

Assessing the Value of Glyphosate in the South African Agricultural Sector

By

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November 2014

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Acknowledgements

Sincere gratitude is expressed towards Nico Scheltema, Marion Delpont and Adell van Tonder who conducted the farmer interviews and to the farmers who patiently answered our questions. The data contribution by ADI Consultants, Grain SA and analysis by the Bureau for Food and Agricultural Policy (BFAP) is acknowledged and farm-level impact deliberation by Divan van der Westhuizen and document proof-reading by Dr Lindsay Trapnell are greatly appreciated.

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1 Executive summary

This study assessed the value of glyphosate in the South African agricultural sector with focus on the 2012/13 agricultural season. Glyphosate is the most used herbicide in South African and in 2012 more than 23 million litres of glyphosate was sold at an estimated value of R641 million. Glyphosate is a highly effective broad spectrum herbicide and the only herbicide on the market with a systemic mode of action. Glyphosate is considered to be, based on numerous scientific studies environmentally and toxicologically safe when used according to label instructions. Glyphosate is marketed under more than twenty trade-names in SA and is extensively used in the timber, horticulture, sugar and viticulture industries. The main users of glyphosate in SA are however maize, wheat and soybean farmers and in 2012 these farmers used 65% of all glyphosate sold in SA.

Making use of 'with and without glyphosate' scenario comparisons the assessment showed that glyphosate is immensely valuable to the agricultural sector. In monetary terms and depending on rather conservative yield assumptions the value of glyphosate in the maize sector was estimated to be between R525 million and R2.203 billion in 2012 with genetically modified herbicide tolerant and stacked gene maize farmers enjoying the biggest benefit. Assuming a yield loss of 10% in a without-glyphosate scenario for only farmers who make use of herbicide tolerant maize varieties, the value of glyphosate is estimated at R1.328 billion. Glyphosate's value for wheat farmers was estimated to be between R123 million and R485 million with the higher adoption usage rate (75%) and 10% potential damage scenario presenting a realistic value estimation of R335 million for the 2012 season. Soybean farmers making use of conservation tillage practises value glyphosate highly and under a without-glyphosate scenario stand to lose between R148 million and R693 million with the most probable value estimated at around R412 million.

Adoption of conservation tillage practises have increased considerably in SA since the introduction of glyphosate tolerant soybeans in 2001 and maize in 2003. Implementation of different degrees of reduced tillage practises have brought about substantial environmental benefits not only infield (soil) but also in the decreased emission of greenhouse gasses. The study showed that by using glyphosate instead of mechanized weed control, maize and soybean farmers (and wheat farmers to a lesser extent) were able to save about 23 million litres of diesel with a yearly CO₂ emission equivalent of 12 thousand average cars.

Determining the socio-economic impacts of glyphosate use in SA requires a larger and more in-depth assessment. However, the majority of the surveyed large-scale farmers planting HT maize and soybeans indicated the ease of weed control and management as the main benefit. A study of small-scale HT maize adopting farmers also showed the ease of weed control to be a major benefit with especially female household members being able to spend less time doing arduous manual weeding.

The confirmed immense value glyphosate has as a production tool in the South African agricultural sector serves as backdrop to the problem of weed resistance to glyphosate. Worldwide 31 weed species have been reported to be resistant to glyphosate. Three of the 31 reported glyphosate resistance weeds occur in South Africa and resistance has been proven in parts of the Western Cape. With increased adoption of glyphosate tolerant crops and increased sector wide use of glyphosate due to its environmental safety, relative affordability and efficacy, responsible use and stewardship have become even more vital to preserve glyphosate's value for the future.

2 Introduction

Since the registration of glyphosate in South Africa (SA) in the 1970s, this broad spectrum herbicide has increasingly become a vital tool in the control of undesirable plants (weeds) in urban gardens, in control of invasive species and especially in crop production. Glyphosate has been described as the world's leading agrochemical and a "once-in-a-century" herbicide (Duke & Powles, 2008). Glyphosate is a highly effective broad spectrum herbicide and the only one on the market with a systemic mode of action and is considered to be, based on numerous scientific studies (Williams, Kroes & Munro, 2000) environmentally and toxicologically safe when used according to label instructions. Glyphosate is marketed under more than twenty trade-names in SA and is extensively used in the field crop, timber, horticulture, sugar and viticulture industries. In addition, the use of glyphosate in the cultivation of cotton, soybeans and maize has increased significantly since the introduction of glyphosate tolerant varieties in 2001/02 for cotton and soybeans and 2003/04 for white and yellow maize.

It is not clear however, just how much glyphosate is used in SA and what the value of this herbicide is in the South African economy and environment. It is against this background that the Department of Agricultural Economics, Extension and Rural Development of the University of Pretoria (UP) has conducted a study to assess the value of glyphosate in the South African agricultural sector with focus on the 2012/13 agricultural season.

3 Methodology and scope

In a study published in 2010, the UK based ADAS group assessed the value of glyphosate in the UK's agriculture and environment. ADAS' research methodology was based on their substantial history of assessing changing herbicide availability scenarios. Their 2010 study methodology mainly included:

- Calculating crop specific gross margins using standard figures to assess 'current' practises and profitability,
- Extrapolating the gross margin calculations to a national level to assess the national crop value, and then
- Using the UK's Pesticide Usage Survey (2008) and feedback from agronomists (expert opinion), to assess the possible impacts of losing glyphosate as a herbicide.

Through this methodology the ADAS researchers assessed the importance and extent of the use of glyphosate in the UK and determined the possible loss of glyphosate as a herbicide on farmers' profitability, the cost of food, the effect on the environment and other socio-economic issues.

It is possible to assess the value of glyphosate in the South African agricultural sector by using the same general ADAS research approach but with some modifications. The major limiting factor in doing this type of assessment in South Africa is the lack of specific standardised budgets for the production of various crops. The ADAS researchers were able to base their gross margin calculations on nationally standardised production budgets that are published annually in the John Nix Farm Management Pocketbook. However, in SA, detailed enterprise budgets that are updated annually are limited and in many cases non-existent. In addition, compared to a country like the UK, South African grain and oilseed production conditions and practises vary quite substantially between production

regions, districts and farmers. As such, a single national crop production budget cannot supply a representative picture of crop production or herbicide use.

In the initial project proposal it was suggested that to assess the value of glyphosate in South Africa, the study should focus on two main data collection methods:

- For horticultural crops (citrus, potatoes and tomatoes), sugarcane, viticulture and timber, data for the use of glyphosate would be collected from industry experts and extrapolated using crop area estimations.
- For cotton, soybeans and maize and, to a lesser extent, for sunflower seed and wheat, data would be collected from commercial farmers in all the main production areas of South Africa. The idea was, rather than surveying a statistically representative sample of farmers in each district, data would be collected from a number of selected representative farms per district in each main production region to compile typical district and crop specific enterprise budgets.

Following a review of data on the use of glyphosate in South Africa obtained from ADI Consultants and perusal of relatively detailed region specific production budgets obtained from Grain SA, the proposed crop focus and data collection approach was somewhat amended.

As will be shown and discussed in the next sections, maize, wheat and soybeans are the main glyphosate using field crops in South Africa, accounting for 65% of all SA glyphosate usage. Consequently, farm level data collection and production budget analysis focus fell on those three crops. Less than 1.5% of the total SA volume of glyphosate is applied in the production of sunflower seed and cotton. Therefore sunflower seed and cotton are not included in the study.

Similarly, citrus, forestry, vines (wine and table grapes) and sugarcane are significant users of glyphosate but very little glyphosate is used in the production of potatoes and tomatoes. The latter two crops are not included in the study.

Detailed budgets for production of maize, soybeans and wheat were obtained from Grain SA for 2012/13. These budgets are compiled based on Grain SA member farmer feedback and prevailing market prices and are specific for the main production regions. They were compared and verified by using private sector (commercial cooperative) production budgets as well as Bureau for Food and Agricultural Policy (BFAP) information and *agribenchmark* (agribenchmark.org) data.

Farm-level data was collected from 45 farmers farming in the Free State (Reitz, Bethlehem, Bothaville and Viljoenskroon), North West (Rustenburg, Lichtenburg and Sannieshof) and Mpumalanga (Delmas, Standerton, Bethal and Ermelo). Farmers were asked to supply information on glyphosate use on their farms and for specific crops (see questionnaire in annex). By suggesting a hypothetical 'no glyphosate' scenario for the 2012/13 season, farmers were asked how their production practises would have been different and how crop yield would have been influenced. Of the 45 farmers surveyed, 43 were able to provide information on maize (conventional, insect resistant and herbicide tolerant), 26 on soybeans (herbicide tolerant), and 15 on wheat.

For citrus, forestry, vines and sugarcane information was gathered through key informant interviews as well as a literature review.

By analysing the data collected, it is possible to assess the value of glyphosate in the SA agricultural sector. Firstly, light will be shed on the use of glyphosate in the identified crop production systems.

Then the value of glyphosate will be determined in a ‘with and without glyphosate’ scenario, focussing on the potential impact on farmer income (gross margin), potential impact on food price, and to a lesser extent also the potential impact on the environment and socio-economic considerations.

The potential impact on farmer income and food prices will be rigorously assessed by analysing the industry and farmer collected production data, comparing real and hypothetical ‘without glyphosate’ alternatives and by utilising the Bureau for Food and Agricultural Policy’s general equilibrium model for decreased production / price impact scenario modelling.

The environmental impact of a ‘without glyphosate’ scenario will focus mainly on mechanisation alternatives, fuel and associated CO₂ emissions. The study concludes with a section on the socio-economic impacts of herbicide tolerant maize adopted by large-scale and small-scale maize farmers.

4 Glyphosate in South African

Glyphosate has been the most used herbicide in terms of total volume formulated product in South Africa since 2006, when ADI started collecting data on agricultural chemical use in South Africa. In 2012, 23.25 million litres of glyphosate (in Roundup, which is a registered trademark of Monsanto, equivalent litre (REL) 360g/l concentration) was sold at the value of R641 million.

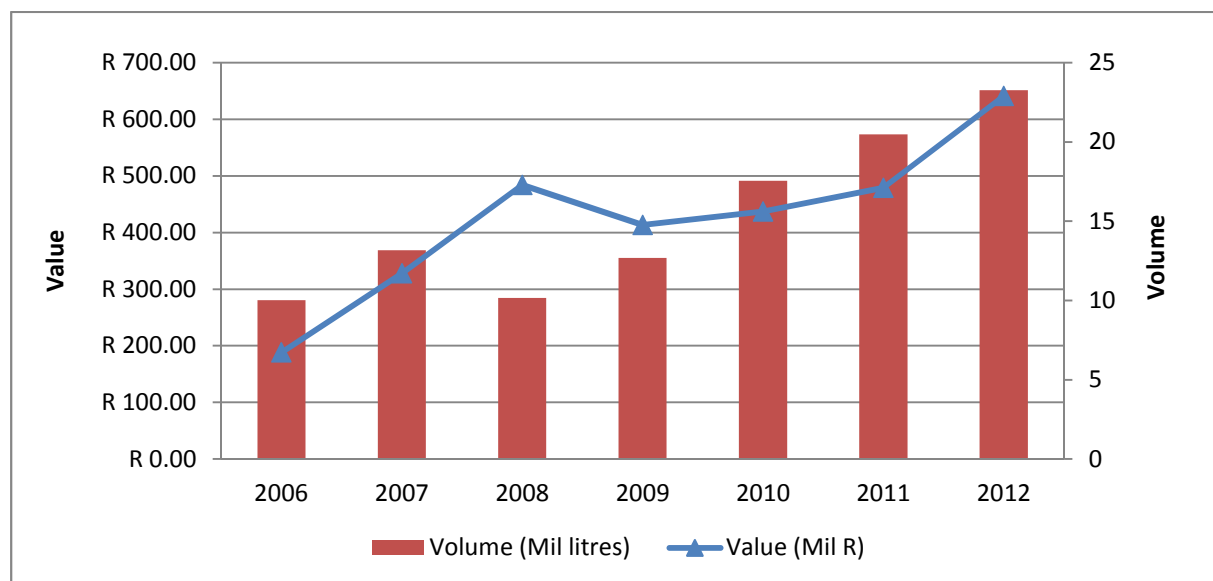


Figure 1: Volume and value of glyphosate sales in South Africa since 2006

Glyphosate, paraquat and glufosinate are the only three broad spectrum herbicides that have been successfully introduced internationally but glyphosate is the only herbicide that controls perennial weeds through its systemic mode of action. When comparing glyphosate use with paraquat, the only chemical near-alternative, it is clear that glyphosate is preferred by SA farmers (Figure 2). In 2012, 1.76 million litres of paraquat (mainly Gramoxone, a registered trademark of Syngenta) was sold compared to 23.25 million litres glyphosate. While paraquat is a contact herbicide and only kills the green plant material it comes into contact with, glyphosate, which is a systemic herbicide, is able to control perennial and established weeds with a bulb or strong rhizomes like creeping grass.

