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GENETICALLY MODIFIED CROPS IN ZIMBABWE:
CURRENT POLICIES AND ALTERNATIVE STRATEGIES FOR ENHANCING CROP, LIVESTOCK PRODUCTION, COMPETITIVENESS, AND EXPORTS

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Acronyms and Abbreviations

AMA Agricultural Marketing Authority of Zimbabwe
ASARECA Association for the Strengthening of Agricultural Research in East and Central Africa
ABSP Agricultural Biotechnology Special Programme
ARIPO African Regional Industrial Property Organization
AU Africa University
BAZ Biotechnology Association of Zimbabwe
BRICS Biotechnology Research Innovation Centers
BRI Biotechnology Research Institute, Zimbabwe
BTA Biotechnology Trust Africa
BTZ Biotechnology Trust of Zimbabwe
CBD Convention on Biological Diversity
CGIAR Consultative Group on International Agricultural Research
CVL Central Veterinary Laboratories, Zimbabwe
CIMMYT International Center for Maize and Wheat Improvement
DAFF Department of Agriculture, Forestry and Fisheries, Republic of South Africa
DNA Deoxyribonucleic Acid
DACST Department of Arts, Culture Science & Technology
ELISA Enzyme Linked Immunosorbent Assay.
FAO Food and Agricultural Organization of the United Nations
GMO Genetically Modified Organism
ICGEB International Center for Genetic Engineering and Biotechnology
IFNFS Institute of Food, Nutrition and Family Science
IPGRI International Plant Genetic Resources Institute
ISAAA International Service for Agri-Biotechnology Applications
ISNAR International Service for National Agricultural Research
KABP Kenya Agricultural Biotechnology Platform
MAMID Ministry of Agriculture, Mechanization and Irrigation Development, Zimbabwe
MLARR Ministry of Lands, Agriculture and rural Resettlement, Zimbabwe
MSU Michigan State University
NARO National Agricultural Research Organization
NGICA Network for the Genetic Improvement for Africa
NGO Non-Governmental Organization
PCR Polymerase Chain Reaction
PPRI Plant Protection Research Institute, South Africa
PGRC Plant Genetics Resources Centre
RAEIN-Africa Regional Agricultural and Environmental Initiatives Network-Africa
SABRAD Strategic Alliance for Biotechnology Research for African Development
SIRDC Scientific Industrial Research and Development Center
S & T Science and Technology
TRB Tobacco Research Board
UNESCO United Nations Education, Scientific and Cultural Organization
USAID United States Agency for International Development
UV Ultra Violet
UZ University of Zimbabwe
WARDA West African Rice Development Agency
WTO World Trade Organization
ZIMBAC Zimbabwe Biotechnology Advisory Committee
Executive Summary

The global population is predicted to reach 9 billion by the year 2050. One in eight people, or about 827 million, are already hungry. So food production must increase by 70–100 percent in the next 34 years (United Nations, 2015). We will need to produce significantly more safe and nutritious food on less land, with less water, energy, fertilizer, and pesticide, as well as address post-harvest losses. There is no single solution that will address these problems. Agriculture is a complex process that depends on various external factors from location to location. However, agriculture can play a key, central role in addressing some of our food security challenges. Modern biotechnology, while not a silver bullet, has already proven to address some of these challenges, and still promises to tackle many more intransigent problems in agriculture.

Globally, the planted area dedicated to biotech crops in 2014 peaked at 181.5 million ha. This represents a cumulative hectarage of 2 billion ha. over the 20-year period since adoption, with economic gains of US$150 billion worldwide. The United States continued to register significant progress on many fronts, as it continues to improve on its regulations and policies to make it easy for commercialization. This progress included new approval for the GM potato, first-time approval for a GM animal food product for human consumption, GM salmon, and a first approval for a non-transgenic genome-edited canola and mushroom. In 2015 India planted 12 million ha. of biotech cotton with an adoption rate of 95 percent, while China planted 4 million ha. with an adoption rate of 96 percent. The world produces 25 million tonnes (or metric tons) of cotton lint annually; India at 6.5 million tons is the world leader followed by China. Elsewhere, Brazil continues to lead in adoption rates, while Africa made significant progress—namely, drought-tolerant maize was approved for general release, and the same maize with added insect control will be released in 2017. Sudan has continued to increase its hectarage of Bt cotton. Moreover, eight other countries in Africa—Cameroon, Egypt, Ghana, Kenya, Malawi, Nigeria, Swaziland, and Uganda—conducted confined field trials on priority crops with traits including nitrogen use efficiency, drought, salt tolerance, nutritional enhancement, and resistance to pests and diseases.

