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Table of Contents

List of Tables

List of Figures

List of Appendices

EXECUTIVE SUMMARY

The global area of cultivation for Genetically Modified (GM) crops, also referred to as Biotech crops, has increased significantly since their adoption and commercial purposes began in the mid-nineties. Although the trade-offs between benefits and adverse effects of GM crops (and other Genetically Modified Organisms – GMOs) are still debatable globally, there is increasing interest from various countries to adopt GM crops because of the anticipated benefits for crop production. South Africa, one of the leading GM crop growing countries globally, has a total of 2.7 million hectares under GM cotton, maize and soybean production. These have all been approved for general release. However, the growth in cultivation areas over the years has not been evaluated in terms of the effects on land-use and productivity trends as well as land cover change, with potential impacts thereof being unknown. For the purpose of this report, we gathered annual production area data (in hectares) for cotton, maize and soybean. We explored trends in land-use and productivity using a Bayesian State Space Model (BSPM) for maize and soybean pre- and post-introduction of GM traits (events). Currently, available cotton data was discarded due to various irregularities and an insufficiently long time series. In addition, land cover change from 1990-2014 was explored using the 2013-2014 South African National Land-cover dataset produced by GEOTERRAIMAGE with comparison of vector based agricultural fields being the main priority. The GEOTERRIAMAGE Report was used to infer on land use-land cover change impact to contextualise some of our findings.

Results show an overall acceleration in increase of land-use for soybean since the introduction of GM traits. Maize land-use area has experienced some declines but seem to be fairly constant in recent years. These trends are, however, highly variable at provincial levels, with several provinces making gains while others remain on a stable trend in production areas. Productivity output in ton per hectare has consistently increased for both maize and soybean, but no significant acceleration effect of this trend was detected post GM introductions. Land cover changes show an increase for cultivated commercial annual crops pivot and cultivated subsistence crops, as opposed to cultivated commercial annual crops non-pivot. Grasslands are the most affected in area loss resulting from these cultivation increases. However, based on the available data it was not possible to directly attribute this emerging pattern to GM crops, since the respective cultivation areas are inclusive of other crop types. Further analysis using disaggregated annual provincial production area data for GM crops is essential for producing more accurate trends and predictions before any conclusions can be reached for the effect of GM crops on land-use, productivity and land cover change. Further analyses will enable the detection of any GM crop cultivation decreases and/or increases that impact directly on land cover for each province.

1. INTRODUCTION

1.1 Global status of Genetically Modified crops

Genetically Modified (GM) crops are modified using genetic engineering techniques to introduce a new trait to the plant, which does not occur naturally in the species (Southgate *et al*. 1995). These plants can either be food crops, pharmaceutical agents, biofuels and those used for bioremediation. For GM crops in particular, newly introduced traits are designed to improve nutrient profile of the crop or protect the crop from certain pests, diseases and environmental conditions (Wieczorek 2003; James 2013). The adoption of GM crops globally for commercial purposes began around 1995/6, covering 1.7 million hectares (Table 1). By 2012, GM crops covered 170.3 million hectares (Table 1). The most recent period (2005-2012) indicated acceleration in the increase in area-use for GM crops from 90 to 130 million hectares, resulting in almost a doubling of GM crop land-use (James 2013).

Table 1: Global introduction of land-use for GM crops for the period 1996-2012

Year	Hectares (million)	Acres (million)
1996	1.7	4.3
1997	11	27.5
1998	27.8	69.5
1999	39.9	98.6
2000	44.2	109.2
2001	52.6	130
2002	58.7	145
2003	67.7	167.2
2004	81	200
2005	90	222
2006	102	252
2007	114.3	282
2008	125	308.8
2009	134	335
2010	148	365
2011	160	395
2012	170.3	420
Total	1427.3	3531.8

Source: Clive James (2012)

GM crop cultivation area has since reached 181.5 million hectares in the year 2014, an increase of 6.3 million hectares from 175.2 million hectares in 2013 (James 2014). However, the uptake of GM crops is highly variable among countries, with developing countries having a more rapid uptake. The United States of America (USA), Brazil, Argentina, India and Canada remain the top five countries globally for the largest area of GM crop production (James 2014). South Africa ranks ninth in the world and first in Africa in terms of area of GM crop production.

1.2 GM crops of significance: maize, cotton and soybean

Globally, maize soybean and cotton are the most widely adopted and cultivated GM crops. According to the 2014 International Service for the Acquisition of Agri-biotech Applications (ISAAA) report, GM maize is cultivated in 17 of the 28 countries that have adopted GM crops while cotton is cultivated 15 (James 2014). These remained unchanged from 2013 (refer to James 2013). Although there was one additional country that adopted a GM crop (bringing the total to 28), in Bangladesh, the approval was for the cultivation of Brinjal/Eggplant. A recent report by the Canadian Biotechnology Action Network (CBAN) shows that half of the global area used is planted with GM soybeans. GM corn accounts for 30% of the total global GM area coverage and GM cotton accounts for another 14% and GM canola accounts for 5% of the total GM land-us. The cultivation and use of maize, soybean and cotton varies in different countries. Maize is one of the most important cereal crops worldwide and is not only an important human nutrient, but also a basic element of animal feed and a raw material for the manufacture of many industrial products (Shaw 1988; Ranum *et al*. 2014). Soybean uses range from production of soybean oil, provision of meals for human consumption (i.e. flour and infant formula) to production of animal feed (FAO 2006). Cotton is mostly referred to as a cash crop, due to its high preference for fibre (Proto *et al*. 2000). Other uses of cotton include the production of cooking oil and feed for livestock, poultry and fish (Chapagain *et al*. 2006).

The GMO Compass (2014) reports on the cultivation of GM cotton, maize and soybean from 1997-2013 (Figure 1). Their analysis divided the data into worldwide (other countries) and the top three producing countries for the respective crops. Results from the aforementioned analysis showed that, after initial sharp increases in the early years, land-use of GM cotton plateaued around 2000-2003 in the USA and China, with only a small increase since then. India experienced a delayed, but rapid decrease in cotton land use between 2005 and 2009. At a global scale, the increase in cotton land-use was steady and approximately linear from 1997 before a slight decrease in 2013. Genetically Modified Maize land-use increased throughout 1997-2013 for South Africa. The USA experienced a constant increase in GM maize land-use for most years except during 2000 and 2013. Soybean acreage for the USA peaked from 1997, experienced a decrease in 2009, picking up consistently from

2010 to 2013. This trend was almost similar to that of Argentina, although the decrease for Argentina occurred in 2004, before levelling off from 2005 to 2010 with a slight increase until 2013. Worldwide acreage for soybean increased for all years, with decreases only experienced for 2011 and 2013. For Brazil, a decrease in land-use was only experienced during 2002-2003.

Annual acreage increases or decreases are mostly controlled by factors relating to: 1) uncertainties in climatic conditions; 2) market trends (supply versus demand) related to the economic climate, public perceptions and lobbying by different organisations (i.e. anti-GMO groups); 3) development of new/favourable cultivars resulting in farmer preferences; and 4) changes in regulations that affect both exporting and importing countries (see James 2014; Lucht 2015).

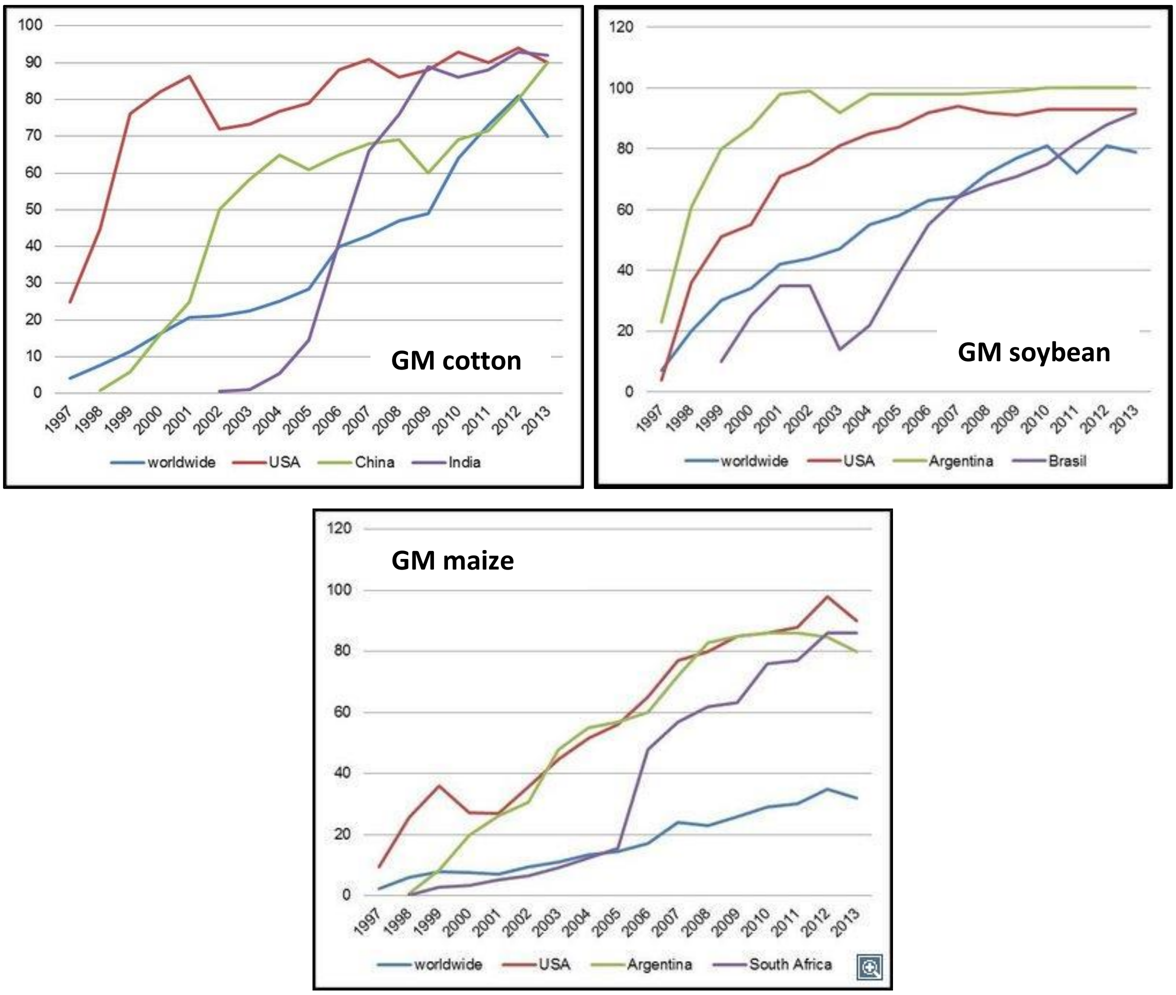

Figure 1: GM cotton, maize and soybean share in the total acreage (million hectares) of a country from 1997 – 2013. Source: GMO Compass (2014).