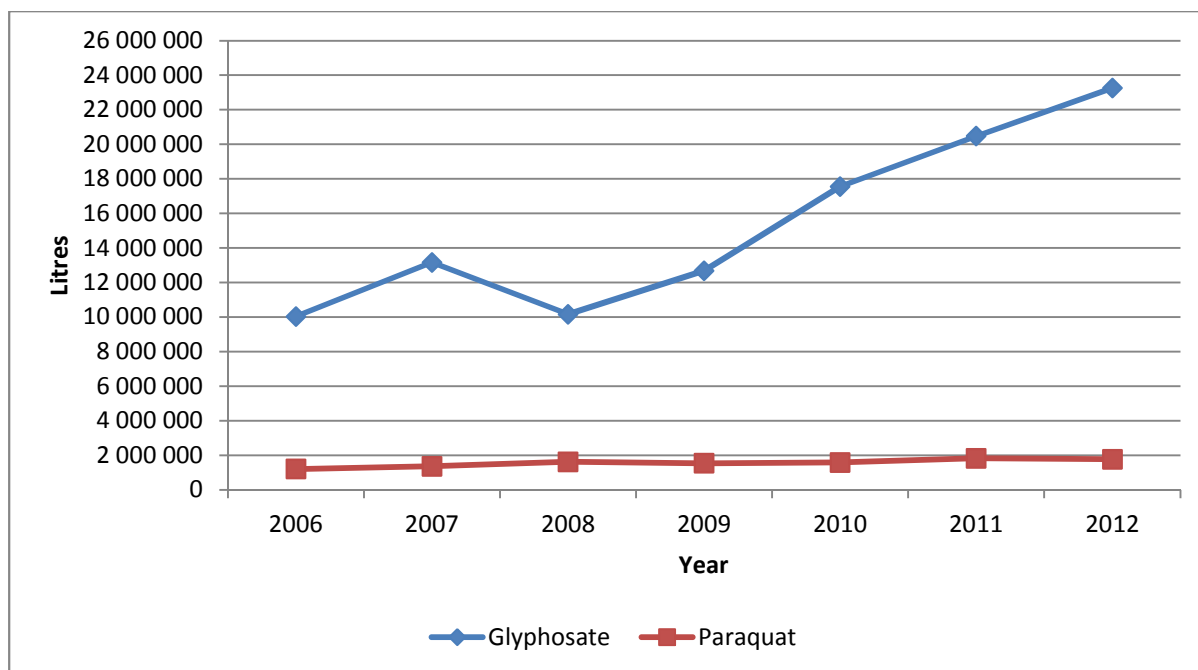


Figure 2: Comparison between glyphosate and paraquat volume sales

In addition to the control of perennial weeds, glyphosate, compared with paraquat, is also a more affordable herbicide (Figure 3). When comparing the cost of a recommended 1.6 litre per hectare glyphosate application to that of a 2 litre per hectare paraquat application, glyphosate was about 19% cheaper in 2012 and 23% cheaper on average over the seven years 2006-2012. The exception came in 2008 when low international glyphosate stocks resulted in a price spike.

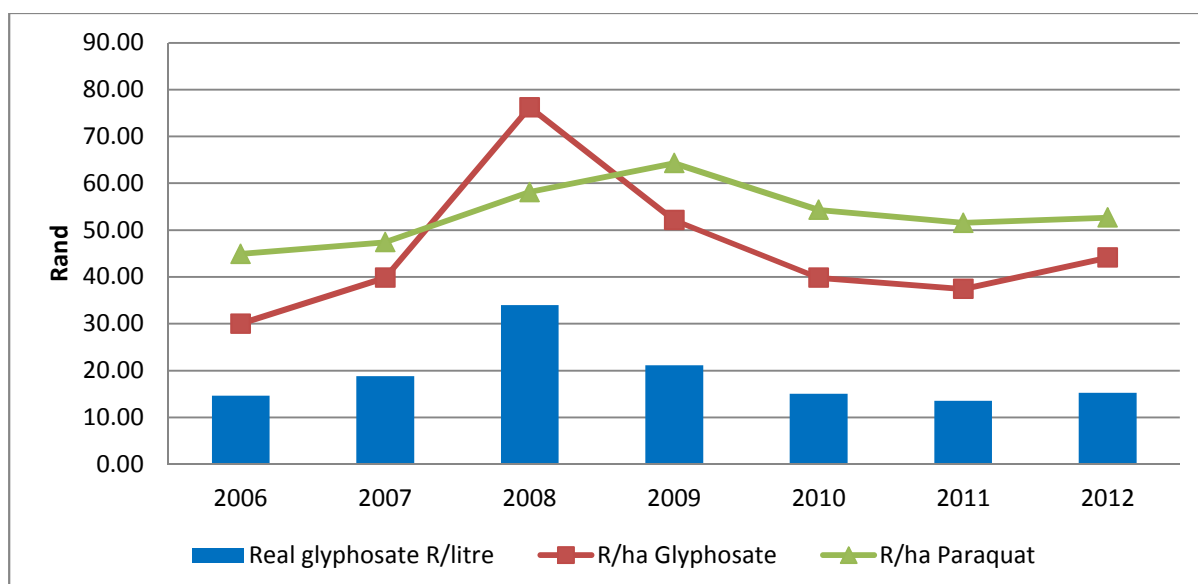


Figure 3: Glyphosate and paraquat cost per hectare comparison

The decreasing price trend since 2008 is also apparent from the real Rand per litre (REL) indication. These lower prices were mainly driven by increased production in China (the world's largest glyphosate producer) resulting from investment in additional production capacity as a result of the

high glyphosate prices of 2007 and 2008. However, prices started to increase again in 2013 following, amongst others, consolidation in the Chinese glyphosate industry and the removal of the export tax rebate on N-phosphonomethyl aminodiacetic acid (PMIDA), an important precursor chemical to glyphosate, by the Chinese government.

5 Crop specific glyphosate use

Table 1 indicates the volume of glyphosate used in 2012 in South Africa according to crop type. The total crop area estimations for 2012 are also presented in order to contextualise the glyphosate usage but it is clear that production of some crops required more glyphosate. Maize farmers are by far the biggest users of glyphosate with almost half of all glyphosate sold in South Africa in 2012 applied in maize fields. Wheat farmers were in second place with 13% of total glyphosate and soybean farmers in fourth place with 6% behind industrial glyphosate use (8%). It is quite interesting that wheat farmers used more than double the amount of glyphosate than soybean farmers while the area planted under these two crops were quite similar in 2012. Citrus farmers (in 5th place) used slightly more glyphosate than the forestry industry and surprisingly, when table and wine grape farmers' glyphosate usage is pooled, viticulture used more glyphosate than soybeans.

Table 1: National glyphosate use by crop for 2012

Rank	Crop	Volume (1000 litres)	Percentage of total	Total 2012 crop area in hectares
1	Maize	10 590	46%	2 699 200
2	Wheat	2 928	13%	511 200
3	Industrial	1 946	8%	-
4	Soybeans	1 311	6%	516 500
5	Citrus	1 196	5%	62 000
6	Forestry	1 000	4%	1 270 000
7	Wine grapes	995	4%	100 093
8	Table grapes	611	3%	25 872
9	Sugarcane	515	2%	264 409
10	Sorghum	398	2%	48 550
11	Pome fruit	395	2%	33 866
12	Sunflower seed	266	1%	504 700
13	Barley	187	1%	84 940
14	Pastures	167	1%	n a
15	Nuts	148	1%	>25 000
16	Stone fruit	135	1%	11 876
17	Groundnuts	125	1%	51 000
18	All other	341	1%	
	Total	23 253		

Source: ADI, SAGIS, SA CANEGROWERS, BFAP, Hortgro, SAMAC

Glyphosate recommended application rates (litre/ha) vary according to active ingredient formulation, solution, weed type, age or development stage of weeds and in some instances the crop itself. In addition, weed spectrums in crops fields are variable and differ between regions, soil type and climatic conditions that change from season to season. It is generally recommended that young annual

grasses and broad leaf weeds (smaller than 100 mm in height or 8 leaf stage) can be controlled with a single 1.3 l/ha glyphosate application at 2% solution while older weeds (100-200 mm or up to 12 leaf stage) require 1.7 l/ha of the same solution¹. Some weed species like *Commelina benghalensis* (Wandering Jew), *Ipomoea purpurea* (Morning glory) require up to two, 2 l/ha applications for total control. While a single 2 l/ha 2% glyphosate application should be sufficient to control a number of biennial and perennial weeds, *Cyperus esculentus* (yellow nutsedge) and grasses like *Cynodon dactylon* (couch / common quick grass) and *Panicum maximum* (Buffalo grass) require a 2 l/ha spray before the four leaf stage and another 2 l/ha spray 10-20 days later.

The main glyphosate using crops are discussed next.

5.1 Maize

Maize is South Africa's most important field crop and in 2012/13 covered 2.699 million hectares. Herbicide is, by a considerable margin, the main chemical crop protection expenditure on maize (Figure 4). In 2012 maize farmers spent R1 489 million on crop protection of which herbicides made up about R1 008.9 million.

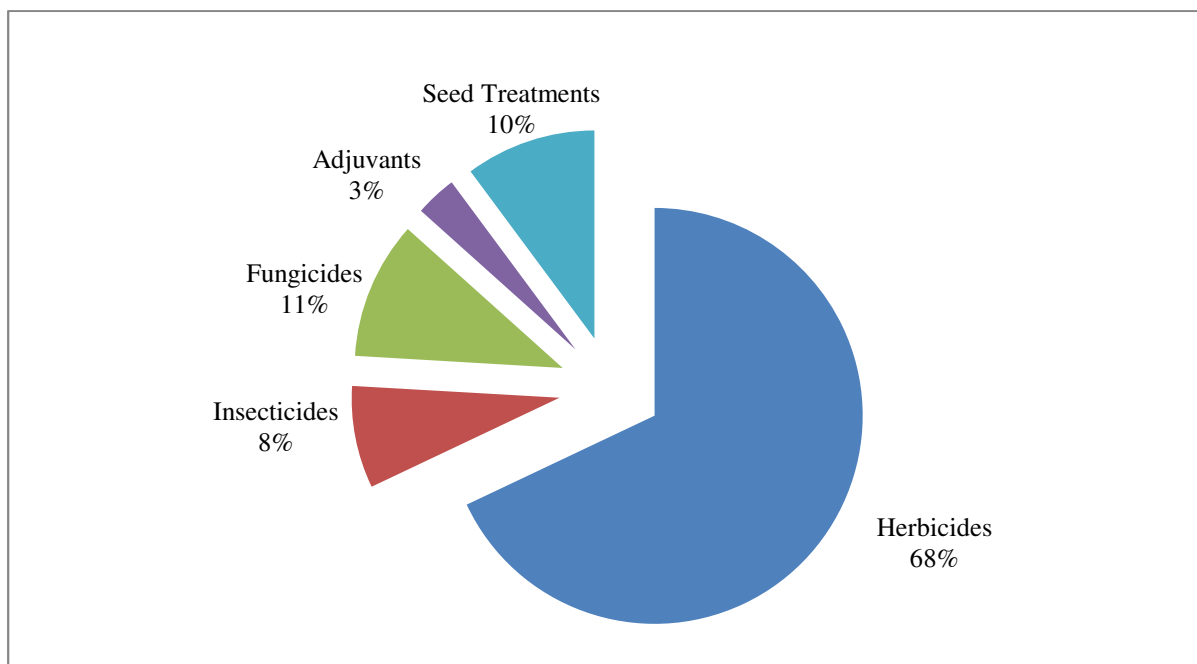


Figure 4: Maize chemical crop protection value for 2012

R296.4 million or 29.4% of total herbicide expenditure was spent on glyphosate. Proprietary products (with novel active ingredients and or formulations) made up the second most applied herbicide group and mainly combinations of residual and selective herbicides the rest. In maize production, glyphosate is used in pre-plant burn-down of weeds but also increasingly post-emergent on herbicide tolerant maize.

¹ Based on Roundup Power Max recommendations – with 540g active ingredient per litre

Table 2: Value of herbicides used in maize production in 2012

Product	Value (R million)
Glyphosate	R296.4
Proprietary products	R263.4
Metolachlor mixed with triazines	R72.2
Atrazine/terbuthylazine	R70.8
Acetochlor 840g/l	R56.3
Metolachlor 960g/l	R33.4
Dimethenamid	R26.4
Atrazine/sulcotrione	R22.3
Acetochlor 900g/l	R19.9
Acetochlor/atrazine/terbuthylazine	R18.1
Other	R129.7
Total	R1008.9

Herbicide tolerant (RoundupReady also known as RR or HT) maize was introduced in 2003/04 and the adoption of this technology has been increasing steadily, especially since the introduction of stacked (BR) maize with both insect resistant and herbicide tolerant traits. HT maize adopters make use of mainly Monsanto’s Roundup formulations and ADI estimated that approximately 67% of the 10.59 million litres of glyphosate applied in 2012, was Roundup.