South Africa has maintained a lead in biotechnology development in the African continent. New crops are being developed by academics, private seed companies, and public research institutions. To date, more than a dozen GM crops have been approved for commercial release, with one soybean, eight cotton, and four maize lines. The increase in yield of the Bt maize compared to conventional varieties ranges from 31 percent to 134 percent, and similarly Bt cotton shows an increased yield of 11 percent.

Burkina Faso, where $40 million was spent annually for pesticides for the cotton crop, is now reaping benefits. The average yield increase of Bt cotton over conventional varieties has been 18 percent, with an increase in profits of $62 per ha. Despite the limitation and challenges that countries face in both the development and application of the technology, the outlook for Africa remains bright. While Africa has moved toward a critical mass of scientific expertise in certain countries, in some cases using public-private partnerships such as the African Agricultural Technology Foundation (AATF) and sharing facilities, technical know-how, and equipment reduced both the cost and the time needed for biotechnology development.

While fear, skepticism, lack of information and familiarity with the technology are holding Africa back, some biosafety initiatives operating in Africa have given the countries the information, training, technical support, and networks necessary for their policy makers and the general public to make informed decisions. Regional integration is key. Efforts to harmonize regulatory frameworks, such as the COMESA policy designed to share data, regional assessments, and decision-making, is to be applauded,
especially in an environment in which the costs for regulatory services are prohibitive if each country were to do it alone. COMESA has, to a large extent, fulfilled its objectives albeit with mixed success rate because out of 19 member states, only two countries, Malawi and Swaziland, made significant strides toward the commercialisation of Bt cotton.

Even though Zimbabwe is signatory of the Cartagena Biotechnology Protocol and the legal framework for biotechnology is in place with an established national biotechnology authority, the country has not made any progress in agricultural biotechnology. This is against a backdrop of having been among the first countries in the world to conduct confined field trials (CFT) on both maize and cotton. Meanwhile, the ban on cultivation of GM crops is in place, citing potential loss of export markets especially to Europe. However, Zimbabwe’s largest trading partner and neighbor South Africa commercialized GM crops as early as 1997. In terms of global adopters of biotech crops in 2015, South Africa ranked 9th in the world with 2.3 million ha. under cultivation. In 2014, Zimbabwe imported 3,988 tonnes of chicken from South Africa, while South Africa exported 66,355 tonnes to regional markets. This poultry was most likely fed GM-based stock feed given that 70 percent of maize, 95 percent of soya bean, and 95 percent of cotton produced in South Africa is GM. This means South African poultry producers have competitive advantage against Zimbabwean producers who are not allowed to grow GM products.

Zimbabwe cotton production has fallen from 350,000 tonnes to less than 40,000 tonnes in 2016. Farmers are abandoning the crop because it is no longer profitable, and pest infestation is high leading to low yields. Meanwhile, Indian and Chinese farmers are benefitting from biotech cotton, achieving higher yields, higher incomes, and improved livelihoods. India is the world’s largest producing country and China is the world’s highest consumer of cotton and exporter of finished products. Meanwhile 98 percent of Zimbabwe’s cotton is exported in its raw form to European and Asian markets that consume GM cotton. Therefore, Zimbabwean farmers are disadvantaged because they are competing with farmers who use improved technologies.

The scope of the National Biotechnology Authority (NBA) Act of 2006 includes regulating issues of biosecurity and also products of synthetic biology, which are not in line with international best practice. Already other countries are not regulating products derived from genome editing. For example, the release of SU Canola in the United States has already approved. Similarly, the quest by the NBA to charge prohibitive registration fees of $2,000 per facility will jeopardize technology development at public research institutions.