The global increase in the adoption and cultivation of GM crops has been credited to the perception of the technology as a powerful tool for efficient contribution in agriculture production (James

2014). Reviews by Carpenter (2010), Finger *et al*. (2011), Green (2012), Klumper & Qaim (2014), indicate some benefits relating to reduced chemical pesticide use, increased crop yields and increased farmer profits. These benefits can be attributed to favourable properties of GM crops for improving pest management, therefore reducing or eliminating losses from insect damage or weed competition, thus indirectly improving yields substantially. Also, increases in crop yields allow less land to be dedicated to agriculture than would otherwise be necessary (Carpenter 2011). In contrast, there is a multitude of concerns about the impact of GM crops on the environment (Wolfenbarger *et al.* 2000; Garcia & Altieri 2005; Mannion & Morse 2013). Key issues in the environmental assessment of GM crops are putative invasiveness, vertical or horizontal gene flow, other ecological impacts, effects on biodiversity and the impact of presence of GM material in other products (see Hails 2000; Poppy 2000; Conner *et al*. 2003; Prasifka *et al*. 2007; Bøhn *et al*. 2008; Lang & Otto 2010; Cambers *et al*. 2010).

1.3 Impacts of GM crops on natural areas and other crops

Agricultural practices are generally documented to have negative impacts on the environment (see Moorehead & Woolmer 2001; Firbank *et al*. 2008, Power 2010). In relation to GM crops and land, Brookes & Barfoot (2010) found that more land would be converted into agricultural use were it not for various GM crops traits. James (2014) also supports this, indicating that GM crops contribute towards biodiversity conservation. He further alludes that biotechnology (biotech; equivalent to GM crops) crops are a land-saving technology, capable of higher productivity on arable land, and thereby can help preclude deforestation and protect biodiversity in forests and in other in-situ biodiversity sanctuaries. Furthermore, if the additional high output tonnage of food, feed and fibre produced by biotech crops during the period 1996 to 2013 had not been produced by biotech crops, an additional 132 million hectares of conventional crops would have been required to produce the same tonnage. In essence, James (2014) demonstrates that the use of GM crops for high yields is highly viable over small acreage.

At the same time, GM crops can also encourage increases in crop land-use, particularly where farmers decide to increase acreage planted with GM crops at the expenses of other farming activities or through expansion into natural areas (Carpenter 2011; Brookes *et al*. 2010.). In their report, Bindraban *et al*. (2009) used an increase in GM soybean production in Latin America to illustrate its impacts on natural areas. They concluded that GM soybean impacted negatively on natural areas as the increase in production areas led to the conversion of conservation (natural) and pasture areas into arable land for soybean production. This also had a ripple effect on livestock farmers in the area as they also expanded their practice to other natural areas to sustain their farming. Similar trends were also observed in Argentina, Paraguay and Brazil relating to soybean and maize, whereby the cultivation of GM soybean contributed directly and indirectly to the loss of natural areas. Not only do GM crops result in loss of natural areas, they can also replace other crops when used as season cash crops (see Bindraban *et al*. 2009). For example, in Argentina, increases in GM soybean production resulted in the loss of various pastures and areas used for maize cultivation as opposed to natural areas (Bindraban *et al*. 2009).

1.4 Documenting and monitoring GM crop land use patterns

The assessment of agricultural productivity levels and trends is important given that the amount and composition of agricultural output of a particular country or region of the world tends to change over time (Brady & Sohngen 2008). Moreover, spatial dynamics of agriculture can be complex where data is inadequate or non-existent. At times, influential factors relating to weather and climate, soils, and pest pressures might need to be considered when assessing decreases and increases in agricultural land use. Consequently, agricultural expansion, production and productivity can be influenced by other factors (natural), as opposed to just the desire to adopt a particular technology. However, recent trends outlining increases in global GM crop production areas (James 2012, 2013 and 2014) creates an assumption that the technology has brought about benefits that promotes expansion of agricultural areas. Although, conventional and organic farming does lead to an increase in production area (Dimitri & Greene 2002), increases resulting from the uptake of GM crops has been rather rapid. At the same time, GM crops are depicted to have high outputs (yields) at smaller planting scales (see section on GM crops and land use). Ausubel *et al.* (2013) also alludes to combinations of agricultural technologies which have raised yields, keeping downward pressure on the extent of cropland, and therefore sparing land for nature.

Perhaps a question to then ask would be “if the planting area of GM crops is increasing annually (in terms of acreage), is the increase at the expense of other agricultural crops or the clearing of natural areas and degraded areas?” Examples from Latin America, Argentina, Paraguay and Brazil indicate all three scenarios to be possible (Bindraban *et al*. 2009). But what are the implications for each of these scenarios? Concerns range from carbon loss and climate change, biodiversity loss to top soil loss, and many others (Brady & Sohngen 2008). Given the mismatches in benefits and negative impacts of GM crops regarding increases in land use area, it is highly imperative to document, monitor and report GM crops activities in relation to production area.

1.5 GM crops and land use in South Africa

South Africa approved its first GM crops for commercial release between 1997 and 2005 (Wolson 2007). Some of the initial traits/events approved included Insect-resistant cotton, Insect-resistant maize (yellow), Herbicide-tolerant cotton, Herbicide-tolerant soybeans, Herbicide-tolerant maize and Stacked-gene cotton (insect resistance and herbicide tolerance) (refer to DAFF 2005; Wolson & Gouse 2005). To date, South Africa has approved a total of 67 events. Argentine Canola - *Brassica napus* has four (4) events, Cotton - *Gossypium hirsutum* L. 10 events, Maize - *Zea mays* L.: 40 events, Rice - *Oryza sativa* L.: one (1) Event and Soybean - *Glycine max* L.: 12 events. However, both canola and rice were only approved for commodity clearance (i.e. processing for human consumption and animal feed) in 2001 and 2011 respectively, as opposed to cotton, maize and soybean permits ranging from field trials to commercial planting (http://www.daff.gov.za/daffweb3/Branches/Agricultural-Production-Health-Food-Safety/Genetic-Resources/Biosafety/Information/Permits-Issued).

There is a general perception that the area under GM crop cultivation in South Africa increases annually as a result of planting GM maize, cotton and soybean. The ISAAA 2010 confirms this by outlining GM crops plating area from 2001-2010 (Table 2). The total area of GM crops increased from 197 thousand hectares in 2001 to 2.2 million hectares in 2010. The report also makes special mention on total area increases in white GM maize production. It is shown that total area of GM maize increase from 166 thousand hectares in 2001 to 1.9 million hectares in 2010. This indicates that GM maize accounted for more than 85% of the total production area of GM crops in South Africa. The increase in total production area increased to 2.2 million hectares in 2011 (James 2011), increased to 2.9 million hectares in 2012 (James 2012) and remained unchanged in 2013 (James 2013), then decreased to 2.7 million hectares in 2014 (James 2014).

Table 2: Land-use area of GM crops in South Africa, 2001 to 2010. [adjusted]

Year	Total land-use of maize, soybean and cotton (million hectares)	Total land-use of GM maize (million hectares)	Total land-use of GM white maize (million hectares)	Percentage of GM white maize of total white maize area
2001	19.7	16.6	0.6	< 1%
2002	27.3	23.6	6.0	3%
2003	40.4	34.1	14.4	8%
2004	57.3	41.0	14.7	8%
2005	61.0	45.6	28.1	29%
2006	1412	1232	704	44%
2007	1800	1607	1040	62%
2008	1813	1617	891	56%
2009	2116	1878	121	79%
2010	2229	1898	1139	75%
Total	11427	9841	5624	

Source: Compiled by ISAAA, 2010

These increases in GM crop production area, with the exception of a decrease in 2014, might be a good indication in terms of the technology adoption and its positive attributes. At the same time, it poses a dilemma of determining if the increases take place at the expense of natural areas or other crops (cultivated land). Schoeman *et al*. (2013) conducted a study to determine the extent of transformed landscape change within South Africa over a 10-year period between 1994 and 2005. Using five classes of land cover change (Urban, Mining, Forestry, Cultivation and Other) they concluded that at a national level there has been a total increase of 1.2 % in transformed land specifically associated with Urban, Cultivation, Plantation Forestry and Mining. On a finer national scale, cultivated land had decreased from 12.4% to 11.9%. When considering these findings, it is difficult to ascertain where the increases in GM crop area outlined in Table 2 took place. The logical explanation here could be that GM crops expanded at the expense of other commercial crops, but this is difficult to prove without any data. It is for this reason that Schoeman *et al*. (2013) recommend that any research on change in land cover should include investigation into the transformed cover classes with the objective of identifying the drivers and type of change that has occurred, as well as the social, environmental and economic impacts of these changes over time.