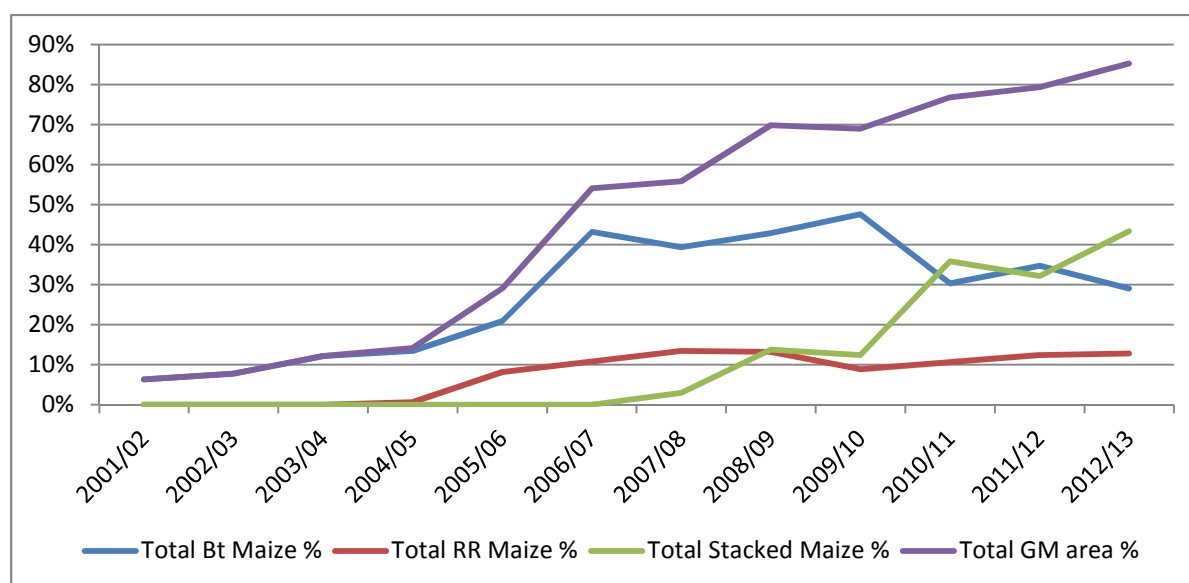


Figure 5: Adoption of genetically modified maize in South Africa (percentage of total maize area)

The correlation between the use of glyphosate (mainly Roundup) and the increase in the national maize area planted to herbicide (glyphosate) tolerant maize is evident from Figure 6.

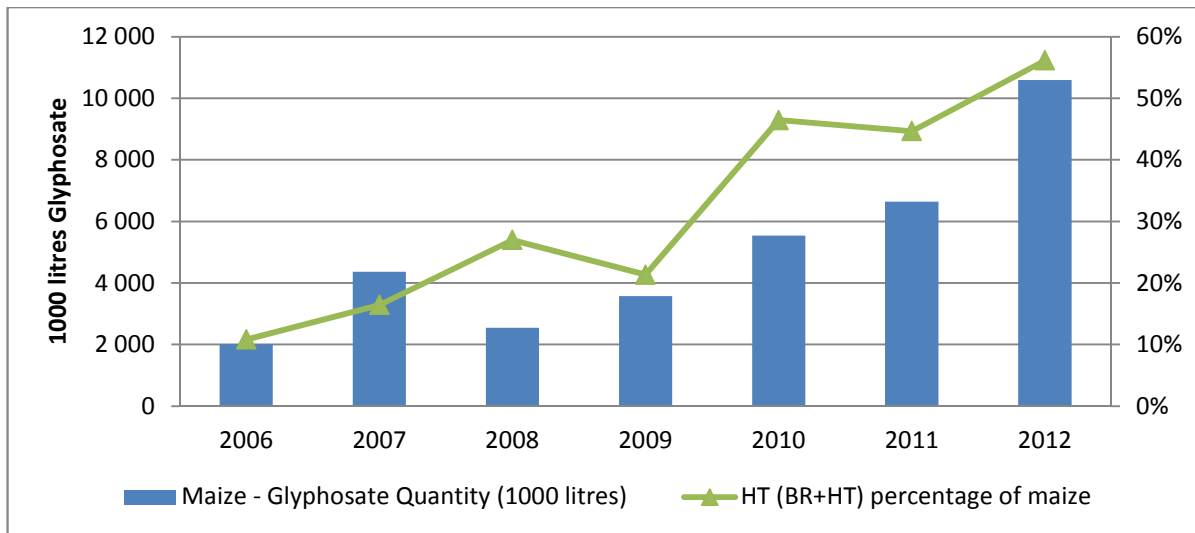


Figure 6: Correlation between increase in glyphosate use by maize farmers and percentage of national maize area under herbicide tolerant maize

In 2006 approximately 11% of the national maize area was planted to HT seed and approximately 2 million litres of glyphosate (REL 360g/l) was used. In 2012 the national area under HT maize (HT+BR) had increased to 56% and the glyphosate use to 10.59 million litres. Where production conditions allow, there has been a substantial shift towards conservation tillage practises (no or reduced till) and HT seed in combination with a broad-spectrum systemic herbicide (glyphosate) forms the backbone of this arguably more sustainable and environmentally friendly production system.

5.2 Wheat

Wheat is South Africa's second most important grain crop and in 2012 covered a total of 511 200 hectares. Herbicides also dominate wheat chemical crop protection with 61% of total crop protection expenditure which in 2012 added up to R312 million. Of the total herbicide expenditure, glyphosate made up 42%. As there is no herbicide tolerant wheat, glyphosate is predominantly used for pre-plant weed burn-down where the broad spectrum systemic mode of action is preferred. Wheat farmers used 2.9 million litres of glyphosate in 2012, accounting for 12.6% of total South African glyphosate use.

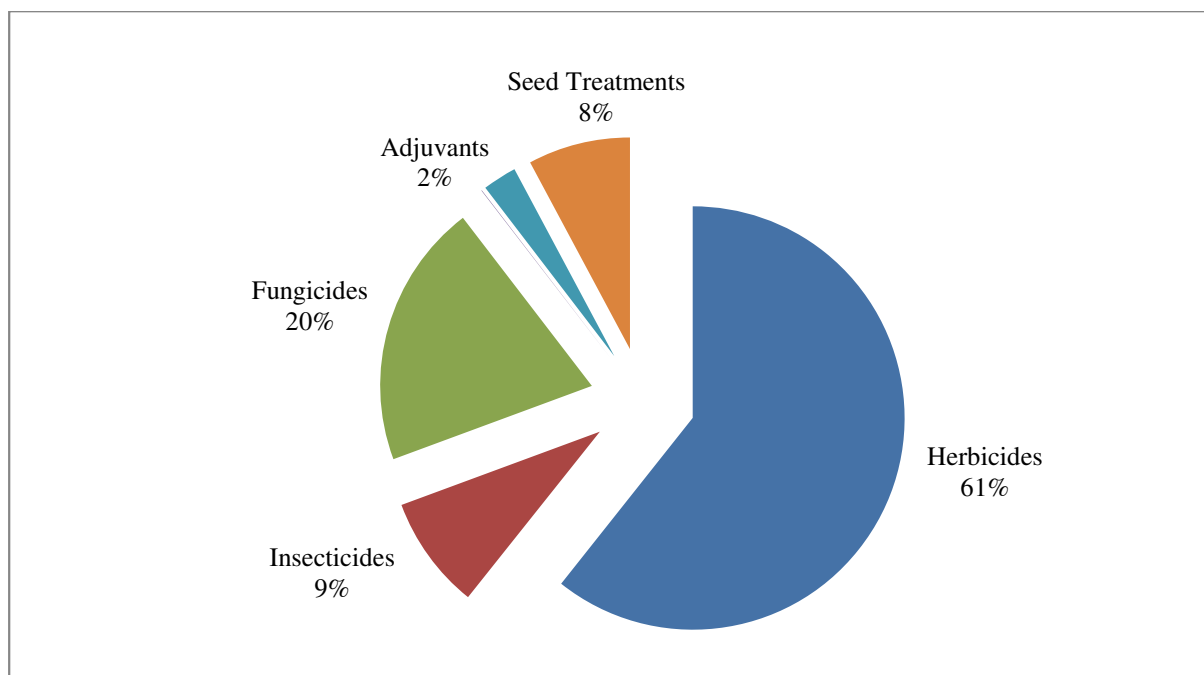


Figure 7: Wheat chemical crop protection value for 2012

Table 3: Value of herbicides used in wheat production in 2012

Product	Value (R million)
Glyphosate	R 79.6
Proprietary products	R 38.1
Other sulfonylurea	R 10.7
Trifluralin	R 10.5
MCPA	R 8.7
Bromoxynil 450	R 8.0
Clodinafop	R 5.8
Metsulfuron-methyl 600	R 5.4
Metsulfuron mixes	R 3.9
Bromoxynil 225	R 3.1
Other	R15.7
Total	R189.4

From Figure 8 it is apparent that the use of glyphosate in the production of wheat has increased considerably with the year on year glyphosate litres increasing substantially despite a decline in the area planted to wheat. This disparity might be linked to the fact that the wheat area is mainly declining in the summer rainfall dryland production area and not in the winter rainfall area where glyphosate is used more intensively. Increased resistance development to different herbicide groups by a number of weeds in the Western Cape, including *Lolium spp.* (Rye grass), *Avena barbata*, *fatua* and *ludoviviana* (slender, common and winter wild oats) and at least twelve others, has pushed farmers toward more aggressive pre-plant weed control. In the winter wheat production areas of the Western Cape (Swartland), it is not uncommon for farmers to apply two glyphosate sprays in combination with light cultivation to control weeds before planting. Over-use / increased use of a single herbicide is however not the solution to resistance development prevention.

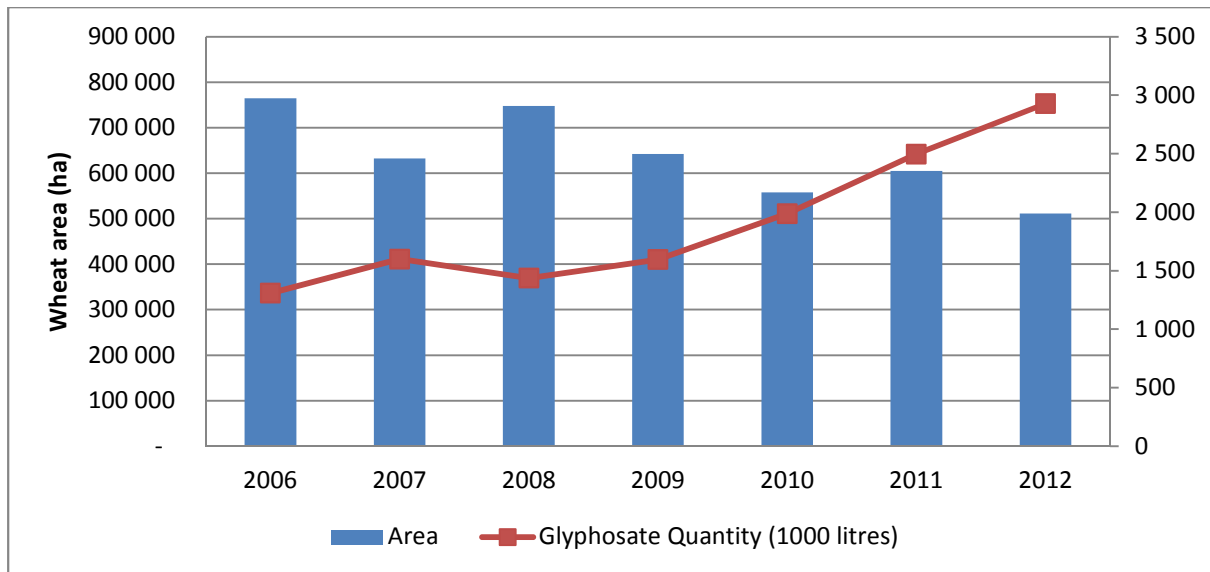


Figure 8: Wheat area and glyphosate litres applied

Wheat farmers make predominantly use of generic glyphosate brands and another reason for the increase in glyphosate use is the affordability of generic glyphosate products compared to other herbicides.

5.3 Soybeans

Soybean production in SA has increased remarkably in the last six to eight years with farmers reacting to higher soybean prices, driven by increased local crushing capacity, increasing local demand for soybean cake due to the growing animal feed sector and a move towards a more sustainable crop rotation system with maize and soybeans.

