

Comparing verification analysis outcomes of local and international maize crop suitability models, the total South African modelled production outcome, as presented in Table 4.3 and Table 4.4 above, do not correlate with the GAEZ agro-ecological maize crop model outcomes. The same local crop type classification data (Column A, Table 4.3 and Table 4.4) for Mpumalanga and Free State was delineated according to actual field crop boundaries. Within both provinces, these field crop boundaries were used to extract production estimates associated with the relevant GAEZ agro-ecological maize crop model grids, based on a high input regime. This high input regime can be explained as an advanced management assumption, in which the production system is based on "improved high yielding varieties, fully mechanized, optimum applications of nutrients and chemical pest, disease and weed control"

(IIASA/FAO, 2012). Finally, this high input regime is also directed towards the commercial market and not for informal or subsistence use (IIASA/FAO, 2012).

**Table 4.5: Dryland GAEZ maize crop suitability and the 2013/2014 dryland maize crop**

| | Mpumalanga | | | Free State | | |
|---|---|---|---|---|---|---|
| **Maize Crop Suitability (Authors Classification)** | Maize Hectares Cropped (2013/2014) | Average GAEZ maize yield (t/ha) - **High Input Regime** | Average Calculated Production (tons) | Maize Hectares Cropped (2013/2014) | Average GAEZ maize yield (t/ha) - **High Input Regime** | Average Calculated Production (tons) |
| **Very High** | 16 795 | 9 | 151 154 | 11 296 | 9 | 101 668 |
| | 34 078 | 10 | 340 780 | 2 265 | 10 | 22 652 |
| | 1 359 | 11 | 14 946 | 0 | 11 | 0 |
| **High** | 76 730 | 7 | 537 109 | 76 921 | 7 | 538 447 |
| | 39 306 | 8 | 314 444 | 21 865 | 8 | 174 918 |
| **Suitable** | 100 009 | 5 | 500 044 | 282 447 | 5 | 1 412 233 |
| | 169 654 | 6 | 1 017 923 | 123 839 | 6 | 743 035 |
| **Marginal** | 29 768 | 3 | 89 304 | 60 179 | 3 | 180 538 |
| | 28 375 | 4 | 113 500 | 193 303 | 4 | 773 214 |
| **Low** | 1 352 | 0 | | 303 217 | 0 | |
| | 3 508 | 1 | 3 508 | 1 560 | 1 | 1 560 |
| | 9 004 | 2 | 18 008 | 20 935 | 2 | 41 870 |
| **Calculated Dryland Production** | 509 937 | | 3 100 721 | 1 097 828 | | 3 990 134 |
| **Actual Reported Dryland Production (tons) (2013/2014)** | | | 2 586 600 | | | 5 720 500 |
| | Over-estimated | | **514 121** | Under-estimated | | **1 730 366** |

*Source: Own compilations based on BFAP (2014b), DAFF (2014), AGIS (2013), Grain SA (2014b) and (IIASA/FAO, 2012)*

The findings from the GAEZ agro-ecological maize crop model, presented in Table 4.5: Dryland GAEZ maize crop suitability and the 2013/2014 dryland maize crop above, show that in Mpumalanga dryland maize production was over-estimated by 514 121 tons and in the Free State under-estimated by 1 730 366 tons. Similar to the local maize crop model, spatial outputs from the GAEZ model show that under drier production conditions (such as the Free State) crop models could not fully account for technology adoptions and advanced production methods. This under-estimation of potential production can be seen in the results of GAEZ crop suitability overlaid with actual production in the Free State (Map A.4, Appendix A). From the modelled outcomes shown in Map A.4, Appendix A, and represented in Table 4.5, it was calculated that 303 217 hectares of actual maize production in the Free State would be unaccounted for in the GAEZ maize crop suitability model.

The findings confirm that a general maize suitability datasets can provide some valuable information for future production potential, given that enough data is available to verify actual production. In Mpumalanga, both production seasons allocated roughly 50 per cent of the total hectares planted to maize on marginally suitable land. Similarly, the Free State province had 60 per cent of its 2013/2014 production seasons' maize allocated to low suitability land. These findings in Mpumalanga and the Free State verify that it was not necessarily the highest suitability class which favours the highest allocations, from which it can be concluded that biophysically modelled limitations are not necessarily production limitations. This is in line with literature by Beddow, Hurley, Pardey, and Alston (2014:353) regarding their yield gap analysis, since yield is an object of choice for producers, determined by decisions regarding technology adoption, management and input utilisation, conditioned by uncontrolled elements in nature. It is from this perspective that yield gaps reflect variances in the condition of production that cannot be fully controlled (Beddow et al., 2014:353) or in the research case be fully modelled for. Beddow et al., (2014:354) further adds that "even if farmers do not directly participate in output (or input) markets, they do make optimizing decisions based on the opportunity cost (or shadow prices) of inputs and outputs."

Future maize allocations will most probably have to determine which suitability class has the most "logic" to it, given that integrated maize production systems may be the highest contributor towards crop allocation. These integrations refer to economic attributes, such as markets and infrastructure, which are linked to technical production adaptation, ultimately driven by profit maximisation.

#### *4.3.2.3 Utilisation of maize crop suitability data*

Maize was identified as being a vital crop for reaching the targets of Fetsa Tlala, hence the development of a suitability database for the maize crop to biophysically identify possible focus regions for maize production (AGIS, 2013).

As was pointed out in the introduction of Section 4.3, spatial verification is important for analyses that identify where land might be brought into cultivation, as spatial reallocation is linked to the understanding of where land is currently being cultivated. Unfortunately, no individual field crop production data currently exist for the former homelands (Beukes, 2015) at the level of detail required to do similar analysis as performed in the previous section. Many of the former homeland field crop boundaries (FCB) identified during 2011 (AGIS, 2011) should probably have never been cultivated owing to soil quality restrictions (Laker, 2004:363). Therefore, verifying which FCB to use is an important part of this research. Given that actual production data are unavailable for the FHREC, estimations derived from Mpumalanga's crop suitability verification analysis (Table 4.6 below) were used to estimate potential future maize production in the FHREC. The parsing process enabled a crop allocation process in the FHREC which accounts for some level of crop competition as is currently the case in Mpumalanga.

**Table 4.6: Mpumalanga dryland maize production allocation (2013/2014)**

| | | (A) | (B) | (C) = (B)/(A) | (D) | (E) = (D)/(B) |
|---|---|---|---|---|---|---|
| **Maize Suitability Class** | | All Field Crop Boundaries (FCB) Hectares Identified on "Maize Suitable Land" | All Dryland Grain & Oilseed Hectares (FCBs) on "Maize Suitable Land" (2013/2014) | % of Grain & Oilseed Hectares planted on suitability class, from all (FCB) | Selected Actual Maize (FCBs) Hectares Cropped (2013/2014) | % Maize Hectares planted on suitability class, from Grain & Oilseed (FCB) |
| **H** | **High** | 12 425 | 4 205 | 34 % | 2 242 | 53 % |
| **S** | **Suitable** | 222 964 | 164 378 | 74 % | 123 474 | 75 % |
| **M** | **Marginal** | 395 896 | 249 580 | 63 % | 182 070 | 73 % |
| **L** | **Low** | 224 203 | 125 839 | 56 % | 80 501 | 64 % |
| **Total** | | 855 488 | 544 003 | | **388 286** | |

*Source: Own compilations based on BFAP (2014b) and AGIS (2011)*

Therefore, to first calculate the percentage utilisation of grain and oilseed field crop boundaries within Mpumalanga's maize suitability layer, all the field crop boundaries were selected (Table 4.6, Column A). Secondly, the total quantity of grain and oilseed production per field, per maize suitability class was estimated (Table 4.6, Column B and Column C).

Finally, a selection process based on remote-sensed crop classification data was used to identify how much of the grain and oilseed hectares are found within the maize suitability layer (Table 4.6, Column D and Column E). This selection process used provincial remote-sensed crop classification data, which shows crop specific data per field crop boundary, to extract the field crop boundaries which had maize or oilseeds planted on them. The selection process was followed to calculate the relative share between maize and non-maize hectares, which finally helps to capture the crop allocation percentages to be pared to the FHREC.

Applying the maize crop suitability yields to derive production estimates, while not knowing which areas in the FHREC are currently cultivated to maize, crop allocation assumptions had to be made. One of the assumptions made was that all identified field crop boundaries in FHREC that spatially concord with maize suitability areas are potential areas of future maize production. By applying the same crop allocation criteria or percentages derived from Mpumalanga (Table 4.6, Columns C & E) to the selected field crop boundaries in the FHREC (Table 4.7 below), production estimates were calculated per maize suitability class.

