THE EFFECT OF GENETICALLY MODIFIED MAIZE ON BIODIVERSITY IN SOUTH AFRICA

BY

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ABSTRACT

South Africa is a maize producing country. Similar to many other African countries, maize is one of the primary staples. Genetically modified (GM) maize was introduced in 1997 to the South African agricultural sector by multinational seed companies. At present thirteen yellow and six white GM maize hybrids are grown in all the major local cultivation areas. About 10% of all local maize hectares are under GM cultivars, which is about half of the global average for GM maize producing countries.

Biotechnology has been the focus of much controversy. This is hardly surprising, since it is a technology that exerts a change on the environment and therefore causes a shift in biodiversity. This study focuses on the effect that GM maize has on biodiversity and the factors that contribute to this change in the maize industry.

The effects of biotechnology can be felt in the political, economical and environmental arenas of society. The United States of America and the European Union are locked in a trade war over the safety of bio-engineered crops. Certain African countries are very reluctant to import GM maize due to these prevailing uncertainties. At a global level, the Cartagena Protocol on Biosafety seeks to address these concerns. On a national level, South Africa has enacted the Genetically Modified Organisms Act (Act No. 15 of 1997) to provide a mechanism to implement South Africa's obligations to the Cartagena Protocol.

The farming community has been struggling to cope with the new biotechnology, which places a heavy burden of responsibility on them. The struggle to protect non-GM and organic crops against contamination from cross-pollination seems never-ending. The labelling of GM products in order to have liability and traceability in the event of mishaps has been requested around the world.

All of these factors contribute to the rapid change that is observed in biodiversity. It is apparent that a large pool of new genetic material is available now and the impetus is there to take advantage of this. It remains to be seen if biotechnology will be the answer to the looming question of world hunger. At the very best, it is an immediate solution toward safe-guarding crops against certain pests and diseases.

OPSOMMING

Suid-Afrika is ′n mielie-produserende land. Soortgelyk aan ander Afrika-lande is mielies een van die hoof stapelvoedsels. Geneties gemanipuleeerde (GM) mielies is in 1997 deur multinasionale saadmaatskappye aan die Suid-Afrikaanse mark bekendgestel. Tans word dertien geel- en ses witmielie kultivars geplant in al die hoof landboustreke. Ongeveer 10% van alle plaaslike mielie-hektaar word deur GM kultivars beslaan, wat die helfte is van die gemiddelde vir GM produserende lande.

Biotegnologie word huidiglik vurig gedebateer. Dit is verstaanbaar, aangesien dit ′n tegnologie is wat ′n invloed uitoefen op die omgewing en dus ′n verandering in biodiversiteit teweeg bring. Die fokus van hierdie studie is gerig op die effek wat GM mielies het op biodiversiteit in Suid Afrika, asook die faktore wat daartoe bydra.

Die effekte van biotegnologie kan waargeneem word in die politieke, ekonomiese en omgewingsarenas van die samelewing. Die Verenigde State van Amerika en die Europese Unie is gewikkel in ′n handelsoorlog oor die veiligheid van biotegnologiese produkte. Sekere Afrika-lande is huiwerig om GM mielies in te voer todat die kwessie opgelos is. Op ′n internasionale vlak streef die Cartagena Protokol daarna om hierdie sake te oorbrug. Op ‘n nasionale vlak het Suid-Afrika die Genetiese Gemanipuleerde Organisme Akte (Akte No. 15 van 1997) aanvaar om meganismes te skep vir die land se verpligting ten opsigte van die Cartagena Protokol.

Die landbougemeenskap ondervind uitdagings om die nuwe biotegnologie te bemeester en te verantwoord. Verder moet organiese en nie-GM oeste beskerm word teen gene-besoedeling as gevolg van kruisbestuiwing. Verder word die etiketeering van GM produkte, om naspeurbaarheid en verantwoordbaarheid te vergemaklik indien ′n ongeluk sou vookom wêreldwyd aangevra.

Al die faktore dra by tot ′n verandering in biodiversiteit wêreldwyd. Dit is duidelik dat ′n groot hoeveelheid nuwe genetiese materiaal nou beskikbaar is en voordelig benut kan word. Dit is onseker of biotegnologie die oplossing gaan wees vir wêreldhongersnood, maar dit verminder ten minste die hoeveelheid plaagbestryders wat gebruik word en verleen beskerming teen sekere plantpeste en plantsiektes.

ACKNOWLEDGEMENTS

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CHAPTER 1 – INTRODUCTION

1.1 Introduction

South Africa is a maize producing country. Similar to many other African countries, maize is one of the primary staples. Multinational seed companies such as Monsanto, Pioneer and Pannar introduced genetically modified (GM[1]) maize in 1997 to the South African market. For the 2003/2004-crop season these companies marketed 13 yellow and 6 white GM maize hybrids that were grown in all of the major cultivation areas.

The availability of GM maize and the farmers' willingness to adopt biotechnology products enabled the multinationals to grab a substantial portion of the South African maize market in a short period of time. It is estimated that 20% of yellow and 5% of white maize in South Africa will be of the GM variety for the 2003/2004-crop season. That amounts to 300 000 hectares or 10% or the total planted maize area. A definite alteration in the maize market has been set in motion. This change is manifested in two ways: firstly an increase in the number of available GM maize cultivars and secondly a shift in maize production patterns in favour of GM maize cultivars.

To put the GM maize development in South Africa in perspective, it is necessary to recognise the phenomenal growth that took place in the GM industry. The International Service for the Acquisition of Agri-biotech Applications (ISAAA, 2003) reported that for the 7-year period 1996 to 2002, the total global GM cultivated area increased by 35-fold. ISAAA further stated that the global area of GM crops continues to grow at a sustained rate of more than 10% per year. These two observations give some indication of what might be in store for South Africa in the future. If South Africa follows the world-wide trend as observed in the GM crop markets, there will be an increase in local GM crop production. This will especially be

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[1] Genetic Modification – "Is a scientific alternation that uses biotechnology to change an organism to capitalise on selected/chosen characters such as frost resistance, insect or disease resistance and larger yields. Gene splicing and cross-species breeding are made possible through genetic engineering." (Nevin, 2002).

visible in the local maize industry, which is one of the biggest consumers of biotechnology.

Such a big change towards GM crop technology does however have a few important implications. The first implication is that a change in the environment is taking place, in particular a change in biodiversity. The second implication is that this transformation in biodiversity is a process that happens over time and is governed by certain rules. The third implication is that GM technology is an agent of change that is introduced by mankind into nature and as such is driven by people.

1.2 Background

At the root of the quest for biotechnology is hunger. The drive to improve food production has been part of man's psyche since the dawn of time. Demographers warned that the continued world-wide population explosion will demand that new solutions be investigated to feed the projected 9 billion people of the year 2050 (Nevin, 2002).

The first big breakthrough in generating adequate amounts of food came with the Green Revolution in the 1960s, which increased food production by the use of higher-yielding varieties of rice, wheat and maize to feed the growing populations of especially the developing nations.

With the Green Revolution the proportion of undernourished people dropped to 40% and remained so until today. Though the global food production is enough to feed the current world population, the distribution of food for various reasons is inadequate to realise this requirement. By increasing food production locally the world's hungry populations can be fed. It is therefore clear that a second Green Revolution is needed to make up for local food shortages and biotechnology will be the means as to achieve this goal.

Wisniewski *et al*. (2002) states that the second Green Revolution has been termed as "*Doubly Green*" because of the need for this new agricultural revolution to be both more productive and more environmentally friendly in terms of avoiding accompanying pollution and the conservation of natural resources.

What form will the second Green Revolution take on? Plant breeders feel that they have most likely exhausted the potential to improve crops using within-species genetic diversity. The arrival of sciences where genes can be moved in-between species has opened up a whole new avenue for crop improvement. These sciences were aggregated into one, namely biotechnology.

South Africa is the only member of the 14-nation South African Development Community (SADC) that licensed the production of Genetically Modified Organisms (GMOs). This government policy has opened the doors in South Africa for multinational seed companies and farmers alike to take advantage of the benefits of biotechnology, especially in the maize industry. As can be expected, there are proponents and critics to this new policy.

The critics list a wide range of issues that should be addressed regarding genetically engineered foods (Uzogara, 2000):

(i) the right of the consumer to know what is in the food they buy;
(ii) the right of individual countries to set up their own standards;
(iii) the relationship between multinational companies, scientists, farmers and the government regulators;
(iv) the impact of GM crops on biological diversity;
(v) the possible negative impacts of GM crops on the security of the food supply;
(vi) the possible spread of antibiotic resistance to man and livestock;
(vii) the possible development of resistance by insects to GM plant toxins;
(viii) the ecological impact of growing GM foods.

On the other side of the spectrum, the proponents of genetic engineered foods advocates that (Nevin, 2002; Uzogara, 2000):

(i) the genetic engineering techniques had become simplified, which enables the application of these methods to the large scale production of food and drugs;

(ii) the possibility to produce faster growing, disease-, weather-, and pest-resistant crops and herbicide tolerant crops with higher yield per hectare in both size and quantity;

(iii) the production of tastier, safer, more convenient, more nutritious, longer lasting and health enhancing foods;

(iv) the solving of world food shortages and feeding the hungry;

(v) the reduction in use of herbicides and pesticides.

Gwin (2001) declared that the three major concerns of the critics boiled down to the possible effects of GM crop production on human health, the environment and trade. The proponents again argue that GM crops will increase food production and make better use of existing resources. Against that background the following question needs to be asked: What is going to happen in the maize industry in South Africa?

1.3 Purpose of the Study

The aim of this study is to investigate the effect which GM maize cultivars have on biodiversity in South Africa. The study is important because a new agricultural revolution is occurring which is changing the natural selection processes that would otherwise take place in nature. The process is driven partially by man and partially by nature, which makes it a high-risk exercise because control is not centralised anywhere. The introduction of biotechnology into the food chain therefore comes with certain benefits and risks, which should be clearly understood from an environmental perspective.

The substitution of non-GM maize hybrids with GM maize hybrids carries an inherited risk. The risk is a loss of genetic diversity in the maize populations, which is needed to protect all species that depend on maize as a source of food. A loss in biodiversity is viewed with the same concern as a change in climate, because both sustain life on Earth.

1.4 General Problem Definition

The genetic manipulation of crops has become a growing business globally. The success of biotechnology can be observed by noting that GM markets are expanding rapidly at the cost of non-GM markets. The impetus behind biotechnology and the new agricultural revolution is the search for higher yields to feed the growing world populations, particularly in the developing countries.

As with any emerging technology, biotechnology and its application in the agricultural sector come with various problems, issues, impacts and mitigatory measures. The most profound effect that biotechnology will have on the environment will be *a change in biodiversity*. The natural plant selection processes have been accelerated by the introduction of artificial gene swapping as orchestrated by scientists. The question that needs to be answered is as follows**: To what extent will biodiversity be affected by the introduction of GM crops?**

For the purpose of this study, the term "*a change in biodiversity*" will indicate the following: It will be an alteration in the genetic makeup within the different populations of a specific specie. Biodiversity consists of three components in the environment, namely genetic diversity, specie diversity and ecosystem diversity. The genetic manipulation of crops occurs on the genetic level, hence this study focus on the genetic diversity component of biodiversity. A change in biodiversity therefore means an increase or decrease in the variety and abundance of populations within a specific specie.

1.5 Specific Problem Definition

Due to the adaptability of maize, it spread rapidly around the globe after the Spaniards exported the plant from the Americas in the 15th and 16th centuries. Most countries in the world produce maize and it is the 3rd most planted field crop after wheat and rice. In South Africa maize ranks 1st as a staple food, which emphasises its importance locally. It stands to reason that a change in biodiversity will be most noticeable in the South African maize environment. This change has already started, with the cultivation of yellow GM maize in 1997 and white GM maize in 2002.

GM maize is entering the local food chain two-fold. Firstly by South African farmers which plant GM maize in the expectation of better yields and less toxic insecticide consumption due to the GM seed's resistance to the stalk borer worm. Secondly, GM maize enters the local food chain via imports when South Africa buys maize on the world markets to supplement local shortages (Ferreira, 2002; Namibian, 2002).

In a South African context, the specific problem that needs to be answered is as follows: **To what extent will the biodiversity of South African maize be affected and what are the factors or processes that will facilitate this change?**

In order to achieve the primary objective of the study, a number of sub problems will be investigated. These sub problems define the boundaries of the specific problem, because these factors either enhance or diminish the rate of GM maize adoption by farmers in South Africa. GM maize is therefore the driving force behind the change in maize biodiversity in the environment.

Sub problems:

Multinational seed companies have penetrated the South African maize market, with various GM maize cultivars available to suit the needs of the individual farmers. The following questions will give an indication as to how big a shift in biodiversity has occurred and can be expected.

(i) How many different GM cultivars are available now?

(ii) How widely are GM cultivars currently being used in cultivation?

(iii) Taking world and local trends into account, what forecasts can be made in terms of GM maize market growth for South Africa?

International and national politics play a major role in the implementation of biotechnology in the agricultural sector. The influence of the European, American and African viewpoints have a direct impact on the progression of the South African GM maize market, particularly in terms of world markets, trade treaties and legislation. The following factors need to be taken into account:

(i) What are the American, European and African viewpoints on biotechnology?

(ii) Which international and national treaties and legislation are in effect?

GM maize can only be financially viable if there is a market for it, and people determine the market. The higher the demand in the market, the bigger the change in biodiversity that will occur due to farmers who plant GM maize. It is therefore crucial to understand the views of the South African public regarding the consumption of GM products. The issues that will be examined are:

(i) How aware is the South African public of foods that contains GM products?