**Recommendations**

- The Government of Zimbabwe should lift the ban on GM stockfeeds.
- Government must create an enabling environment that resuscitates agriculture using GM technologies where appropriate.
- Government must set up a science-based regulatory framework and functionalize the existing regulatory authority.
- Zimbabwe can apply the services of existing biosafety initiatives to build its capacity for biosafety review.
- Government should immediately permit confined field trials of GM cotton and other GM crops.
- Regulatory authorities, in addition to assessing socio-economic impacts of GM crops, must also carry out risk: benefit analysis.
- Government should align National Biosafety Framework to international best practices.
• Zimbabwe should take a cautionary approach to regulate GM crops as opposed to the precautionary principle that will completely halt progress.
• Regulatory authorities must develop protocols for continuous monitoring of GM crops post-commercialization and inspect for regulatory compliance by the technology purveyors.
1. Introduction to the Genetically Modified Organisms

This review focuses on the role of biotechnology in the agricultural sector in Zimbabwe, and on how specific genetic events can be applied to address some production constraints in this sector. In this light, this section introduces the science of genetically modified organisms.

The Science of Genetically Modified Organisms

Whether referred to as genetically modified cotton (GM cotton), or biotech cotton, transgenic cotton (used as an example, in this illustration) is developed by introducing a foreign gene, using recombinant DNA technology and transformation technologies.

Expression in plants is driven by a promoter, and the gene is introduced into the cells of the desirable cotton variety, using one of the following techniques:

- Agrobacterium-mediated
- Particle bombardment using a gene gun
- Pollen tube pathway

The transformed cells carrying a gene of interest are selected using a selectable marker gene, usually coding for an antibiotic or herbicide resistance. The cells are then regenerated back into a whole plant. Coker 312 is the most popular variety that is used for transformation of cotton because it regenerates with relative ease. Following regeneration, plants with the best agronomic performance and consistent levels of expression of a gene of interest are selected, and selfing is done to produce homozygous plants. The progeny is crossed with a preferred variety and back crossed, over several generations, to recover the preferred variety with the gene of interest (Sithole-Niang and Komen 2009).

Definition of modern biotechnology

Modern biotechnology is a collection of tools and techniques drawn from the natural sciences and engineering sciences. The broad definition of biotechnology is simply the industrial use of living organisms or parts of living organisms to produce foods, drugs, or other products. Modern biotechnology came into being with the onset of the ability to manipulate macromolecules of cells based on the accumulated knowledge of modern or new biology since the discovery of the structure of deoxyribonucleic acid (DNA) in the early 1950s.

Traditional biotechnology includes the fermentation and use of tissue culture in plant and animal breeding. Fermentation is used in the processes of making bread, beer, wine, and cheese. Plant breeding employs vegetative, micro-propagation, embryo-rescue and tissue culture, while animal breeding uses techniques such as artificial insemination, superovulation, and embryo transfer.

Modern biotechnology permits the transfer of genes among species regardless of origin, resulting in an organism with entirely new combination of properties (Bailey, Willoughby, and Grzywacz 2014). Other definitions of modern biotechnology include specific techniques such as marker-assisted selection used in both animal and plant breeding (Appendix A). Almost all newer techniques in life sciences, since the discovery of DNA cutting enzymes, now constitute modern biotechnology. They include synthetic biology, nano-biotechnology,
and systems biology as well.

Source: gefoods.wordpress.com
2. Agricultural Biotechnology Development in Zimbabwe

In the face of an increasing human population and the need to increase agricultural productivity, agricultural researchers have to look for new technologies that will help achieve increased productivity. The notion, commonly held in Zimbabwe, that agricultural biotechnology can only benefit commercial farmers is not accurate because there are examples in other countries of successful adoption of biotechnology by smallholder farmers (James 2015). In this light, this section looks at the past, present, and future of agricultural biotechnology development in Zimbabwe to suggest pathways for increasing productivity.

The Past: History of Traditional Biotechnology in Zimbabwe

Traditional biotechnology has been in existence in Zimbabwe since the early 1970s. However, modern biotechnology (molecular biology, genetic engineering, or gene modification) has only been in practice since the 1990s.

More than five decades ago, Zimbabwe was the second country in the world to adopt hybrid seed technology, while modern biotechnology activities in Zimbabwe date all the way back to the early 1990s, when stakeholders came together to chart a roadmap for the country. Subsequent to that, the Research Act was amended in 1998 to establish a biosafety board. Statutory Instrument (SI) 20/2000 Research (Biosafety) Regulations gave statutory authority to the Biosafety Board. In 2000 Zimbabwe signed the Cartagena Protocol on Biosafety to the Convention on Biological Diversity and ratified it in 2003. In 2005 the Biotechnology Policy was approved. The SI 20/2000 was then revised to be in line with the Cartagena Protocol on Biosafety, and in 2006, the National Biotechnology Act of 2006 [Chap. 14: 31] was also approved, paving the way for the establishment of the National Biotechnology Authority (NBA).