2. REPORT OBJECTIVE AND RATIONALE

2.1 Objective

Based on various aforementioned reports, the GM crop production area is increasing in South Africa, but there is considerable uncertainty regarding the impact that this has on land use or land cover change. Possible scenarios of the increases are that farmers are either expanding into natural vegetation or opting not to plant other crops that they used to plant before. The objective of this report was to conduct an analysis to: 1) predict and forecast underlying trends in land-use and productivity; and 2) to evaluate if the introduction of GM maize and soybean seeds to South Africa in 1998 and 2001, respectively, had a significant effect on the land-use and production trends. For this preliminary report, GM cotton data was discarded due to data availability for analysis representing only post GM seed introduction years for the period 2004-2015. This precluded a comparison of pre and post GM introduction trends for both land use and productivity. The report also gives a brief account of land cover change between 1990 and 2014.

2.2 Rationale

Analysis findings will enable an understanding in GM land-use and production trends for cotton, soybean and maize to improve predictions of future trends and related impacts on land-use and land cover. Improved reporting and monitoring can be initiated as part of environmental management and conservation strategies where applicable.

3. DATA SOURCING AND ANALYTICAL METHODS

3.1 Data sources for GM maize and soybean

Annual South African census data on land-use in hectares (ha) and productivity in tons per hectare (tons/ha) of maize and soybean were sourced for the period 1987 to 2016 – this data is collected annually for these and other crops. Data was provided by the Crop Estimates Committee (CEC), a Branch of the Department of Agriculture, Forestry and Fisheries (DAFF). These annual figures were separately reported per provinces, but data were incomplete for the Western- and Eastern Cape, with some years missing figures. The current year (i.e. 2016) was excluded from the analysis because of likely underestimates of total land-use due to incomplete cycles. Similarly, the soybean data for 1987 were largely missing or appeared to be lacking as a result of underreporting and were therefore omitted. Initial analysis trials showed, however, that this had little effect on the overall trends.

3.2 Data sources for land cover change

The land cover analysis made use of the South African National land Cover datasets (Department of Environmental Affairs, 2014) for 2009 and 2013/2014. These datasets were produced by GEOTERRAIMAGE and an open license has been purchased by the Department of Environmental Affairs (DEA) in this regard. The datasets have been generated from digital, multi-seasonal Landsat 8 multispectral imagery, acquired between April 2013 and March 2014 and 1990 and 1991.

For comparison of vector based agricultural fields, the Agricultural Field boundary data captured by SIQ (Spatial IQ, 2014) was obtained from DAFF. A previous version of the data offered a second point in time. Please note that the date of data capture for the datasets varies (refer to Appendix 1). The data encompasses all the field crop boundaries in the provinces of South Africa. Field crop boundaries are defined as the result of different cropping patterns within one field boundary, planting different crops or the same crop at different planting dates. This separation is not always fixed, and could vary from year to year. The dataset was developed to serve as the sampling frame dataset for the Producer Independent Crop Estimation System (PICES) for the provinces. PICES is a system developed by the National Crop Statistics Consortium (NCSC) which utilises in-season satellite imagery combined with a point frame statistical methodology to objectively determine the area under grain crops in a province.

3.3 Analysis for GM maize and soybean

A Bayesian State Space model (BSPM) framework (Meyer and Millar 1999) was implemented for the trend analysis of land-use (area occupied) and productivity (production per hectare) for soybean and maize. The BSPM represents a powerful tool for time series analysis (de Valpine 2002), which allows accounting for both process error (environmental year to year variation) and potential reporting error (Thorson *et al.* 2014). The BSPM was fitted to the reported land-use (ha) and production (tons/ha) data per province. The change in the trend determined by the response variable Y (i.e. land-use or productivity) follows a Markovian process, which means that, for example, Y_{t+1} in the following year $t + 1$ will depend on the Y_t in the current year t (Kery & Michael Schaub 2012). Responses for each variable (i.e. Y for crop type), crop type, land use (metric) and province are explained further in Appendix 2. Bayesian credibility intervals for the model used are also accounted for.

3.4 Analysis of land cover change

Three methods were used to analyse spatial change in agriculture. The first was to review the report made by GEOTERRAIMAGE on all categories of land cover change between 1990 and 2013 in South Africa (Department of Environmental Affairs, 2014), see Appendix 1 to view the pertinent table listed in the report. The second was to analyse the spatial data underlying this report with the aim to focus on the change of land cover to agricultural land use in 2013/2014 only. The third method made use of vector data showing the agricultural field boundaries and compared boundaries captured in 2007 to those captured in 2011.

The comparison of the two land cover data sets was problematic in that they are each big in size (approximately 4 Gigabyte), therefore compromising the computational analysis power. The methodology had to prioritise the reduction of the data file size in order to process the final result. The symmetric difference tool (Diff function) in ArcGIS Spatial Analyst was used to compute the difference between the two land covers. This function created a data layer showing the land cover values for 1990 that were different from the values in 2014. The 2014 land cover was then reclassified to show only those classes pertaining to agriculture. The resultant layer was used to extract the changed area between 1990 and 2014. This resulted in a layer which showed the land cover in 1990 that changed to agriculture in 2014; see Figure 2 below for a visual representation of this process. A table was created by multiplying the number of raster cells in a land cover category by the cell size ($30m^2$). This was done for the changed area, as well as the area in 1990 and 2014. The changed area in the table only shows how much of the land cover have changed to agriculture;

changes between other land cover categories between 1990 and 2014 are not shown. These land cover datasets were generated using remote sensing and vector data and which has an approximate accuracy of 85%. With this accuracy in mind, it is worth noting that the least accurate categories are Natural vegetation categories, Bare ground and Built up areas (Department of Environmental Affairs 2014). Thus the resulting areas of change to agriculture should only be seen as an approximation.

For comparison of vector based agricultural fields, a symmetrical difference function was used to overlay the two datasets (metadata for 2007 – 2010 and metadata for the data for 2011) with the results showing areas where the two datasets were did not coincide. Also see Appendix 3 for additional comparison figures of agricultural areas between 1990 and 2013/2014. The following columns were created in the dataset:

- OArea: Original polygon area (original area of the crop)
- NArea: New area (calculated area of the polygon showing the difference between the layers)
- Type: Agriculture type (contains any descriptive information form either layer about what agriculture is happening in the polygon)
- Captured: Year that the polygon was captured

Refer to notes in Appendix 4 for further information on the identification of new fields, and data errors which were likely to be the result of spatial data capture corrections.

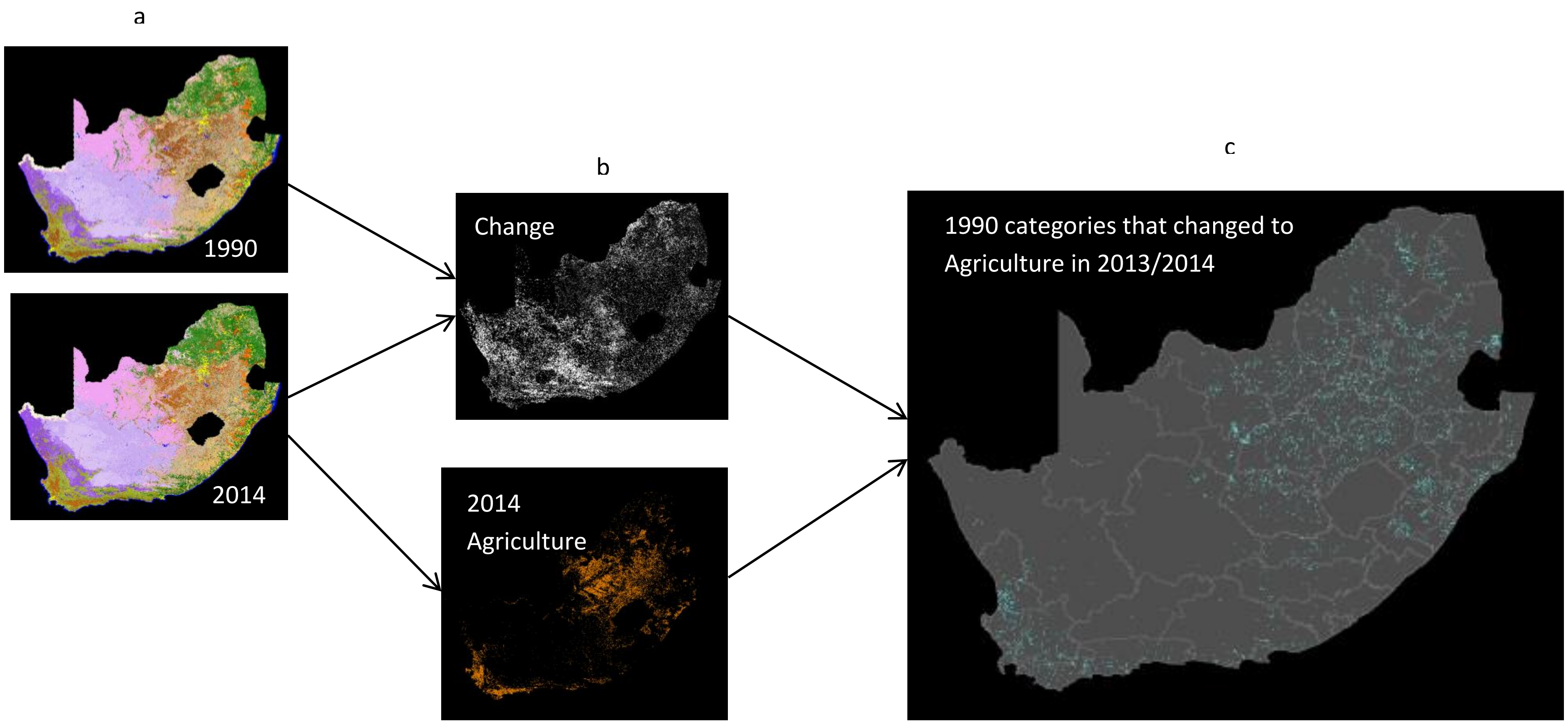

Figure 2: Analysis of land cover change indicating the changed area between 1990 and 2014. This resulted in a layer which showed the land cover in 1990 (2a) that changed to agriculture in 2014 (2c). The visual process for the change can be observed in 2b.