(ii) Does the public require that GM food products be labelled to enable them to exercise their right to an informed consumer choice?

Farmers play a vital role in the containment of seed contamination and cross-pollination between GM and non-GM maize fields. The role of farmers will be investigated in terms of:

(i) What best practice farming methods are available to enable farmers to segregate GM and non-GM crops?

(ii) Do farmers practise due diligence in their farming methods?

If biodiversity is going to be changed on a major scale, it is important to look at the benefits that come with such a change. The advocates of biotechnology predict that GM crops are the answer in feeding the growing world population by producing higher yields and using less herbicides and pesticides. That is a bold statement. Taking it in the maize context, the following issues need to be scrutinised:

(i) Is GM maize the answer to the world's maize needs?

(ii) Does South Africa need GM maize to feed its people?

To answer that, the world and the South African maize scenarios will be investigated in terms of the amount of hectares under cultivation, ton per hectare yield, per capita consumption and population growth.

1.5.1 Study Area

The study area is defined as within the boundaries of South Africa, with emphasis on all the major maize cultivation areas. The Free State, North West and Mpumalanga provinces contribute 90% to the total national area that is cultivated by maize.

Biotechnology that drives the change in biodiversity has it roots in American multinational seed companies; hence it is necessary to include the international aspects of the problem. This is however not limited to America, but also includes the European and African viewpoints.

1.6 Research Methodology

A specific problem was identified that exists in the environment. The specific problem was broken down into a number of sub problem statements, which forms the basis of the research that is to be performed. Each sub problem consists of one or more questions that focus upon a certain critical aspect of the specific problem. This approach was necessary because of the holistic nature of biodiversity in the environment. It is therefore not possible to study biodiversity without looking at the factors that influence it.

The sub problems will each be addressed in a separate chapter, by investigating, analysing and interpreting relevant data, as obtained from literature reviews, statistical data collections and personal communications with industry experts. A conclusion at the end of each chapter will mark the end of that specific sub problem.

The synthesis will give an overview of the study that will be conducted, together with concluding remarks regarding the specific problem. The synthesis will be divided into sections consisting of an overview of the problem, the data analysis, and will finish with the results, the recommendations and the conclusion.

The Research Framework as depicted by Figure 1 gives a short overview of the research process that will be followed. The framework has a top-to-bottom structure, which starts with the specific problem statement and ends with the conclusion. The data analysis will be conducted in two phases, first by investigating the current status of the environment in terms of GM penetration in the South African maize market and secondly, by investigating the factors that influence and affect maize biodiversity globally and specifically in South Africa.

RESEARCH FRAMEWORK

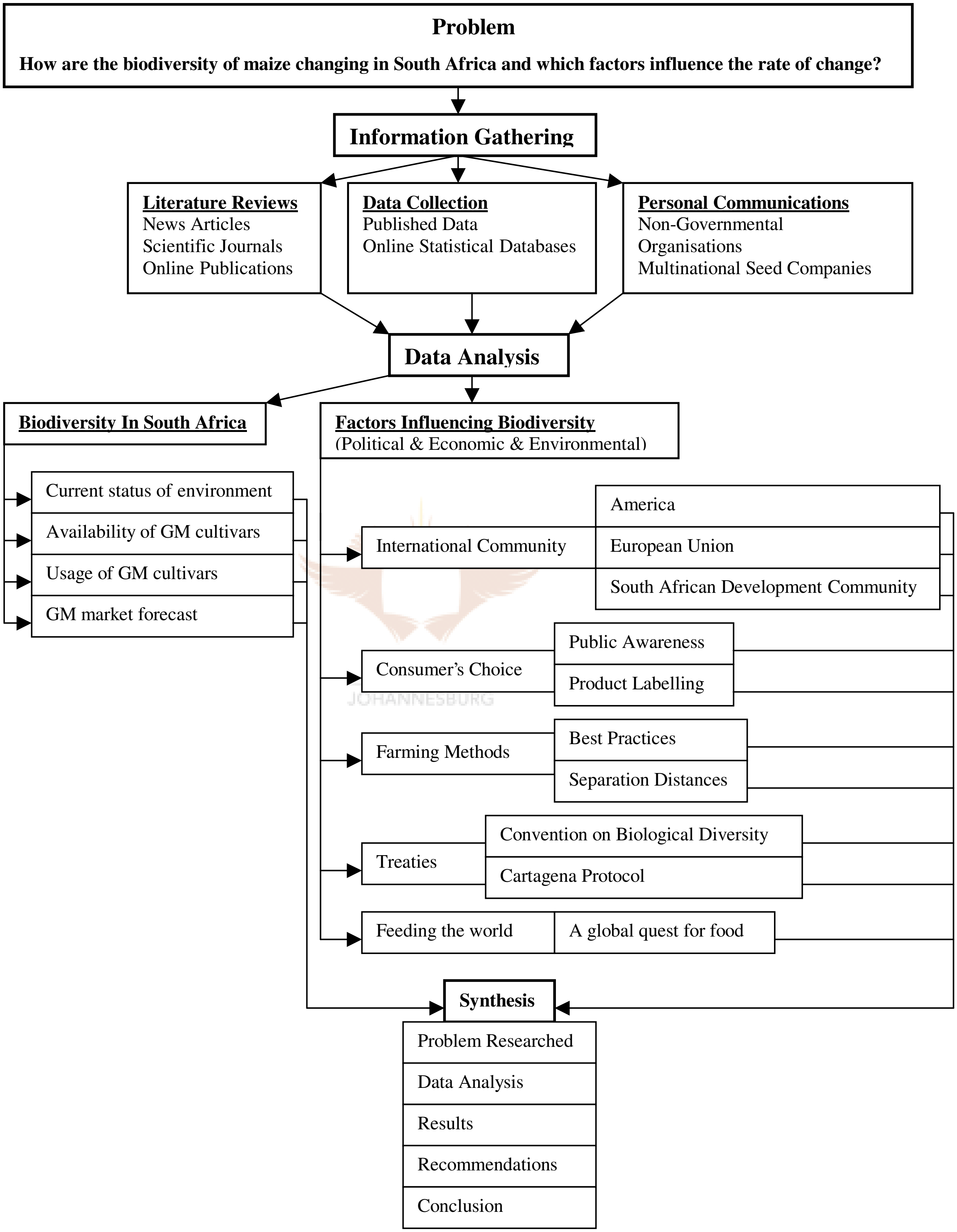

Figure 1: Research Framework

CHAPTER 2 – GM MAIZE IN SOUTH AFRICA

2.1 Introduction

Multinational seed companies have penetrated the South African maize market, with various GM maize cultivars available to suit the needs of the individual farmers. This has lead to the widespread use of GM maize cultivars, which again resulted in an increase in biodiversity. To gain an understanding of the scope of GM maize usage in South Africa, the following issues will be investigated:

(i) How many different GM cultivars are available now?

(ii) How widely are GM cultivars currently being used in cultivation?

(iii) Taking world and local trends into account, what forecasts can be made about the potential growth in the South African GM maize?

2.2 Geographical Distribution

Maize is cultivated in all the provinces of South Africa. Figure 2 indicates the percentage contribution of each province to the total hectares that were planted with maize in 2002/2003. The Free State, the North West and Mpumalanga provinces contributed 90% of the total area. A total of 3.1 million hectares of maize were planted in 2002/2003, with white maize contributing 2.08 million hectares and yellow maize contributing 1.02 million hectares. (CEC, 2003).

2.3 Cultivars

In South Africa GM maize is being sold mainly by three companies, namely Pioneer, Pannar and Monsanto. Nineteen hybrid varieties were on the market in 2003, with a breakdown of 6 white varieties and 13 yellow varieties as is illustrated in Table 1. The hybrids can be differentiated on the grounds of their variance in adaptability, acid soil tolerance, drought tolerance, dry down time, prolificacy, standability and yield potential (Engelbrecht[1], 2003; Green, 2003[2]; Van Der Walt[3], 2003).

[1] Personal communication: Interview with Mr. W. Engelbrecht of Pioneer (2003).

[2] Personal communication: Interview with Mr. W. Green of Monsanto (2003).

[3] Personal communication: Correspondence with Mr. P. van der Walt of Pannar (2003).

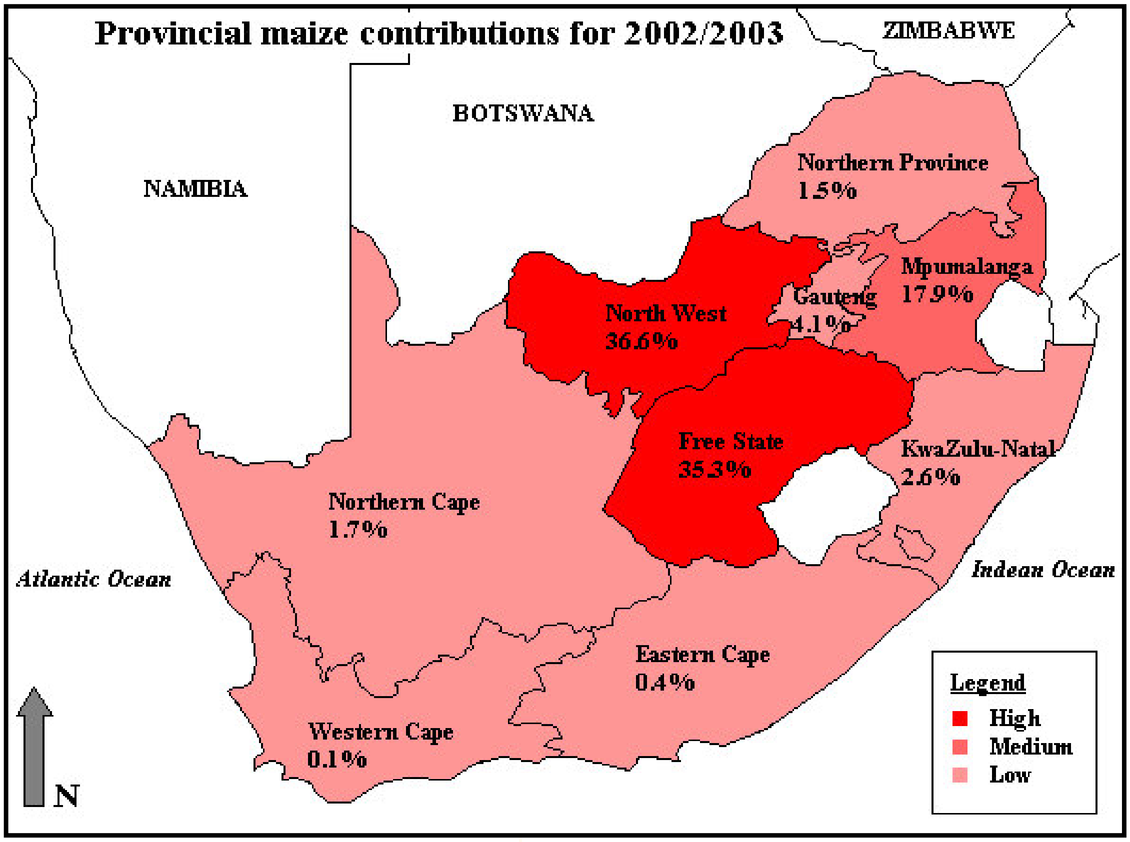

Figure 2: Provincial maize contributions in hectare for the season 2002/2003 (data from the CEC, 2003).

Table 1: Genetically modified maize varieties available in South Africa (Engelbrecht, 2003; Green, 2003; Van Der Walt, 2003).

Company	Yellow (GM)	White (GM)
Pioneer	Phb 33A14 Bt Phb 31B13 Bt	Phb 32Y53 Bt Phb 32A05 Bt
Pannar	PAN 6128 RR PAN 6124 Bt PAN 6012 Bt PAN 6000 Bt PAN 6314 Bt PAN 6994 Bt PAN 6326 RR	PAN 6995 Bt PAN 6013 Bt
Monsanto	CRN 4760 B SNK 2340 Bt SNK 2962 Bt DK618 Bt	CRN 4549 B DKC 7815 Bt

*Note: Bt/B varieties are pest resistant and RR varieties are herbicide resistant.

The Bt hybrids have been designed to protect against the maize stalk borer. *B. thuringiensis* is a bacterium that produces reasonably specific insecticidal proteins known as crystal (Cry) proteins or delta-endotoxins. After feeding on these Bt-proteins, the digestive system of the stalk borer becomes paralysed and the infected stalk borer stops feeding within hours. Bt-affected insects generally die from starvation, which can take several days (IPM, 2003; Wisniewski *et al*., 2002).

The development of a maize hybrid that is resistant against the maize stalk borer worm is significant in the South African context, because South African farms are constantly under attack by this pest. Better protection against the maize stalk borer worm reaps a benefit for the farmer in terms of higher yields and profit, as well as for the consumer, which enjoys lower prices and a steadier supply of maize.

The RR hybrids have been genetically altered to make them resistant to the Roundup Ready herbicide, which is manufactured by Monsanto. The tolerant gene comes from certain micro-organisms, which are found in the soil and have the ability to damage glyphosate. The gene is responsible for an overproduction of the enzyme EPSP (5-enolpyruvyl-shikimate-3-phosphate synthase) in the maize so that it can withstand a dose of glyphosate. Glyphosate is the active ingredient in the herbicide that kills almost all vegetation that it comes in contact with (Goldsbrough, 2003; PFCCQ, 2003).