Related to these developments were other key initiatives that the government put in place, including the establishment of the Scientific and Industrial Research and Development Centre (SIRDC) in 1993, as well as the masters in biotechnology degree at the University of Zimbabwe's in 1991. To date, this program has trained 89 graduates who are employed locally, regionally, and globally. In addition, key biotechnology-related activities took place under the Biotechnology Trust of Zimbabwe, including organizing public awareness activities around biotechnology issues especially GMOs. Currently Zimbabwe has a moratorium on GMO development and cultivation. Importation of GMOs that can reproduce is prohibited, but imports of GMOs in milled form are allowed.

Zimbabwe ratified the Cartagena Protocol on Biosafety in 2005 and has a National Biosafety Framework in place. Currently, GMOs are regulated by the National Biotechnology Authority Act of 2006 [Chapter 14:31]. The cultivation of GM crops is banned in Zimbabwe, yet the consumption of GM products is allowed. In fact, in 2013 and 2014, Zimbabwe imported 215,000 tonnes of GM maize grain from South Africa for human consumption (Republic of South Africa 2014). In a presentation to Parliament, the Minister of Agriculture pronounced that his Ministry stands firm to protect the national germplasm against foreign companies that want to introduce their own patented GM varieties for adoption by the farmers (MAMID 2015).
A lot of interest in GM crops has been shown by members of Parliament, particularly the Portfolio Committee on Agriculture and the Portfolio Committee on Science and Technology. Parliament asked experts from the private sector to present papers on the benefits of GM crops. During the presentation, it was observed that some Members were well informed about the GM technology, while others had little knowledge—for example, some believing chicken imported from Brazil was GM.

In this context, Zimbabwean Members of Parliament were invited to Malawi to tour Bt cotton confined field trials (CFT) at Chitala Research Station in Salima during July 27–29, 2015. For the first time, Members saw non-GM cotton and GM cotton trials side by side—and noted that the non-GM cotton had fewer bolls than the GM cotton crop because the non-GM cotton had been attacked by bollworms. It was clear to the Members that the GM cotton was resistant to bollworms. Then in September 2015, they also attended a workshop on biotechnology held in Masvingo, where biotechnology expert presented papers on the benefits of GM crops.

**The Present: Status of Modern Biotechnology in Zimbabwean Agriculture Crops**

Tissue culture is being used in Zimbabwe for the transformation of cassava (*Manihot esculanta*), sweet potato (*Ipomoea batatus*), tobacco, maize, and the provision of pathogen-free planting material for sweet potato. The provision of these pathogen-free planting materials is an ongoing activity at the Biotechnology Research Institute in collaboration with the Tobacco Research Board and the Horticulture Research Centre (HRC) in Marondera. This activity was previously funded by the Biotechnology Trust of Zimbabwe (BTZ), and more recently, the work at HRC has been funded by the Southern African Network for Biosciences (SANBio) through the NBA. The Legume Inoculant Factory at the Grasslands Research Station in Marondera produces Rhizobium inoculants. This facility is largely used by the commercial farmers. The BTZ initiative was aimed at assisting small-scale farmers, in collaboration with the University of Zimbabwe’s Department of Soil Sciences. The HRC, within the Ministry of Agriculture, is involved in tissue culture of vegetable and ornamental crops, such as sweet potato and cut flowers, while private companies, such as Agribiotech, use tissue culture technology for generating disease-free planting materials for Irish potato, sweet potato, and cassava. Africa University near Mutare and the BTZ-funded project at the University of Zimbabwe’s Department of Biological Sciences were both investigating the use of various agricultural waste materials in spawn production. Nowadays mushroom spawn is largely produced by individuals with no clear concerted effort or adequate supply for small-scale farmers.