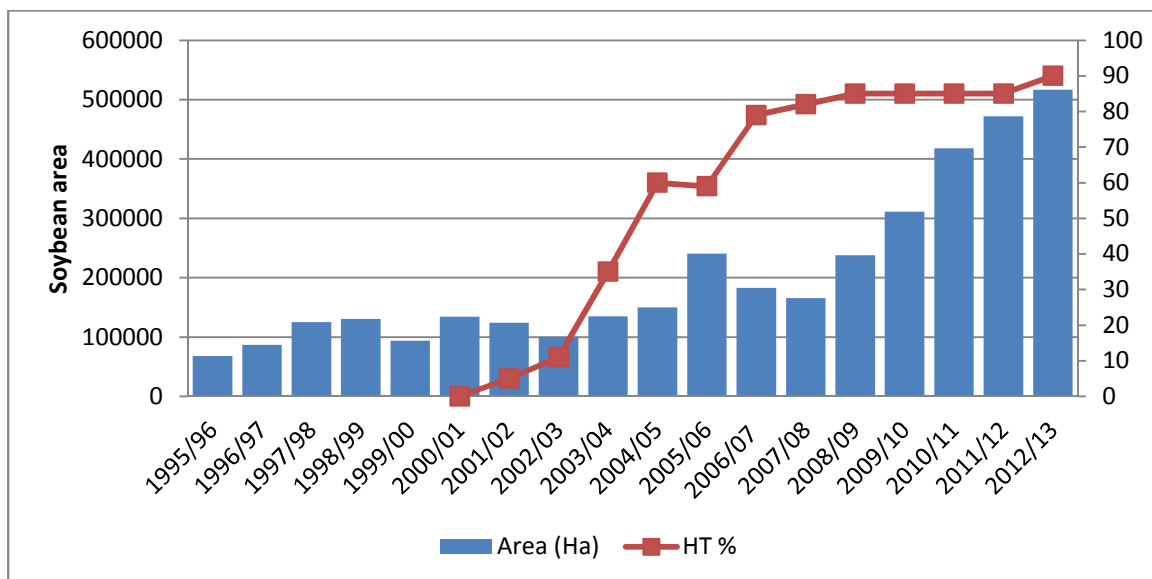


Figure 9: Soybean area and HT soybean adoption

It is apparent from Figure 9 that the introduction of herbicide tolerant soybeans in 2001/02 also contributed to the increase in soybean production. Similar to farmers in the US and Argentina (Fernandez-Cornejo, Hendricks & Mishra, 2005; and Trigo, 2011) South African farmers indicated the ease of HT soybean production (management benefit) as the main reason for adoption. In 2012, expenditure on herbicides accounted for 79% of the total soybean pest control budget of R86.2 million.

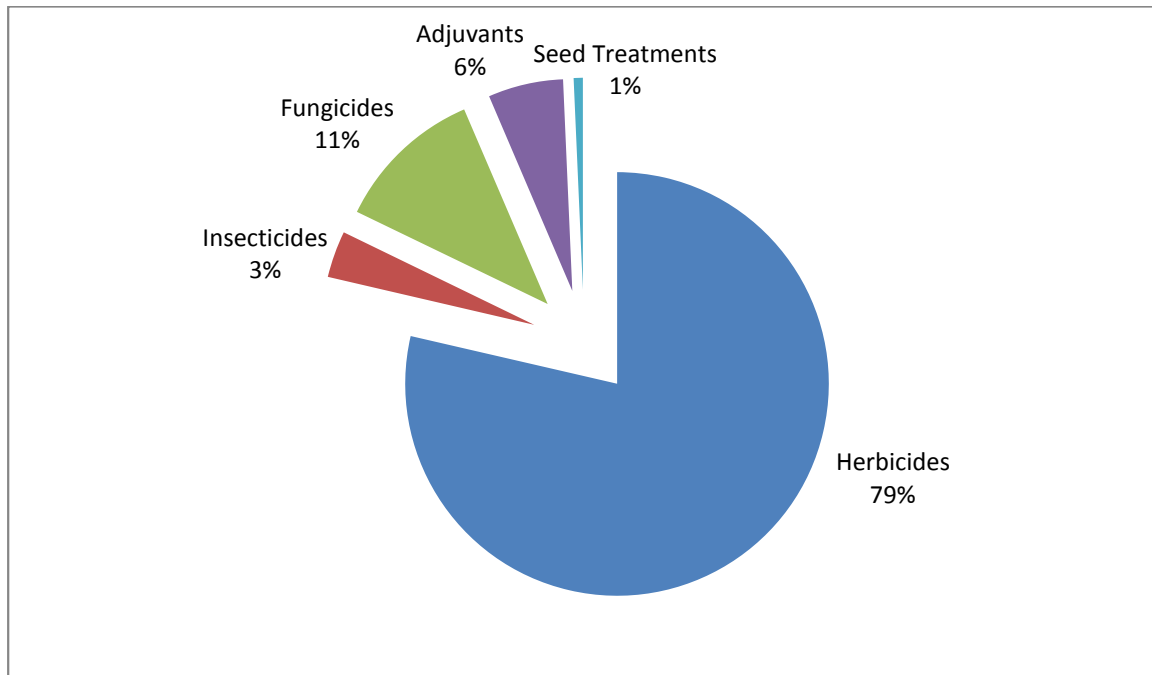


Figure 10: Soybean chemical crop protection value for 2012

Glyphosate represented 53% of the total herbicide expenditure value followed by metolachlor 960 with 16.9% of the value. Due to the fact that nearly the total South African soybean crop is HT, this is not surprising and the bulk of the 1.3 million litres of glyphosate applied, was Roundup.

Table 4: Value of herbicides used in soybean production in 2012

Product	Value (R million)
Glyphosate	R 36.1
Metolachlor 960	R 11.4
Chlorimuron-ethyl 500	R 5.4
Propaquizafop	R 2.7
Flumetsulam	R 2.5
Other cyclohexene oxime	R 1.8
Proprietary products	R 1.6
Acetochlor 750	R 1.3
Dimethenamid	R 0.8
Other triazinone	R 0.8
Other	R3.3
Total	R67.8

Though glyphosate use by soybean farmers also displays an increasing trend (Figure 11) which corresponds with the increasing adoption of HT soybeans and increased area under soybeans, the correlation is not as clear-cut as that of maize. The lower glyphosate use were in the seasons when glyphosate prices were relatively high and it is possible that farmers only applied Roundup post-emergent and used another herbicide like paraquat for the pre-plant burn-down.

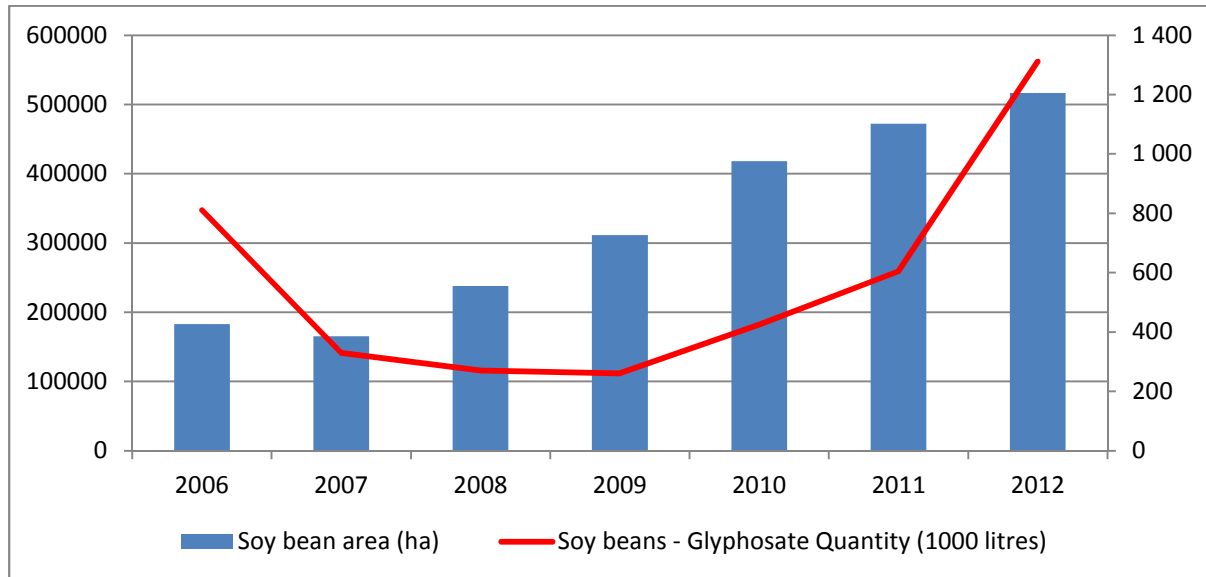


Figure 11: Soybean glyphosate quantity (1000 litres)

5.4 Citrus

Expenditure on herbicides made up a rather small portion of the total 2012 citrus pest control budget of R367 million. Insecticide and fungicide expenditure accounts for 82% of the total pest control budget. Glyphosate is however crucial in weed management and accounts for 85% of herbicide expenditure.

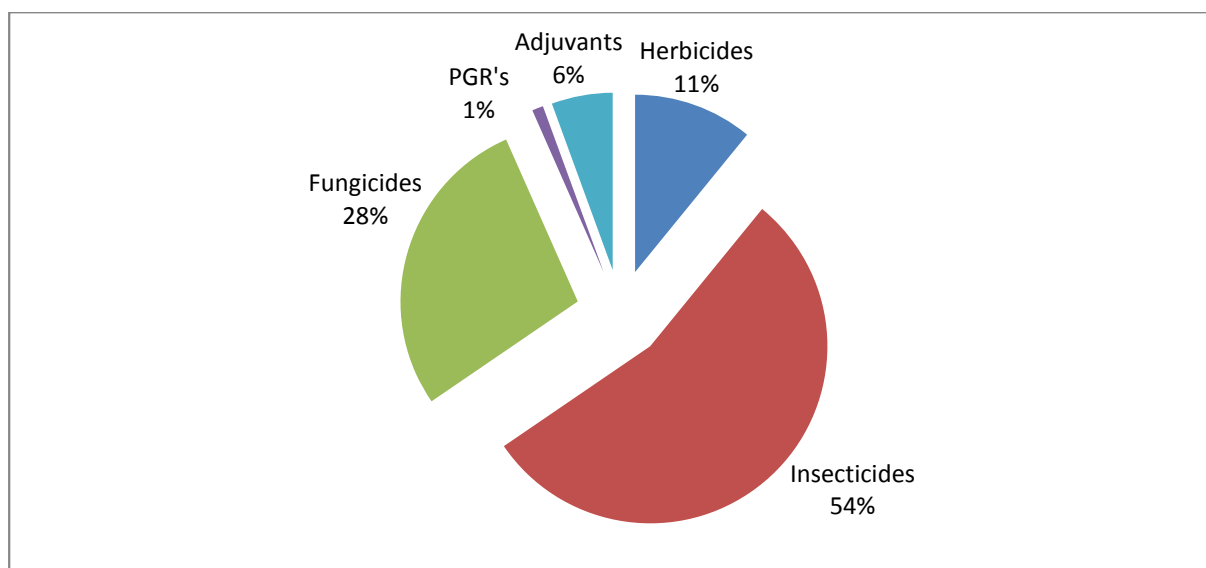


Figure 12: Citrus chemical crop protection value for 2012

In 2012 citrus covered an estimated 62 000 hectares and citrus farmers applied 1.2 million litres of glyphosate (5.1% of total glyphosate volume). Glyphosate is used in weed control in citrus orchards for young trees to prevent water and nutrient competition by weeds. For young and older trees, it is important to keep citrus orchards clean from weeds as weeds harbour the main citrus pests. Systemic broad spectrum herbicide like glyphosate is ideal to keep orchards clean from especially creeping grasses and trees older than 3 years are not effected by trunk contact with glyphosate. In the subtropical climate of Mpumalanga’s citrus production regions, weed control can get out of hand quite easily and glyphosate is considered to be an indispensable tool. While the citrus area has not increased substantially, glyphosate use in the citrus industry has more than doubled between 2009 and 2012, largely due to the comparable affordability of generic glyphosate.

5.5 Forestry

South African timber covers about 1.27 million hectares. Weed control in timber production is a vital activity as weeds smother tree seedlings, compete for moisture and nutrients and so doing reduce timber volumes and obstruct workers tending to trees. As a result herbicides dominate forestry crop protection expenditure at 91% of the total R66.7 million. Glyphosate accounts for 48% of the total herbicide expenditure followed by proprietary products and mainly selective broad leaf herbicides.

Glyphosate is predominately used for weed control in compartments when new trees are established and one pre-plant application will generally be followed up with another two sprays during the first year. Gum tree stumps are generally killed with a stump or foliar application of Triclopyr, Picloram or Imazapyr.

Table 5: Value of herbicides used in forestry industry in 2012

Product	Value (R million)
Glyphosate	R 29.0
Proprietary products	R 15.5
Triclopyr 480	R 7.6
Triclopyr 360	R 2.3
Fluroxypyr	R 2.0
Picloram	R 1.7
Paraquat	R 0.9
Metazachlor	R 0.6
Other pyridine	R 0.4
Imazapyr 100	R 0.2
Other	R 0.6
Total	R60.7

In South Africa the Forestry Stewardship Council (FSC) limits the number of herbicides that can be used in timber production. While the use of glyphosate is considered to be acceptable, paraquat for instance is considered to be highly hazardous and special permission is required from the FSC to apply this herbicide without losing one’s valuable ‘responsible forestry management’ certification (Meyer, 2014).

5.6 Viticulture

In 2012 South Africa grew 25 872 hectares of table and dry grapes (Hortgro, 2013) and 100 093 hectares of wine grapes (SAWIS, 2012). Herbicides make up 33% of the total chemical pest control budget in grape production with fungicides accounting for 51%. Glyphosate contributed 55% to the total herbicide expenditure and approximately 1.6 million litres of glyphosate was used in 2012. Glyphosate is applied 2 to 3 times through the season to control weeds between rows. Glyphosate is applied with directed spray on (away from) young (green) vines as they are susceptible and often a glyphosate spray is followed by a pruning of green plant material low down on the vine base. Two year old vines with more mature trunks without low growing green foliage are not affected by glyphosate applications on the base of the trunk. Glyphosate is vital in control of especially creeping grasses.