This characteristic of RR maize hybrids is noteworthy, because it enables farmers to use less herbicide to control weeds with and obtain larger crop yields. A single dosage of Roundup Ready herbicide will usually destroy all non-RR vegetation. Before RR maize hybrids, a portion of the maize crop was also wiped out during the spraying of standard herbicides, which resulted in smaller crop yields. RR maize hybrids were the solution to limit the excessive usage of pesticides and obtaining larger crop yields.

However, Bt and RR hybrids both come with an inherited danger. Biotech critics frequently mention the dangers of creating so called "*super weeds*[*]". How will the

[*] In this context, the term "*super weed*" refers to any plant (domesticated or wild) that received a gene that is not part of its original makeup.

environment be challenged when transgenic super weeds "*escapes*" into the wild or on farms? This question might be answered in view of the fact that genetically modified plants that are engineered to be more resistant to herbicides have the same chance of survival in the wild than their non-modified siblings. Unfortunately, the plants are also modified to be better adapted for drought, pest and disease resistance, which give it an advantage over other non-modified varieties. For example, each maize hybrid could be engineered to resist a different type of herbicide, but natural occurring crossbreeding could result in the creation of a new maize plant that is immune to any or all types of herbicides. Farmers will need to resort to harsher chemicals to kill these super plants, loosing the advantage of using more environmentally friendly or standard herbicides. This natural occurrence of cross-pollination and mutation of species are also referred to as gene stacking, which could become a real danger in the future (Connor, 2002; Gwin, 2001; Leake, 2001).

In spite of the possible detrimental effects that super weeds will have on the environment, multinational seed companies are still pursuing genetic manipulation as a means to increase crop yields and company profits. Biotechnology is an advanced science, which give multinational seed companies an edge over their non-GM competitors. On the other hand, farmers have the choice to plant non-GM maize hybrids, but they are also in a competitive agricultural market that demands a high return on investment. Furthermore, faced with an increasing GM orientated seed market, the farmers might not have much choice in the matter at the end of the day.

2.4 Usage

A spokesperson of Pioneer estimated that 20% of yellow and 5% of white maize in South Africa would be of the GM variety for the 2003 maize season. That amounts to 300 thousand hectares or 10% of the total planted maize area. A further indication of the potential of GM maize is the fact that Pioneer was sold out of seed in 2003 (Engelbrecht, 2003).

The usage of GM maize cultivars depends on its availability and variety as being manufactured by the multinational seed companies. As previously stated, 19 GM maize cultivars were available for the 2003 season. Monsanto, Pioneer and Pannar combined had 82 maize hybrids available for cultivation. The breakdown between GM and non-GM maize hybrids was 19 to 63, which constitutes a distribution of 23% GM versus 76% non-GM. As mentioned previously, only 10% of the total maize area was cultivated by GM hybrids. This will increase as marketing strategies becomes more prominent.

Monsanto promoted their GM maize hybrids by handing out free seed samples to maize farmers in selected areas. Marketing initiatives like these could promote an even higher rate of adoption of GM maize in the future (Green, 2003).

These facts indicate that GM maize was well received by farmers and is having a definite impact in the maize industry. The rate of adoption of GM maize by the industry will be analysed in the next section.

2.5 Adoption Profile and Forecast

An adoption profile for GM maize in South Africa can be calculated if the historic global development of GM crops and in particular GM maize are taken into consideration. In particular, 1) the global transgenic crop market status, 2) the market share by GM maize producing countries and 3) the global GM maize adoption rate will be used to create an adoption profile for South Africa.

2.5.1 Global transgenic crop market status

The global transgenic market is dominated at the moment by four GM crops, namely soybean, maize, cotton and canola. These four crops make up nearly 100% of all GM cultivated crops. Individually, soybean contributes 62%, while maize (23%), cotton (10%), and canola (5%) fills the reaming 38% of the global GM market. Figure 3 shows the distribution between GM and non-GM cultivars within the same crop type. Even though GM soybean has a bigger market share in hectare than GM maize, the maize market is by far the biggest in terms of total hectare (141 million) under cultivation and thus has the largest scope for growth.

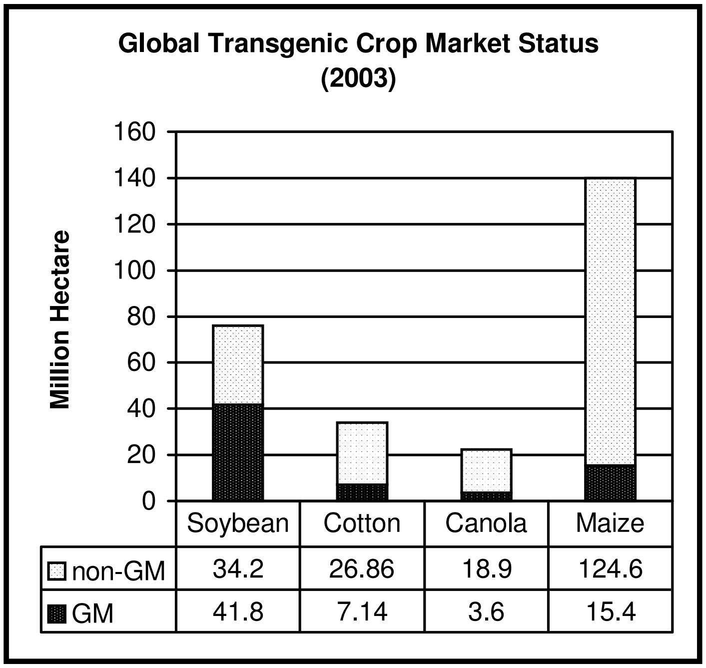

Figure 3: Global transgenic crop market share for 2003 (ISAAA, 2003).

2.5.2 Maize market share by country

Six countries are currently producing 99.4% of the world's transgenic crops, namely: Argentina, Brazil, Canada, China, South Africa and the United States of America. Collectively, these six countries contribute 51% to the global cultivated maize area and the rest of the world only 49%. As can be seen in Figure 4, South Africa has a 2% share while the United States of America dominates the market with a 20% share. China is the second biggest stakeholder at 17%. The six countries produced 15.5 million hectares of GM maize, which is 11% of the total 141 million hectares and 21% of their collective production. The most important finding from the data is the fact that on average countries that produce GM crops had a 21% adoption rate of GM maize in 2003.

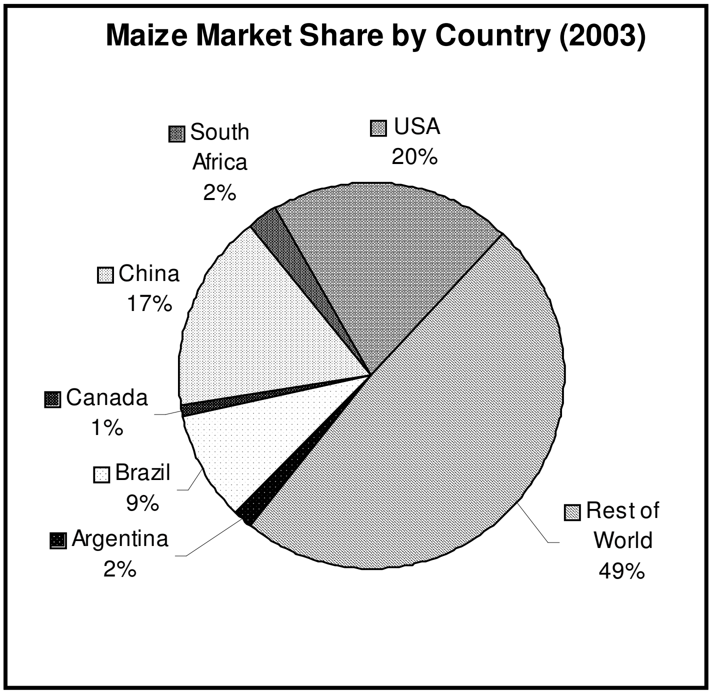

Figure 4: Maize market share by country for 2003 (ISAAA, 2003).

2.5.3 Global GM maize adoption rate

The global GM maize adoption rate gives an overview of the market penetration as depicted in Figure 5. For 2002 and 2003 the year-on-year increase in area was 26.5% and 25.0% respectively. These percentages were derived from the following data entries as depicted in Figure 5.

Year	Million Hectare	Equation	Percentage
2001	9.8	n/a	n/a
2002	12.4	(12.4 – 9.8) / 9.8 * 100	26.5%
2003	15.5	(15.5 – 12.4) / 12.4 * 100	25%

Although the linear trendline shows a steady increase, there was a slight decrease in the total hectare under cultivation for the period 2000 to 2001. Different market factors such as low seed availability, unsatisfactory seed performance, poor customer satisfaction, stringent technology agreements and government legislation could explain the decrease. Of the four major crops, canola displayed the same decrease for that period and again the subsequent increase afterwards. Soybean and cotton were unaffected during this period and continued to show an increase.

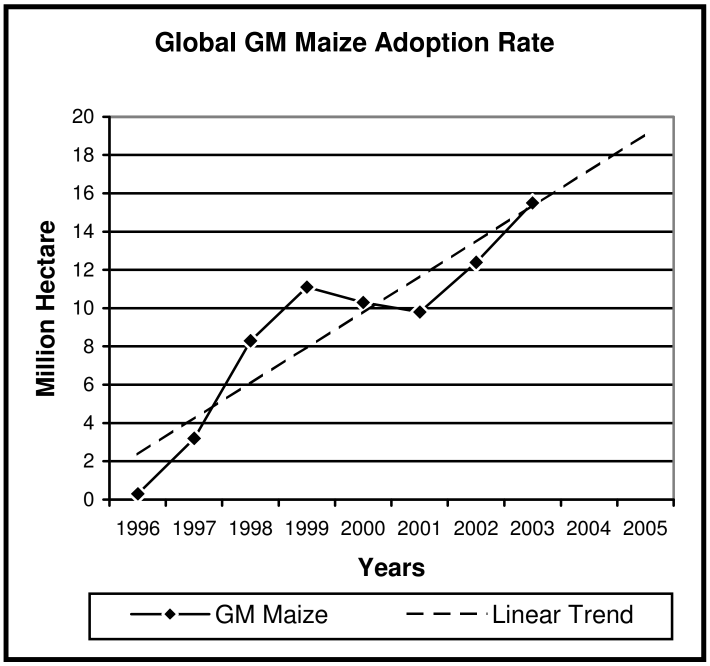

Figure 5: Global GM maize adoption rate (ISAAA, 2003).

If GM maize continues to grow globally at the rate that the linear trendline indicates, a predicted area of 19 million hectare will be under cultivation in 2005. If growth however continues at the higher year-on-year of 25.8% (the average of 26.5% and 25% as observed for the 2002 to 2003 periods), 24 million hectares will be under cultivation by GM maize in 2005. (Refer to Table 2 for further information regarding the linear equation used in the prediction, as well as the predicted values for both the linear trend and the year-on-year trend.)

The six major GM maize countries collectively produce 72.2 million hectares of maize. At the linear rate, this area will be covered 100% by GM maize in 30 years, or if the rate is at the higher year-on-year, GM maize will replace non-GM maize in a mere short 7 years. The most important fact to note from the global GM maize adoption rate is that there was a positive increase in GM maize hectare cultivation over the period 1996 to 2003. This has resulted in an 11% global adoption rate of GM maize in hectare planted.

2.5.4 South African Adoption Profile

The adoption profile of GM maize is significantly different between white and yellow cultivars. This can be contributed to the fact that yellow GM maize cultivars were first planted in 1997 while white GM maize cultivars were only introduced to the market in 2002. The head start of yellow GM cultivars can further be noticed in the discrepancy between the amount of cultivars available in 2003, 13 for yellow and 6 for white as sold by the three biggest multinational seed companies.

Table 2 lists the GM adoption rates of South Africa and the six major GM contributing countries. The table lists for each year the combined GM and non-GM maize hectare, as well as the percentage that the GM portion consists off. As can be seen, the total amount of maize hectare had stayed virtually constant over the years. Taking this fact into account, 72.2, 2.00 and 0.99 million hectares were used to calculate the 2004 and 2005 GM predicted values for each section in the table.

There is a remarkable high correlation between the South African yellow GM maize adoption rate and those of the six major GM maize producing countries. In South Africa yellow GM maize constitutes 20% of the total SA yellow maize production, while the six countries have a 21.5% GM share. As previously mentioned, South Africa has only started in 1997 with the production of white GM maize cultivars, hence the low market penetration of 5%. White maize production in South Africa follows more closely the early GM maize adoption profile as displayed by the six major countries. This is indicated by the arrows in Table 2 where the predicted adoption values for white GM maize were based upon the adoption rates of yellow GM maize for the period 1998 to 1999

The six countries' year-to-year prediction is slightly higher at 19.5 (2004) and 24.5 (2005) million hectares opposed to the respective 17.2 (2004) and 19.0 (2005) million hectares of the linear trend. The six countries are a very good indicator of what to expect that will happen in the future with GM maize adoption on a global scale.

The South African adoption profile is based upon the six countries' trends. However, the profile is rather different between white and yellow GM cultivars. Table 2 shows this difference clearly. White GM cultivars will most likely follow the GM maize adoption profile of the six major countries as displayed for the years 1997 to 1999, or rather 4.3% to 15.1%.

Table 2: GM maize Adoption Rates (data from ISAAA, 2003 and the CEC, 2003).