4. RESULTS

4.1 GM maize and soybean

Patterns in land-use (ha) and productivity (ha/tons) showed substantially different patterns for soybean and maize (Figures 3 and 4). The top two provinces in terms of land-use for soybean were the Free State and Mpumalanga (Figures 3a). For maize, Free State, North West and Mpumalanga had the highest land use (Figure 4a). However, both North West and Mpumalanga show a decrease in maize area in the early 2000s' onwards (Figure 4a). The Western and Northern Cape provinces had the lowest land-use for both crops in general.

On a national scale, land-use for soybean showed a substantial increase at a rate of 13% per annum. At this rate, it was predicted that there is 50% probability that total land-use for soybean will exceed 2 million hectares by 2021 (Figure 3b). The national land-use trend for maize showed a consistent decline until 2007, but appeared to have stabilized thereafter. Projections at current rates suggest a minimal decline by less than 1% per annum and therefore fairly constant land-use until 2021 (Figure 4b). The national average in productivity (i.e. production in tons per hectare) has increased since 1988. Soybean productivity was lowest between 1992 and 1995, but recovered quickly in 1996 to the 1990 levels, and increased consistently since then at a fairly low average rate of increase of 0.5% per annum (Figure 3c). Maize productivity, by contrast, showed a steeper and almost linear trend of increase with an estimated annual rate of growth in productivity by 3.7% (Figure 4c).

The introduction of GM soybean in 2001 resulted in significant increases in land-use trends for a number of provinces (Figure 3d). Among the three provinces with the highest land-use for soybean, only the Free State showed significant increase after the GM introduction by close to 23%, whereas Mpumalanga and Kwazulu-Natal revealed no acceleration of the land-use trend (Figure 3d). Notably, the provinces with very low overall land-use showed the highest increase after the GM introduction. In contrast, to observed change in the rate of increase in land-use, none of the provinces, but Mpumalanga (+5%), showed a significant increase in productivity compared to the long-term trend (Figure 3e). The introduction of GM maize in 1998 resulted in significant increases in the land-use trends for Western-Cape, Eastern Cape, and Gauteng (Figure 4d). Therefore, the provinces, which are among the least important for national maize production, indicated an increase in land-use following the GM introduction, whereas the main producing provinces showed no divergence from the fairly stable long-term trend in land-use for maize. Similar to soybean productivity, no significant increase in maize productivity per hectare land was detected.

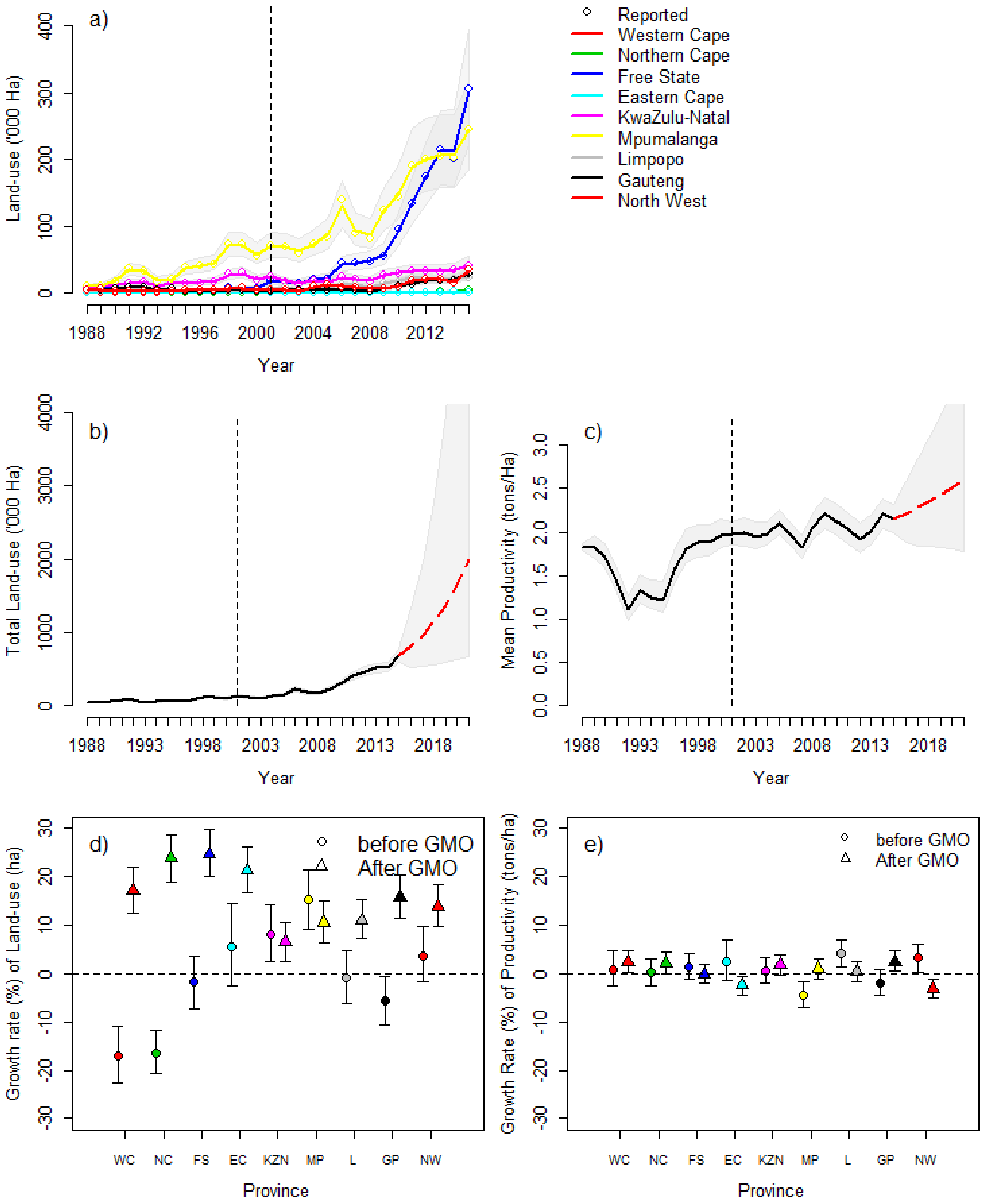

Figure 3: Results from soybean land-use and productivity analyses, illustrating a) reported and model predicted land-use (ha) by province (1988-2015), trends in b) National total land-use and c) mean productivity, projected until 2021; and growth rates for d) land-use and e) productivity before and after the GMO introduction. Vertical dashed lines indicate the year of GMO introduction and gray-shaded area and error denote 95% Confidence Intervals (CIs). Non-overlapping error bars indicate significant differences.

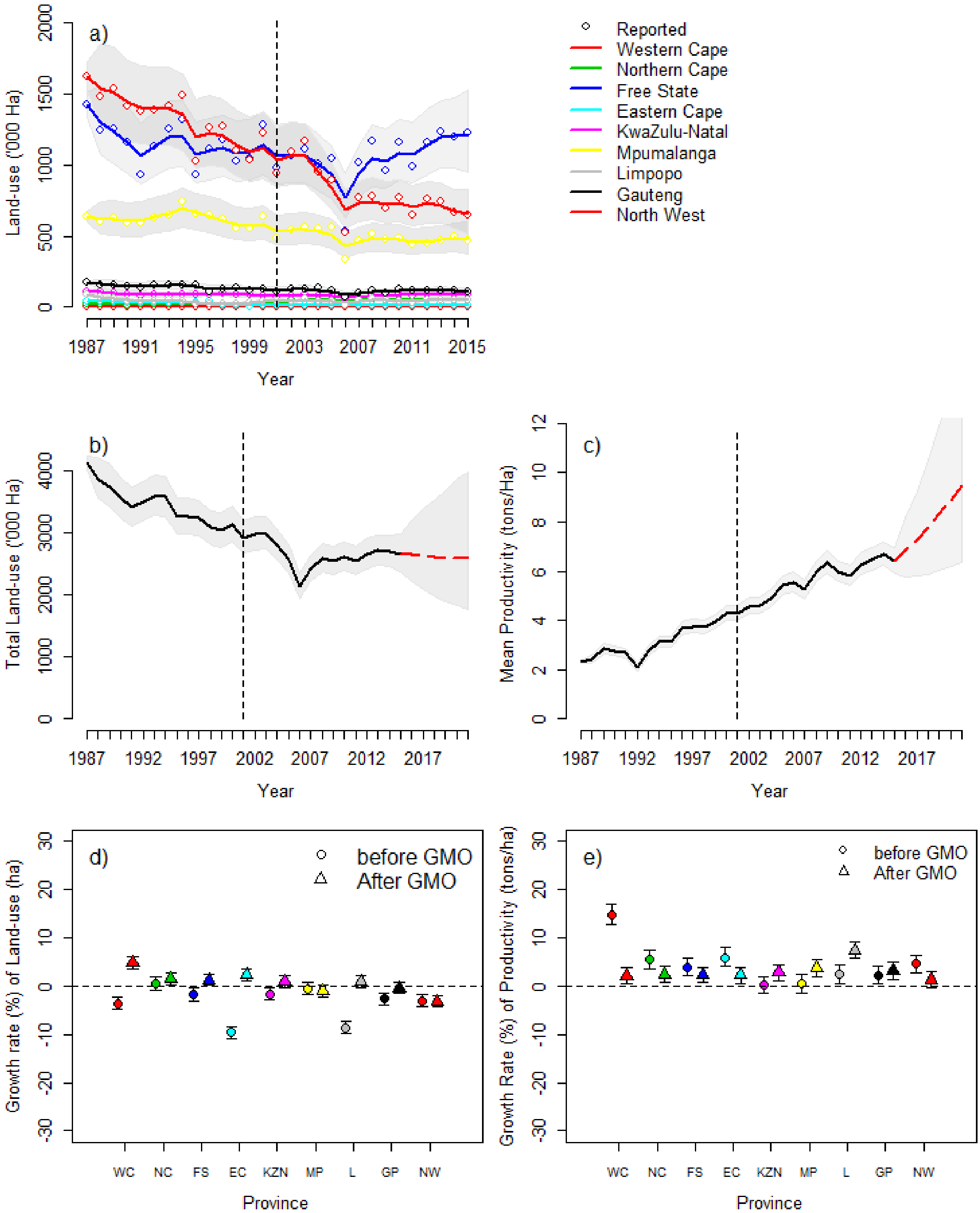

Figure 4: Results from maize land-use and productivity analyses, illustrating a) reported and model predicted land-use (ha) by province (1988-2015), trends in b) National total land-use and c) mean productivity, projected until 2021; and growth rates for d) land-use and e) productivity before and after the GMO introduction. Vertical dashed lines indicate the year of GMO introduction and gray-shaded area and error denote 95% CIs. Non-overlapping error bars indicate significant differences.