**Table 4.7: Former Homeland Region of the Eastern Cape and the potential dryland maize production**

| | | (1) | (2) = (1)*(C) | (3) = (2)*(E) | (4) | (5) = (4)*(3) |
|---|---|---|---|---|---|---|
| **Maize Suitability Class** | | Maize Suitable Land (Hectares) identified within Field Crop Boundaries (FCB) | Allocated Dryland Grain & Oilseed Hectares to potentially be cropped, from Maize Suitable Land | Potential Dryland Maize Hectares | Potential average maize yield (t/ha) – Lower yield | Average Production Potential (tons) |
| **H** | **High** | 91 642 | 31 015 | 16 533 | 5.9 | 97 548 |
| **S** | **Suitable** | 169 404 | 124 892 | 93 813 | 3.9 | 365 871 |
| **M** | **Marginal** | 319 612 | 201 490 | 146 988 | 2.9 | 426 264 |
| **L** | **Low** | 114 282 | 64 144 | 41 033 | 2 | 82 066 |
| **Total** | | 694 940 | 421 540 | **298 367** | **3.7** | **971 750** |

*Source: Own compilations using data from AGIS (2013) and DRDLR (2013)*

Table 4.7 above illustrates that 693 940 ha of the FHREC was identified as being suitable for maize crop production within the existing or previously identified field crop boundaries. This calculation is based in the work done by DRDLR (2013), which was discussed in Section 3.3 above. When the suitable hectares which add up to the 694 940 ha are given the derived allocation rate in Table 4.6, Column C, the reallocated dryland grain and oilseed hectares to potentially be cropped, based on the maize suitable land, is calculated to be 421 540 hectares. To calculate the amount of hectares that can potentially be reallocated to maize production alone, Column E in Table 4.6 was multiplied by Column 2 in Table 4.7. The total potential dryland maize hectares to be reallocated in the FHREC is therefore estimated at 298 367 hectares.

In this research it was highlighted that a maize suitability layer alone might not estimate sufficient production figures. Yields in the FHREC were therefore re-estimated per suitability class, linked to actual maize production regions in the FHREC. This re-estimation had to match prior research from Grain SA's extension staff (Grain SA, 2014a) working in the FHREC, as well as literature that reviewed maize production programs in the FHREC (Tregurtha, 2009:12). To finally calculate an estimated figure for potential future maize production in the FHREC, Column 4 from Table 4.7 used a re-estimated lower bound yield estimate from the Fetsa Tlala maize crop suitability model (subsection 4.3.2.2 above), which was adapted according to the prior research mentioned.

Yield estimates from different international crop models, such as GAEZ, SPAM and CERES-DSSAT, might have also been used in this study, but the purpose of the research was to evaluate the existing local maize crop suitability model (AGIS, 2013) and the proposed implications for future research in policy initiatives, such as Fetsa Tlala. Even though the existing local maize crop suitability model was primarily used in the research, verification analysis from the international GAEZ agro-ecological maize crop model was still introduced to compare a range of production estimates. The GAEZ agro-ecological maize crop model outcomes were again delineated according to FHREC actual field crop boundaries, similar to Mpumalanga and the Free State. The local field crop boundaries was used to allocate production estimates associated with the relevant GAEZ agro-ecological maize crop model grids, but this time based on an intermediate input regime for the FHREC.

This intermediate input regime can be explained as an improved management assumption, in which the production system is based on “improved yielding varieties, manual labor with hand tools and/or animal traction and some mechanization, uses some fertilizer application and chemical pest, disease and weed control” (IIASA/FAO, 2012). In addition, this intermediate input regime is partly market oriented or directed towards the commercial market as well as subsistence production (IIASA/FAO, 2012).

**Table 4.8: Dryland GAEZ maize crop suitability and the production potential for the FHREC**

| | | (1) | (2) = (1)*(C) | (3) = (2)*(E) | (4) | (5) = (4)*(3) |
|---|---|---|---|---|---|---|
| **Maize Suitability Class (Authors Classification)** | | GAEZ Maize Suitable Land identified within Field Crop Boundaries (FCB) | Allocated Dryland Grain & Oilseed Hectares to potentially be cropped, from Maize Suitable Land | Potential Dryland Maize Hectares | Potential average maize yield (t/ha) - **Intermediate Input Regime** | Average Potential Production (tons) |
| **H** | **High** | 35 062 | 11 866 | 6 326 | 7 | 44 280 |
| | | 70 989 | 24 025 | 12 807 | 6 | 76 845 |
| | | 67 030 | 22 685 | 12 093 | 5 | 60 466 |
| **S** | **Suitable** | 219 501 | 161 825 | 121 556 | 4 | 486 224 |
| **M** | **Marginal** | 135 511 | 85 429 | 62 321 | 3 | 186 962 |
| **L** | **Low** | 109 853 | 61 657 | 39 443 | 2 | 78 886 |
| | | 72 985 | 40 965 | 26 205 | 1 | 26 205 |
| **Total** | | **710 931** | **408 453** | **280 751** | **4.0** | **959 867** |

*Source: Own compilations based on DAFF (2014), AGIS (2013), DRDLR (2013) and (IIASA/FAO, 2012)*

Comparable to the local maize crop suitability model's outcome in Table 4.7, is the GAEZ modelled outcome, presented in Table 4.8 above, which illustrates that 710 931 ha of the FHREC was identified as being suitable for maize crop production within the existing or previously identified field crop boundaries. Based on the GAEZ agro-ecological maize crop model, suitable land for dryland maize production is calculated to be 280 751 hectares. Similar to the results from the local maize crop model, the GAEZ agro-ecological maize crop model determines that the total potential maize production on the reallocated hectares in the FHREC amounts to 959 867 tons of maize.

Verified production allocations in Mpumalanga created a baseline to the reallocation analysis for the FHREC. It was finally calculated that roughly 970 000 tons of maize can be produced in the FHREC (with existing technology), on an estimated 300 000 hectares of varyingly suitable land. This analysis implies an average yield of 3.7 t/ha (ranging from 5.9 t/ha to 2 t/ha across crop suitability classes), which concords with the findings of Tregurtha (2009:12), who studied the Eastern Cape's Siyakhula (or

Massive maize project), reporting that the highest average yield throughout a season was 3.7 t/ha.

### 4.3.3 Conclusion

The aim of this section was to verify current land capability and crop suitability layers with actual crop production, so as to inform future allocation of production. Spatial verification was deemed to be important for analyses which identify where land might be brought into cultivation, as spatial reallocation is linked to the understanding of where land is currently being cultivated. This process was followed to derive a possible maize reallocation potential for the Former Homeland Region of the Eastern Cape, and concluded that almost a million tons of maize could potentially be grown in the FHREC, subject to the substantial list of assumptions detailed above. This estimate is based largely, but not entirely, on biophysical suitability criteria. We now explicitly turn to a consideration of certain economic factors.

## 4.4 LOCAL MAIZE MARKETS

The preceding section mainly highlighted production economic elements that are linked to biophysical crop production. However, other economic elements, such as spatial markets, need consideration. Furthermore, one of the objectives of this study was to illustrate what the potential impact on regional balance between demand and supply can be and the potential implications for prices and therefore the economics of production, within the Former Homeland Region of the Eastern Cape. Economic elements can broadly be defined in a basic regional supply and demand analysis, which implicitly involves value chains.

Dynamics within regional supply and demand can be linked to economic incentives or disincentives through regional price analysis. These dynamics govern the conversion or intensification of potential cropland (Lambin et al., 2013:893).

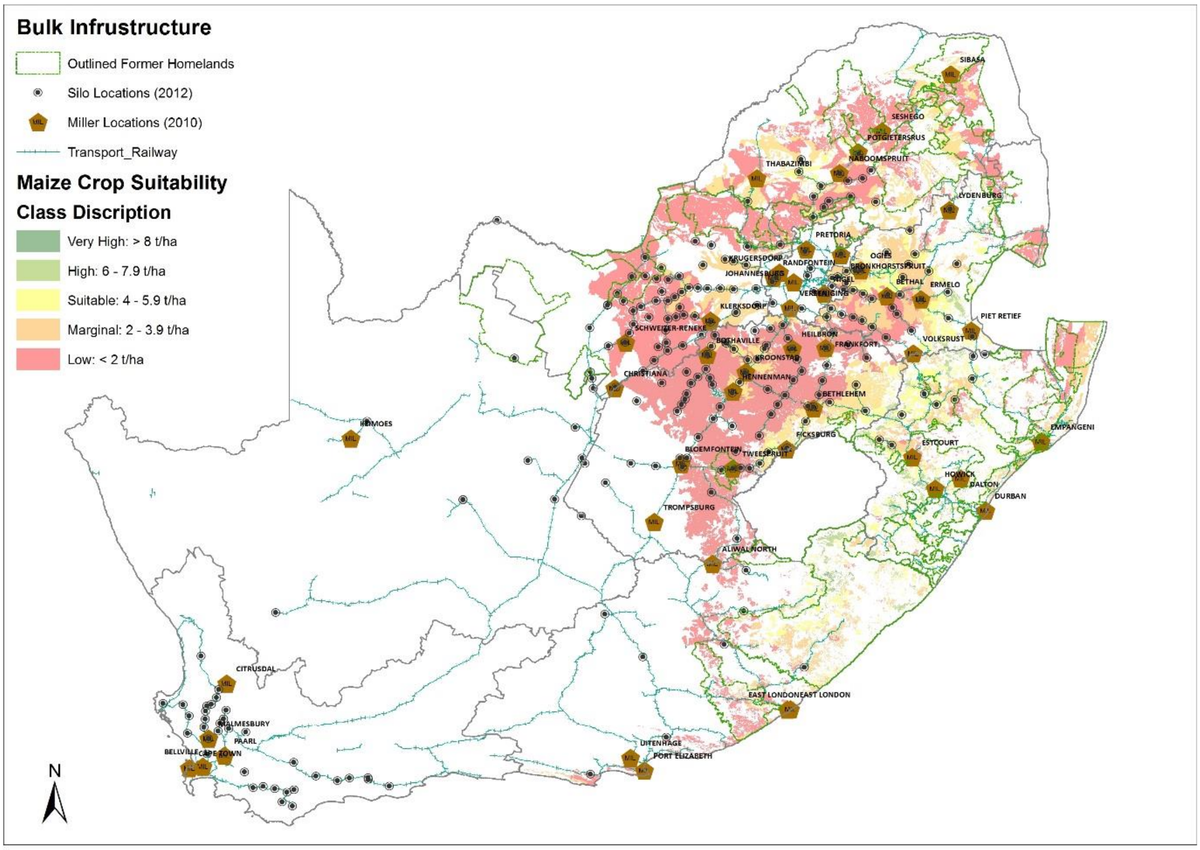
The consideration of infrastructure is important when evaluating value chains. The lack of transportation infrastructure and storage facilities limits access to local and international markets, such that areas with only extensive cropland would require well-structured investments to develop the value chains associated with mechanised production and input use (Lambin et al., 2013:900). This was the case with most of the development that took place under the old apartheid government, which left self-governing territories (the former homelands) deprived of certain infrastructure development investments, from which the repercussions can now be seen in Figure 4.1 below.