GM Maize Adoption Rates

YEAR	Six GM Producing Countries: Non-GM & GM (million ha)	Six GM Producing Countries: GM only (million ha)	Six GM Producing Countries: %	SA White: Non-GM &GM (million ha)	SA White: GM only (million ha)	SA White: %	SA Yellow: Non-GM & GM (million ha)	SA Yellow: GM only (million ha)	SA Yellow: %
1996	73.3	0.3	0.4%		n/a			n/a	
1997	74.2	3.2	4.3%		n/a			n/a	
1998	73.1	8.3	11.4%		n/a			n/a	
1999	73.3	11.1	15.1%		n/a			n/a	
2000	72.0	10.3	14.3%		n/a			n/a	
2001	71.8	9.8	13.7%		n/a			n/a	
2002	71.4	12.4	17.4%		n/a			n/a	
2003	72.2	15.5	21.5%	2.00	0.10	5.0%	0.99	0.20	20.0%
	Linear Prediction*			**Linear Prediction****			**Linear Prediction***		
2004	72.2	17.2	23.8%	2.00	0.23	11.4%	0.99	0.24	23.8%
2005	72.2	19.0	26.3%	2.00	0.30	15.1%	0.99	0.26	26.3%
	Year-to-Year Prediction			**Year-to-Year Prediction**			**Year-to-Year Prediction**		
2004	72.2	19.5	25.8%	2.00	0.13	25.8%	0.99	0.25	25.8%
2005	72.2	24.5	25.8%	2.00	0.16	25.8%	0.99	0.31	25.8%

***Note: Linear prediction formula Y = 1.8583X + 0.5**

****Note: White GM maize is still in the early stages of the adoption profile**

This is most probable, noting that white maize is currently at a 5% market share. The South African yellow GM maize cultivar will follow the normal trend as currently observed in the six major GM maize producing countries' adoption profile.

2.6 Conclusion

South Africa is a GM maize producing country. This is evident from the variety of GM maize hybrids (currently 19) that are available on the market as it is being sold by the multinational seed companies that engage in the practise of biotechnological development. This is further evident from the amount of hectare (10% of the total) that is being cultivated by GM maize hybrids. And finally, the South African yellow GM maize market has been mirroring the international GM maize adoption profile, in particular that of the six major GM maize producing countries. With white GM maize only recently being introduced to the South African agricultural sector, it is expected that it will start to show an accelerated adoption rate and will significantly contribute to the local GM maize market share.

These facts clearly indicate that South Africa will therefore continue to expand its GM maize component in the future. The availability of more and better-suited GM maize cultivars in the South African market will lead to an expansion of the local GM maize market share. The outcome of these actions is simple to predict: More GM maize hybrids will be available in the future, with non-GM maize hybrids being overtaken by better suited GM maize hybrids. This will ultimately result in a limiting of the biodiversity of maize, as non-GM hybrids become less used or even extinct.

In the next chapter the driving forces of politics and legislation will be investigated, to understand what impact that has on the implementation of GM maize hybrids in the agricultural sector.

CHAPTER 3 – POLITICAL VIEWS AND LEGISLATION

3.1 Introduction

The role of politics and economics in the implementation of GM crops in the agricultural sector cannot be emphasised enough. Governments set their GM policy by evaluating environmental, political and economic factors. In order to understand the current rate of GM implementation globally and specifically in South Africa, it is necessary to take a closer look at what is happening on the political and economic world stage. The influence of the European, American and African viewpoints have a direct impact on the progression of South African GM maize. If a favourable international climate exists for GM crops, there will be an accelerated adoption of biotechnology and an increase in biodiversity. To comprehend the international and national status quo, the following issues will be investigated:

(i) What are the American, European and African viewpoints on biotechnology?

(ii) Which international and national treaties and legislation are in effect?

3.2 America versus the European Union

The two major players in the biotechnology race are the United States of America (USA) and the European Union (EU). The outcome of this race will determine the future of biotechnology. This is by no means any normal race. On the one hand the USA and its allies are promoting the use of biotechnology, while on the other hand the EU is trying to prevent the use of biotechnology. The winner of this contest will definitely influence the global perception on the use of biotechnology.

The World Trade Organisation (WTO) will be the mechanism that will have to decide the global fate of biotechnology. The USA and EU have each taken a number of steps, which finally resulted in the USA logging a complaint with the WTO Settlement Body on 18th August 2003. The USA alleged that the EU's five -year moratorium on GM agricultural and food products had restricted their exports to the EU. The USA further claimed that this practise is hindering trade and illegal (NPII, 2003).

The dispute between the USA and the EU started in February 1997 when Austria banned Novartis Bt176 corn, which was already approved by the EU under Directive

90/220. This was quickly followed by a trend of other EU Member States banning various other EU-approved GM products. In October 1998 the EU Commission and Member States stopped the approving of all biotech crops and in June 1999 they called for a moratorium on the new approval of any agricultural biotech product. The EU Environmental Council stated that the approval of biotech products should be linked to two new rules, namely (USDA, 2003a; USDA, 2003b):

- **Traceability:** Companies must be able to trace minute levels of biotech products in food products through the commercial chain.
- **Labelling:** Food products that contain biotech products must be labelled.

The Deliberate Release Directive 2001/18 (on the traceability and labelling of GM food and feed) was then implemented in October 2002 and repealed the old Directive 90/220. The new Directive thus nullified the previous Directive hence consolidating the EU Council's position to keep the moratorium in place until the issues of labelling and traceability had been resolved (FoEE, 2003; IndyMedia Biotech, 2003; USDA, 2003a; WHI, 2003).

It is clear that the EU's moratorium would hurt the USA's export of GM products. The USA Government and biotech companies hold the position that GM foodstuffs are *"substantially equivalent"* to conventional foods or "*generally recognised as safe*" and therefore do not require explicit GM labelling, which is in direct violation of the Deliberate Release Directive 2001/18 (Smith, 2003, CFS, 2003).

The other side of the story is that the USA claims the moratorium will block GBP 2.8 billion worth of exports per year. The USA's case is further strengthened by the fact that GM crops had been introduced about five years ago into the USA markets and are eaten by millions of Americans to date without any ill effect (Daily Mail, 2002; Globeinvestor, 2003; SARPN, 2003).

The USA has also accused the EU of barely hidden protectionism to help their own farms and food industry. This accusation can be substantiated in light of the EU's High Court ruling on 9th September 2003: 'It recognises that Member States have a right to protect consumer's health, a right that clearly prevails over the freedom-of-trade principle" (Globeinvestor, 2003).

This accusation doesn't hold much weight in view of the fact that with the introduction of the new USA Farm Bill, subsidies of US$ 190 billion has been granted over the next decade to farmers (The Times, 2002).

The stage is set for a major clash between the EU and USA led camps at the WTO Settlement Body. The first step in the process was filing the case with the WTO, which is then followed by 60 days of requesting and conducting consultations. If no satisfactory resolution has been reached by then, the USA may seek the formation of a Dispute Settlement Panel, which will hear further arguments. This procedure typically takes 18 months to complete. It is highly likely that the case will go before the Dispute Settlement Panel, because whichever side looses the case, will definitely appeal. The final outcome of the case is expected in mid-2005 (USDA, 2003b).

In conclusion, it seems that the case as being brought before the WTO Settlement Body is about market share. The country that can produce the most and best GM cultivars will dominate the agricultural market eventually. The EU has opted not to compete in the GM race, but rather to protect its domestic market with legislation.

Both sides have admirable goals, which sound great on the surface. The USA wants to "feed the world". President George W. Bush in fact accused the EU of being indirectly responsible for Africa's starvation with its obstructionist stance with the moratorium on GMOs. Bush linked the stance of many African countries to reject GM food directly to the EU's position. Bush further stated that the EU's stance is based on "unfounded and unscientific fears" (Deutsche Welle, 2003).

The EU on the other hand wants traceability, labelling and liability for biotech products. This is tied in with consumer health. These objectives will be achieved by the implementation of special environmental legislation (USDA, 2003a).

In the end, the outcome of this global food fight will have a major impact on the direction that GM crops will take. If the USA led camp wins, biodiversity will increase with the influx of more GM cultivars. If the EU camp wins, world opinion on the safety of GM foodstuffs will shift and the USA won't be able to sell their products globally.

3.3 South African Development Community

The South African Development Community (SADC) was formed in 1992 when the Heads of State signed a Declaration and Treaty. At present the SADC has 14 Member States namely: Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. It is clear from the objectives of the Community that they intend to influence the political, economic and environmental situation in the Southern Africa region. From the list of SADC objectives, the following point deals with the environment (SADC, 2003):

> To achieve sustainable utilisation of natural resources and effective protection of the environment.

The SADC is very aware of biotechnology and GM crop production. This can be observed from the concerns that were raised regarding GMO maize and their effects in particular at a meeting of the SADC Post Season Regional Forum in Lusaka, Zambia 14th – 15th August 2002 (SADC, 2003):

- The effects on food safety.
- The impacts on the environment.
- Ethical issues.
- Trade with non-GMO partners.
- Intellectual property rights and access to seeds by small-scale farmers.

In response to these issues, the SADC made the following recommendations to Member States whom choose to accept GMO maize (SADC, 2003):

- Awareness campaigns should be undertaken to ensure that GMO maize is not planted.
- Member States should ensure that all GMO maize is milled into flour before any distribution to beneficiaries.

- Member States should develop capacity to deal with the GMO issues particularly for testing and monitoring.

The SADC has been monitoring the biotechnology industry closely, because it has a direct impact on the Southern Africa region. This region is frequently exposed to food shortages, which are then alleviated by food aid from the United Nations World Food Programme (UN WFP). The food from the UN WFP and other agencies are either from a GMO or partially GMO origin, which is a source of contention for the SADC countries.

International food aid to the SADC countries creates markets for GM maize producers. The size of this market is clear from a meeting held by the SADC Ministers of Food, Agriculture and Natural Resources in Mozambique on 5th July 2002, where it was announced that the region faced a cereal deficit of 5.19 million tons and a maize deficit of 3.20 million tons. It was the worst food crisis since the 1992 drought and an estimated 13 million people in the region would need food assistance until the next harvest in 2003 (SADC, 2003).

The SADC is taking a cautious approach regarding the implementation of biotechnology in its agricultural sector and in doing such, it has joined the EU camp. The SADC countries will consume GM maize if they have no other choice, but won't plant it.

3.3.1 South Africa

South Africa is the only member of the SADC countries that licensed the production of GMOs. By licensing GMOs, South Africa broke ranks with the other members of the SADC countries that are more in favour of a wait-and-see approach.

The licensing of GMOs in South Africa was not without controversy. Evidently, a senior legislator confirmed that the South African parliament planned an urgent discussion on whether the country had been rushed into accepting GM foods for its population. 'In 1994 it was just too soon for the new government to be able to apply their minds adequately to the new legislation. If we feel the legislation was rushed, we need to bring back public participation and amend the laws" the legislator concluded. The legislation that enabled South Africa to pioneer the use of GM crops in the region was prepared by the old apartheid government and enacted just months after the first democratic election (Boyle, 2002).

Currently, the Department of Environmental Affairs and Tourism (DEAT) and the National Department of Agriculture (NDA) both have responsibilities for nature conservation. This resulted in the GMO issue not being met by a united front. The NDA is responsible for creating national GMO policy in the form of the GMO Act, while the DEAT is responsible for the Convention of Biodiversity and the Cartagena Protocol. (See Sections 3.4 and 3.6.)

The division of responsibilities between national departments comes from yonder years. The South African Green Paper on Biodiversity (SA Government, 2003 online) states that 'the fragmented, polarised, and inefficient administrative and legislative structures created by apartheid resulted in no fewer than 17 government departments having a primary responsibility for nature conservation prior to the April 1994 election. Divided responsibilities, together with a duplication of effort, a profusion of laws, and most importantly a lack of co-ordination, have been major factors hampering the effective conservation of biodiversity."

It seems that the South African government had made progress by reducing the number of departments that were involved with nature conservation and building out their regulatory capacity. Reynolds (2002) reported that South African authorities stated that they are the only country within the SADC that has access to the necessary research information to make decisions on the safety of GM crops. The Directorate of Genetic Resources confirmed the statement that countries in the SADC do not have the regulatory systems in place to determine whether GMO food is safe.

The other SADC Member States apply the Precautionary Approach (see Section 3.5) when dealing with the risks of GMO production and consumption. The perception is that South Africa is making its lone stand now and will eventually become the regional leader of GMOs, acting as a springboard for western biotechnology into the rest of Africa.

3.3.2 Zambia

Of all the SADC Member States, Zambia took the most stringent view over the imports of GMO food. Zambia cried foul by mouths of their President, Levy Mwanawasa, who was quoted on international television as saying: 'It is necessary to examine the maize before we give it to our people… we will rather starve than get something toxic." (Ferreira, 2002). Mwanawasa further stated that 'Zambia stands by its stance to reject GMO maize. Other countries have accepted it because they have no choice." (Esipisu, 2002).

Zambia's circumstances are similar to what other food stricken African countries find themselves in. What sets Zambia apart from the rest is their non-negotiable stand regarding the GMO controversy. Zambia has sited a number of reasons for their reluctance to accept any GMO maize (Esipisu, 2002; Pearce, 2002; Xinhua, 2002a; Xinhua 2002b):

- There is an absence of conclusive scientific evidence that GM grains are safe for human and animal consumption.
- Zambia lacks the biotechnology and biosafety policy to manage the effects of GM grains.
- Zambia lacks the capacity to detect and manage the entry of GM grains into the environment.
- The GM variety of grains might contaminate other non-GM grains if planted by farmers.
- Export to European markets might diminish if there is a suspicion that African livestock destined for export had been raised on GM grain.

Zambia might be taking a hard-line policy regarding GM maize, but has allowed the UN WFP to distribute GM maize among refugees living within its borders. Nearly 300 thousand refugees from Angola, the Democratic Republic of the Congo, Burundi and Rwanda had been affected by food shortages in their host countries. Zambia however still refused GM food aid to be distributed to its own famine-stricken rural people (Xinhua, 2002a).