4.2 Land cover change

The comparison of the 1990 to the 2014 land-cover at national level using the 30m^2 raster format data indicated land cover change across various classes except for the *Nama* and *Succulent Karoo (Forests),* which were not represented in either land cover dataset (Table 3, value 20 and 26). Because this report focuses on the change in agricultural land cover (specifically GMO related), GM crops appear (and thus likely to be spectrally) similar to *Vineyards* and *Orchards.* However, GM crops are annual crops and that result in their spectral signature varying during the year, rendering the use of land cover categories 6, 7 and 10 only in the analysis. Please note that these categories are not exclusive to maize, soybean and cotton, neither do they explicitly represent GM based cultivars/events.

The following trends were noted when examining the area of land cover change between 1990 and 2013/2014. In Table 3 below, most of the agricultural categories have increased in size between 1990 and 2013/2014, with the notable exception of *Cultivated commercial annual crops non-pivot*, which has decreased by approximately 8%. This is likely due to this class being spectrally similar to natural vegetation, such as *Grasslands*. *Cultivated commercial annual crop pivot* has increased dramatically. Pivot circles are easily identified in remote sensing due to their clear boundary with the surrounding non-irrigated vegetation; this makes it a better indicator of change in annual crop land cover. The remaining vegetation has increased marginally; this could be actual change or could be attributed to subtle changes in the spectral signature of the area on its borders.

Table 3: Area of agricultural land cover

Agricultural land cover category	Area in 1990	Area in 2013/2014	Difference in Area between 1990 and 2013/2014
Cultivated commercial annual crops non-pivot	11 486 583	10 610 838	-875 746
Cultivated commercial annual crop pivot	244 269	782 049	537 781
Cultivated commercial permanent orchards	313 572	346 950	33 379
Cultivated commercial permanent vines	162 354	188 711	26 357
Cultivated subsistence crops	1 984 303	2 040 527	56 224

In Table 4, only six land cover categories had experienced more than 3% change in area from a category in 1990 to an agricultural category in 2013/2014. All the agricultural categories show above average percentage change from their category in 1990 to an agricultural category in 2013/2014. This suggests that between 1990 and 2013/2014 different crops have been planted, foliage on crops has increased, thus altering the spectral signature of the crop, or irrigation has been installed in the field. *Wetlands* have shown a high percentage of conversion to agriculture, these areas do have richer soil and are more abundant in water and so are likely to be cultivated. However wetter seasonal conditions in 1990 resulted in *Wetlands* being more easily identified in 1990 than the 2013/2014 imagery. *Wetlands* may have been misclassified in 2013/2014 since they were drier than in the 1990 imagery. Lastly, *Fynbos* and *grassland* areas have shown a high percentage of conversion to agriculture, these areas are likely to be cultivated. However it has been noted that the G*rassland* was problematic to model in the land cover dataset (Department of Environmental Affairs 2014).

The figures shown in the GEOTERRAIMAGE land cover change report (Department of Environmental Affairs 2014) support the findings in the previous paragraph. With *Cultivated commercial annual: non-pivot* being classified as one of the other agricultural categories in 1990 or as *Wetlands* or *Grasslands*. A notable change identified in 2013/2014 is *Cultivated subsidence crops* being identified as degraded areas in 1990. It is possible that this is an indication of a 4% increase in subsistence agriculture.

Table 4: National level land cover change to agriculture in 2013/2014

Land cover category in 1990	Area in 1990	Area changed to Agriculture	% Change to Agriculture in 2013/2014
Indigenous Forest	346291	1324	0.38%
Thicket /Dense bush	5916089	122513	2.07%
Woodland/Open bush	9788274	132987	1.36%
Low shrub land	18278554	136006	0.74%
Plantations / Woodlots	1922819	33400	1.74%
Cultivated commercial annual crops non-pivot	11486583	429743	3.74%
Cultivated commercial annual crop pivot	244269	29319	12.00%
Cultivated commercial permanent orchards	313572	31827	10.15%
Cultivated commercial permanent vines	162354	6912	4.26%
Cultivated subsistence crops	1984303	49955	2.52%
Settlements	2742920	19011	0.69%
Wetlands	1526138	58534	3.84%
Grasslands	25317439	678951	2.68%
Fynbos: forest	30360	213	0.70%
Fynbos: thicket	283922	8141	2.87%
Fynbos: open bush	211541	3951	1.87%
Fynbos: low shrub	5919755	142767	2.41%
Fynbos: grassland	534043	21746	4.07%
Fynbos: bare ground	149179	569	0.38%
Nama Karoo: forest	0	0	
Nama Karoo: thicket	170367	4656	2.73%
Nama Karoo: open bush	520970	4076	0.78%
Nama Karoo: low shrub	12893194	36805	0.29%
Nama Karoo: grassland	1222157	12942	1.06%
Nama Karoo: bare ground	10561152	5070	0.05%
Succulent Karoo: forest	0	0	
Succulent Karoo: thicket	275606	3174	1.15%
Succulent Karoo: open bush	487004	3074	0.63%
Succulent Karoo: low shrub	4048359	5964	0.15%
Succulent Karoo: grassland	417329	3044	0.73%
Succulent Karoo: bare ground	1702221	514	0.03%
Mines	291757	1231	0.42%
Waterbodies	2202041	4369	0.20%
Bare Ground	1489898	1585	0.11%
Degraded	1489360	23710	1.59%

5. DISCUSSION

5.1 GM maize and soybean land-use area and productivity

Genetically modified crops have been adopted rapidly and cultivated commercially in a numbers of countries over the past 23 years (Aldemita *et al*. 2015). The results presented in Figures 3 and 4 illustrate the trends in local land-use for both soybean and maize, respectively. Soybean had a considerably smaller production area pre GM introduction. The opposite was true for maize. Soybean production increased substantially over the years and predictions indicated even higher increases in the future. In contrast, maize tends to go through gradual declines and increases over certain periods. Similar trends are observed in other countries for both crops (see Figure 1). Locally, maize and soybean are typically grown in the same season as their climatic requirements are similar. However, soybeans flower over a long period, which makes them less susceptible to drought during this stage than maize (Pannar 2006). This may be a possible explanation in the fluctuation decreases in land use for maize cultivation in certain years (i.e. 1998-2007) versus soybean. These years were possibly drought prone seasons. Worth noting is the steady increase in maize production post 2007, likely due to improving rain conditions and transgenic seeds. It is also not surprising that land under soybean production increased substantially post 1997, after the enacting of the Genetically Modified Organisms Act (Act no. 15 of 1997) and its subsequent amendments Genetically Modified Organisms Act Amendment (Act no. 23 of 2006). Dlamini *et al*. (2015), report that between 1997/8 and 2012, land set aside for soybeans increased from 93 790 ha to 472 000 ha due to an increase in the supply of quality transgenic seed. Our analysis here indicates that soybean production area has a 50% chance of reaching 2 million hectares by 2021. This means the production area would have increased three folds since 2012. For maize, however, a fairly constant land use is forecast.

Because this analysis took into account fluctuations in environmental conditions (e.g. caused by yearly rainfall variations), a possible scenario is that if dryer conditions persist, inhibiting growth in maize production area, soybean is likely to replace maize in most areas (provinces) across the country, unless additional areas would be cleared to accommodate the predicted expansion based on the current trend. Maize and soybean economic and nutrition importance differs significantly within the African continent, but the demand for soybean is well established in South Africa and throughout the Southern Africa Development Community (SADC) (Opperman & Varia 2011). Given the current drought conditions, most farmers are likely to opt to producing soybean compared to maize. This would imply that areas previously under maize production might be under soybean production, which would also reduce the need of clearing new areas for land-use. However, if planting both crops were likely to lead to higher profit margins, demands for further increases in production area would be pertinent.

Soybeans are produced nearly in all the provinces in South Africa, but at varying magnitudes and this explains the increase in planting area over time (Dlamini *et al*. 2015). Blignaut & Taute (2010) outlined rainfall areas suitable for soybean production in South Africa. They indicate Mpumalanga, KwaZulu-Natal, some parts of Gauteng, Eastern Cape and the Free State to be suitable for soybean production. Our analysis here concurs with that of Blignaut & Taute's, as Free State, KwaZulu-Natal and Mpumalanga were the top three provinces in terms of land-use for both maize and soybean (see Figure 3). This also tells us that maize and soybean compete for production area, and are thus likely to outweigh one another in terms of production area depending on annual rainfall patterns. It is also important to note that the approval for general release of drought tolerant GM maize events such as MON87460 could counter such competition, although it is still early to make any assumptions or conclusions.

Soybean and maize share comparable environmental requirements, making them compatible, but also competitive, substitutes for one another. James (2014) points out a trend of consistently increasing interest in adoption of GM crops from farmers in several countries. For South Africa, this trend was indicative at provincial levels. Provinces that had little contribution on maize production nationally, showed increased production area post GM maize introduction. This can be attributed to interest relating to the technology potential.