5.7 Sugarcane

In 2012, sugarcane chemical crop protection expenditure amounted to R176 million of which 95% was for herbicides. Glyphosate made up 7% of the total herbicide budget with cane farmers spending more on proprietary products (18%) such as hexazinone (11%) and diuron (8%). While glyphosate used to be applied as a ripener, more effective ripeners have reached the market in the last couple of years and glyphosate is mainly used for weed control. Glyphosate is crucial in control of creeping grasses such as *Cynodon dactylon* (couch or common quick / kweek grass), *Cynodon nlemfuensis* (Stargrass) and *Digitaria abyssinica* (Digitaria) in fallow fields due for replanting. Glyphosate is also used for chemical cane stool eradication and in-field spot-spraying with shields and under-canopy spray when dry leaves protect the base of cane stalks (Campbell, 2013).

Use of glyphosate by cane growers increased to 800 000 litres in 2010 but has decreased to 556 000 litres and 515 000 litres for the 2011 and 2012 seasons. This decrease could be due to the move away from using glyphosate as a ripener.

6 Economic value of glyphosate

The economic value of glyphosate was determined by calculating gross margins per hectare for the main glyphosate using crops in a hypothetical ‘no glyphosate’ scenario for the 2012/13 season. The gross margin calculations took into consideration changes in yield which affected the gross income as well as changes in the production system which effected production expenditure. Though the ‘without glyphosate’ scenario was useful to identify and assess the value of glyphosate for a specific season, it could be expected that in an actual scenario where glyphosate is removed from the market, farmers would react and endeavour to limit losses by testing and employing alternative weed control and production practises over a number of seasons.

In 2012/13, maize, wheat and soybean farmers used 65% of the nationally consumed glyphosate volume and 71% of the total volume of glyphosate used in the production of crops. As a result, the economic value assessment focusses on these three crops.

Production region specific production budgets, obtained from Grain SA, were used to construct the actual ‘with glyphosate’ scenarios for different seed types. Farmer survey information as well as actual ‘without glyphosate’ production practice information were used to construct the ‘without’

scenarios. Production budgets were compared to BFAP and *agribenchmark* budgets to ensure that the information was accurate. Farmer practises varied considerably, even within regions, and for analysis it was necessary to assume that the amended Grain SA budgets are representative of production practises in the specific production regions.

6.1 Maize

Of the 2.699 million hectares of maize planted in 2012 in South Africa, 88% was planted in three Provinces, namely the Free State, Mpumalanga and North West and the study focusses on these three Provinces. Detailed and representative production-region specific Grain SA production budgets were condensed in order to include only the main production expenditures with the objective of calculating a comparable gross margin for different seed technologies and production systems. For this assessment white and yellow maize were grouped together as maize, and no distinction regarding price or production area was made. This is a necessary assumption as white and yellow maize specific regional data is sketchy. A number of other assumptions are made, informed by industry data as well as survey farmer and specialist information. Some of the more general assumptions in this maize section are also applicable to the value assessment analyses for wheat and soybean.

Assumptions:

- According to updated Maize Trust supported FoodNCropBio research, conventional maize (non-GM hybrids) covered 15% of the total maize area in 2012/13; Bt maize as a single event covered 29%, herbicide tolerant maize (HT) as single event covered 13% and stacked maize (Bt+HT referred to as BR) covered 43% (Van Der Walt, 2014). It is assumed that this national adoption figures are similar on provincial and production region level.
- It is assumed that the ‘no glyphosate’ impact on the remaining 12% or 324 200 ha of maize not in the Free State, Mpumalanga or North West, is equal to the average of the impacts in the three main production Provinces.
- For the hypothetical without glyphosate comparisons, farmers planting conventional maize and Bt maize are grouped together and HT and stacked (BR) farmers are grouped together. This could be done because these groups generally control weeds in the same manner.
- It is necessary to assume that stem borer pressure was not significant in the 2012/13 season and that conventional and Bt maize had the same yield. HT and BR maize were thus also assumed to have the same yield. This is done to remove the additional variability linked to potential stem borer damage and the Bt technology and to isolate the glyphosate impact on weed control activities, expenditure and efficacy.
- It is also assumed that Bt seed and conventional seed prices are similar and HT and BR seed prices are similar. Again this is done to remove any gross margin impacts that are not linked to weed control practises.

- Based on the seed technology adoption figures and above mentioned grouping, conventional and Bt maize (C+Bt) covered 1 187 648 ha (44% of total maize area) and HT+BR covered 1 511 552 ha (56% of the total).
- All production is assumed to be on dryland. This is however an erroneous assumption as it is estimated that more than 200 000 ha of maize are irrigated or enjoys supplemental irrigation. Information on irrigation areas is however limited and therefor adding irrigation maize for the three main production regions would complicate the assessment considerably. By assuming only rain-fed maize it is ensured that the value of glyphosate is not over-estimated as the value of a 5 or 10 percent yield impact on irrigation farming would be considerably larger than for maize grown on dryland conditions.
- It is assumed that 100% of the HT+BR group of farmers use glyphosate as the use of a post emergent glyphosate application is after all the point of planting HT seed.
- It is assumed that only 50% of the C+Bt group of farmers use glyphosate. Based on industry information it would seem as if substantially more than 50% of C+Bt farmers use glyphosate, but a number of farmers indicated that glyphosate usage on C+Bt maize depends on the specific season and ‘problem areas/fields’. For this reason and in order not to over-estimate glyphosate usage, this conservative usage assumption is made.
- For the hypothetical ‘no glyphosate’ scenarios, actual C+Bt maize and HT+BR maize Grain SA budgets for farmers using glyphosate in their production systems are adjusted based on actual Grain SA C+Bt budgets for farmers not using glyphosate.
- The yield damage affect is assumed not to have a harvesting and transport expenditure impact as this would be minimal.
- For the Free State Province it is assumed that the production system and yield potential for the Northern and Western Free State (for which data is not available) is on par with that of the South Eastern Free State. The Eastern Free State has a slightly lower production potential. Production region (sub-provincial) production figures are not available and it is assumed that the Free State consist of 1/3 Eastern Free State and 2/3 South Eastern (also representing Northern and Western) Free State.
- As farmers in especially the North West Province experienced a lower than average rainfall in 2012/13, a yield, based on longer term data, was assumed for the gross margin calculations.
- A large number of maize and soybean farmers are moving towards conservation tillage practises, largely enabled by herbicide tolerance technology. There are however a number of types of conservation tillage and the level or scale of adoption by farmers depend on amongst others the crop, soil type, rotation system and available implements. The different types of conservation tillage generally include:
 - No till – no cultivation takes place and seed is planted via broadcast and rolling (the term no-till is often used erroneously when direct drilling is meant)

- Direct drilling – No overall cultivation is done and planting is done with a heavy planter with a cutting blade to open a small furrow into which seed and fertiliser is deposited and a pressure wheel which covers the furrow.
- Strip tillage – a narrow band of cultivation takes place along the plant line while the inter-row is left uncultivated and mechanical weed control can take place.
- Stubble mulch tillage – Crop residue is chopped up and left lying on the soil surface. A chisel plough is used for overall cultivation and weed control is done either chemically, with a tined cultivator or by a combination of both.

Farmers tend to employ versions and combinations of the above. The choice would depend on their individual production conditions and crop choice but generally a farmer planting HT seed and controlling weeds with a post-emergent glyphosate application would employ a type of conservation tillage practise. However, from the detailed HT and conventional maize farmer budgets obtained from Grain SA, it was not always clear where HT planting farmers made use of different cultivation or planting practises compared with their conventional and Bt seed planting counterparts. In the South Eastern Free State, for example, HT and BR farmers' fuel expenditures were similar to that of conventional and Bt maize planting farmers while in the North West, farmers planting herbicide tolerant varieties spent 10% less on fuel and 7% less on maintenance.

Based on farmer surveys, the use of HT and glyphosate resulted in a yield increase (weed damage limitation) of 13% on average with some farmers indicating a yield increase of up to 20% in drier seasons and other farmers indicating that they did not observe a significant yield effect. For HT+BR farmers under the 'no-glyphosate' scenario, a yield loss of 5% is assumed for the gross margin calculations in Tables 6-9 and the impact of a 10 and 15 percent impact is illustrated in Table 10. For C+Bt farmers NO yield impact is assumed for the assessment. This is in contrast with what glyphosate using farmers suggested but is done in order not to over-estimate the glyphosate effect and it is assumed that farmers (in a no-glyphosate scenario) should be able to minimise yield losses through alternative herbicides and additional cultivations (mainly harrowing). It is argued that HT+BR farmers might struggle to limit a potential weed linked yield loss in the absence of glyphosate with the premise that this was to some degree exactly why they adopted the HT technology.

By running various yield impact scenarios in BFAP's sector model it was found that an assumed 5% yield decrease for HT+BR farmers under a 'no glyphosate' scenario would have a very small producer price effect and even a 15% yield decrease would result in only a 2.1 – 3.0 percent increase in producer price. The reason for this is that South Africa produced a relatively large maize crop in 2012/13 and a production decrease would have resulted in a decrease in exports – not really affecting the domestic maize price. For this reason, it is safe to assume that prices remained constant under the 'no glyphosate' scenario and the gross margin comparisons are not influenced by a price effect. The producer and consumer price effects are further discussed in section 7.

Tables 6-9 present C+Bt maize and HT+BR maize production systems with glyphosate with a C+Bt production system without glyphosate (the baseline). In the final two columns of these respective Tables the value of glyphosate is calculated by subtracting the 'no glyphosate' baseline gross income and expenditures from that of the actual 'with glyphosate' production systems. For both C+Bt and HT+BR the loss of glyphosate would result in a decrease in gross margin. Though there is some variation between regions it is clear that fuel expenditure as linked to mainly additional post emergent harrowing under the 'no glyphosate' scenario. Repairs and maintenance expenditure per hectare as linked to these additional cultivations (one or two) are also higher. The impact of a 'no glyphosate'

situation on total herbicide expenditure is less clear-cut. While most HT+BR farmers would spend less on herbicide when switching to a conventional maize or Bt maize production system with no glyphosate, it would seem that C+Bt farmers could spend more or less, depending on the production region. Whereas the gross margin for C+Bt farmers is only influenced by production expenditure changes (no yield impact), HT+BR farmers are expected to suffer a yield loss (5% for Tables 6-9) with the loss of glyphosate as a production tool and the gross margin decreases are, as a result, more substantial. The gross margin impacts are calculated by subtracting the change in expenditure on inputs from the change in gross income.

Table 6: North West Province gross margin per hectare and ‘no glyphosate’ scenario impact calculation for maize

North West Province			NO glyphosate	NO Glyphosate	NO Glyphosate
	C+Bt with glyphosate	HT+BR with glyphosate	Baseline production system (C+Bt without glyphosate)	Impact for C+Bt	Impact for HT
Yield (t/ha)	4	4.2	4	0.0	-0.2
Farm gate price	2 196	2 196	2 196	0	0
Gross income	8 784	9 223	8 784	0	-439
Production Expenditure (R/ha)					
Fertilizer	1 492	1 492	1 492	0	0
Fuel	639	573	758	120	185
- Operations before plant	262	262	338	76	76
- Operations at plant before harvest	218	153	262	44	109
- Harvest and transportation	159	159	159	0	0
Herbicide	339	381	262	-77	-119
- Pre-plant	77	77	0	-77	-77
- At plant	114	114	114	0	0
- Post emergent	148	190	148	0	-42
Repairs and maintenance (direct allocated)	473	441	539	66	97
- Operations before plant	177	177	222	45	45
- Operations at plant before harvest	184	153	205	21	52
- Harvest and transportation	112	112	112	0	0
Seed	529	669	529	0	-140
TOTAL PRODUCTION COST	3 472	3 557	3 581	109	24
GROSS MARGIN	5 312	5 666	5 203	-109	-463

Table 7: Eastern Free State gross margin per hectare and ‘no glyphosate’ scenario impact calculation for maize

Eastern Free State			NO Glyphosate	NO Glyphosate	NO Glyphosate
	C+Bt with glyphosate	HT+BR with glyphosate	Baseline production system (C+Bt without glyphosate)	Impact for C+ Bt	Impact for HT
Yield (t/ha)	4.5	4.7	4.5	0.0	-0.2
Farm gate price	2 138	2 138	2 138	0	0
Gross income	9 621	10 102	9 621	0	-481
Production Expenditure (R/ha)					
Fertilizer	2 450	2 450	2 450	0	0
Fuel	844	831	831	-14	0
- Operations before plant	487	473	473	-14	0
- Operations at plant before harvest	199	199	199	0	0
- Harvest and transportation	159	159	159	0	0
Herbicide	185	293	232	46	-61
- Pre-plant	77	0	0	-77	0
- At plant	0	123	123	123	0
- Post emergent	109	170	109	0	-61
Repairs and maintenance (direct allocated)	646	608	629	-17	21
- Operations before plant	301	284	284	-17	0
- Operations at plant before harvest	233	212	233	0	21
- Harvest and transportation	112	112	112	0	0
Seed	793	1 021	793	0	-228
TOTAL PRODUCTION COST	4 919	5 203	4 934	16	-268
GROSS MARGIN	4 702	4 900	4 687	-16	-213

Table 8: South Eastern Free State gross margin per hectare and ‘no glyphosate’ scenario impact calculation for maize