Zambia and the UN WFP had recently locked heads regarding the GM maize issue. The UN WPF had been delivering GM food as emergency aid for the last seven years, without informing the countries concerned. The UN WFP defended themselves by making the statement that they are under no obligation to alert authorities on the GM classification of maize they deliver as food aid. "We are just the middle man. If the food meets the national standards of the donors, we accept it." (Pearce, 2002).

Allegations were made that the USA is exploiting Southern Africa's drought to create markets in Africa for its large unsold stocks of GM maize. The UN WFP lashed back by saying; "We think the starving would rather eat GM grain than dirt." African countries disagreed, declaring that there is enough GM-free maize available on the world markets that could rather be supplied (Pearce, 2002).

The UN WFP eventually backed down and indicated that they would join other UN agencies such as the Food and Agriculture Organisation (FAO), the World Health Organisation (WHO) and the UN Children's Fund (UNICEF) to ensure that Zambia receives non-GM foods. The Executive Director of the UN WFP had reportedly stated: "We fully respect your right and responsibility to make the decision of rejecting GM food. We will be as responsive and as forthcoming as we can possibly be." The UN WFP had subsequently undertaken to extract GM maize from Zambia and rather distribute it to Lesotho, Malawi, Mozambique, Swaziland and Zimbabwe. (Wendo, 2003; Xindua, 2002a; Xinhua, 2002b).

The Zambia saga had set the tone for the SADC Member States most opposed to the import of GM food products and GM seed. A restriction in the import and cultivation of GM maize in the region will definitely protect non-GM maize cultivars against cross-contamination. The exception is GM producing South Africa, which does have a major influence in the region. It remains to be seen if the SADC countries will follow the lead of Zambia or South Africa.

3.4 International Treaties

The role of international treaties is vital in the conduct between sovereign states. Treaties form part of international law, which consists of treaties, customs, general principles of law, judicial decisions and the teachings of qualified publicists. International law is only binding for a state if they give consent that an international tribunal will have jurisdiction over them. If a signatory state violates a treaty, they can be subjected to sanctions or additional taxes on their export commodities.

The international community has a growing concern regarding the world-wide loss of biodiversity. Many experts believe that the current rate of specie extinction is on par with what occurred 65 million years ago at the time when the last dinosaurs walked the Earth. The Convention on Biological Diversity (CBD) and the Cartagena Protocol were the result of these experts and governments working together towards a common goal to protect the planet's biodiversity (UNEP, 2003; Fletcher, 1995).

3.4.1 Convention of Biological Diversity

Under the guidance of the United Nations Environment Programme (UNEP), the CBD was the first global treaty providing a comprehensive framework that addressed all the aspects of biodiversity, namely: ecosystems, species and genetic diversity. The Convention was opened for signature in June 1992 and came into force on 29 December 1993. To date, the Convention has 187 Parties. Only six countries in the world are not party to this Convention, which includes the USA (Environment Canada, 2003; UNEP, 2003).

The Convention has three objectives (Environment Canada, 2003):

- The conservation of biodiversity.
- The sustainable use of the components of biodiversity.
- The fair and equitable sharing of the benefits arising from the use of genetic resources.

The Convention has a membership of 187 Parties. This sends a clear signal as to the importance of the conservation of biodiversity. This paper investigates the effect that the invasion of various new GM maize hybrids into the natural maize biota will have on the biodiversity of maize. Two observations can be made; the first is that the amount of different maize cultivars is increasing. As can be seen in Section 2.3, 19 GM maize cultivars were cultivated on South African farms in 2003. The second observation is that this influx occurred at the cost of other non-GM maize cultivars, which are now only being planted in limited quantities or not at all. It stands to reason that some if not all non-GM maize cultivars might eventually be replaced by GM maize cultivars.

Why the need to protect biodiversity? At the moment, biodiversity in the maize biota is on the increase with all the new GM maize cultivars entering the bio system. Mankind has been conditioned over the years to protect the environment against the extinction of species. However, an increase in biodiversity as engineered by mankind can be equally hazardous on the long run. The creation of super weeds is but one danger associated with biotechnology. On the other hand, if GM maize hybrids turn out to be very successful in the future, they might replace non-GM maize hybrids in totality. This will be a tragedy, as it will limit specie diversity that is necessary for the survival of all species in the food chain in the event of a catastrophe with GM maize hybrids for some unforeseen reason.

It is significant to note that the USA, which is the world leader in the biotechnology field, would be cautious to sign a treaty such as the CBD with its primary objective the conservation of biodiversity. Do they think it is an unobtainable objective, or is it because it would require them to protect biodiversity, share in their scientific discoveries and open themselves to disciplinary action by other Member States if there are treaty violations? There should be no issue however, because other GM crop producing countries like Argentina, Brazil, Canada, China and South Africa had become parties to the Convention.

3.4.2 The Cartagena Protocol

The Cartagena Protocol[1] was a natural extension of the objectives of the Convention on Biological Diversity. It was the first international agreement that dealt with the regulation of importing and exporting Living Modified Organisms (LMOs). The Protocol was adopted in January 2000 by 135 countries and entered into force on 11th

[1] The Biosafety Protocol is known as 'the Cartagena Protoco l on Biosafety to the Convention on Biological Diversity" (UNEP , 2003).

September 2003. The Protocol received 60 Parties thus far, with South Africa becoming a Party to the Protocol on the 11th December 2003 (UNEP, 2003).

The development of the Cartagena Protocol was driven by the recognition that biotechnology raises concerns that new genetic combinations could manifest in ways that could be risky to the environment. The Protocol further strives to ensure an adequate level of protection in the use, handling and transfer of LMOs during transboundary movements. This was accomplished by the establishment of an Advanced Informed Agreement (AIA) procedure to guarantee that countries are provided with all relevant information before agreeing to the importation of LMOs (Moyle, 2000; UNEP, 2003).

South Africa has taken an active part in the Protocol governance by first being a member of the Intergovernmental Committee for the Cartagena Protocol (ICCP) tasked with the preparations necessary for the fist meeting of the Parties to the Protocol. South Africa and ten other countries were subsequently elected by the respective regional groups to serve on the international ICCP Bureau (UNEP, 2003).

The Cartagena Protocol came ten years after the Convention on Biological Diversity and therefore is still in the process of being evaluated by potential Parties. The USA has again abstained from becoming a Party, which has come as no surprise seeing that the Protocol is a natural extension to the objectives of the Convention. Both of these international treaties play an important role in the protection and regulation of biodiversity. Without such treaties, the influx of unregulated GM crops would increase and the impact on biodiversity could be devastating.

The biggest concern with transboundary movements of LMOs is that off contamination of the food chain with species that are unfit or deemed unfit for human or animal consumption. Since all countries are autonomic, each country has a different set of rules of what is acceptable or not. It stands to reason that over time, because of the laws of diffusion the global standard will drop to the lowest common standard.

3.5 The Precautionary Approach

The Precautionary Approach guides the conduct of States when they lack scientific evidence to support their decisions. Basically, it can be summarised as 'better to be safe than sorry." This approach is particularly important when dealing with the threat of destroying biodiversity through human projects and developments.

The Cartagena Protocol (UNEP, 2003) was therefore written in accordance with the Precautionary Approach as contained in Principle 15 of the Rio Declaration on Environment and Development. The UN Conference on the Environment and Development (UNCED) at Rio de Janeiro in 1992 (also known as the Earth Summit) adopted 27 principles that embrace sustainable development. Principle 15 states that 'In order to protect the environment, the Precautionary Approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation (UN, 1993 Annex I)."

Elements of the Precautionary Approach as stated in Principle 15 can be found in the following sections of the Cartagena Protocol (UNEP, 2003):

- Article 10.6 and 11.8, stating:

  'Lack of scientific certainty due to insufficient relevant scientific information and knowledge regarding the extent of the potential adverse effects of an LMO on biodiversity, taking into account risks to human health, shall not prevent a Party of import from taking a decision, as appropriate, with regard to the import of the LMO in question, in order to avoid or minimise such potential adverse effects."
- Annex III, stating:

  'Lack of scientific knowledge or scientific consensus should not necessarily be interpreted as indicating a particular level of risk, an absence of risk, or an acceptable risk."

It is clear from the Precautionary Principle that Parties have the autonomy to decide for themselves whether the importation of a certain LMO is within the boundaries of "acceptable risk". The Protocol is therefore rather geared towards the disclosure of the nature of the LMO that is scheduled for export by its host country.

The Protocol has a few definite shortcomings. Firstly, the Parties to the Protocol do not collectively agree on the risk status of an LMO. It is rather left to the discretion of each Member State to import the LMO, as they deem fit. Secondly, because there is no collective agreement, the country where the LMO originated will continue to export the product to Member States that have more flexible controls regarding that specific LMO. And thirdly, due to a lack of consensus, there is no pressure by the Protocol Member States that the LMO must be destroyed if it is deemed harmful to the environment.

3.6 Genetically Modified Organisms Act (No. 15 of 1997) of South Africa

The Genetically Modified Organisms Act (Act No. 15 of 1997) provides the mechanisms to implement South Africa's obligations to the Cartagena Protocol. The National Department of Agriculture (NDA) promulgated the GMO Act in 1997 and is responsible for making sure the agricultural sector adheres to it.

The following regulations from the GMO Act govern the GMO industry in South Africa (Moyle, 2000):

- All facilities using or developing GMOs have to be registered.
- All activities classified as being of moderate to high risk require a permit.
- Permits will be issued for imports, exports, commercial releases and greenhouse, field or clinical trials.
- Environmental Impact Assessments (EIAs) and Risk Assessments (RAs) are obligatory to determine the biosafety of all activities.
- Contingency plans ought to be in place and the Register immediately notified in the case of an accident.
- Strategies must be in place for the effective management of waste.
- Fees will be charged for all submitted applications.

The GMO Act is in line with international requirements and is therefore a milestone for South Africa, which has embarked on the production of GM crops, and in particularly GM maize cultivars.

The NDA (2004a) has published a document entitled "Application for general release of Genetically Modified Organisms (GMOs) in South Africa" that requires companies that applies for a GMO permit to:

- Identify any plants in the area of general release that may become cross-pollinated with the genetically modified pollen.
- Describe if seed dispersal will occur what volumes of seed are likely to be dispersed, how this seed will interact in the environment and what long term effects the seed is likely to have on the environment.
- Describe methods to be used to limit vegetative spread of the genetically modified plant into the environment.
- Provide protocols for the detection of the foreign genes in the environment including sensitivity, reliability and specificity of the techniques.
- Detail whether the genetically engineered plant is able to initiate resistance, in any biotic component of the environment, to any biologically active foreign gene product.
- Detail the results of experiments undertaken to determine the toxicity of the foreign gene products (including marker genes) to humans and animals.
- Detail any long-term effect the general release of the genetically modified plant is likely to have on the biotic and abiotic components of the environment.
- Specify what effect the general release of the genetically modified plant will have on biodiversity.
- Specify the measures to be taken in the event of the plant or product being misused or escaping into an environment for which it is not intended.

These requirements are very focussed upon the prevention of hazards and managing risk when dealing with GMOs. The NDA (2004b) issued another document entitled "Guideline document for use by the Advisory Committee when considering proposal/applications with Genetically Modified Organisms" to assess if a permit should be issued. The guideline document states the following regarding risk assessment:

- The Herbicide or Insect Resistant Crop (HRC/IRC) may pollute the gene pool of non-transgenic relatives growing in the same or adjacent areas, depending on cross pollination characteristics and agents such as wind or by insects. In some instances where the population size of native relatives is low, genes from the transgenic crop may come to dominate the native population and lead to their extinction. The compatibility between the HRC/IRC and non-target species is of utmost importance in this regard.
- In case of IRC the engineered traits may increase fitness of volunteers or weedy hybrids, thus making a crop turn into a weed that can interfere with future crop production or aggravating the negative impact of existing weed species. The incorporation of resistance into a non-target species may also alter its competitive ability and displace other native species.
- Intensive use of IRC may select insect strains resistant to the toxins produced by the plant as a result of the genetic alteration.

Based upon the fact that various GM maize hybrids has been approved by the NDA for growing in South Africa, the assumption can be made that the government deems the bio engineering of maize as an acceptable or no risk venture. This viewpoint is debateable.

3.7 Conclusion

The GMO industry is highly regulated in every individual country to either promote or to discourage the use of biotechnology, depending on the country's official position regarding biotechnology. The future of biotechnology will eventually be decided by the World Trade Organisation that has the unthankful task of deciding which concern weighs the most: Opening European markets unconditionally to American GM products or to the keep the European moratorium on the approval of any new GM products. By ruling on the case, the WHO will indirectly state if they agree with the American statement that GM foods are "*substantially equivalent*" to conventional foods, or if they agree with the European stance that every country has the right to protect their consumer's health and the right to adequate measures of product labelling and traceability. The show-off between these two power blocks has been in the making for a long time, and will be a pivotal point for the further development of GM products.

South Africa has broken ranks with the South African Development Community with their approval of GM cultivars. Even though South Africa is Party to the Convention on Biological Diversity and the Cartagena Protocol, it seems that the Precautionary Approach is not adhered too in its strictest sense when it is applied in practise. The supplementary guideline documents for the GMO Act lists the possible risks of GM crop cultivation on the environment and biodiversity in particular clearly. However, permits are issued for GM maize hybrids, which indicates a loose interpretation or rather acceptance of the possible risks involved. On the other hand, it can be argued that there will never be any progress if some risks are not taken. That is a valid viewpoint, but it must be done within an agreed framework by all interested and affected parties.