**Figure 4.1: Infrastructure, services and facilities found in production regions**

*Source: Stats SA (2003)*

Besides the separated development strategies of self-governing territories in the 1960s, commercial white agriculture in the rest of South Africa followed a different infrastructure development route, as shown in Map 4.9 below.

Most of the millers and processors are located in the Gauteng industrial areas, as this was considered to be one of the largest consumption hubs. Additional development took place in the highest maize suitability regions, which assured supply and cost savings in the supply chain (rail and storage silos). In addition, Randfontein in the Gauteng province was established as the central location for the maize futures price, which means that all grain transport costs are calculated back to this location as a reference price.




**Map 4.9: South Africa’s bulk grain infrastructure**

*Source: Own compilations based on DAFF (2014) and AGIS (2013)*

Prices that are indexed by location and attained in competitive markets can influence the allocation of resources in space (Beckmann, 2009:35). If consumers and producers are located apart from one another, distance intervenes and transaction costs for transportation arise, with the result being that ordinary market theory become deferred, such that the “law of the single price” is violated (Beckmann, 2009:35). This result is inherently the formation of spatial markets that can potentially ignite the evolution of innovation (Beckmann, 2009:35) or be an impediment to market access.

Such innovation can be in the form of new technologies which can decrease the cost of investment to bring marginal lands into use (Lambin et al., 2013:900), as typically observed in the Free State and North West provinces of South Africa.

This section will primarily evaluate the market component in the value chain context to explain more about the possible producer break-even levels and how local prices could potentially be driven by regional changes in production and consumption, which has a further effect on the profitability of primary production.

### 4.4.1 Markets in the Former Homeland Region of the Eastern Cape

In an effort to understand informal markets in Tsolo, Qumbu, and Umtata (Former Homeland Region of the Eastern Cape production areas), expert knowledge was provided by Grain SA's extension services (Grain SA, 2014a). It was found that during the 2013/2014 production season, maize produced in the Qumbu, Umtata and Tsolo regions sold for R70 per 40 kg bag (R1750/ton) at the Co-operative in Ugie (Table 4.9 below). If producers sold the same bag of maize to local villagers or in the informal market, they received an average of R130 per 40 kg bag (R3 250/ton). Some producers would store harvested maize cobs in their huts to sell at a higher price of R4 000/ton in November/December, when demand is high and supply to the region is much lower.

**Table 4.9: Maize prices in the Former Homeland Region of the Eastern Cape**

| Selling Month (Year – 2014) | Production Year: 2013/2014 | Local Price (bag price) | | Reference Price (bulk price) |
|---|---|---|---|---|
| | | Price per bag (40 kg) | Price per ton (1000 kg) | Average SAFEX Farm-gate price (1000 kg) |
| **May – August** | Formal Market (Co-op) | R 70 | R 1 750 | R 1 770 |
| **Nov – Jan** | Formal Market (Co-op) | R 80 | R 2 000 | R 1 870 |
| **May – August** | Informal Market (Traders / In Villages) | R 130 | R 3 250 | R 1 770 |
| **Nov – Jan** | Informal Market (Traders / In Villages) | R 160 | R 4 000 | R 1 870 |
| | Average | R 110 | R 2 750 | R 1 820 |

*Source: Own compilation*

Adam Smith's economic theory explains that markets naturally return to equilibrium, i.e. Supply = Demand (Meyer, 2006). Based on Table 4.9, this theory seems to hold. When there is a spike in supply in the region, which is during commercial harvest months (May – August) and the local FHREC harvest period (June – July), prices tend to be lower. When the demand grows relative to supply during December, and surpluses are lowered due to local consumption, producers tend to receive higher prices.

Once local supply reaches local demand, producers either have to store their maize and sell at a possible higher price in December (due to higher demand), or they have to sell to the nearest cooperative or local trader. This would imply exposure to commercially related SAFEX prices.

An over-supply in the former homelands would be beneficial to the local consumers. Maize meal prices would supposedly be lowered if local milling capacity can manage to mill the volumes, where sufficient storage is available in the area and supply is constant. However, this study focuses on production factors and this research is interested in the potential impact on local farm-gate price. The locally derived price, if high enough, would have a positive effect on production expansion, as well as on the economic sustainability of production in this region. If local producers could produce profitable returns at the average SAFEX price, they would most possibly be able to compete with other production regions, such as Mpumalanga. But as was previously emphasised, surplus production might possibly force farm-gate prices down, which would have a negative effect on future smallholder maize production, if not mitigated in advance. The alternative would be to either produce other crops, or become technically more efficient, i.e. Increase yields while reducing costs and selling in the local informal market at higher prices. In order to calculate the break-even optimum point, local demand needs to be calculated as the previous section calculated potential future maize production or supply, which has the potential of reaching more than 1 million tons.

#### *4.4.1.1 Consumption estimation*

To derive an annual average maize demand in the Former Homeland Region of the Eastern Cape, various data sources had to be collected and restructured to calculate first the annual average consumption of maize meal. Secondly, an imposed conversion assumption of maize grain to maize meal had to be used to calculate the annual average maize grain required in the respective area.

A rural demand framework was constructed to calculate the average annual demand for maize grain and maize meal in the Former Homeland Region of the Eastern Cape, as depicted in Figure 4.2 below.

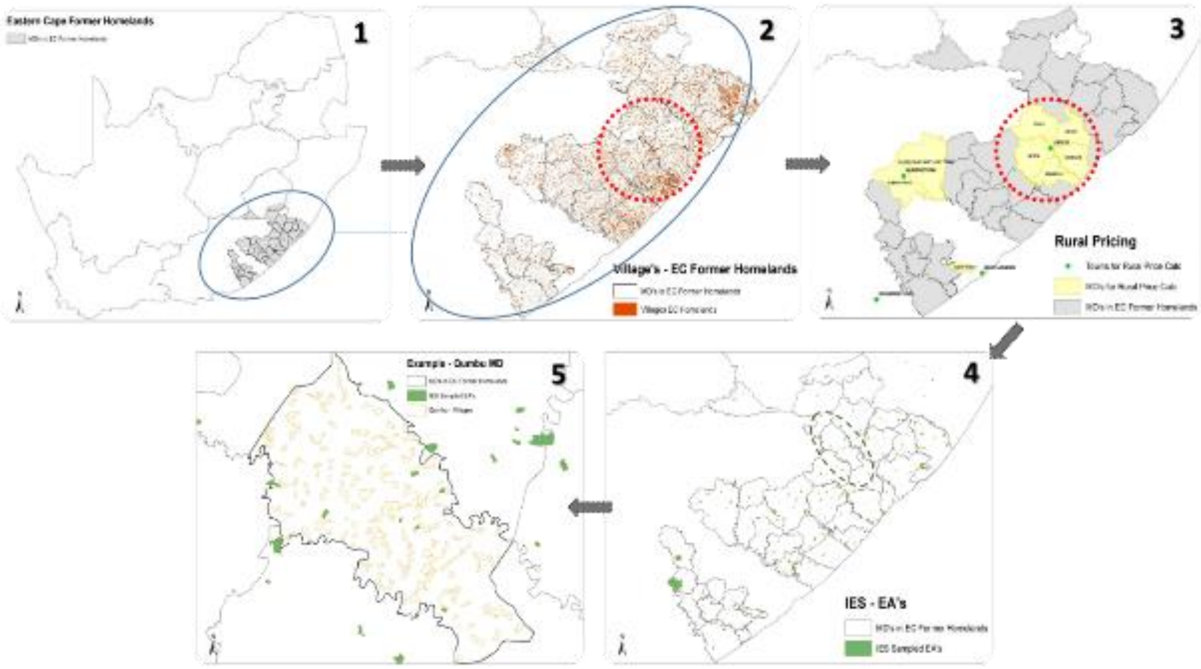



**Figure 4.2: Rural Demand Framework**

*Source: Own compilation*

Figure 4.2 displays the process that was followed to estimate average human maize meal demand in the specified area, which will follow after points 1 to 5, in Table 4.10. Five stages of data analysis were followed, which were:

**1 & 2) Calculate the Number of Households (NH) = Total number of households per Magisterial District (MD)**

The first stage of the process was to identify the total number of households in each magisterial district. By using the DWA (2007) village database, a census of all individuals and households in a specified village is shown in part 2. From this analysis it is possible to estimate the population and household numbers of each MD within the Eastern Cape and within former homeland territories.