Some of the reviewed literature in this report supports GM crops increasing productivity at both high and small scale planting areas. Although our analysis showed an overall increase in productivity for both maize and soybean since 1998 (Figures 3c & 4c), there was evidence that this trend had significantly accelerated post GM introduction. The results therefore indicate that the increase in land-use was faster than the increase in productivity. The productivity of Soybean, for example, was at a fairly consistent rate (see Figure 3c), whereas land-use area showed significant acceleration post GM introduction (Figure 3b). In contrast, maize projections indicate overall higher productivity increases (Figure 4c), whereas overall land-use trends are marginally declining (Figure 3b). As observed with increases in land-use area for provinces, maize productivity increased in provinces such as Mpumalanga, Limpopo and KwaZulu-Natal (Figure 4e). Soybean showed no obvious increases in productivity provincially post GM introductions (Figure 3e), even though the land-use area was shown to increase post-GM introduction. The results here suggest that increases in land-use area do not always result in increase in productivity.

Overall assumptions in GM crops having smaller land-use areas for high yields might be evident in some parts of the world (see Taheripour *et al*. 2016). The results presented provided clear evidence to support these trends. However, there are several scenarios that could have obscured a potential increase in productivity of GM crop: 1) non-GM crops reaching a threshold in productivity increase, therefore levelling, while GM introduction facilitates to maintain a consistent rate of increase; 2) inefficient use of GM crops– for example, the inability to detect damage from pests thus resulting in high percentage of crop loss; 3) erratic climate conditions (i.e. drought); 4) farmers' own interest in a certain crop or GM event not similar to the one currently produced and 5) market demand related trends**.**

5.2 Land cover change

Land cover change results from 1990 to 2014 (Table 3) indicate Area/Ha gain for cultivated commercial annual no-pivot and cultivated subsistence crop, but not cultivated commercial annual pivot. It is however uncertain or inconclusive if these changes (increase and decrease) are brought about by the expansion or reduction of the crops explored in this report, due to the various cultivated areas encompasses other crop types (i.e. sunflowers). Imperative of Tables 5 (refer to Appendix 1) is the reduction in respective areas (i.e. grasslands and, thicket) at the expense of various cultivated areas. Grasslands are the most affected in this regard both at national and land cover inter-class changes.

We do know that the area under GM crop cultivation in South Africa has been increasing until 2013 (see James 2014) and our analysis in this report indicates future increases – particularly for soybean. However, what we do not know is what impact this has on outlined changes in land cover and subsequently land use. Unless we have accurate statistics on GM crop acreage and planting boundaries, it will continue to be difficult to account for GM crops land use. Also, the justification of high yields over small scale plantings will be impossible, so is supporting the assumption that farming with GM crops prevents the loss of natural areas (see Taheripourin *et al*. 2016).

6. CHALLENGES ENCOUNTERED IN COMPILING THE REPORT

- Data sourcing for GM crops relating to production areas proved challenging, and does not form part of this preliminary report. Hence the analysis took into account land use pre and post GM crops introduction.
- Gaps in data availability meant that limited statistical methods could be explored for the analysis.
- Lack of Land Satellite monitoring data, required to monitor the impact of conversion of natural vegetation to cultivation, meant that we had to rely on other published material.
- National mapping of land cover is under taken via remote sensing; this is currently the only viable way to map South African land cover. However the accuracy of this data could be increased through field verification.
- Lack of reporting data from farmers indicating reasons for increase or decrease in the planting of various GM crops leads one to assume that increases are based on scenarios of land area expansion or replacement of other crop types. Inputs versus outputs costs for the various crops could also not be considered in this report to determine their increase or decrease in production area.
- Aggregated reporting for GM and non-GM crops on provincial level precluded direct comparison of productivity.

7. RECOMMENDATIONS FOR MONITORING WORK

The following recommendations are outlined to enable an effective, efficient and accurate reporting system for land use patterns regarding GM crops. These will help in collecting long-term data to be used as part of the post-market monitoring work:

- Annual data for land use changes for GM crops versus conventional (non-GM) crops needs to incorporate reasons for decrease or increase in planting area for that particular year (e.g. drought, input costs, market demand etc.).
- Collected data should state whether the increase in GM crop production area occupies: 1) new area (resulting in the clearing of not previously cropped land – disturbed or undisturbed), 2) replaces a non-GM crop or 3) replaces a GM Crop.
- Provincial trends in land use (increase vs decreases) needs to be explored further, taking into account the interesting trends for this report. This would require field verification or additional data compiled from available agricultural reports. Provincial boundaries for various GM crops also need to be accounted for.

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Appendix 1: Table 5 used for reporting land cover change for inter-classes and national level.

Table (5) below describes the actual 1990 - 2013/14 inter-class land-cover changes for the whole of South Africa, expressed in terms of the percentage of the original 1990 class extent and what it has become in 2013/14. For example, 81.84 % of what was mapped as indigenous forest in 1990 is still indigenous forest in 2013/14, and 11.85% of what was indigenous forest in 1990 is now mapped as thicket / dense bush in 2013/14:

				2013																	
		Quantitative units: ***Percentage of original 1990 extent in 2013 (only read table across rows)***		Indigenous Forest	Thicket/dense bush	Woodland/open bush	Low shrubland	Plantations/woodlots	Cultivated commercial annual: non-pivot	Cultivated commercial annual: pivot	Cultivated commercial permanent orchards	Cultivated commercial permanent vines	Cultivated subsistence crops	Settlements	Wetlands	Grasslands	Mines	Waterbodies	Bare ground	Degraded	TOTAL Change (%)
	ORIGINAL VALUE		RECODE VALUE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1990	1	Indigenous Forest	1	81.84	11.85	2.08	0.38	0.24	0.22	0.00	0.18	0.00	0.26	0.54	0.37	1.79	0.07	0.01	0.15	0.01	100
	2	Thicket/dense bush	18	0.73	56.19	19.47	5.77	0.17	1.53	0.14	0.35	0.06	0.77	0.71	0.62	12.70	0.13	0.16	0.33	0.15	100
	3	Woodland/open bush	35	0.09	13.86	50.59	11.89	0.33	0.88	0.31	0.11	0.02	0.65	0.74	0.21	16.76	0.14	0.11	1.47	1.86	100
	4	Low shrubland	52	0.01	1.47	3.48	77.42	0.03	0.56	0.16	0.03	0.03	0.02	0.14	0.09	10.09	0.02	0.03	6.15	0.26	100
	5	Plantations/woodlots	69	1.39	7.07	2.40	1.27	76.78	1.34	0.03	0.33	0.04	0.12	1.43	0.80	6.65	0.19	0.07	0.05	0.03	100
	6	Cultivated commercial annual: non-pivot	86	0.01	0.81	1.94	3.48	0.26	81.31	3.39	0.28	0.08	0.15	0.24	0.31	7.05	0.33	0.02	0.09	0.27	100
	7	Cultivated commercial annual: pivot	103	0.00	1.16	2.36	1.17	0.05	10.19	79.77	1.43	0.38	0.14	0.39	0.19	2.18	0.27	0.02	0.07	0.23	100
	8	Cultivated commercial permanent orchards	120	0.05	4.71	2.72	1.91	0.51	5.76	1.17	74.68	3.22	1.29	0.34	0.30	3.13	0.02	0.04	0.06	0.09	100
	9	Cultivated commercial permanent vines	137	0.00	3.12	0.34	3.27	0.12	1.79	0.36	2.11	87.02	0.00	0.34	0.42	0.89	0.00	0.10	0.11	0.01	100
	10	Cultivated subsistence crops	154	0.01	4.20	9.10	0.68	0.10	2.27	0.09	0.14	0.01	77.63	0.44	0.07	3.93	0.07	0.05	0.29	0.91	100
	11	Settlements	171	0.04	2.60	1.22	0.69	0.51	0.65	0.00	0.03	0.01	1.14	89.04	0.14	3.63	0.05	0.02	0.12	0.11	100
	12	Wetlands	188	0.24	10.20	5.28	8.72	0.58	3.13	0.40	0.15	0.15	1.02	0.24	41.54	26.69	0.13	0.77	0.66	0.10	100
	13	Grasslands	205	0.09	6.12	11.16	14.14	1.00	2.31	0.25	0.04	0.01	0.84	0.70	0.59	60.36	0.19	0.08	0.80	1.33	100
	14	Mines	222	0.00	2.55	6.45	3.02	0.29	0.38	0.04	0.00	0.00	0.14	0.43	0.63	17.20	67.36	0.07	0.89	0.54	100
	15	Waterbodies	239	0.01	1.22	0.69	1.27	0.04	0.17	0.01	0.01	0.01	0.04	0.05	2.49	1.60	0.01	88.18	4.18	0.02	100
	16	Bare ground	256	0.00	0.59	1.53	25.43	0.01	0.02	0.01	0.00	0.02	0.00	0.03	0.06	1.39	0.01	0.20	70.68	0.02	100
	17	Degraded	273	0.00	1.55	16.12	14.72	0.20	1.09	0.44	0.06	0.00	4.33	0.58	0.36	35.78	0.04	0.03	11.51	13.19	100

Appendix 2: Outline of variables and parameters for the Bayesian State Space model (BSPM) framework for GM maize and soybean data analysis.

For each response variable $Y_{i,j,t}$ of crop type *i* (soy or maize) and metric *j* (land-use or production) and province *k* in year *t*, an exponential growth model was assumed, such that:

$$Y_{i,j,k,t+1} = Y_{i,j,k,t}\lambda_{i,j,k,t}$$

Where $\lambda_{i,j,t}$ is the growth rate in year *t*. Growth rate $\lambda_{i,j,t}$ was allowed to vary to accommodate fluctuations in environmental conditions (droughts, rain etc.). State-space models are hierarchical models that explicitly decompose an observed time-series of the observed responses into a process variation and an observation error component (Simmons *et al.* 2015). On the log scale, the process equation becomes (e.g. Simmons *et al.* 2015)

$$\mu_{i,j,k,t+1} = \mu_{i,j,k,t} + \beta_{i,j,k,t} \qquad \beta_{i,j,t} \sim N(0,\sigma^2_{i,j})$$

where $\mu_{i,j,k,t+1} = \log(Y_{i,j,k,t})$ and $\beta_{i,j,k,t} = \log(\lambda_{i,j,k,t})$, with variations in log-growth rates realized as a random normal walk given the estimable process error variance $\sigma^2_{i,j}$. The observation process equation was then

$$\log(y_{i,j,t}) = \mu_{i,j,t} + \varepsilon_{i,j,t} \qquad \varepsilon_{i,j} \sim N(0,\tau^2_{i,j})$$

where $y_{i,j,t}$ denotes the reported values for crop type *i* for response metric *j* in province *k* and year *t*, and $\tau^2_{i,j}$ is the observation variance. For computational reasons, $\tau^2_{i,j}$ was fixed to 0.1^2, which means that a CV ~ 10% was admitted to account for inaccurate reporting in the census data.