The South African government is pro-GM in its political stance and interpretation of the relevant legislation that governs GM cultivation. It sends a clear signal to the agricultural industry to proceed on the current path of developing more GM hybrids, which is already observable in the maize sector. This implies that biodiversity will increase with the influx of more GM maize hybrids, but then decline in the long run as non-GM maize hybrids are replaced with GM maize hybrids. Biodiversity in the maize biota will be subject to many changes over time and certain maize cultivars will become limited, altered or extinct.

The next chapter will focus on the important role that the consumer has in defining the market as well as the government's labelling laws. Both shape the environment into either being pro-GM or anti-GM or a mix of the two settings.

CHAPTER 4 – CONSUMER'S CHOICE

4.1 Introduction

The population in South Africa is very diverse in terms of its cultures, beliefs and education. This has a profound influence in the acceptance of new ideas and concepts by different groups. Without the public accepting GM products as a viable food source, biotechnology will not gain any market share in the agricultural sector. This of course will directly affect biodiversity in the South African maize environment. The influence of the following factors on public opinion will be investigated:

(i) How aware is the South African public of foods that contains GM products?

(ii) Does the public require that GM food products be labelled to enable them to exercise their right to an informed consumer choice?

4.2 Public Awareness

A survey to probe the South African consumer's knowledge regarding GMO s was conducted by the Pretoria Technikon on behalf of AfricaBio in the Gauteng province. The survey revealed that of the 1022 people interviewed, only 27% knew about GMOs. The majority (74%) knew absolutely nothing about gene technology as a subject. On the safety of GM foods, 30% thought it was safe, 25% thought it was unsafe and 45% were uncertain. Of those interviewed, 65% did not know of any GM foods that were available in South Africa and only 9% indicated they knew about GM maize (AfricaBio, 2003).

The statistics reveal one alarming fact. The South African consumer is unacquainted with GM products as well as GM maize in particular. Thus, the public buys only what is available, without any conscious decision for or against GM products per se. This creates uncertainty for the GM industry, because the research has shown that only 30% of the consumers indicated that they thought GM products were safe for consumption. The breakdown of safe (30%), unsafe (25%) and uncertain (45%) by the respondents conforms to a typical distribution where there is a general lack of information regarding a subject. Although improved knowledge about GM products may have an effect on sales in the market, the response of the sample indicates that it should only have a definite negative impact on approximately 25% of future GM product sales. The remaining 45% of respondents will most likely split 50/50 into either the pro (safe) or anti (unsafe) GM grouping when they have access to relevant GM information. This prediction is based upon the nearly 50/50 distribution of the safe (30%) and unsafe (25%) figures. It can therefore be reasoned that the consumer's choice will have little impact on the sales patterns of maize in South Africa, until GM maize starts to constitute levels of 50% or more of the total bulk volume of maize being sold.

4.3 Product Labelling

South Africa has joined the world community by providing regulations for the labelling of GM food. The government took the position that labelling will be mandatory only if the foodstuff differs *significantly* from its conventional counterpart. (See draft regulations below.) This view correlates with that of biotech companies and the USA Government, which states that labelling is not required because GM foodstuffs are *"substantially equivalent"* to conventional foods (CFS, 2003).

In South Africa's (draft) Regulations Governing the Labelling of Foodstuffs obtained through certain techniques of Genetic Modification (No. R. 366 of 4th May 2001) this stance becomes evident in paragraph 2 (AfricaBio, 2003):

<ins>Paragraph 2:</ins>

No foodstuff obtained through certain techniques of genetic modification shall be sold in the following circumstances, unless such foodstuff is labelled in accordance with these regulations:

a) If the composition of such a foodstuff *differs significantly** from the characteristic composition of the corresponding existing foodstuff, the label shall contain such additional words or phrases as may be necessary to inform the consumer of its true composition.

The South African government did give the food industry some leeway by saying that voluntary labelling may be introduced by them as they see fit. A product can therefore be labelled as "not genetically modified" or "prepar ed without certain techniques of genetic modification" if it complies with certain conditions. A product may equally be labelled as "enhanced" if it displays enhanced characteristics such as composition, nutritional value and reduced causation of hypersensitivity obtained through certain techniques of genetic modification (AfricaBio, 2003).

The labelling of a product as "GM-Free" has been prohibited as can be seen from paragraph 7 of the draft regulations. It is most likely due to the negative (or positive) connotation associated with "Fat-Free" products.

Paragraph 7:

No label of a foodstuff shall bear a claim indicating that such a foodstuff or food ingredient is free from genetically modified material or *GM-free** or use similar words to mean that nucleic acids and/or proteins or any residues thereof derived from genetically modified organisms are completely absent.

4.4 Conclusion

It is evident from the lack of knowledge about GM foods that the public was never informed about developments in the food industry. Two factors formed the most likely impetus for this apparent ignorance: Firstly, the government does not require food companies to label food products as containing GM ingredients if they do not "*differ significantly*" from their conventional counterparts. This is an arbitrary term, which leaves itself open to interpretation. Secondly, 25% of the population holds the perception that GM foods are unsafe for consumption that might cause a slight drop in sales figures, favouring non-GM maize above GM maize.

The analysis of the consumer survey showed that despite the preferences of the anti-GM consumer, there will be no significant if any effect on the further introduction of GM maize cultivars, because only 25% of the consumers indicated that they see it as unsafe for consumption. Further growth in the GM maize sector of South Africa can therefore be expected for the future.

Equally, labelling legislation will not have an impact on the choices of the consumer in a negative sense, as it is geared towards prohibiting the definite categorisation of GM products as such and even go as far as barring the identification of products as

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* Author's italicisation

GM-free. This means that even the 25% of the consumers that currently thinks GM products are unsafe for consumption will be unable to distinguish GM from non-GM products. Therefore, it is certain that GM products and especially GM maize will continue to increase its total market share at the cost of other non-GM alternatives. If multinational seed companies persist in developing GM hybrids and farmers keep on favouring those for its higher yield potential, it certainly will lead to a change in the biodiversity of maize.

The role of the farmer in conserving biodiversity by preventing cross-pollination between GM and non-GM maize hybrids will be investigated in the next chapter.

CHAPTER 5 – FARMING PRACTICES

5.1 Introduction

Farmers play a vital role in the containment of seed contamination and cross-pollination between GM and non-GM maize fields. Farmers however are also facing a dilemma. On the one hand the government licenses the growing of GM cultivars and supports biotechnology, while on the other hand farmers need to acknowledge and protect their organic and non-GM export markets. How farmers deal with this issue will be investigated in terms of:

(i) What best practice farming methods are available to enable farmers to segregate GM and non-GM crops?

(ii) Do farmers practise due diligence in their farming methods?

The farmers' competence in successfully handling these issues has a direct influence on the degree of how much biodiversity will be affected.

5.2 Best Practice Farming Methods

Farmers have a choice if they want to prevent the contamination of non-GM crops with GM crop cultivars. As a first step, the main sources of GM contamination on a farm have to be identified. As a second step, the best practice farming methods need to be identified as to aid the farmer to prevent the possible GM contamination of crops. These two steps can greatly increase the chance of lessening the impact of GM contamination on crops.

GeneWatch (2003) has listed the following three sources as the main cause of GM contamination on a farm:

- **Seed contamination:** Non-GM seed might have been contaminated during growing or transport. During the growth season, these seeds will then further contaminate the crop. The situation might occur where a farmer starts of with a non-GM crop, but ends up with a GM crop. The European Commission (2003) defines a crop as GM if the GM contamination level is higher than 0.9%.
- **Cross-pollination:** Pollen from GM crops can travel on the wind or via insects to contaminate non-GM crops.

- **Farming equipment:** GM seed might be left in a field during harvest and contaminate subsequent non-GM planted crops. Or during the transport of GM crops spillage along the route to the silos or markets might occur near non-GM fields, which will result in contamination there.

The EU Commission gave a non-exhaustive "Indicative Catalogue of Measures for Co-existence" for implementation to facilitate the co-existence between GM and non-GM commercial and organic crops. This list combined with additional industry experts' recommendations can be summarised into a Best Practices Action List as follows (European Union, 2003; Riddle, 2003):

Best Practice Action List for the Farmer:

- Specific separation distances between GM and non-GM fields per crop type.
- Pollen traps and barriers such as hedgerows.
- Specific crop-rotation systems.
- Destruction of volunteers[1].
- Cleaning of farming machinery.
- Better seed saving customs.
- Separate harvesting of field margins.
- Segregation at harvesting, transport and storage.
- Avoidance of spillage during transport.
- Field monitoring.
- Identification of GM fields with computer generated maps.
- Long-term record keeping by farmers.
- Insect Resistant Management Programme (IRMP).

Best Practice Action List for the Farming Community:

- Joint planning with neighbourhood farmers.
- Arrangement of different sowing dates to prevent cross-pollination.
- Conciliation procedures in order to solve cases of disagreement between neighbouring farmers.

[1] Seeds remaining in the soil after harvest and growing to produce new plants in the following year(s).

- Training courses and extension programmes.
- Establishment of control schemes and bodies.

By identifying the three main sources of contamination and providing farmers with a list of best practice farming methods, the contamination of non-GM crops by GM crops can be reduced and biodiversity preserved in that way.

5.3 Separation Distances

The most important factor in preventing cross-pollination between adjacent non-GM and GM crop fields is the distance separating them. (The separation distance is at the top of the list of the *Best Practice Action List for the Farmer* as can be seen in the previous section.) Experts such as Dr. Mary Rieger of the Australian Weed Management co-operative Research Centre in Adelaide stated that the completely GM-free ideal of organic farmers was unworkable, because gene flow does occur and it is unpredictable. Dr. Jean Emberlin of the National Pollen Research Unit (NPRU) indicated cross-pollination could occur up to 180 km away from the maize pollen point source, depending on weather conditions such as convection cells and frontal storms (Emberlin *et al*., 1999; Smith, 2002).

Pollen concentrations get diluted over distance as it moves away from its source. To understand the dynamics behind pollen dispersion, refer to Figure 6 for a graphical representation of pollen that is distributed via a prevailing wind and insect movement from two GM fields to an adjacent non-GM field. The field row labelled A has the highest levels of cross-pollination, while field rows B and C have proportionately lower levels due to the buffering effect caused by adjacent rows. Fields D to F have zero cross-pollination, with the exception of certain cells that were pollinated due to the random movement of insects.

The levels of cross-pollination or "GM contamination" are at the heart of the matter. As previously stated by Dr. Rieger, gene flow does occur as a matter of fact. The guidelines by the National Institute of Agricultural Botany (NIAB) recommends a separation distance of at least 200m to ensure that cross-pollination levels stays at 1% or lower.

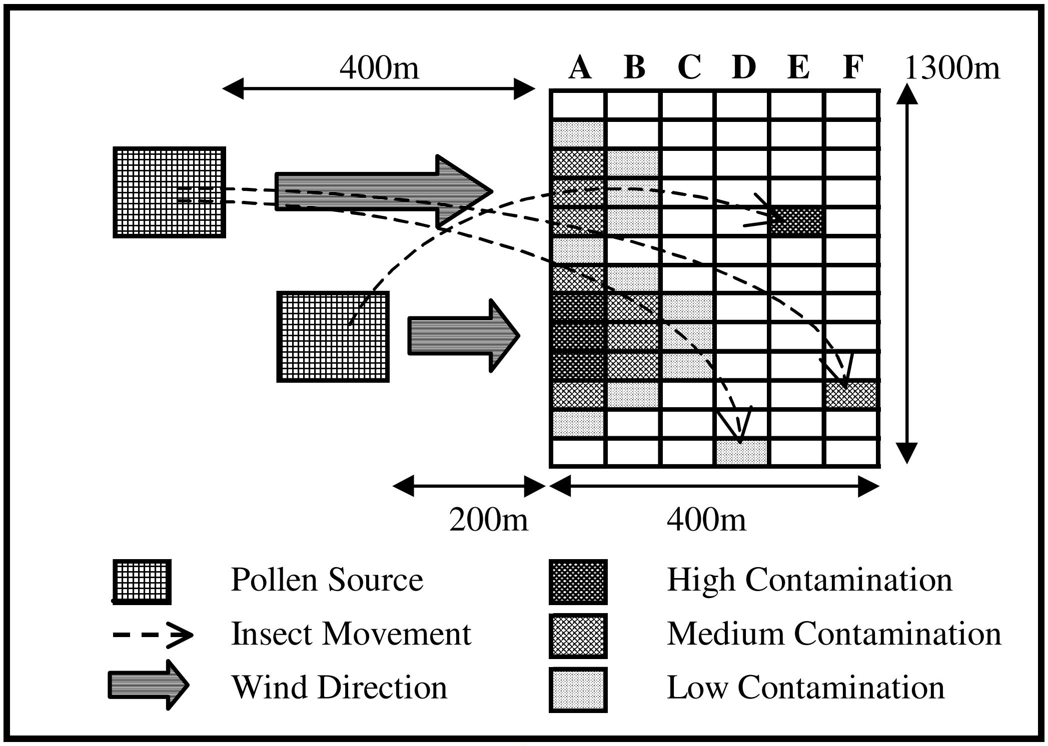

Figure 6: Model of pollen movement and cross-pollination.

The NIAB published the following recommendations (refer to Table 3) for separation distances of adjacent GM/non-GM maize fields in order to minimise cross-pollination (MAFF, 2001):

Table 3: Separation distances for recommended contamination thresholds (adapted from the MAFF, 2001).