**3) Price (P) = Spatially located rural maize meal prices (R/kg)**

The National Agricultural Marketing Council's (NAMC) rural price survey data was used to derive prices for maize meal in the specified MDs (NAMC, 2010). This survey captures rural prices by enumerating various informal retailers throughout South Africa. More specifically, in the Eastern Cape the following towns were selected and indicated with the green dots in Figure 4.2 above (Picture frame 3): East London, Umtata and Queenstown. Using the 2010 price information, an average consumer purchase price was calculated for each MD for a bag of 2.5 kg maize meal. This was the only price available at district level and it was noted that a 10 kg bag price would have been more representative as the average consumer prefer a 10 kg carry weight (Grain SA, 2014a). The Umtata maize meal price was used as a reference price for the surrounding MDs, which were Tsolo, Libode, Ngqeleni and Mqanduli. Due to the unavailability of the other MD prices, a total average former homeland price was used as a representative consumer price, which was the average price among the three towns mentioned.

**4 & 5) Expenditure (EXP) = Spatially calculated average household expenditure on maize meal (R/annum)**

Statistics South Africa (Stats SA) conducts a national Income and Expenditure Survey (IES) once every five years. This survey is used for various analyses of South African consumer behaviour and to calculate the Consumer Price Index (CPI). Income and expenditure data is captured at the household level and gives the rand values for all the products listed in the survey. Each household enumerated has an Enumerator Areas (EA) code which is the smallest geographic unit used to divide a country for census purposes.

Utilising a similar approach to Pienaar and von Fintel (2014), the EA codes were used to spatially locate households within the Eastern Cape former homeland areas. One of the food items surveyed in the IES is maize meal expenditure per household in nominal rand values (Stats SA, 2012). Stage 4 therefore creates a new layer which was developed by clipping the IES (2010) information within the boundaries of each MD of the former homeland areas, as shown in part 4. The “UNION” function in ArcGIS was used to join specific EAs to link-up with the villages at the same location. To illustrate with a typical example, Stage 5 displays a higher resolution of the Qumbu MD and shows how sampled EAs are located within certain villages. This union therefore creates a new layer database used to calculate the average expenditure per household for a selected village, as the number of households in each particular village is known, given that this particular village is covered by an EA.

The average household expenditure per MD could finally be calculated, as the average expenditure per household for selected EA joined villages was now known. The average expenditure per household was used to calculate the average household expenditure per magisterial district by multiplying the average expenditure per household by the number of households per MD, as derived in part 1.

**Average household consumption (C) = Average maize meal consumption per household per MD (kg/household)**

From the analytical outputs derived in Figure 4.2 above, maize meal consumption per MD could be calculated as:

$$C = (EXP / P) * NH$$

**Total Consumption (C) = Average annual maize demand per MD**

To finally derive a point estimate of the demand for maize in the region, a maize meal conversion factor was used to convert the maize meal back to a maize seed equivalent For the purposes of this study, a roller milling process was considered. This process implies an average meal to chop ratio of 68:32, such that for every ton of maize milled, 680 kg of maize meal is delivered and 320 kg of maize chop, assuming no losses. Therefore, for every 1000 kg (ton) of maize meal required, 1471 kg of maize needs to be milled. Total derived demand and supply will be analysed together to estimate an “equilibrium” point in the FHREC.

#### *4.4.1.2 Maize Consumption versus Production*

Following the framework discussed in the previous section, the total value of maize consumed by residents in the FHREC could be estimated (Table 4.10 below). During 2010, the estimated maize meal expenditure in the FHREC was over a billion rand. This expenditure translates into a total consumption of roughly 260 000 tons of maize required to supply the FHREC with sufficient maize meal.

**Table 4.10: Maize and maize meal demand in the FHREC**

| | A | B | D = A * B | C | E = (D/C)/1000 | E * 1.4706 | F |
|---|---|---|---|---|---|---|---|
| **Magisterial District** | Number of households | Annual average maize meal expenditure | Total expenditure on maize meal | Average 2.5kg bag maize meal price (R/kg) | Annual maize meal consumption (tons) | Annual maize seed demand at 68% meal extraction (tons) | Hectares required at 2 t/ha yield (Subsistence Yield Estimate) |
| **Source:** | (DWA, 2007) | (IES, 2010) | | (NAMC, 2010) | | | |
| PEDDIE | 18 716 | R 1 631 | R 30 526 442 | R 5.92 | 5 156 | 7 583 | 3 447 |
| VICTORIA EAST/ALICE | 14 473 | R 661 | R 9 560 664 | R 5.92 | 1 615 | 2 375 | 1 080 |
| MPOFU/SEYMOUR | 2 695 | R 1 300 | R 3 503 500 | R 5.92 | 592 | 870 | 396 |
| MDANTSANE | 5 366 | R 1 867 | R 10 016 534 | R 5.92 | 1 692 | 2 488 | 1 131 |
| MIDDLEDRIFT | 13 710 | R 416 | R 5 705 779 | R 5.92 | 964 | 1 417 | 644 |
| ZWELITSHA | 75 668 | R 738 | R 55 809 113 | R 5.92 | 9 427 | 13 864 | 6 302 |
| KEISKAMMAHOEK | 17 311 | R 1 050 | R 18 172 182 | R 5.92 | 3 070 | 4 514 | 2 052 |
| HEWU/WHITTLESEA | 23 332 | R 859 | R 20 043 646 | R 5.92 | 3 386 | 4 979 | 2 263 |
| CACADU/GLEN GREY/LADY FR | 48 261 | R 1 171 | R 56 492 111 | R 6.09 | 9 276 | 13 641 | 6 201 |
| COFIMVABA/ST. MARKS | 23 042 | R 960 | R 22 125 047 | R 5.92 | 3 737 | 5 496 | 2 498 |
| XALANGA/CALA | 16 426 | R 2 141 | R 35 170 037 | R 5.92 | 5 941 | 8 737 | 3 971 |
| HERSCHEL/STERKSPRUIT | 34 994 | R 1 043 | R 36 481 651 | R 5.92 | 6 162 | 9 062 | 4 119 |
| MDANTSANE I | 55 040 | R 325 | R 17 887 337 | R 5.52 | 3 240 | 4 765 | 2 166 |
| LUSIKISIKI | 52 659 | R 1 133 | R 59 654 185 | R 5.92 | 10 077 | 14 819 | 6 736 |
| BIZANA | 42 278 | R 1 527 | R 64 573 122 | R 5.92 | 10 908 | 16 041 | 7 291 |
| SIPHAQENI/FLAGSTAFF | 32 315 | R 973 | R 31 436 032 | R 5.92 | 5 310 | 7 809 | 3 550 |
| MASIXEBENI/MT.AYLIFF | 19 650 | R 1 250 | R 24 561 714 | R 5.92 | 4 149 | 6 101 | 2 773 |
| CENTANI/KENTANI | 21 466 | R 1 074 | R 23 056 435 | R 5.92 | 3 895 | 5 727 | 2 603 |
| GCUWA/BUTTERWORTH | 22 906 | R 562 | R 12 883 862 | R 5.92 | 2 176 | 3 200 | 1 455 |
| ENGCOBO | 36 823 | R 831 | R 30 611 185 | R 5.92 | 5 171 | 7 604 | 3 456 |
| TSOMO | 15 399 | R 664 | R 10 218 870 | R 5.92 | 1 726 | 2 538 | 1 154 |
| NQAMAKWE | 24 822 | R 939 | R 23 319 442 | R 5.92 | 3 939 | 5 793 | 2 633 |
| DUTYWA/IDUTYWA | 22 714 | R 1 156 | R 26 252 337 | R 5.92 | 4 435 | 6 521 | 2 964 |
| GATYANA/WILLOWVALE | 25 664 | R 1 087 | R 27 888 602 | R 5.92 | 4 711 | 6 928 | 3 149 |
| UMTATA | 60 873 | R 599 | R 36 462 554 | R 6.15 | 5 929 | 8 719 | 3 963 |
| TSOLO | 27 670 | R 1 105 | R 30 578 424 | R 6.15 | 4 972 | 7 312 | 3 324 |
| MQANDULI | 35 992 | R 888 | R 31 970 494 | R 6.15 | 5 198 | 7 645 | 3 475 |
| XHORA/ELLIOTDALE | 20 547 | R 1 074 | R 22 066 424 | R 5.92 | 3 727 | 5 482 | 2 492 |
| NGQELENI | 39 255 | R 1 079 | R 42 347 203 | R 6.15 | 6 886 | 10 126 | 4 603 |
| LIBODE | 33 511 | R 817 | R 27 377 725 | R 6.15 | 4 452 | 6 547 | 2 976 |
| UMZIMVUBU/PORT ST. JOHNS | 14 256 | R 1 481 | R 21 109 572 | R 5.92 | 3 566 | 5 244 | 2 384 |
| MT. FLETCHER | 35 737 | R 855 | R 30 555 653 | R 5.92 | 5 161 | 7 590 | 3 450 |
| QUMBU | 27 899 | R 962 | R 26 844 152 | R 5.92 | 4 534 | 6 668 | 3 031 |
| KWABHACA/MT. FRERE | 40 024 | R 1 256 | R 50 283 184 | R 5.92 | 8 494 | 12 491 | 5 678 |
| MATATIELE/MALUTI | 28 971 | R 1 268 | R 36 743 128 | R 5.92 | 6 207 | 9 127 | 4 149 |
| TABANKULU | 30 425 | R 1 541 | R 46 891 177 | R 5.92 | 7 921 | 11 648 | 5 295 |
| **Total** | **1 060 890** | | **R 1 059 179 519** | | **177 802** | **261 474** | **118 852** |
| **Average** | | **R 1 063** | | **R 5.95** | | | |

*Source: Own compilation based on DWA (2007), Stats SA (2010) and NAMC (2010)*

Even if the demand analysis shown in Table 4.10 is considered to be a lower-bound estimate of maize consumption in the FHREC, it creates a basis for analysis of market demand required in this research. In the previous section, potential future maize production in the FHREC was estimated to be close to 1million tons. Considering that total annual direct human consumption was calculated to be roughly 260 000 tons of maize, a scenario for future surplus production in the FHREC remains very tangible. Given that the annual population growth rate of South Africa is expected to grow by less than 1 per cent annually (BFAP, 2014), local demand in the FHREC would have to increase by more than 300 per cent in order to reach the biophysical production potential of 1 million tons.