South Eastern Free State			NO Glyphosate	NO Glyphosate	NO Glyphosate
	C+Bt with glyphosate	HT+BR with glyphosate	Baseline production system (C+Bt without glyphosate)	Impact for C+Bt	Impact for HT
Yield (t/ha)	6	6.3	6	0.0	-0.3
Farm gate price	2 163	2 163	2 163	0	0
Gross income	12 978	13 627	12 978	0	-649
Production Expenditure (R/ha)					
Fertilizer	2 735	2 735	2 735	0	0
Fuel	749	749	779	30	30
- Operations before plant	403	403	389	-14	-14
- Operations at plant before harvest	188	188	232	44	44
- Harvest and transportation	159	159	159	0	0
Herbicide	331	672	306	-26	-367
- Pre-plant	69	69	0	-69	-69
- At plant	160	139	160	0	21
- Post emergent	102	464	146	44	-319
Repairs and maintenance (direct allocated)	511	511	515	4	4
- Operations before plant	219	219	202	-17	-17
- Operations at plant before harvest	180	180	201	21	21
- Harvest and transportation	112	112	112	0	0
Seed	577	729	577	0	-153
TOTAL PRODUCTION COST	4 902	5 396	4 911	9	-485
GROSS MARGIN	8 076	8 231	8 067	-9	-164

Table 9: Mpumalanga (Eastern Highveld) gross margin per hectare and ‘no glyphosate’ scenario impact calculation for maize

Mpumalanga			NO Glyphosate	NO Glyphosate	NO Glyphosate
	HT+BR with glyphosate	HT with glyphosate	Baseline production system (C+Bt without glyphosate)	Impact for C+Bt	Impact for HT
Yield (t/ha)	6	6.3	6	0	-0.3
Farm gate price	2 164	2 164	2 164	0	0
Gross income	12 984	13 633	12 984	0	-649
Production Expenditure (R/ha)					
Fertilizer	2 761	2 761	2 761	0	0
Fuel	858	844	875	17	30
- Operations before plant	487	473	473	-14	0
- Operations at plant before harvest	212	212	242	30	30
- Harvest and transportation	159	159	159	0	0
Herbicide	518	762	609	91	-153
- Pre-plant	128	0	0	-128	0
- At plant	0	219	219	219	0
- Post emergent	390	543	390	0	-153
Repairs and maintenance (direct allocated)	642	625	629	-13	4
- Operations before plant	301	284	284	-17	0
- Operations at plant before harvest	229	229	233	4	4
- Harvest and transportation	112	112	112	0	0
Seed	1 057	1 155	1 057	0	-98
TOTAL PRODUCTION COST	5 836	6 147	5 931	95	-216
GROSS MARGIN	7 148	7 486	7 053	-95	-433

Table 10 supplies a summary of gross margin impacts of different yield decrease assumptions for the production regions. The impact for only the HT+BR group of farmers are presented as the C+Bt farmers' gross margin impact remains constant (as shown in Tables 6-9) as it is not linked to a yield impact. It is clear that a higher yield loss would result in a considerable decrease in gross margin, resulting in farmer income loss. ADAS (2010) assumed yield reductions of up to 20% for a number of crops and some surveyed maize farmers also indicated that weeds could cause a yield decline of 20% or more in low rainfall seasons. The more conservative upper damage level of 15% assumed for this study quite clearly impacts the gross margins for the different production regions considerably. Under a 5% yield loss assumption North West HT and stacked maize farmers' gross margin per hectare would decrease by R463, while under a 10 and 15 percent loss assumption, it would decrease by R902 and R1 341 respectively.

Table 10: Gross margin decrease per hectare under different yield loss assumptions for HT+BR maize farmers (ZAR/ ha)

Yield loss	5%	10%	15%
North West	463	902	1 341
Eastern Free State	213	694	1 175
South Eastern Free State	164	813	1 462
Mpumalanga	433	1 082	1 731

Table 11 summarises the total impact of a 'no glyphosate' scenario for the South African maize sector. By multiplying the provincial maize area for each seed technology by the seed specific gross margin impact, it is possible to calculate a national impact. The value of glyphosate is indicated for the main production provinces as well as for the remaining maize area. Because of the sheer size of the per hectare gross margin impact for especially HT+BR farmers and the fact that more than 1.5 million hectares of HT and BR maize were planted, the national impact of a hypothetical glyphosate loss, i.e. the value of glyphosate in the SA maize sector, is substantial.

Table 11: Total impact of a "no-glyphosate" scenario for the South African maize sector under different yield damage assumptions for the 2012/13 season (ZAR)

5% yield impact	C+Bt	HT+BR	Total
Percentage of seed specific group	50%	100%	
Loss in Free State	2 847 011	117 151 203	
Loss in Mpumalanga	9 377 042	109 043 021	
Loss in North West	18 365 973	198 229 077	
Loss on remainder	5 111 553	65 102 950	
TOTAL	35 701 580	489 526 250	525 227 830
10% yield impact	C+Bt	HT+BR	Total
Loss in Free State	2 847 011	502 331 523	
Loss in Mpumalanga	9 377 042	272 641 421	
Loss in North West	18 365 973	386 382 528	
Loss on remainder	5 111 553	166 853 792	
TOTAL	35 701 580	1 328 209 264	1 363 910 844

15% yield impact	C+Bt	HT+BR	Total
Loss in Free State	2 847 011	887 511 843	
Loss in Mpumalanga	9 377 042	436 239 821	
Loss in North West	18 365 973	574 535 808	
Loss on remainder	5 111 553	268 604 611	
TOTAL	35 701 580	2 166 892 082	2 202 593 662

The value of glyphosate in the SA maize sector, under relatively conservative assumptions and a 5% loss in yield is estimated at more than R 525 million for the 2012/13 season. This is nearly double the R296 million maize farmers spent on glyphosate in 2012. If the potential yield loss (for HT+BR farmers only) is increased to 10%, the value of glyphosate is estimated at R1.364 billion and at a 15% loss at R 2.203 billion (7.4 times the value of maize farmer glyphosate expenditure in 2012).

6.2 Wheat

In 2012/13, 79% of the South African wheat crop was planted in the Western Cape and the Free State. Production budgets for the Central and Eastern Free State and the Rûens and Swartland regions of the Western Cape were obtained from Grain SA and used to calculate and compare gross margins. An average of the Central and Eastern Free State budgets was assumed to be representative of the Free State Province and the Rûens and Swartland production systems and budgets, for the Western Cape.

Assumptions

- In 2012, approximately 42 000 hectares of wheat were planted in the Northern Cape covering 8% of the total South African wheat area. However, because Northern Cape wheat is produced under irrigation, this region contributed 15% to the total wheat crop. According to farmer and industry information, the use of glyphosate on irrigation wheat in the Northern Cape is minimal. Glyphosate in wheat production is mainly used as pre-plant weed burn-down and due to the fact that in the Northern Cape there is for all practical reasons no precipitation between the period when maize is harvested and when wheat is planted, there is usually no need for pre-plant chemical weed control. As basically all Northern Cape wheat is produced on irrigation schemes, it is assumed that no glyphosate is used in the production of wheat in the Northern Cape.
- It is assumed that the ‘no glyphosate’ impact on the remaining 13% or 67 200 ha of wheat not planted in the Western Cape, Free State or Northern Cape is equal to the average of the per hectare impacts in the two main producing Provinces and that wheat is only produced on dryland.
- Even though wheat farmers used the second largest share of nationally consumed glyphosate (13% of total glyphosate volume), a large share of surveyed farmers, mainly in the Free State indicated that they do not use glyphosate in wheat production. There is no data on how many wheat farmers actually use glyphosate. However, we know that in 2012/13 wheat farmers used 2.9 million litres of glyphosate on 511 200 ha, i.e. glyphosate use by wheat farmers was considerable. Gross margin impact findings are extrapolated to a national level assuming two

possible glyphosate use scenarios, namely 50 and 75 percent glyphosate use. The 2012 glyphosate usage figure for wheat farmers however suggests that more than 75% of wheat farmers (based on area and not actual farmer numbers) use glyphosate.

Tables 12 to 15 show that if glyphosate was removed from the market, production cost would increase especially in the Free State due to increased cultivation and expenditure on alternative herbicides. In the Free State, typically, a pre-plant glyphosate application would be replaced by a paraquat and 2.4 D application and an additional pre-emergent application of trifluralin and sulfonyleurea. In the Western Cape, based on available information, herbicide use is already considerable and only additional cultivations were predicted. The yield effect (5% assumed for the presented budgets) is the main driver of the gross margin difference between the two production systems.

Table 12: Central Free State gross margin per hectare and ‘no glyphosate’ scenario impact calculation for wheat

Central Free State		No glyphosate	No glyphosate
	With glyphosate	Baseline production system	Impact
Yield	3	2.85	-0.15
Farm gate price	2 810	2 810	-
Gross income	8 430	8 009	-422
Production Expenditure			
Fertilizer	1 434	1 434	-
Fuel	829	875	46
- <i>Operations before plant</i>	601	601	-
- <i>Operations at plant before harvest</i>	71	117	46
- <i>Harvest and transportation</i>	157	157	-
Herbicide	131	324	193
- <i>Pre-plant</i>	86	83	-4
- <i>At plant</i>	-	197	197
- <i>Post emergent</i>	45	45	-
Repairs and maintenance	555	599	43
- <i>Operations before plant</i>	344	344	-
- <i>Operations at plant before harvest</i>	89	132	43
- <i>Harvest and transportation</i>	122	122	-
Seed	350	350	-
TOTAL PRODUCTION COST	3 299	3 581	282
GROSS MARGIN	5 131	4 427	-704

Table 13: Eastern Free State gross margin per hectare and ‘no glyphosate’ scenario impact calculation for wheat

Eastern Free State		No glyphosate	No glyphosate
	With glyphosate	Baseline production system	Impact
Yield	3	2.85	-0.15
Farm gate price	2 810	2 810	-
Gross income	8 430	8 009	-422
Production Expenditure			
Fertilizer	1 434	1 434	-
Fuel	829	875	46
- <i>Operations before plant</i>	601	601	-
- <i>Operations at plant before harvest</i>	71	117	46
- <i>Harvest and transportation</i>	157	157	-
Herbicide	215	324	109
- <i>Pre-plant</i>	161	83	-79
- <i>At plant</i>	-	197	197
- <i>Post emergent</i>	54	45	-9
Repairs and maintenance	555	599	43
- <i>Operations before plant</i>	344	344	-
- <i>Operations at plant before harvest</i>	89	132	43
- <i>Harvest and transportation</i>	122	122	-
Seed	350	350	-
TOTAL PRODUCTION COST	3 383	3 581	199
GROSS MARGIN	5 047	4 427	-620

Table 14: Rûens (Western Cape) gross margin per hectare and ‘no glyphosate’ scenario impact calculation for wheat

Rûens (Western Cape)		No glyphosate	No glyphosate
	With glyphosate	Baseline production system	Impact
Yield	3.5	3.33	-0.18
Farm gate price	2 570	2 570	-
Gross income	8 995	8 545	-450
Production Expenditure			
Fertilizer	1 665	1 665	-
Fuel	666	721	54
- <i>Operations before plant</i>	331	331	-
- <i>Operations at plant before harvest</i>	168	222	54
- <i>Harvest and transportation</i>	168	168	-
Herbicide	474	399	-75
- <i>Pre-plant</i>	158	83	-75
- <i>At plant</i>	197	197	-
- <i>Post emergent</i>	120	120	-
Repairs and maintenance	553	589	37
- <i>Operations before plant</i>	242	242	-
- <i>Operations at plant before harvest</i>	193	229	37
- <i>Harvest and transportation</i>	118	118	-
Seed	520	520	-
TOTAL PRODUCTION COST	3 879	3 895	16
GROSS MARGIN	5 116	4 651	-466

Table 15: Swartland (Western Cape) gross margin per hectare and ‘no glyphosate’ scenario impact calculation for wheat

Swartland (Western Cape)		No glyphosate	No glyphosate
	With glyphosate	Baseline production system	Impact
Yield	3.2	3.0	0.2
Farm gate price	2 570	2 570	-
Gross income	8 224	7 813	-411
Production Expenditure			
Fertilizer	1 740	1 740	-
Fuel	687	741	54
- <i>Operations before plant</i>	351	351	-
- <i>Operations at plant before harvest</i>	168	222	54
- <i>Harvest and transportation</i>	168	168	-
Herbicide	398	331	-68
- <i>Pre-plant</i>	233	165	-68
- <i>At plant</i>	46	46	-
- <i>Post emergent</i>	120	120	-
Repairs and maintenance	553	589	37
- <i>Operations before plant</i>	242	242	-
- <i>Operations at plant before harvest</i>	193	229	37
- <i>Harvest and transportation</i>	118	118	-
Seed	402	402	-
TOTAL PRODUCTION COST	3 779	3 803	23
GROSS MARGIN	4 445	4 010	-435

Table 16 indicates the gross margin impacts for the Free State (average of Central and Eastern) and the Western Cape for different yield decrease assumptions. It is clear that the assumed yield loss percentage plays a big role in assessing the value of glyphosate. The ADAS group assumed a 20% yield loss under a ‘no glyphosate’ scenario for the UK. This study errs on the conservative side by assuming a maximum of 15% yield loss. Even under the lowest 5% assumption for loss of yield, the ‘no glyphosate’ scenario results in a 13 and 9 percent gross margin decrease (farm income loss) for Free State and Western Cape farmers, respectively.