Maize Type	Maxim threshold level of cross-pollination		
	1.0%	0.5%	0.1%
Sweet corn	200m	300m	N/A
Forage[1]	80m	130m	290m

Separation distance is one of the most important tools the farmer has at his disposal to prevent cross-contamination. It is however not always practical to have a 200m buffer zone between fields due to the pressure of making use of all available agricultural land.

[1] Grain accounts for no more than 50% of the total weight of crop harvested for forage (ACRE, 2003).

5.4 The South African Farmer

South African farmers have adopted the pro-GM position of the Government. It is therefore no surprise that in an interview with The Namibian (2002) a farmer from the Bothaville district stated that "I do not keep my GM maize separately from the rest of the maize I grow because they do not test for it so there is no point." Grain South Africa confirmed this with a similar statement to The Namibian saying: "There are regulations but practice has shown us that where we have genetically modified yellow maize there is no control at intake points. The silos just take it in, food manufacturers don' t complain and the millers mix it."

The South African National Chamber of Milling (NCM, 2002) took a different position. In their "GMO Position Paper" they stated that the NCM supported the principle of consumer choice and will therefore service a consumer led market for grain and grain products. The NCM also encourages identity preservation within the grain supply chain to enable clear labelling of products. In another article, the NCM said that South Africa has an identity preservation system, which can segregate GM from non-GM maize. Segregation however comes at a cost and since the South African Government supports GM technology, GM is the de facto standard and non-GM products the niche market exception (De Villiers, 2003).

It is clear from comments like these that the farmers and the food supply chain have embraced the Government's pro-GM stance. Without an active commitment to segregate GM and non-GM crops, there will be a natural occurring integration between the two types.

5.5 Conclusion

Farmers play a vital role to protect biodiversity in the way they run their farms. Best practice farming methods such as separation distances, segregation at harvest, adequate transport methods and storage facilities can greatly aid in preserving non-GM cultivars from GM contamination.

It is quite clear that although the South African farmer can possibly limit the contamination between GM and non-GM maize, it is not being done currently. There is no incentive to limit contamination by practising segregation and best farming methods, hence in practise GM and non-GM maize are mixed together.

This means that GM maize will contaminate non-GM maize in South Africa to the extent where it will be impossible to recognise a GM from a non-GM maize seed. It is not possible to visually discriminate between GM and non-GM maize seeds, as the changes are on the genetic level. It can be predicted with certainty that no "pure" or "non-GM" maize will remain if contamination goes unchecked. This will have a definite negative impact on biodiversity, as the biodiversity of maize will be undermined.

In the next chapter, the benefits of GM maize cultivation will be investigated in terms of feeding a world population and those living in South African in particular.

CHAPTER 6 – BENEFITS OF GM CROPS

6.1 Introduction

The world is facing a food crisis of major proportions today. Approximately one billion or one out of six people on the planet are undernourished. That is no small number. Biotechnology and in particular GM maize is presented as the means to eliminate this problem.

In a way, biodiversity is traded away for food. To understand the pressure that the world is facing, the global maize scenario will be investigated in this section. That will clearly indicate why the current course of action is imperative in securing food for everyone. There are other benefits to GM maize as well, such as a reduction in herbicide and pesticide usage.

To substantiate the changes that biotechnology introduces into the environment, the following questions need to be answered for the maize industry:

(i) Is GM maize the answer to the world's maize needs?

(ii) Does South Africa need GM maize to feed its people?

6.2 Feeding the World

Why are one out of six people in the world undernourished? The intuitive answer is poverty (people can't buy the food, even if it is available), droughts, inadequate food distribution and limited access to food aid. These problems are normally associated with developing countries, but there is an even bigger problem looming on the horizon that will impact the developed countries as well. Simply put, the world is running out of agricultural land to feed a growing world population. In order to understand the magnitude of this recent development, the global maize situation will be investigated at the hand of certain criteria as illustrated in Figure 7.

The first important element is the amount of land cultivated for maize production. Since 1961 until 2000 the global hectare has increased from 105 to 138 million hectares. The increase however stopped 10 years ago and remained around 139 million hectares. This was the first indication that just expanding the amount of land cultivated by maize was not an option any longer. The reasons for halting land expansion can be contributed to market forces such as pressure from other cash crops for cultivation area as well as the fact that maize is a commodity that has to be financially viable to be produced. Maize cannot be cultivated in areas that will give low crop yields, because the commercial farmer will then be running the farm at a loss. An optimum has been reached between production cost and profit margins during the past 10 years, therefore it is unlikely that there will be any further expansion of cultivation area.

The second important element is the ton per hectare maize yield. The average global ton per hectare has increased from 1.9 to 4.3 ton per hectare for the period 1961 to 2000. The increase can be contributed to more advanced agricultural methods such as better seed hybrids and fertilisers, as well as the usage of pesticides and herbicides. However, there was stagnation in the global ton per hectare for the period 1985 to 1995, as can be observed from the following data: 1985 (3.72 ton/ha), 1990 (3.67 ton/ha) and 1995 (3.79 ton/ha). In 2000 the ton per hectare has started to increase again with a value of 4.28 ton/ha. This increase might be contributed to the effect of GM maize cultivars on the industry.

The last important element is the size of the current world population. From 1961 until 2000, the world population has grown from 3.02 to 6.07 billion people. The whole process of maize production is basically driven by a need for food by a continuously growing world population. The WHO (2003) predicted there will be 8.92 billion people living by 2050, which means that the population will continue to increase in the future. The amount of maize production will have to keep increasing as well, as to provide for a bigger world population.

The WHO (2003) published data concerning their population predictions until the year 2050. This data was used to forecast a scenario where the global ton per hectare and the hectare under cultivation for maize production stayed static while the world population continued to grow. Figure 7 clearly indicates how the maize per capita will drop globally (and even worse for Africa) should such a scenario play itself out.

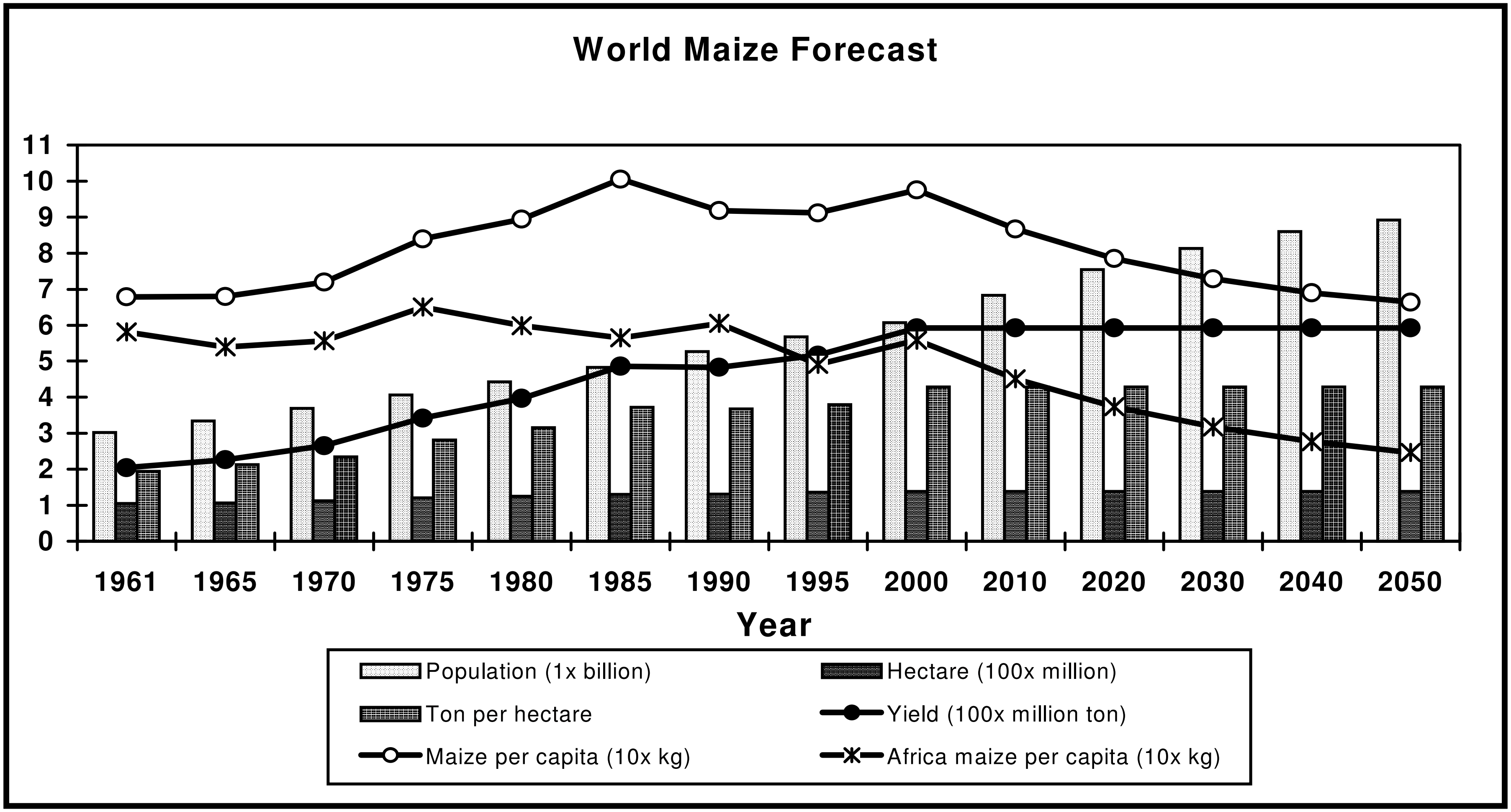

Figure 7: World maize forecast (data from FAO, 2003; WHO, 2003).

There are two possible ways available to alleviate this current crisis. The first is to increase the ton per hectare yield by applying biotechnology in the agricultural sector. GM maize that gives substantially higher yields could be sufficient to fill the production gap. The second method is to plant GM maize in areas that were previously unsuited for maize production. These areas would primarily be those in drier climates, hence the GM maize must be engineered to have drought resistance.

Failing to increase maize production would be disastrous, especially for those nations that depend heavily on maize as a staple. Other alternative, such as lowering the world population or to plant maize on unsuitable agricultural lands are impractical.

6.3 South Africa

In view of the current global situation, it is important to see where South Africa fits in. Figure 8 gives an overview of where South Africa finds itself in the maize industry in terms of hectare planted and ton per hectare yield. It is evident from Figure 8 that the ton per hectare yield is on a steady increase while the hectare under cultivation is decreasing.

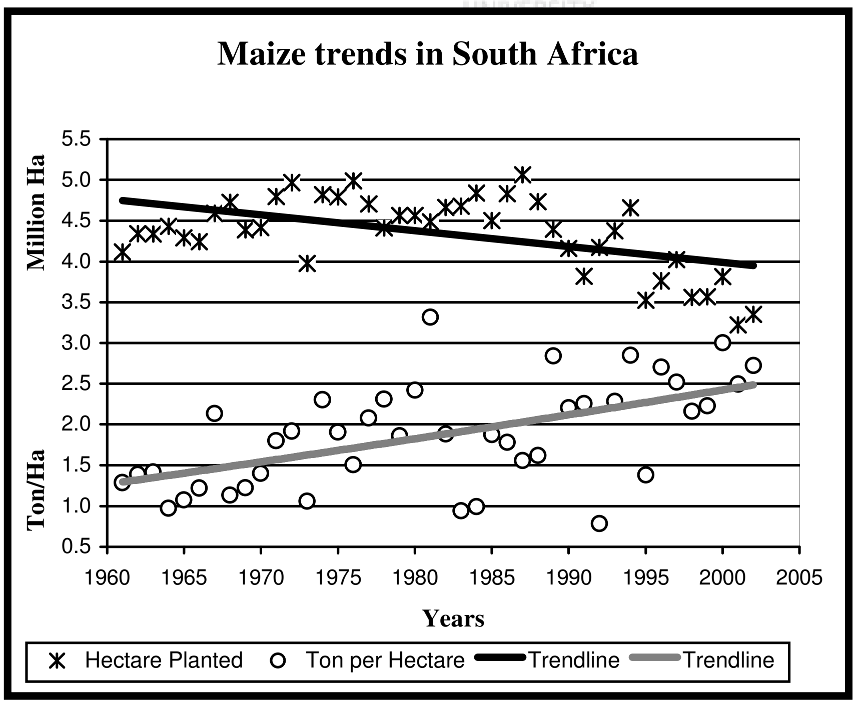

Figure 8: Maize trends in South Africa (data from the FAO, 2003).

South Africa is not a highly agricultural viable land, as can be inferred from its low rainfall. It is therefore no big surprise that the country's average ton per hectare was only 2.72 in 2002, which is well below the world average. The importance of maize as a staple food in South Africa becomes evident when it is noted that despite a low rainfall South Africa produced 214 kg maize per capita for its population, which is more than twice the world average.

South Africa needs GM maize as a solution to feed its population even more than other countries, which do not have maize as a staple. South Africa also has a responsibility towards the rest of Southern Africa in terms of food aid when droughts occur. To have an adequate supply of food and in particular maize is a top priority.

6.4 Increased production

The lepidopteran pests, particularly the stalk borer complex, are a constraint to increased productivity. This constraint must be put into context by noting that the global losses due to all insect pests are 9%, equivalent to 52 million ton of maize. Losses associated with lepidopteran pests, which can be controlled by cry1Ab, are estimated to cause losses of 4.5% that is equivalent to half the total losses from insect pests of maize (ISAAA, 2002). (Refer to Section 2.3 for pest resistant maize hybrids.)