Since the regional supply and demand dynamics implicitly involve value chains, regional over-production or under-production influence more than just the primary producer. Giving further consideration to infrastructure, transaction costs, informal trade and local investment is important for the less-developed maize value chains.

The lack of transportation infrastructure and storage facilities limits access to formalised markets. These areas would require well-structured investments to develop the value chains associated with mechanised production and higher input use, as this will be required to close possible yield gaps is the region. Production regions are not currently geared towards the transport of surplus production, storage or value adding. Since the region is not well equipped to deal with surplus production, additional value chain costs will ultimately be deducted from the farm-gate price.

### 4.4.2 Spatial gross margin analysis – production economics

If projected production were to exceed likely consumption in the FHREC, then local prices would be affected. National surpluses drive SAFEX prices to export parity levels, as indicated in subsection 4.4.1, Figure 4.2, above. Similarly in the FHREC, anticipated local production–consumption imbalances can have the same effect, as local prices may follow commercial SAFEX movements. If a surplus is produced in the Eastern Cape, prices might move closer to the SAFEX reference price, as indicated in subsection 4.4.1, and small-scale producers would have to sell some portion of their maize at this commercially calibrated price. Small-scale producers are therefore directly competing with commercial producers.

Considering the above-mentioned market factors, spatial gross margin analysis between regions of production becomes an important variable to consider in the economics of reallocation. Coherently, when spatial markets and biophysical variables of production are integrated, economically suitable spatial allocation may follow.

The gross margin analysis, shown in Table 4.11 below, jointly factors spatial variables to calculate gross margins under selected farming systems. This is a similar approach to the Potentially Available Cropland (PAC) analysis of Chamberlain et al. (2014:53), discussed in section 3.2 of Chapter 3.

**Table 4.11: Dryland maize gross margin analysis (2013/2014)**

| Maize Gross Margin Analysis (2013/2014) | | (A) | (B) | (C) | (D) | (E) | (F) |
|---|---|---|---|---|---|---|---|
| | | **Mpumalanga**<br>High Yields<br>Commercial Market | **Mpumalanga**<br>Low Yields<br>Commercial Market | **Eastern Cape Former Homelands**<br>High Yields<br>Commercial Market | **Eastern Cape Former Homelands**<br>Low Yields<br>Commercial Market | **Eastern Cape Former Homelands**<br>Observed Yields<br>Commercial Market | **Eastern Cape Former Homelands**<br>Smallholder Yields<br>Informal Market |
| Yield | T/ha | **7** | **4.5** | **7** | **4.5** | **3.7** | **2.2** |
| Safex Price | R/ton | 2102 | 2102 | 2102 | 2102 | 2102 | |
| Transport differential | R/ton | 200 | 200 | 100 | 100 | 100 | |
| Marketing costs | R/ton | 0 | 0 | 0 | 0 | 0 | 0 |
| **Farm-gate price** | **R/ton** | **1902** | **1902** | **2002** | **2002** | **2002** | **2865** |
| Informal Price | R/ton | | | | | | 3250 |
| Local Transport | R/ton | | | | | | 385 |
| **Gross Income (Silo delivery/Market)** | **R/ha** | **R 13 314** | **R 8 559** | **R 14 014** | **R 9 009** | **R 7 407** | **R 6 303** |
| **Variable Costs** | | | | | | | |
| **Pre Harvest Costs** | | | | | | | |
| Seed | R/ha | 1495 | 1495 | 1785 | 1350 | 1350 | 900 |
| Fertilizer | R/ha | 2964 | 1482 | 2964 | 1600 | 1600 | 696 |
| Lime | R/ha | 419 | 419 | 1000 | 500 | 500 | 0 |
| Chemicals | R/ha | 1150 | 1005 | 950 | 650 | 650 | 0 |
| Casual Labour | R/ha | 0 | 0 | 0 | 0 | 0 | 0 |
| Crop Insurance | R/ha | 466 | 300 | 490 | 315 | 259 | 0 |
| **Mechanisation Costs** | | | | | | | |
| Fuel | R/ha | 360 | 360 | 340 | 340 | 340 | 0 |
| Contracting - Tillage | R/ha | 600 | 600 | 800 | 800 | 800 | 900 |
| Contracting - Plant | R/ha | 350 | 350 | 400 | 400 | 400 | 430 |
| Contracting - Spray | R/ha | 250 | 250 | 250 | 250 | 250 | 280 |
| Contracting - Harvest | R/ha | 400 | 400 | 600 | 600 | 600 | 440 |
| Transport | | 40 | 40 | 80 | 80 | 80 | 50 |
| ** Repair & Maintenance (N/A) | R/ha | 0 | 0 | 0 | 0 | 0 | 0 |
| ** Interest on Working Capital (N/A) | R/ha | 0 | 0 | 0 | 0 | 0 | 0 |
| Total variable costs | R/ha | R 8 494 | R 6 701 | R 9 659 | R 6 885 | R 6 829 | R 3 696 |
| **Gross Margin** | **R/ha** | **R 4 820** | **R 1 858** | **R 4 355** | **R 2 124** | **R 578** | **R 2 607** |
| **Source:** | | PRF(2014), Grain SA (2014) & BFAP (2014) | PRF(2014), Grain SA (2014) & BFAP (2014) | Grain SA (2014) | Grain SA (2014) | Grain SA (2014) | Grain SA (2014) |

*Source: Own compilation based on PRF (2014), Grain SA (2014a) and BFAP (2014)*

Under the high yielding, commercially related input regimes represented in Columns A & C of Table 4.11, gross margins are slightly higher in Mpumalanga due to lower variable costs. One of the main resource limitations mentioned in section 4.2 was low soil pH levels in the FHREC. The combination of low pH, which results in additional lime application, and the lack of infrastructure, results in higher farm-level lime costs in FHREC. Basic contracting costs are also slightly higher under all input regimes in the FHREC due to production location constraints, which can be linked to infrastructure and contracting economies. Contracting economies refer to economies of size in Mpumalanga's maize production region, such that demand for contracting work is lower and supply can easily be met, due to more contractors being available. The reverse is true for the FHREC, which increases the relative price of contracting per hectare.

Considering the lower yielding and lowered input regimes, represented in Columns B, E & F of Table 4.11, if poverty alleviation and food security initiatives, such as Fetsa Tlala, were to succeed in the FHREC, cognisance should be taken of the respective gross margins of semi-commercial low yielding producers and the smallholder, informal market producers. If modelled yield levels from the maize suitability analysis are implied, FHREC producers (Column D) would slightly outperform Mpumalanga producers (Column B) on a rand per hectare basis. However, observed yield levels reflect a different outcome, as shown in Column E, Table 4.11. If producers in the FHREC are not reaching target yields due to production constraints, a possible revised strategy should be considered.

Even though smallholder producer yields are lower than all other producers, gross margins for these producers are still higher than the average semi-commercial producer due to higher informal market prices and some lower input costs. If all the identified future maize production areas in the FHREC were to be brought into production, smallholder producers would have to sell maize at commercial prices. This is already the case when there is excess supply in the harvesting season. The "autarky" point of self-sufficiency is therefore a vital factor to consider for production systems chosen in policy initiatives like Fetsa Tlala.

#### *4.4.2.1 Concluding on local market economics*

To summarise, a possible scenario considering the potential of the Former Homeland Region of the Eastern Cape area to out-produce itself was considered to be a conservative estimate. Section 4.3.3 produced a plausible future scenario that potential maize production in the FHREC might be approximately 1000 000 tons, with demand estimated at roughly 260 000 tons. This is under the assumption that most of the land suitable for cropland expansion in the FHREC is allocated to dryland maize production. With a conservative view on the future potential production FHREC, a significant surplus of maize could be produced. It was estimated that even under a scenario of eight to ten per cent growth in population over the next decade, supply would exceed local demand by more than 60 per cent.

This implies that programmes focussing on reallocation in the FHREC will have to take into consideration infrastructure development (storage, processing, and transport) and more importantly, either the development of external markets or the optimisation of the value chain (localised village milling capacities). If the reallocation process were to be implemented in the FHREC, smallholder producers that depend on local market demand could be negatively affected by market prices favouring larger producers. Their economic profitability depends on informal market dynamics, which is very sensitive to over-supply scenarios.