Total annual land-use (ha), summed for the whole of South Africa, was then modelled as a function of:

$$TLU_{i,t} = \sum_k \hat{Y}_{i,j,k,t}$$

where $\bar{Y}_{i,j,k,t}$ is the expected land-use (ha) for crop type *i* in province *k* and year *t*. BSPM fits were then used to forecast the trend in land-use (ha) over the next five years until 2021.

Next, a second-stage log-linear mixed-effect model was implemented to test for potential changes in land-use and production as result of the introduction of GMO seed into South Africa. As input for this model, the expected values for $\hat{Y}_{i,j,k,t}$ and the associated standard errors $\hat{s}^2_{i,j,k,t}$ were extracted from the BSPM fits. The mixed-effect model accounts for error-variables by incorporating the estimation variance arising from the use of BSPM estimates of land-use and production. The log-linear mixed-effect model was formulated to estimate the relative change in the log-linear after the introduction of GMO seeds:

$$\mu_{i,j,k,t} = \gamma_{i,j,k} + \omega_{i,j,k} t + \varepsilon_{i,j,k,t} \qquad \text{if } t < \text{year of GMO introduction}$$

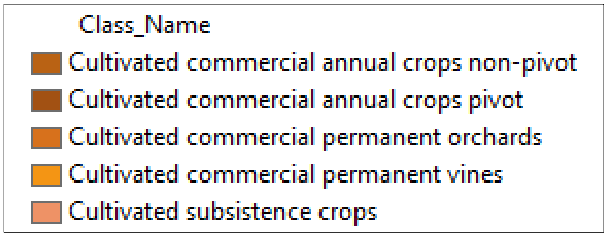
$$\mu_{i,j,k,t} = \varsigma_{i,j,k} + \varphi_{i,j,k} t + \varepsilon_{i,j,k,t} \qquad \text{if } t \geq \text{GMO year}$$

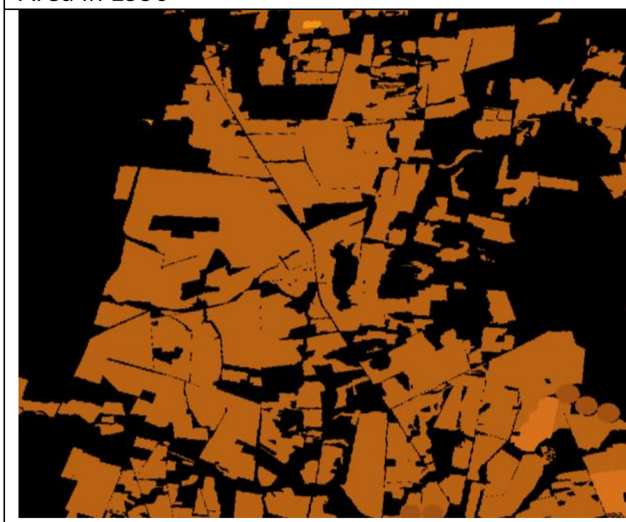
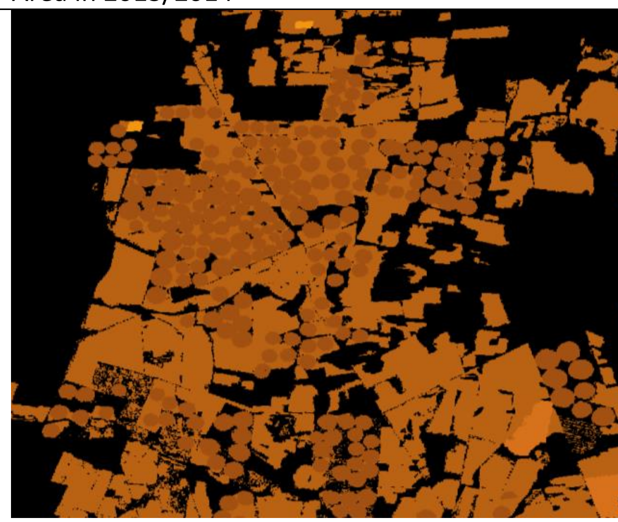
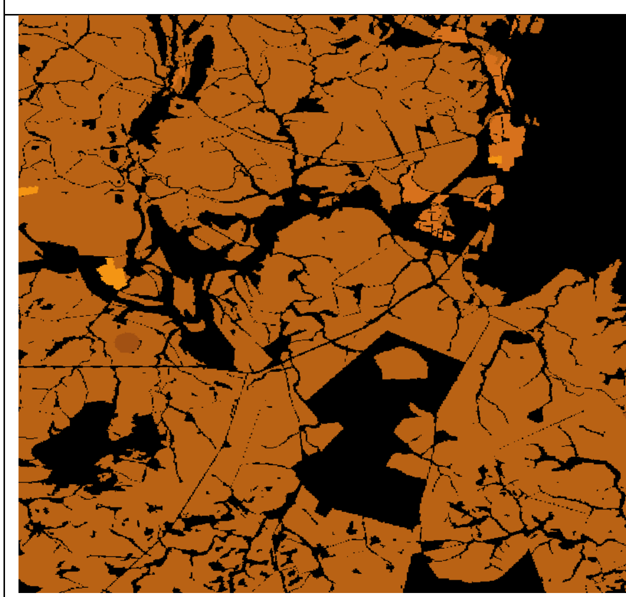
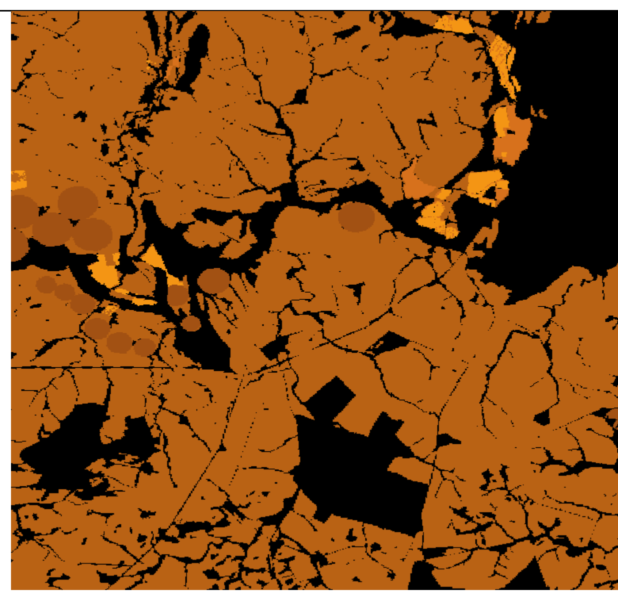
where $\mu_{i,j,k,t}$ = log($\hat{Y}_{i,j,k,t}$), $\gamma_{i,j,k}$ and $\varsigma_{i,j,k}$ are the intercept s for each period (before and after GMO), $\omega_{i,j,k}$ and $\varphi_{i,j,k} t$ are the period-specific slopes of interest (growth rates) and $\varepsilon_{i,j,k,t}$ denote the error terms expressed as the sum of individual variance estimates $\hat{s}^2_{i,j,k,t}$ and an additional estimable variance term, such that $\varepsilon_{i,j,k,t} = N(0, \sigma^2_{i,j} + \hat{s}_{i,j,k,t})$.