Even if Bt maize hybrids are capable to shield 100% against the maize stalk borer worm, it will only generate an increased global maize production yield of 4.5%. If GM maize hybrids can be effective against all types on pests, it will yield an increase of 9% on the global maize production figures. That is significant, but viewed against the fact that the world population will have grown by 50% over the next 50 years, it is still not enough to eradicate the problem of adequate food production.

6.5 Conclusion

The world is out of options to increase food production via natural farming methods. Biotechnology, which is the tool to produce genetically modified crops, is just the latest in a whole series of solutions that has been implemented to see how successful more food can be produced on the same amount of land for a growing world population.

The different GM maize hybrids show much promise in delivering higher production yields per cultivated area, especially the Bt variety that is resistant against the stalk borer worm. However, globally pests accounts for 52 million tons of maize losses. Indirectly, that means that if all pest losses can be eliminated global maize production will increase by 9%, which is a big improvement. GM maize hybrids should be further developed for drought resistance, increased crop size and nutritional value to meet the demands of a growing world population.

If GM maize cultivars prove to be superior to normal maize cultivars in the future and GM cultivars becomes the de facto standard, it means that the biodiversity of maize will undergo a significant shift away from where it stands today.

CHAPTER 7 – SYNTHESIS

7.1 Problem researched

The aim of the study was to investigate the effect that GM maize cultivars have on biodiversity of maize in South Africa. This was accomplished by examining the extent to which GM maize has already penetrated the South African agricultural sector and investigating the factors or processes that facilitate and motivate this ongoing change on a national as well as international level. Where possible speculation based upon available data were undertaken to predict the extent to which non-GM maize hybrids would be replaced by GM based maize hybrids. This act constituted a change in biodiversity, in particular genetic diversity as observed in the different cultivar populations within the maize specie.

The boundaries of the study were defined in terms of the factors that enable the incursion of GM maize hybrids into the South African agricultural sector. This is easily identified from the sub problem definitions, which encapsulated the study area in a natural way:

- Firstly – To what extent is GM maize cultivated in South Africa at the moment?
- Secondly – On a global scale, what is the importance of politics upon the implementation of GM maize and what legislation governs these processes on a state level?
- Thirdly – What effect has consumer choice and labelling on the acceptance of GM food products?
- Fourthly – What farming practises are available to help restrain the contamination of non-GM maize hybrids by GM maize hybrids?
- Fifthly – What is the possible benefits in terms of food production to engage in the practise of using GM maize cultivars instead of non-GM cultivars?

These sub problems were adequate to predict if a change is occurring in the biodiversity of maize in South Africa.

7.2 Information gathering

Information and data were obtained from the following sources:

- Personal interviews were conducted with spokespersons from seed companies.
- Email correspondence with various industry experts who clarified certain aspects.
- Historical data was obtained from online statistical databases.
- Background information was procured from topical email lists.
- Newspaper articles from published online sources provided information regarding international and national political developments.
- Articles from reputed journals provided information concerning past and ongoing scientific research.

The data was sufficient to reach an answer to the problem that was researched in this study. A shortcoming was that exact seed sales figures are proprietary data of the multinational seed companies and therefore was not available to augment other data sources.

The political and legislative research proved that many sources had to be consulted to gain a full picture of the circumstances around a specific subject. As can be expected, each party only reported their side of the story, hence it is suggested that care should be taken when researching subjective material.

It was observed that many directives were open to interpretation and subject to change frequently. It was further noticed that international governmental policies now and then changed even before it was legally binding; therefore actions were taken without the proper jurisdiction. Care should therefore be taken when coming across directives and policies, because it might or might not be adhered to in practise.

7.3 Data analysis

Agricultural data for statistical analysis was obtained from the Crop Estimates Committee (CEC), the International Service for the Acquisition of Agri-biotech Applications (ISAAA), the Food and Agricultural Organisation of the United Nations (FAO) and the World Health Organisation (WHO). The statistical analysis was achieved by drawing up graphs to identify short and long-term trends in the data sets. This was a complex process, as the number of variables was many and the relationships between them spanned both long and short intervals.

Legislative, economic and political data were procured from various online sources and interpreted at the hand of the prevailing sentiment regarding biotechnology in the specific country or region from where it originated.

The data analysis was satisfactory to reach a conclusion regarding the problem that was researched.

7.4 Results

The study confirmed that GM maize had been cultivated in South Africa since 1997. The current market penetration of GM maize is approximately 20% for yellow maize hybrids and 5% for white maize hybrids, which gives an overall market share of about 10%. The swift adoption of GM maize by the agricultural sector was aided by a pro biotechnology policy of the Government, as well as multinational seed companies that marketed various GM cultivars locally. With 13 yellow and 6 white GM maize hybrids available today, the South African farmer has a large variety available to choose from.

It is clear that GM maize is pushed as a solution for higher yields in South Africa. If South Africa follows a similar adoption profile as other GM crop producing countries, it is predicted that South Africa will reach the 20% GM market segment share as well and even surpasses that in the near future.

The amount and variety of GM hybrids that are planted primarily affect the biodiversity of maize in South Africa. As stated above, about 10% of maize hectare is currently cultivated by GM cultivars. The cross-contamination between non-GM and GM cultivars further but to a lesser extent affects biodiversity as well. The cause of this change in biodiversity in maize can be contributed to the actions of mankind that introduced new genetically modified organisms into the environment.

Recognising the importance of the influence of mankind, Table 4 gives a summary of the factors that enable the effect of the biodiversity of maize. These factors were categorised with ratings of low, medium or high, depending on their current status and predicted status in the future. For example, the public awareness of GM maize is currently low, but the importance of the public's view was rated as high in the long term. If the public eventually views the consumption of GM maize as hazardous, the GM maize market will implode and less GM maize will be planted, reducing the overall impact of GM maize cultivars on the biodiversity of maize. Another example would be number of GM maize cultivars that are available to farmers. It is rated as high at the moment and will continue to increase in the future. The availability of a high selection of GM maize cultivars will enable farmers to adopt biotechnology faster; hence there will be a greater effect on biodiversity.

In a similar way the rest of the factors were reviewed in Chapters 2 to 6. The evaluation indicates that 11 of the factors at present have been rated with a status of "high". This value will increase to 19 in the future as GM maize becomes even more relevant on a national as well as international level (see Table 4).

The importance of these factors must be emphasised. Any one of these factors could potentially "pull the plug" for the implementation and adoption of GM maize cultivars in South Africa and put a stop to any additional impacts on biodiversity.

The study has without a doubt indicated that maize is undergoing a shift away from non-GM hybrids towards GM hybrids in South Africa. Since the genetic composition of non-GM and GM hybrids differs, this means that there is currently a change occurring in the genetic diversity of the maize complex.

7.5 Recommendations

With the continuous influx of new GM maize hybrids every year into the South African agricultural sector, the following recommendations are made in order to protect the biodiversity of maize and the environment at large:

- There should be adequate distances between any GM maize test farms as operated by seed companies and those of commercial farmers in order to protect other maize cultivars from cross pollination and contamination.

Biodiversity of Maize

Factors that influence maize biodiversity in South Africa

	Low	Medium	High
A Agricultural situation in South Africa			
1) Number of different GM maize cultivars available (19)			X
2) Number of companies producing GM maize cultivars (3)	X		
3) GM maize hectare planted (10% of total = 300 000 hectare)	X		
4) Predicted GM maize cultivar usage in future		X	
B Agricultural situation in the World			
1) Implementation rate of GM maize cultivars in pro-GM countries		X	
2) Global GM maize market share (11%)	X		
3) GM maize market share in pro-GM maize countries (21%)		X	
4) Year-to-year adoption rate of GM maize (25%)			X
5) Predicted global GM maize cultivar usage in future		X	
C Political Views			
1) American influence (pro-GM)			X
2) European Union influence (anti-GM)			X
3) African influence (SADC)	X		
4) South Africa (in World)	X		
5) South Africa (in South Africa)			X
6) Zambia	X		
D Treaties and Legislation			
1) Convention of Biological Diversity		X	
2) The Cartagena Protocol		X	
3) The Precautionary Approach Principle			X
4) Genetically Modified Organisms Act (No. 15 of 1997)			X
E Consumer's Choice			
1) Public awareness	X		
2) Product Labelling	X		
F Farming Practices (Preventative)			
1) Best Practice Farming Methods			X
2) Separation Distances			X
3) The South African farmer (pro-GM)			X
G Benefits of GM maize			
1) Feeding a growing world population		X	
2) Feeding the South African popuplation			X
Potential to be a high influnce factor in the future — Total	3	4	19
X Current influnce factor — Total	8	7	11

Table 4: Factors that influence maize biodiversity in South Africa.

- The occurrence of super weeds should be carefully monitored. Gene stacking in maize hybrids should be prevented at all costs, as to inhibit one maize population from becoming a dominant group.
- It should be mandatory in South Africa to segregate GM from non-GM maize cultivars, on all levels, from the seed company to the end consumer.
- In the event that a certain commercial GM maize hybrid is found by scientific evidence to be unfit for either human or animal consumption, it should be destroyed with immediate effect before it can cause further damage to the environment.
- Seed companies should be held liable if their products cause environmental damage.
- Stringent controls should be exercised by both seed companies and government to ensure that a new GM maize hybrid had been thoroughly field tested before it become commercially available.
- There must be a moratorium placed on the use of GM maize to produce any form of pharmaceutical or industrial product. The practise of injecting genes into GM hybrids which is unfit for human and animal consumption is just too big a risk.
- The effect on the food chain should be monitored, especially of those species that feed on the lepidopteran pests, particularly the stalk borer worm.

These are but a few of the important issues that need to be monitored and mitigated over time. Non Governmental Organisations will play an important role in the protection of the environment in this regard, acting as watchdogs.

7.6 Conclusion

The evidence gathered in this study indicated that non-GM maize hybrids are being replaced by GM maize hybrids in the South African agricultural sector to some extent thus far. The biodiversity of maize has been directly affected as a result of this development. Biotechnology operates on the genetic level, consequently a change in genetic diversity occurred because of the injection of new genes into the maize complex. These genes came from various sources to strengthen the natural abilities of maize cultivars to protect themselves against threats. The Bt maize hybrid is resistant against the stalk borer worm, while the RR maize hybrid has been strengthened against herbicides.

The biodiversity of maize is changing due to a number of enabling factors, the most prominent being the availability of GM maize hybrids and their improved qualities which make it a product of choice by the commercial farmer. Other factors that facilitate the change from non-GM to GM maize hybrids are cross-pollination and the lack of segregation between the two groups.

It could be argued that biodiversity is in fact increasing with the entry of more GM maize hybrids. Under normal circumstances this argument would be valid, but in this case mankind is the driving force behind the expansion of the genetic diversity. Equally, it is most likely that after an initial increase in biodiversity, there will be less maize hybrids available because only the best would survive the "unnatural" selection process of the commercial farmer. The end result may very well be a smaller selection of GM maize hybrids.

The protection of biodiversity is important because it guards all species against extinction. A reduction in the biodiversity of maize will cause a ripple effect in the food chain as some species which is dependant on certain types of maize will be deprived of their natural food source. This will have a knock-on effect on other species higher up in the food chain.

The question that needs to be decided on by society is as follows: Is it an acceptable risk to alter the biodiversity of maize by the introduction of a foreign gene pool into the genetic makeup of the maize complex?

Purely from an environmental viewpoint this risk is not acceptable. Biodiversity should not be traded away for food, because although there is an initial positive payoff in terms of production yields, the reduction of biodiversity could become a ticking bomb for the future. Dependence on just a small group of GM maize hybrids could proof disastrous.

The last factor that should be considered is the effect of cross-pollination. Not only is there diffusion from commercial GM maize to non-GM maize hybrids, but also the potential of genes "escaping" from test farms. These test farms are experimental sites, which perform research on anything from pharmaceuticals to industrial agent genes. Having those genes being mixed into the commercial maize food chain is a serious risk.

In conclusion, it is recommended that non-GM as well as GM maize hybrids are closely monitored for any signs of abnormalities as well as its effect on other species. Furthermore, the maize genetic pool must be protected for today as well as future generations.

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Appendices

Appendix A: Glossary of Terms

$	American Dollar
ACRE	Advisory Committee on Releases to the Environment
AIA	Advanced Informed Agreement
Bt	Bacillus thuringiensis
CBD	Convention on Biological Diversity
CEC	Crop Estimates Committee
DEAT	Department of Environmental Affairs and Tourism
EIA	Environmental Impact Assessment
EU	European Union
FAO	Food and Agricultural Organisation of the United Nations
GE	Genetic Engineered
GM	Genetically Modified
GMO	Genetically Modified Organism
GBP	Great Britain Pound
HRC	Herbicide Resistant Crop
ICCP	Intergovernmental Committee for the Cartagena Protocol
IRC	Insect Resistant Crop
IRMP	Insert Resistance Management Program
ISAAA	International Service for the Acquisition of Agri-biotech Applications
LMO	Living Modified Organism
MAFF	Ministry of Agriculture, Fisheries and Food
NCM	National Chamber of Milling
NDA	National Department of Agriculture
NIAB	National Institute of Agricultural Botany
NPRU	National Pollen Research Unit
RA	Risk Assessment
SADC	Southern Africa Development Community
UN	United Nations
UNCED	United Nations Conference on the Environment and Development
UNEP	United Nations Environment Programme

UN WFP	United Nation World Food Programme
UNICEF	United Nations Children Fund
USDA	United States Department of Agriculture
WHO	World Health Organisation
WTO	World Trade Organisation

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