## 4.5 CONCLUSION

Recognising the spatially explicit nature of agricultural production can be helpful in formulating policies and public actions stemming from the prospective relocation of maize production in South Africa. Complexities in identifying, interpreting and integrating selected variables within spatial allocation analyses need to be addressed to enable more informed policy decisions. This links with the current and past initiatives of policy-driven programmes like Fetsa Tlala and the former homeland "betterment schemes", introduced in Chapter 2. These programmes seldom draw upon spatially explicit biophysical and economic evidence before implementing these programmes Additional examples of past policy programmes that had spatially related consequences, was the establishment and abolishment of the marketing boards in the 1970s and 1980s, also referenced in Chapter 2.

The spatial reallocation of maize from Mpumalanga to the FHREC may change the biophysical and economic realities of maize production in South Africa in ways that were explored in sections 4.2 and 4.3. Reallocation initiatives would be confronted with different biophysical limitations of maize production, higher livestock densities, higher population densities, and the combination of possibly un-fenced, degraded and acidic soils.

Nonetheless, the Eastern Cape has pockets of higher rainfall areas with deep soils that are rich in organic content that will spatially differentiate maize production potentials and development realities. Incorporating economic attributes holds the key to unlocking future crop production in the former homelands of South Africa and policy initiatives will have the greatest impact if there is an integration of economic and biophysical parameters. Spatial markets as an economic attribute is crucial, since the regional balance between production and consumption can easily tip towards an excess-supply that may drive farm-gate prices down with possible negative consequences on the returns to maize production within the Former Homeland Region of the Eastern Cape. If local production initiatives were to be geared towards the transport or storage of surplus production and localised value chains, the former homelands could develop, ultimately creating an environment where smallholder producers are economically viable.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

There is an expectation that there will be a continuous reduction in the area planted to maize as the economics of production and market fundamentals drive the competition for arable land. Besides the economic factors affecting maize production, rapid expansions in mining activities may increase the pressure on the availability of arable farmland for the production of maize in Mpumalanga. In response, reallocation strategies could act as possible mitigating policies for maize production. Spatial analysis is typically utilised to identify suitable areas for production of crops on arable land. Consequently, the former homelands of South Africa were identified as being capable of affecting the potential for reallocation of land suitable for the growing maize. It was emphasised that economic viability or suitability is seldom the focus of multi-criteria (GIS) analysis, and more empirical evidence was needed to assess the potential, capability, suitability and state of the natural resources, with special reference to the quality of the soil. Refinement was necessary to evaluate a field of study where the economics of land use define the spatial allocation of production, instead of only combining land classifications, biophysical models and cross-entropy approaches, as currently occurs in most models for spatial allocation of land.

Since the location of agricultural production does matter, influences on developmental strategies would largely depend upon a better understanding of spatial determinants of agricultural development. Considering the variability of South African maize production, this study questions the ability of traditional multi-criteria GIS modelling techniques to simulate the reallocation of maize production. Based on the disparity between land capability, crop suitability and economic factors influencing production allocation, this study provided an additional approach to multi-criteria GIS modelling to be applied in the field of agricultural land use allocation. The restructured framework for spatial allocation incorporated economic crop suitability analysis, which included possible economic attributes influencing the profitability of maize production.

The primary objective of this study was to undertake a spatially explicit assessment of the likely shifts in the location of maize production resulting from the biophysical and economic factors in play. This was achieved by reviewing and evaluating the suitability of existing spatial models and databases with the aim of informing policies that will affect prospective maize production areas in South Africa. Changes in the regional balance of maize production and consumption had to be considered, as local prices may be affected and consequently influence the economics of production within the Eastern Cape.

Fetsa Tlala, focusses on allocating maize crop production and has used spatial maize suitability analysis to guide future production allocations in the Former Homeland Region of the Eastern Cape. This research found 1 289 205 hectares of land suitable for maize production in the Former Homeland Region of the Eastern Cape. In most instances, the application of multi-criteria analysis was used for deriving results of spatial suitability analysis. In the case of this research, selected criteria were integrated to form the framework of Economically Suitable Spatial Allocation (ESSA), which was derived from four main categories, namely; Resource Factors, Maize Crop Suitability, Agricultural Land Use and Economic Drivers. Each category was separately evaluated and contributed towards the final objectives of the research.

To evaluate biophysical attributes which may have economic implications for the reallocation of maize production, **resource factors**, being a selected ESSA framework category was spatially analysed. It was found that very low to low levels of predicted soil loss areas are found in Mpumalanga (MP), while 30 per cent of the identified field crop boundaries in the Former Homeland Region of the Eastern Cape (FHREC) cover very high to high levels of predicted soil loss areas. Additionally, high levels of lime application are currently required in MP due to low soil pH. Similar acidity levels were also seen in the FHREC and it is calculated that 8 per cent of the identified field crop boundaries fall within a pH level below 5.5 and 18 per cent, with pH levels between 5.5 and 6.0. Stocking densities were calculated to be as high as 1:1 (one livestock unit per hectare), resulting in cropped areas directly competing with grazing land. Livestock entering planted fields is one of the leading causes of the decline in larger field cultivation and it was found that only 18 per cent (approximately 121 000 hectares) of the field crop boundaries found in the maize suitability areas had some form of fencing surrounding them, limiting future crop production.

In the initial high-level allocation process of Fetsa Tlala, emphasis was placed on using the maize crop suitability outputs to inform future production. However, in verifying land capability and maize crop suitability to inform future maize production allocation, it was found that these biophysical layers alone might be misleading. Therefore, this study considered verifying **maize crop suitability** and **agricultural land use,** as categories in the ESSA framework, to calculate the potential future maize production in the FHREC. It was found that 35 per cent of the grain and oilseed crop production in MP takes place on high land capability soils (land capability classes II and III). In terms of maize crop suitability, only 0.4 per cent of the MP maize crop was cultivated on land classified as high maize suitability, and the majority, or 52 per cent, was cultivated within the marginal and low suitability classes. Considering the crop allocation percentages derived from MP, potential dryland maize hectares to be reallocated in the FHREC was estimated at 298 367 hectares. Applying the lower-bound yield estimates of the Fetsa Tlala maize crop suitability analysis, this allocation could potentially result in the production of 971 750 tons of maize in the FHREC.

The final two objectives of this study was to evaluate how the regional balance between **consumption and production** drives **local prices** and therefore the **economics of production** (gross margins) within the Former Homeland Region of the Eastern Cape. Current local maize grain demand in the Former Homeland Region of the Eastern Cape was calculated to be around 260 000 tons of maize. A possible over-production scenario is anticipated in the FHREC, should the Fetsa Tlala initiative be fully implemented. If a surplus were to be produced in the Eastern Cape, prices might move closer to the SAFEX commercial level and smallholder producers would have to sell their maize at a commercially related price.

It was further found that the respective gross margins of semi-commercial low yielding producers and smallholders producing for the informal market have a large difference. If modelled yield levels from the maize suitability analysis are implied, the gross margin of FHREC producers exceeds MP producers by R266 per hectare. However, since producers in the FHREC fail to reach target yields due to possible biophysical production constraints identified in section 4.2, gross margins are too low, at R578 per hectare, for a semi-commercial producer. Even though the smallholder producers' yields are lower than all other producers, gross margins for these producers are still

R2 029 per hectare higher than the average FHREC semi-commercial producer, due to higher informal market prices and lowered input cost structures.

It can be concluded that general maize suitability datasets can provide some contribution towards future maize production potential, but not enough. Biophysically modelled limitations are not necessarily production limitations, if best agricultural practices can be followed, as in the case of Mpumalanga. The break-even level of consumption and production is a key factor to consider for production systems chosen in policy initiatives like Fetsa Tlala. The Former Homeland Region of the Eastern Cape production regions are not geared towards the transport of surplus production, storage or value adding. This implies that additional value chain costs will ultimately be deducted from the farm-gate price, negatively affecting the profitability of the primary producer. If local production initiatives were to be geared towards the transport or storage of surplus production and localised value chains, the former homelands could develop, ultimately creating an environment where smallholder producers can expand production and grow into commercial surplus producers. Under this scenario there will likely be a natural trend of consolidation of farming units, which will also be influenced by land tenure systems. This, however, falls beyond the scope of this study.

## 5.1 RECOMMENDATIONS FOR FUTURE RESEARCH

Spatial analysis applied in the field of agricultural economics is very much a new and un-researched field in South Africa, with many delimitations and gaps existing for future research. Probably not all of these might be mentioned in a study such as this one, but the following areas of research could be considered:

- A final output that would represent growth enhancing or growth limiting factors that could have economic impacts in the spatial reallocation process, comparing the Mpumalanga province with the Eastern Cape former homeland region.

- Future studies should be looking at allocating the correct commodity to a region, which is based on the competitive advantage of the crop. Besides including a broader spectrum of commodities, it is advised to compare relative profitability between livestock and cash crops.

- Future studies should consider land tenure as a spatially explicit economic variable. Secure land tenure or formal titled ownership has a large impact on production. This impact can be viewed from a capital asset perspective in which the producer has access to finance due to the land serving as collateral security, or it can be viewed from a food security perspective, in which the land is not seen as a right but rather as a resource to produce for the food security needs of the country. These issues are fundamental to the full development of the former homelands of South Africa.

- Future studies should include the financial interpretations of representative farms and the return per ton of grain harvested, endeavouring to measure farm profitability and ending with cash surplus/deficit. By doing that, the result would be the cash flow (CF) position of farm businesses as presented by van der Westhuizen (2013). The relationships between cost structures, operations, net margins as a sustainability measure should therefore be evaluated.