Table 16: Gross margin decrease per hectare under different yield loss assumptions for wheat farmers (ZAR/ ha)

Yield loss	5%	10%	15%
Free State	662	1 083	1 505
Western Cape	450	881	1 311

According to Table 17, the value of glyphosate for South African wheat farmers is estimated to be between R122.9 million and R485.1 million. Based on the fact that SA wheat farmers applied 2.928 million litres of glyphosate on 469 200 ha (total wheat area minus Northern Cape) in 2012, it is likely that the minimum value level is above R184.4 million (5% damage at 75% adoption) as the vast majority of dryland wheat producers made use of glyphosate. R184.4 million is 2.3 times the amount wheat farmers spent on glyphosate in 2012.

Table 17: Total impact of a ‘no glyphosate’ scenario for the South African wheat sector under different yield damage and glyphosate use assumptions for the 2012/13 season (ZAR)

50% glyphosate use	5%	10%	15%
Loss in Free State	43 018 206	70 415 706	97 813 206
Loss in Western Cape	61 222 984	119 767 584	178 312 184
Loss in remainder	18 681 391	32 994 571	47 307 751
Total loss	122 922 581	223 177 861	323 433 141
75% glyphosate use	5%	10%	15%
Loss in Free State	64 527 309	105 623 559	146 719 809
Loss in Western Cape	91 834 476	179 651 376	267 468 276
Loss in remainder	28 022 086	49 491 856	70 961 626
Total loss	184 383 871	334 766 791	485 149 711

6.3 Soybeans

Soybean production in South Africa takes place in predominantly Mpumalanga and the Free State with the two Provinces contributing 81% of the total soy area in 2012/13. Grain SA production budgets for Mpumalanga and Free State for soybean production under conventional tillage practices, were condensed to include only the main production expenditures and to calculate comparable gross margins. By using the conventional production budgets and assuming, based on historic and comparable conservation tillage production budgets (with mainly less cultivations, increased planting expenditure and similar herbicide usage) conservation tillage budgets were constructed for the two Provinces for 2012/13. Soybean farmers that were surveyed indicated that most of them were in a process of moving towards a type of conservation tillage approach (where conditions allowed) and many were already using this production system for soybeans.

Assumptions:

- It is assumed that a third of soybean farmers made use of a conservation tillage production system and two-thirds produced using conventional tillage practices.
- Approximately 96 500 hectares of soybeans (18.7% of 516 500 ha) were planted outside of the two main production Provinces. An average ‘no glyphosate’ gross margin impact based on the Mpumalanga and Free State estimations is applied to that area.
- Based on official estimations, 90% of the national soybean crop was planted to HT soybeans in 2012/13 (Van der Walt, 2014) and it is assumed that adoption was similar in the main production Provinces.

- It is assumed that the 10% soybean farmers (soybean area) that do not use HT soybeans, do not use glyphosate at all.
- For seed expenditure it is assumed that farmers bought 50% new seed and used 50% farm-saved seed.
- A 5% yield loss under a ‘no glyphosate’ scenario is assumed for both conventional and conservation tillage farmers for Tables 18 and 19 as farmers felt that even though they can apply a post-emergent selective herbicide and control weeds mechanically with one or two additional cultivations, weed control would not be as effective as with glyphosate. While most international studies on HT soybeans did not find a significant yield difference compared to conventional varieties (Carpenter & Gianessi, 1999; 2000; 2001; Fernandez-Cornejo, Klotz-Ingram & Jans, 2002; Marra, Piggott & Carlson, 2004; Qaim & Traxler, 2005) it is important to note that in the hypothetical ‘no glyphosate’ scenario farmers are ‘switching’ from HT seed with glyphosate to conventional seed with no glyphosate. Surveyed farmers indicated that a yield decrease would be likely to occur.
- Due to data limitations it was assumed that the Eastern Free State’s soybean production system is representative for the whole Free State.
- Though some farmers indicated that a loss of glyphosate as weed control tool would result in slower harvesting speeds due to the increased presence of weeds, this is not taken into consideration for the gross margin calculations.

It is clear from Tables 18 and 19 that under a ‘no glyphosate’ scenario, the production cost of conventional tillage farmers would decrease. This would be mainly due to a decrease in expenditure on herbicides and despite farmers spending more on fuel and repairs and maintenance. Conservation tillage using farmers’ production cost will however increase due to the increased expenditure on cultivations. The majority of soybean farmers felt that it would not be possible to use a conservation tillage system in the absence of glyphosate. In fact, a number of farmers who use conservation tillage, indicated that if glyphosate is removed from the market, they will discontinue the production of soybeans.

Table 18: Mpumalanga (Eastern Highveld) gross margin per hectare and ‘no glyphosate’ scenario impact calculation for soybeans

Eastern Highveld			NO Glyphosate	NO Glyphosate	NO Glyphosate
	HT with conventional till	HT with conservation till	Baseline production system	Impact for conventional till	Impact for conservation till
Yield (t/ha)	3.00	3.00	2.85	-0.15	-0.15
Farm gate price	4 631	4 631	4 631	0	0
Gross income	13 893	13 893	13 198	-695	-695
Production Expenditure (R/ha)					
Fertilizer	2 870	2 870	2 870	0	0
Fuel	770	383	814	44	432
- Operations before plant	473	114	473	0	359
- Operations at plant before harvest	184	155	228	44	73
- Harvest and transportation	113	113	113	0	0
Herbicide	410	461	229	-182	-233
- Pre-plant	0	0	0	0	0
- At plant	152	152	152	0	0
- Post emergent	259	310	77	-182	-233
Repairs and maintenance (direct allocated)	546	353	567	21	214
- Operations before plant	284	95	284	0	190
- Operations at plant before harvest	212	209	233	21	24
- Harvest and transportation	49	49	49	0	0
Seed	847	847	478	-369	-369
TOTAL PRODUCTION COST	5 443	4 914	4 958	-485	44
GROSS MARGIN	8 450	8 979	8 240	-209	-738

Table 19: Eastern Free State (Free State) gross margin per hectare and ‘no glyphosate’ scenario impact calculation for soybeans

Eastern Free State			NO Glyphosate	NO Glyphosate	NO Glyphosate
	HT with conventional till	HT with conservation till	Baseline production system	Impact for conventional till	Impact for conservation till
Yield (t/ha)	2.00	2.00	1.90	-0.10	-0.10
Farm gate price	4 631	4 631	4 631	0	0
Gross income	9 262	9 262	8 799	-463	-463
Production Expenditure (R/ha)					
Fertilizer	1 457	1 457	1 457	0	0
Fuel	784	396	828	44	432
- Operations before plant	473	114	473	0	359
- Operations at plant before harvest	198	169	242	44	73
- Harvest and transportation	113	113	113	0	0
Herbicide	418	490	277	-141	-213
- Pre-plant	0	0	0	0	0
- At plant	127	200	200	73	0
- Post emergent	290	290	77	-213	-213
Repairs and maintenance (direct allocated)	530	338	551	21	214
- Operations before plant	284	95	284	0	190
- Operations at plant before harvest	197	194	218	21	24
- Harvest and transportation	49	49	49	0	0
Seed	679	679	363	-316	-316
TOTAL PRODUCTION COST	3 868	3 361	3 476	-392	115
GROSS MARGIN	5 394	5 901	5 323	-71	-579

As with maize and soybeans, the potential yield loss due to less effective weed control dominates the gross margin impact. Surveyed farmers indicated an expected yield decrease between zero and 50 percent with an average of 19% and a median of 18%. Under a seemingly conservative damage estimation of 15%, conventional till farmers in Mpumalanga would have lost R1 599 per hectare and conservation till farmers R2 128.

Table 20: Gross margin per hectare under different yield loss scenarios for conventional till and conservation till soybeans (ZAR/ha)

Yield loss	5%		10%		15%	
	Conv. till	Cons. till	Conv. till	Cons. till	Conv. till	Cons. till
Mpumalanga	209	738	904	1 433	1 599	2 128
Free State	71	579	534	1 042	997	1 505

Table 21 summarises the income impact of a ‘no glyphosate’ scenario for the South African soybean sector. By multiplying the provincial soybean area for each tillage system with its calculated gross margin, it is possible to calculate the value of glyphosate for soybean farmers. The value is indicated for the main production Provinces as well as for the ‘remaining area’ outside of Mpumalanga and the Free State.

Table 21: Total impact of a “no glyphosate” scenario for the South African soybean sector under different yield damage assumptions for the 2012/13 season (ZAR)

Yield impact	5%	10%	15%
Loss in Mpumalanga	71 154 621	199 317 546	327 480 471
Loss in Free State	46 501 707	136 111 557	225 721 407
Loss in remainder	27 032 942	77 068 830	127 104 717
Total	144 689 270	412 497 932	680 306 595

Under the most conservative yield loss assumption of 5%, the direct value of glyphosate for SA soybean farmers, calculated as a gross margin impact for 2012, is estimated at R 144.7 million and increases to R 680.3 million for a 15% yield loss assumption. Soybean farmers spent R36.1 million on glyphosate in 2012.

6.4 Other crops

In 2012, the citrus, forestry, viticulture and sugar industries spent R 101.5 million on glyphosate, accounting for about 18% of the total glyphosate market. In all four industries a ‘no glyphosate’ scenario would result in additional alternative herbicide applications, increased labour use for manual weed control and additional herbicide applications as well as possible yield impacts. Determining the size and value of possible yield impacts on perennial crops is a rather difficult task and due to the long-term and considerable use of glyphosate in these industries alternative herbicide strategies are not obvious. It is however possible to consider the financial impact of the potential need for additional labour days to apply alternative herbicides or control weeds manually. Table 22 indicates the cost implications for one to five additional labour days for the four industries, using the 2012 minimum agriculture and forestry wage rates. One additional labour day per hectare in a ‘without glyphosate’ scenario, would have cost the citrus, forestry, viticulture and sugar cane industries an additional

R115.14 million in 2012. Due to the higher governmentally enforced agricultural minimum wage rate introduced in 2013 (R105 / day) the same additional day would have cost R178.18 million in 2013. Even if only one additional day of labour is required in a ‘without glyphosate’ scenario, the negative impact on farm profit would be considerable.

Table 22: Cost of potential additional labour days in a ‘without glyphosate’ scenario

	Area (ha)	Daily wage rate (ZAR)	Extra labour days / ha and cost implication				
			1	2	3	4	5
Citrus	62 000	69.42	4 304 040	8 608 080	12 912 120	17 216 160	21 520 200
Forestry	1 270 000	65.94	83 743 800	167 487 600	251 231 400	334 975 200	418 719 000
Wine and table grapes	125 965	69.42	8 744 490	17 488 981	26 233 471	34 977 961	43 722 452
Sugar cane	264 409	69.42	18 355 273	36 710 546	55 065 818	73 421 091	91 776 364
Total cost of extra labour days			115 147 603	230 295 206	345 442 809	460 590 412	575 738 015

With glyphosate ‘freeing-up’ employed labour, farm workers are able to perform other vital farming activities to the benefit of the total farming enterprise. In 2012/13 South Africa exported citrus to the value of R7 981 million rand and table grapes valued at R4 576 million. Any yield reduction in these high value commodities could be extremely costly.

6.5 Economic impact conclusion

By focussing on the gross margin per hectare impact of a ‘no glyphosate’ scenario, the value of glyphosate for South African farmers was estimated. The assessment focussed on the three main glyphosate users, namely maize, wheat and soybeans for the 2012/13 production season. A number of relatively conservative assumptions were made in order to insure that the value of glyphosate is not over-estimated.

Depending on potential yield loss assumptions, the value of glyphosate in the maize sector was estimated to be between R525 million and R2.203 billion with herbicide tolerant and stacked gene farmers enjoying the biggest benefit from the use of glyphosate. Glyphosate’s value for wheat farmers was estimated to be between R123 million and R485 million with the higher adoption usage rate (75%) and 10% potential damage scenario presenting a realistic value estimation of R335 million for the 2012 season. Soybean farmers making use of conservation tillage practises stand to lose the most from a potential loss of glyphosate as a production tool and the value of glyphosate for soybean farmers was estimated between R148 million and R693 million with the most probable value estimated at around R412 million.

In total for the three main glyphosate using crops, maize, wheat and soybeans, the value of glyphosate in the 2012/13 production season is estimated to be between R796 million and R3.381 billion, i.e. between 1.9 and 8.2 times the value of the glyphosate used in the production of these crops.

This assessment only focussed on the direct farm-level impacts (yield and cost of production practice changes) of a ‘no glyphosate’ scenario and the impact of decreased crop production on the rest of the

economy is not taken into consideration. For instance, a decrease in maize production, due to a lower yield, would have led to decreased foreign currency earnings from decreased exports (SA is a surplus maize producer) and decreased wheat and soybean production would have led to foreign currency outflows as SA would have had to import more of these products (SA is a deficit wheat and soy producer). The economic impact of the potential foreign currency loss, taking into consideration the direct and indirect economic multiplier effects, would be considerable. The current account value of glyphosate is not quantified for this assessment but the impact potential decreases in production would have had on commodity and associated food prices is addressed next.