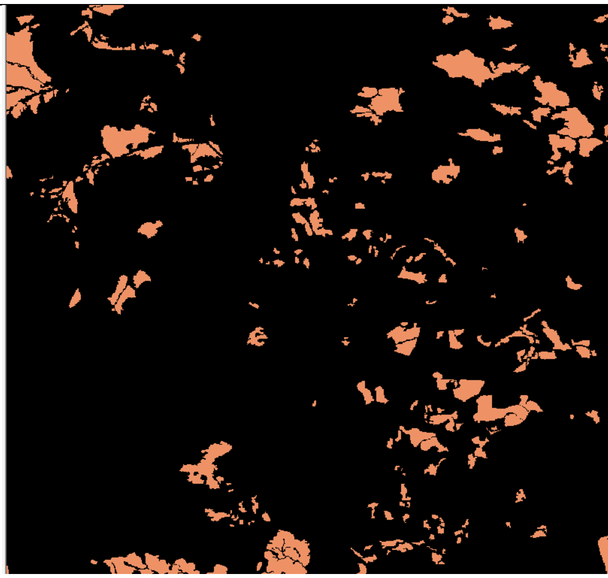
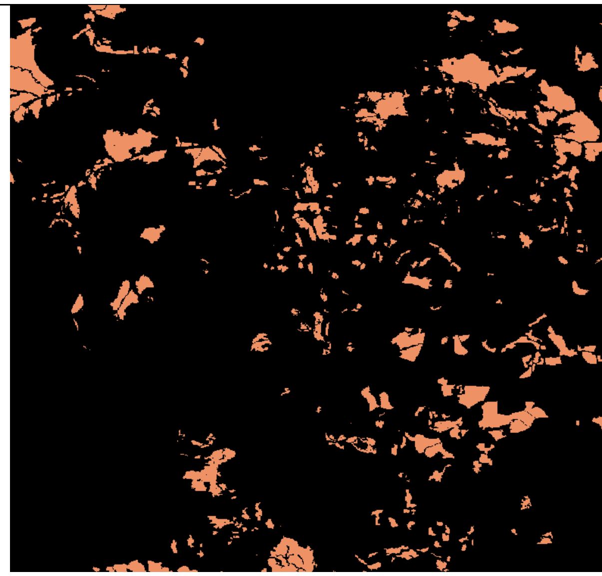
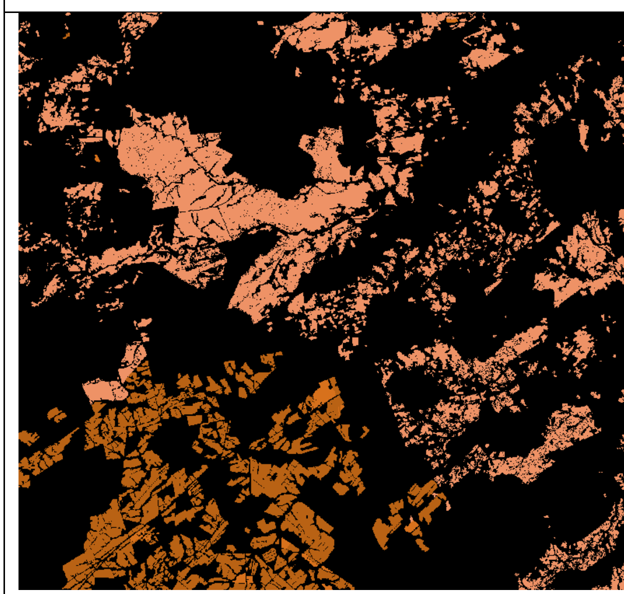
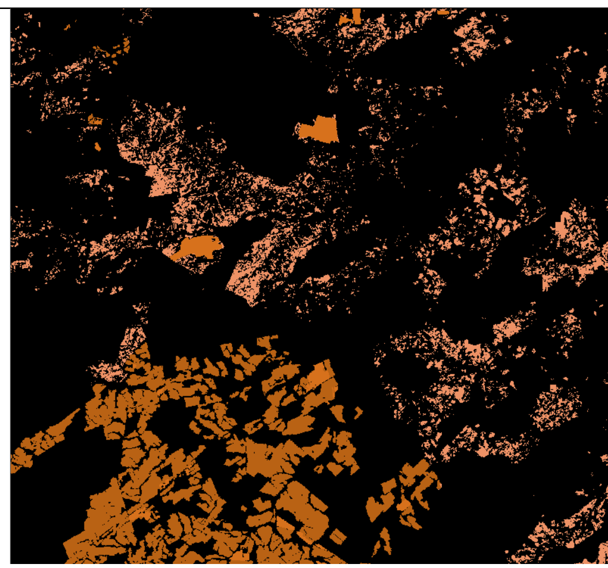
Joint posterior probability distributions of model parameters were estimated using the Metropolis-Hastings Markov Chain Monte-Carlo (MCMC) algorithm implemented in JAGS, called from R using the library jagsUI. The expected values of model parameter and predictions were taken as the mean of the posterior and 95% Bayesian credibility intervals (95% CIs; equivalent to parametric confidence interval) were taken as the 2.5th and 97.5th quintiles of the posterior probability distributions. Convergence of the MCMC chains was diagnosed using the *coda* package (Plummer *et al.* 2006), adopting minimal thresholds of p = 0.05 for Geweke's diagnostic (Geweke 1992) called from R.

Appendix 3: Comparison of agricultural areas between 1990 and 2013/2014.

Legend

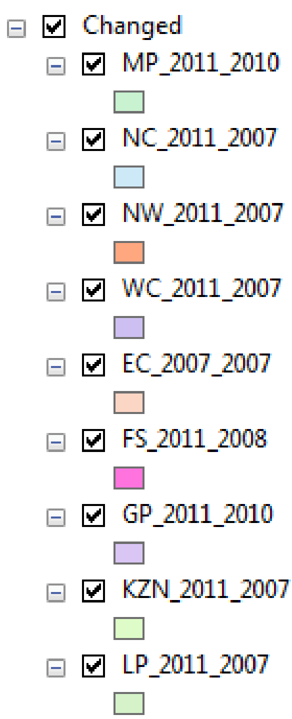


Area in 1990	Area in 2013/2014
	 West Coast: Increase in pivot circles
	 Western Cape: Increase in the number of areas identified as agricultural

	 Eastern Cape: Increase in subsistence agriculture
	 Limpopo: less areas identified as agriculture in 2014

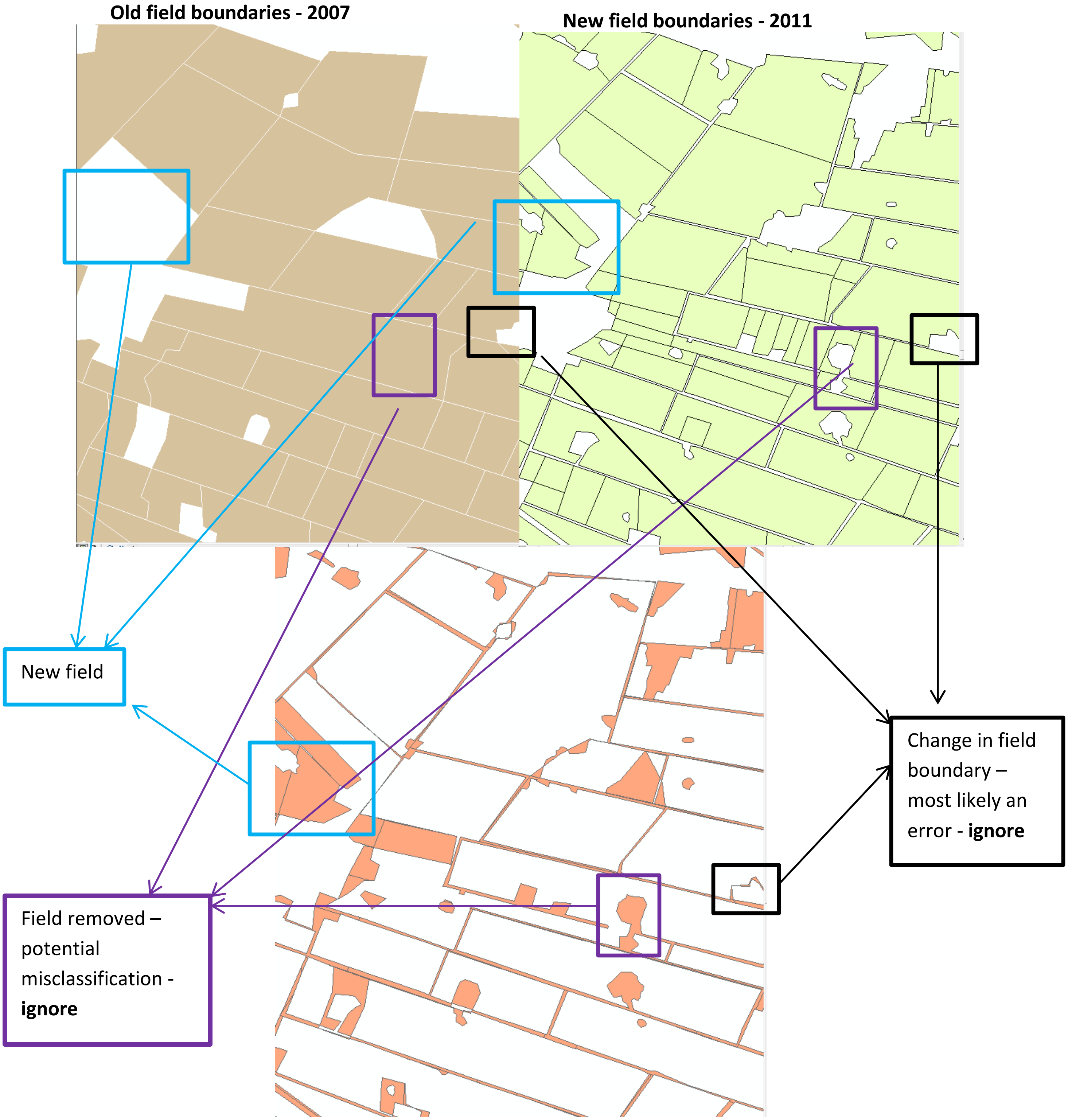
Appendix 4: Vector based agricultural fields, derived from the Agricultural Field boundary data captured by SIQ.

The screen shot screenshot below, shows the variation in capture date for the data set. These varies with the first two letters denoting the province, the first year being the year of data capture for the most current data and the second year being the older version on file. Note that the Eastern Cape (EC) did not have a recent data version.



Analysis of vector agricultural field boundaries

The notes below show the different types of polygons one can expect to see in the results and indicate the likely reason for the type of polygon existing. The user is advised to ignore sliver polygons which are generated due to misalignments in the data.


Old field boundaries - 2007
New field boundaries - 2011
New field
Field removed – potential misclassification - ignore
Change in field boundary – most likely an error - ignore

New Field

OArea	24.33
NArea	24.343893
Type	Annual Crop Cultivation / Planted Pastures Rotation
Captured	2011

A new field is one that appears in the recent layer, e.g. 2011, but not in the old layer, e.g. 2007

A new field should have been captured recently, check the two dates in the Captured column to confirm this, for example in the above information Captured shows 2011 and not 2007.

New fields should also have a large area, in most cases the value shown in OArea should Equal the value shown in NArea (see above), however changes in projections and editing errors can result in area differences.

Type shows you the type of agriculture practiced in this new field

Removed Fields – Data Error

OArea	168.07
NArea	31.266047
Type	High Cultivation
Captured	2007

Removed fields are areas that existed in the old layer, e.g. 2007 and not in the new layer, e.g. 2011. It is likely that when the new fields were captured an error was noted and corrected, perhaps a dam that wasn't seen in the previous imagery. In the above example, OArea is larger than NArea, because this area was part of a larger field, only a small portion of the 2007 field was removed. The date shown in Captured is that of the older layer.

Change in field boundary – Data Error

OArea	94.84
NArea	0.563512
Type	Annual Crop Cultivation / Planted Pastures Rotation
Captured	2011

A change in field boundary between the two data layers causes a silver (small polygon) to form. In the above example you can identify this by the NArea that is significantly smaller than the OArea. The date in Captured could be either 2007 or 2011.