- Future studies should consider social and historical aspects as possible factors of influence on spatial reallocation. Social attributes, such as the farmers themselves, or the social structure of the farming community, as well as historical aspects, might possibly be a variable in determining the success of reallocation.

- Merging identified areas, with high maize demand areas, with identified farmer typologies of Pienaar (2013).

- It was recognised that the verification of land use planning should also be conducted at the farm level, as land use issues combined with their impacts tend to become distorted when evaluated from a national perspective (ARC-ISCW 2004:1).

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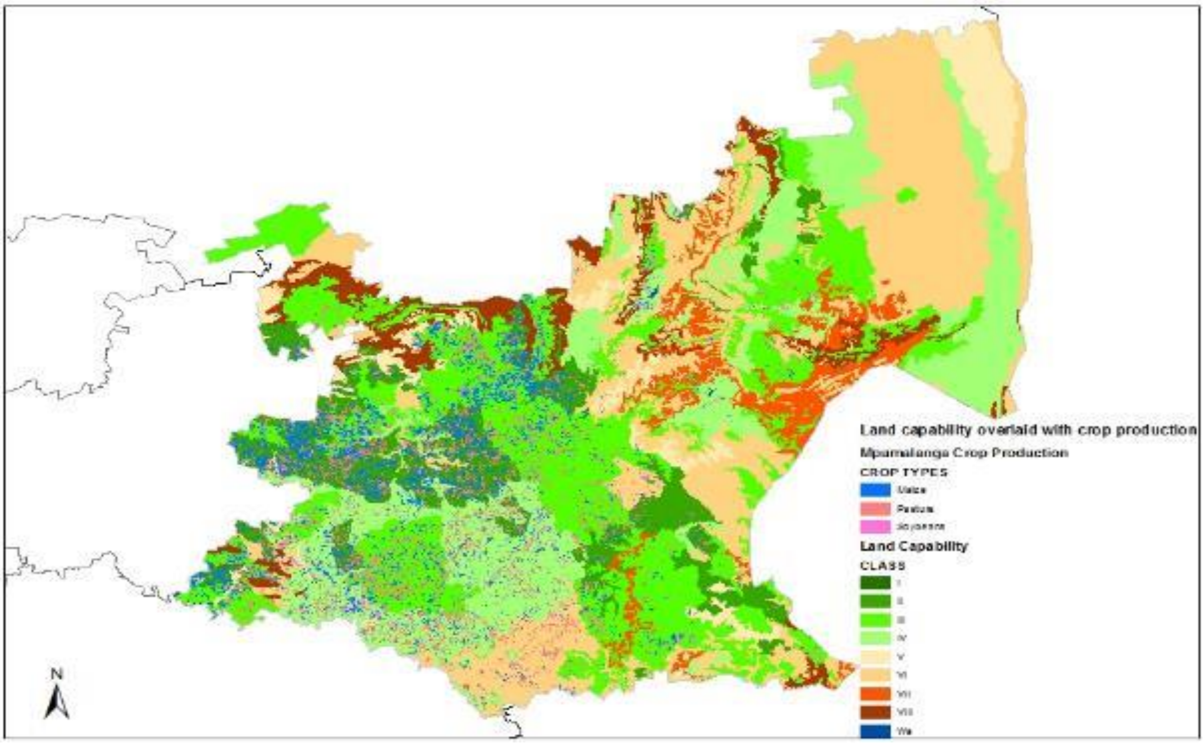
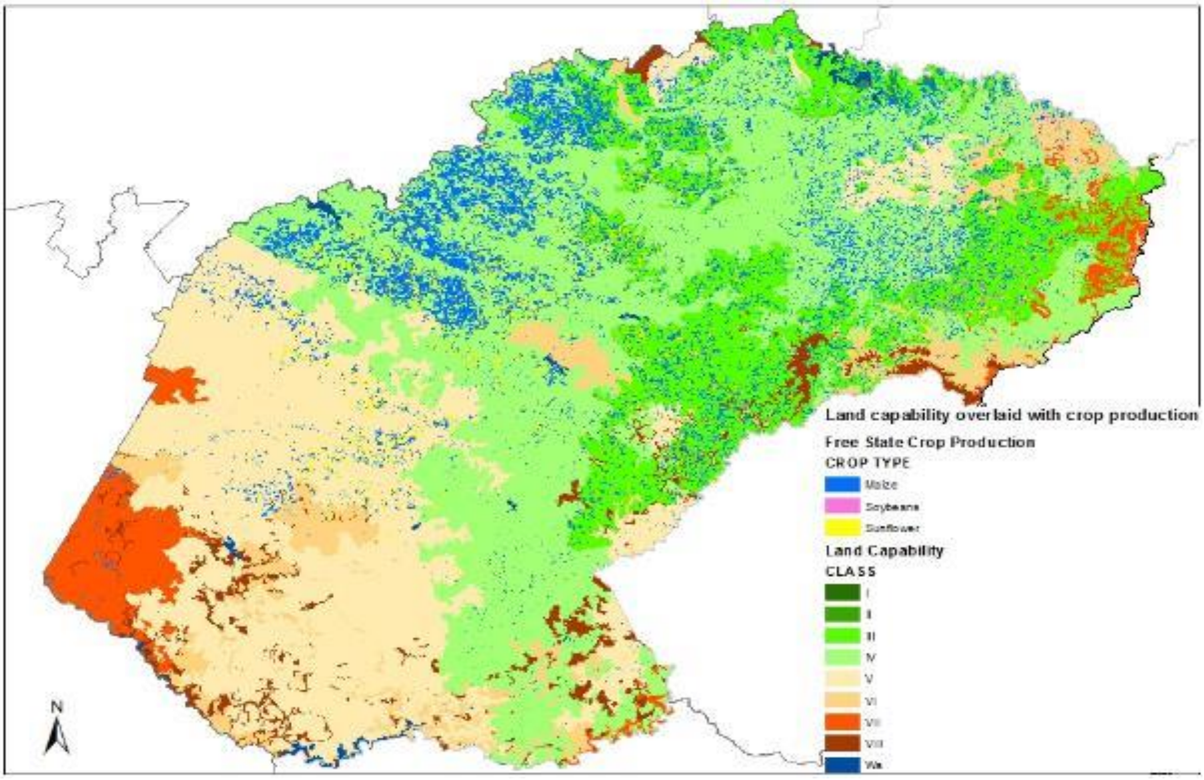
# APPENDIX A – OWN COMPILATIONS