7 Impact on food price

Using BFAP's sector model, which is able to simulate different yield or production impact scenarios for all the main SA crops in a partial equilibrium approach, 5, 10 and 15 percent yield damage scenarios were run for specified maize, wheat and soybean hectares. It was found that these relatively small yield impacts for certain producers had a relatively small impact on the producer and consumer prices.

As was indicated in section 6.1, South Africa is a net exporter of maize and in the 2012/13 season the maize harvest was large enough so that a 5% and even a 15% yield effect for HT+BR farmers would not have resulted in a considerable producer price increase. It was found that an assumed 5% yield decrease for HT+BR farmers under a 'without glyphosate' scenario would have a very small producer price effect (<1%) and even a 15% yield decrease would result in only a 2.1 – 3.0 percent increase in producer price. The producer price increase effect would thus not be large enough to compensate for the yield decrease effect and farmers would be worse-off.

A 5% yield decrease for HT+BR farmers would have resulted in a 2 cent/kg increase in the consumer maize meal (flour) price. This seems hardly significant, but when considering that in 2013 approximately 2.7 million tons of maize meal was sold for human consumption, the aggregate consumer welfare loss value would be substantial. Under a 'without glyphosate' scenario assumed yield loss of 5%, consumers would have lost R45 million and under a possible 15% yield loss, R189 million.

As SA is a net importer of wheat, wheat traded at import parity prices for the 2013 marketing year and an assumed 5 or 15 percent yield impact had no or little effect on the domestic producer or consumer price.

In 2012/13, SA soybeans traded close to the export parity price with SA exporting raw soybean materials due to limited local crushing capacity. This situation is however currently changing with erection of additional crushing plants and it is expected that soybean prices would move closer to import parity levels in the near future. However, the BFAP model showed that in 2012/13 relatively small yield changes had no impact on the producer price or the price of soybean derived products.

8 Environmental impact of glyphosate

Glyphosate is considered to be a low risk herbicide in terms of toxicity and environmental effects (EPA, 1993) and under normal usage conditions studies have found no adverse effects on birds,

mammals, amphibians, fish or insects (Franz, Mao & Sikorski, 1997; Williams, Kroes & Munro, 2000). In glyphosate resistant crop production systems, glyphosate has to a large extent replaced herbicides that are significantly more toxic and that persist longer in soil and water (Shaner, 2000; Cerdeira & Duke, 2006; Duke & Powles, 2008). Under a ‘no glyphosate’ scenario, it is likely that these environmentally more damaging herbicides would see increased usage.

Fernandez-Cornejo, et al. (2012) showed that in the United States there was a direct link between adoption of herbicide tolerant crops and the implementation of conservation tillage practises. This has also been observed in South Africa (Gouse, 2014). Some environmental benefits of conservation tillage includes an improvement in soil structure that facilitates improved drainage and water holding capacity that in turn reduces the extremes of water logging and drought; improvements to soil structure can also reduce the risk of runoff and pollution of surface waters with sediment and chemical pesticides and fertiliser; reducing the intensity and frequency of soil cultivation lowers energy consumption and the emission of carbon dioxide while carbon sequestration is raised through an increase in soil organic matter (Holland, 2004). While conservation tillage can also be practised by farmers planting conventional crop varieties (not HT crops), glyphosate with its systemic mode of action is a rather crucial for the control of deep rooted plants in a conservation tillage production system. It can be expected that in a ‘no glyphosate’ scenario, the employment of conservation tillage practises would be reduced considerably, to the detriment of the environment.

This assessment’s focus on the environmental value of glyphosate is limited to the change in CO₂ emissions linked to the change in weed control practises under the hypothetical ‘without glyphosate’ scenarios for the 2012 production season for maize, wheat and soybeans. By using the *Cool Farm Tool* developed by Unilever, the University of Aberdeen and the Sustainable Food Lab (<http://www.coolfarmtool.org>) the CO₂ emissions for ‘with and without glyphosate’ scenarios were calculated and compared. The difference in CO₂ emissions for the two scenarios is a result of increased mechanised weed control required under the ‘without glyphosate’ scenario as presented in the comparison tables for maize, wheat and soybean in the economic value section (Section 6) of this report. The CO₂ calculations were done in line with Section 6’s assumptions made regarding provincial production of maize, wheat and soybeans, GM crop adoption and conservation tillage and glyphosate usage. This comparison (Table 23) only calculates the direct CO₂ benefit of glyphosate by considering the litres of fuel used in the ‘with and without glyphosate’ scenarios and the benefit conservation tillage has for carbon sequestration is not taken into consideration.

Table 23: Difference between CO₂ emissions under ‘with and without glyphosate’ maize, wheat and soybean production scenarios

	Fuel (diesel) difference (litres)	CO ₂ emission difference (tons)**	Number of average cars (5.1 t/year)
Maize	13 522 000	36 237	7 105
Wheat*	1 700 000	4 557	893
Soybeans	7 682 000	20 588	4 037
Total	22 904 000	61 381	12 036

*A 75% glyphosate adoption rate is assumed

** One litre of diesel produces 2.68 kg of CO₂

In 2012, South African maize, wheat and soybean farmers were able to save about 23 million litres of diesel by using glyphosate. In a ‘without glyphosate’ scenario, mechanical weeding would have

released more than 61 thousand tons of CO₂ into the atmosphere, equivalent to the yearly CO₂ emissions of 12 thousand average cars.

9 Socio-economic impact of glyphosate

A number of international studies showed that the use of glyphosate in combination with glyphosate tolerant crops result in lower expenditure on herbicides, labour, machinery and fuel (Carpenter & Gianessi, 1999; 2000; 2002; Fernandez-Cornejo, Klotz-Ingram & Jans, 2002; Marra, Piggott & Carlson, 2004; Qaim & Traxler, 2005). Though most studies found that HT crops did provide substantial benefits through saving on weed control activities, a number of these studies showed that in some cases, due to the increased HT seed price (compared to conventional) the impact on gross margin was marginal or even negative. Efforts to understand why farmers continue to adopt HT technology, even without clear direct profit advantages found that weed control with HT and glyphosate is easier and there is a substantial saving in management time. Fernandez-Cornejo, Hendricks & Mishra (2005) found that adoption of HT soybeans was associated with higher off-farm income and overall household farm income as HT crops free up labour and management for off-farm employment, leisure or the expansion of the farm. Gardner, Nehring & Nelson (2009) also found savings in management labour and Hurley, Mitchell & Frisvold (2009) showed that these non-pecuniary benefits were the main reason for the remarkable adoption rate in the US especially.

9.1 Commercial maize, wheat and soybean farmers

The majority of SA farmers using HT technology indicated the main benefit of using a herbicide tolerant crop in combination with a broad spectrum systemic herbicide, such as glyphosate, to be the ease of weed control and management. To a large extent this was also indicated by farmers using glyphosate on conventional or Bt crops. Farmers indicated that because pre-plant burn-down can be done effectively they are able to plant at the 'right time', resulting in higher yields. For post emergence weed control, HT crops farmers also indicated that weed control could be done at the right time and more effectively and farmers do not need to worry about not being able to control weeds in wet lands or struggle to apply a number of selective herbicides throughout the rain season. However, these indications are based on only a small group of surveyed farmers and a more in-depth SA HT crops study, drawing on a larger farmer sample would be needed to identify the non-pecuniary impacts and determine how representative these findings are.

9.2 Smallholder subsistence maize farmers

Data on the use of herbicides by South African small-scale and subsistence farmers is not available but there is general consensus that few smallholders make use of herbicides, possibly with the exception of small-scale sugarcane farmers. Maize is the crop planted by most smallholders and subsistence farmers and herbicide use is limited, with post emergence weed control predominately done by family members using hand and hoe. Monsanto introduced herbicide tolerant maize to smallholder farmers in 2003 in a couple of production regions and farmers and government extension officers received training on the use of herbicides through a number of farmer-days. The University of Pretoria has been studying the adoption and farm-level impacts of insect resistant (Bt) maize in these regions since 2001 and also included HT maize in the study focus from 2005. Studying

smallholder farmers in northern KwaZulu-Natal, Gouse (2012) found that farmers who plant HT maize seed and used a no-tillage practise locally referred to as ‘planting-without-ploughing’ while controlling weeds with a post-emergent glyphosate application, enjoyed a yield increase due to more effective weed control but importantly saved considerably on weeding labour.

By analysing three years of data (2006/07, 2007/08 and 2009/10) for farmers planting conventional and HT maize, Gouse, Sengupta and Zambrano (2014) found that HT maize was particularly popular in households headed by female farmers. By considering the labour use implications of HT and glyphosate adoption, the reason for this became apparent. Over the three season period farmers planting conventional and Bt maize and controlling weeds by hand and hoe, spent 19, 17 and 21 days (7 hour days) per hectare on weed control. On average 59% of this manual weeding was done by female household members and 9% was done by children younger than 16. Most HT adopters in contrast did not do any manual weeding. By using HT maize and applying glyphosate post-emergent, smallholder farmers in KwaZulu-Natal were able to save substantially on weeding labour, with female farmers and other female household members benefitting the most. On average HT maize adopting households’ females were able to spend 11 days of weeding less than their conventional and Bt maize planting counterparts; males saved 6 days and children 2 days.

Gouse, Sengupta and Zambrano (2014) found that male farmers and male household member planting glyphosate tolerant HT maize were able to spend more time tending to cattle and goats. Males also spent more time on off-farm income generating activities like building, wood work, ‘piece jobs’, hunting or spending more time on permanent employment. Female farmers and female household members in HT adopting households spent most of their extra time doing housework (cleaning, cooking and tending to children) and working in their own or community vegetable gardens (possible food security impact). Children spent more time relaxing (playing, swimming and watching TV) and doing school homework and housework.

It is important not to contribute the labour saving benefits of a glyphosate tolerant crop to glyphosate only. When comparing a hand and hoe weed control system with a system where smallholders use a herbicide tolerant crop and a post-emergent broad-spectrum herbicide, it is not surprising that the difference in labour use is considerable. When compared to farmers using selective herbicides, the labour saving effect was not as large (Gouse, 2012). However, few smallholder maize farmers in SA (and the rest of Africa) make use of selective herbicides and generally farmers who do, still have to spend time manually hoeing and pulling especially couch grass between and within maize rows.

10 Summary and Conclusion

This study endeavoured to assess the value of glyphosate in the South African agricultural sector with focus on the 2012/13 agricultural season. Glyphosate is the most used herbicide in South African and in 2012 more than 23 million litres of glyphosate was sold at an estimated value of R 641 million. Glyphosate is a highly effective broad spectrum herbicide and the only herbicide on the market with a systemic mode of action. Glyphosate is considered to be, based on numerous scientific studies environmentally and toxicologically safe when used according to label instructions. Glyphosate is marketed under more than twenty trade-names in SA and is extensively used in the timber, horticulture, sugar and viticulture industries. The main users of glyphosate in SA are however maize, wheat and soybean farmers and in 2012 these farmers used 65% of all glyphosate sold in SA.

Making use of 'with and without glyphosate' scenario comparisons the assessment showed that glyphosate is immensely valuable to the agricultural sector. In monetary terms and depending on rather conservative yield assumptions the value of glyphosate in the maize sector was estimated to be between R525 million and R2,203 billion in 2012 with genetically modified herbicide tolerant and stacked gene maize farmers enjoying the biggest benefit. Glyphosate's value for wheat farmers was estimated to be between R123 million and R485 million with the higher adoption usage rate (75%) and 10% potential damage scenario presenting a realistic value estimation of R335 million for the 2012 season. Soybean farmers making use of conservation tillage practises value glyphosate highly and under a 'without glyphosate' scenario stand to lose between R148 million and R693 million with the most probable value estimated at around R412 million.

Adoption of conservation tillage practises have increased considerably in SA since the introduction of glyphosate tolerant soybeans in 2001 and maize in 2003. Implementation of different degrees of reduced tillage practises have brought about substantial environmental benefits not only infield (soil) but also in the decreased emission of greenhouse gasses. This study showed that by using glyphosate instead of mechanized weed control, maize and soybean farmers (and wheat farmers to a lesser extent) were able to save about 23 million litres of diesel with a yearly CO₂ emission equivalent of 12 thousand average cars.

Determining the socio-economic impacts of using glyphosate in SA requires a larger and more in-depth assessment. However, the majority of the surveyed large-scale farmers planting HT maize and soybeans indicated the ease of weed control and management as the main benefit. A study of small-scale HT maize adopting farmers also showed the ease of weed control to be a major benefit with especially female household members being able to spend less time doing arduous manual weeding.

This study confirmed the immense value glyphosate has as a production tool in the South African agricultural sector. It therefore serves as a backdrop to the problem of weed resistance to glyphosate. Worldwide 31 weed species have been reported to be resistant to glyphosate. Three of the 31 reported glyphosate resistance weeds occur in South Africa and resistance has been proven in parts of the Western Cape. With increased adoption of glyphosate tolerant crops and increased sector wide use of glyphosate due to its environmental safety, relative affordability and efficacy, responsible use and stewardship have become even more vital to preserve glyphosate's value for the future.

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