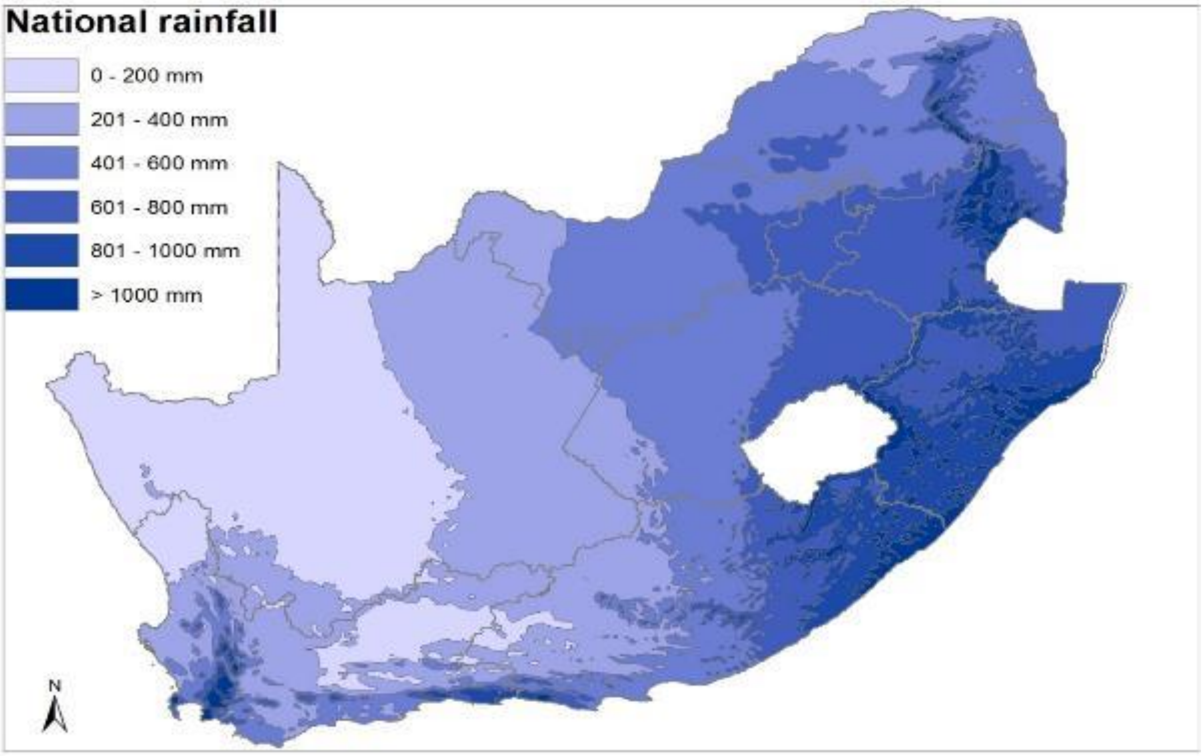

**Map A.1: Mpumalanga`s Land Capability overlaid with actual crop production**

*Source: Own Compilation based on ARC-ISCW (2004)*



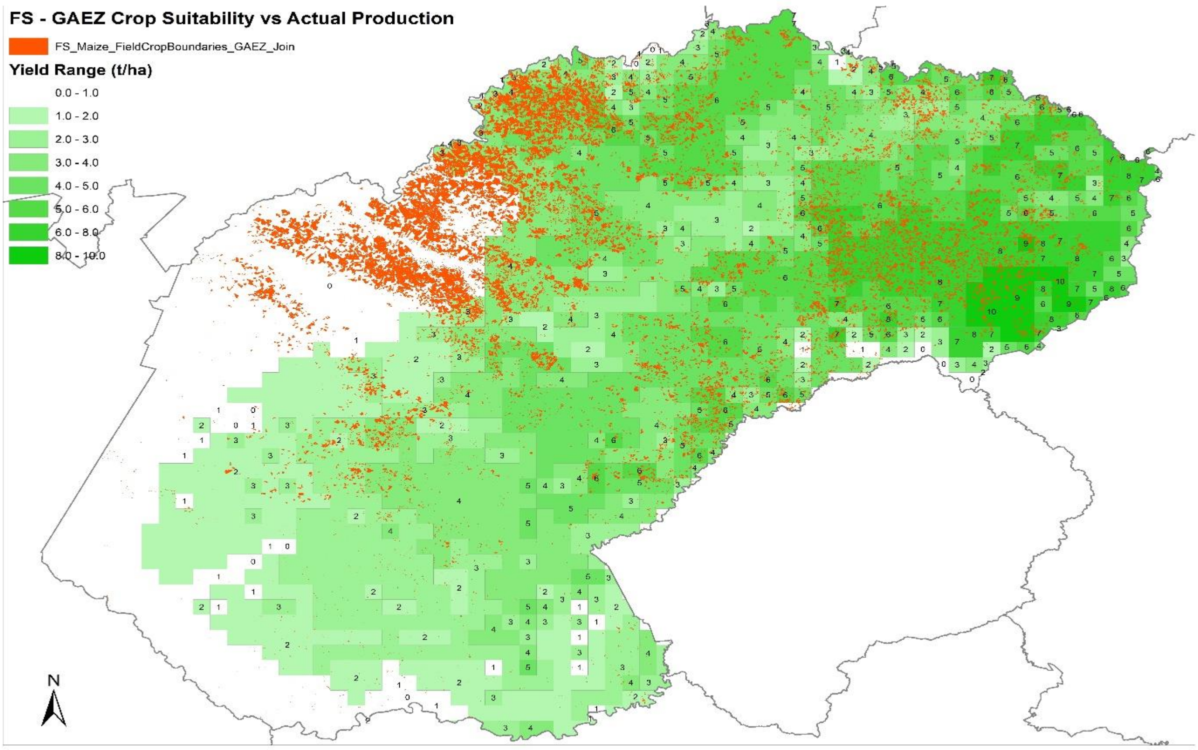

**Map A.2: Free State`s Land Capability overlaid with actual crop production**

*Source: Own Compilation based on ARC-ISCW (2004)*



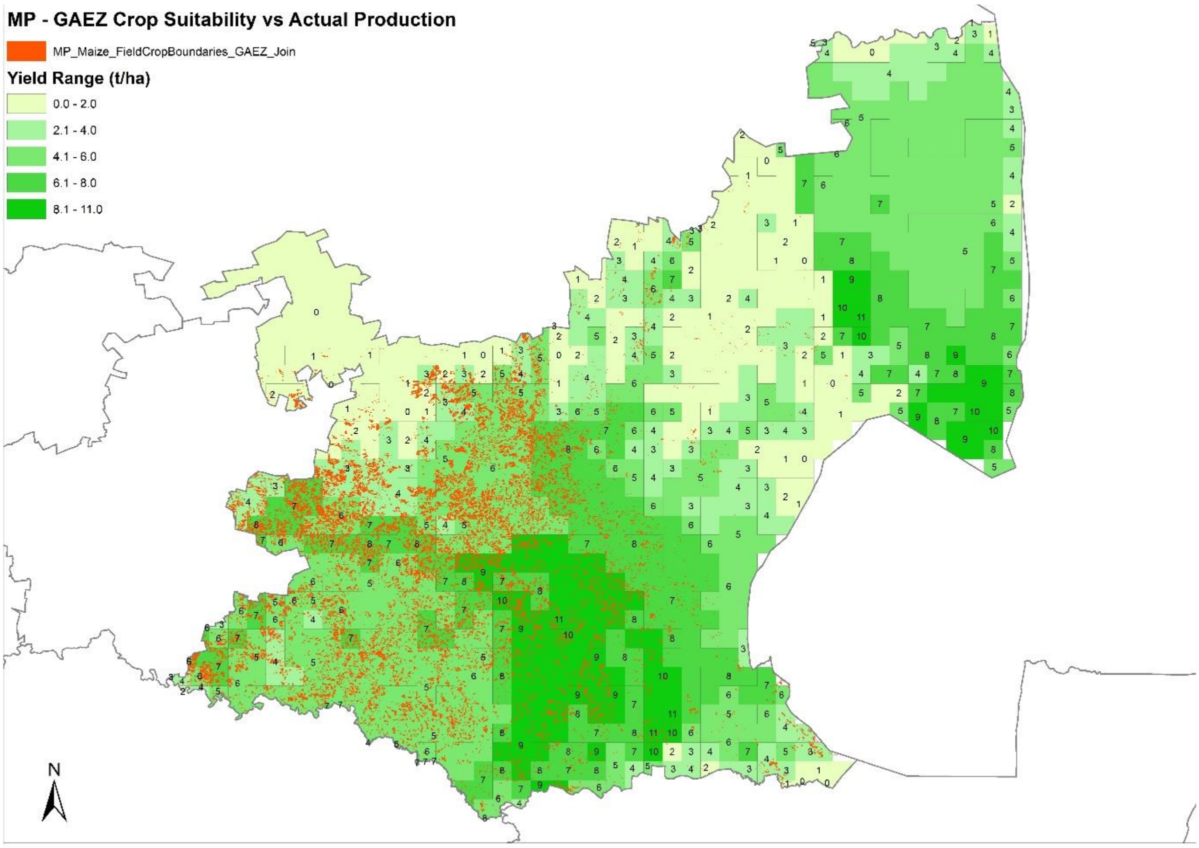

**Map A.3: National rainfall**

*Source: Own compilations based on ARC-ISCW (2004)*




**Map A.4: Free State GAEZ Crop Suitability and Actual Production**

*Source: Own compilations based on (IIASA/FAO, 2012)*




**Map A.5: Mpumalanga GAEZ Crop Suitability and Actual Production**

*Source: Own compilations based on (IIASA/FAO, 2012)*

# APPENDIX B

**Table A.1: Land Capability Classification**

| Class | Land Classification definitions |
|---|---|
| I | Land in Class I has few limitations that restrict its use; it may be used safely and profitably for cultivated crops; the soils are nearly level and deep; they hold water well and are generally well drained; they are easily worked, and are either fairly well supplied with plant nutrients or are highly responsive to inputs of fertilizer; when used for crops, the soils need ordinary management practices to maintain productivity; the climate is favourable for growing many of the common field crops. |
| II | Land in Class II has some limitations that reduce the choice of plants or require moderate conservation practices; it may be used for cultivated crops, but with less latitude in the choice of crops or management practices than Class I; the limitations are few and the practices are easy to apply. |
| III | Land in Class III has severe limitations that reduce the choice of plants or require special conservation practices, or both; it may be used for cultivated crops, but has more restrictions than Class II; when used for cultivated crops, the conservation practices are usually more difficult to apply and to maintain; the number of practical alternatives for average farmers is less than that for soils in Class II. |
| IV | Land in Class IV has very severe limitations that restrict the choice of plants, require very careful management, or both; it may be used for cultivated crops, but more careful management is required than for Class III and conservation practices are more difficult to apply and maintain; restrictions to land use are greater than those in Class III and the choice of plants is more limited. |
| V | Land in Class V has little or no erosion hazard but has other limitations which are impractical to remove that limit its use largely to pasture, range, woodland or wildlife food and cover. These limitations restrict the kind of plants that can be grown and prevent normal tillage of cultivated crops; it is nearly level; some occurrences are wet or frequently flooded; others are stony, have climatic limitations, or have some combination of these limitations. |

| | |
|---|---|
| VI | Land in Class VI has severe limitations that make it generally unsuited to cultivation and limit its use largely to pasture and range, woodland or wildlife food and cover; continuing limitations that cannot be corrected include steep slope, severe erosion hazard, effects of past erosion, stoniness, shallow rooting zone, excessive wetness or flooding, low water-holding capacity; salinity or sodicity and severe climate. |
| VII | Land in Class VII has very severe limitations that make it unsuited to cultivation and that restrict its use largely to grazing, woodland or wildlife; restrictions are more severe than those for Class VI because of one or more continuing limitations that cannot be corrected, such as very steep slopes, erosion, shallow soil, stones, wet soil, salts or sodicity and unfavourable climate. |
| VIII | Land in Class VIII has limitations that preclude its use for commercial plant production and restrict its use to recreation, wildlife, water supply or aesthetic purposes; limitations that cannot be corrected may result from the effects of one or more of erosion or erosion hazard, severe climate, wet soil, stones, low water-holding capacity, salinity or sodicity. |

*Source: Schoeman et al., (2002:8) in ARC-ISCW (2004:94)*