Current biotechnology research began in the 1990s, when Biotechnology Research Institute in collaboration with International Maize and Wheat Improvement Centre (CIMMYT) were developing both insect-resistant and drought-tolerant maize using marker-assisted selection. This project also had a sister project in Kenya, and for Zimbabwe, the effort culminated in a successful event known as *Sirdamaize 113*, which is actually being sold at retail outlets throughout the country. The University of Zimbabwe’s Department of Biochemistry (UZBCH) involved in isolating natural products from various sources, including mushrooms, hot-springs, and medicinal plants, and their associated fungal and bacterial endophytes, and lectins from indigenous trees for use in industry and diagnostics. The Department of Applied
Biology and Biochemistry at the National University of Science and Technology in Bulawayo is involved in research on meta-genomics of kudu and various other sources in search of hydrolytic enzymes that might find application in biofuels amongst other industries, as well as in DNA fingerprinting and paternity testing using their newly acquired Next Generation (NGS) DNA Sequencing machine. Both the University of Zimbabwe and the National University have masters of science program in biotechnology, while the Chinhoyi University of Science and Technology has an undergraduate programme in biotechnology. Other work on molecular diagnostics and paternity testing and identification of humans remains is conducted by the African Biomedical Research Institute (AiBST) housed at Wilkins Hospital in Harare. Chinhoyi University is also working on identifying source of enzymes for the energy sector as well as establishing a molecular diagnostic center for cattle and other wild life at their Animal Biotechnology Department. Finally, the Harare Institute of Technology is working on natural products as well as characterizing indigenous mushrooms from Zimbabwe.

While there is ongoing work on tissue culture, which is often a precursor to the establishment of genetic transformation work, Tobacco Research Board is the only laboratory that is registered and authorized to conduct genetic transformation work in the country. The registration fees are rather steep at USD 2,000 annually for each laboratory. This means that university departments have to part with a lot of money to embark on this type of research—quite a deterrent even if equipped with expertise.

**Livestock**

Traditional biotechnology has had a noticeable impact on Zimbabwe agriculture not only on its crops but its livestock sector as well. Biotechnology is applied in the dairy industry to manufacture local cheeses and in breeding through the use of artificial insemination, embryo transfers, embryo cryopreservation, and in-vitro embryo production for developing of both elite and indigenous breeds. Indeed, the early cases of using biotechnology in the livestock industry in Zimbabwe date back to 1909, when attenuated vaccines were first made locally. Nowadays, biotechnology is also used in the culture of animal pathogens and the production of recombinant antigens for diagnostics. Previously, the BTZ funded two projects on livestock improvement: one on molecular diagnostics of cattle reproductive diseases where farmers are taught how to recognize disease symptoms at the point of care, and the other on livestock feeding strategies, silage making, and forage production. The project on disease diagnosis and detection was in collaboration with small-scale farmers in the Hwedza and Buhera districts and the Central Veterinary Laboratory, whereas the one on nutrition was in collaboration with scientists at the Grasslands Research Station and Africa University.

Bio-pharming is the largest-growing sector in biotechnology product development. Pharming is the production of human pharmaceuticals in transgenic animals and plants. The technology dates back to 1982 when the first transgenic mouse was made. Then in 1987, tissue plasminogen activator (tPA) was produced. The use of recombinant products, such as recombinant bovine growth hormone (also known as bovine somatotropin [rBST]), sparked controversy with dairy farmers in the Mid-Western United States, and yet, the use of pharmaceuticals produced as recombinant proteins goes unquestioned. In Zimbabwe, research was conducted in the early 1990s at the Henderson Research Station to test the efficacy of the recombinant hormone on indigenous breeds (Phipps et al. 1991). Milk yields were increased from 226 kg for the control animals to 993 kg for the treated cows. The recombinant rBST did not only increase the milk yields, but it also prolonged the period of
lactation in the indigenous Mashona cattle, a breed that is well known for its low milk yields and short lactation periods.

Clearly, from the Zimbabwean perspective, it would be more beneficial to extend these trials to small-scale farmers and to ensure that an efficient, workable marketing system is in place to absorb increased milk yields. It would be interesting to see if Chinhoyi University’s Department of Animal Biotechnology would study other technologies to improve milk production in this breed. However, such activities have fallen through and even globally this practice is not entirely popular.

However, before this entire practice of improving milk yields can happen, it would be interesting from a public awareness point of view, to see if the Zimbabwean people will accept the concept of enhancing milk yields using recombinant rBST. The issue of beef exports to Europe would also need to be addressed. In South Africa, transparency is all that is required, as they grow GM-maize and continue to export their grain-fed beef to the United Kingdom and the rest of Europe. Zimbabwe should be aware of this development, as export to Europe has become the most cited excuse for not liberalizing the deployment of GMOs in the country. Interestingly, Namibia has a similar interpretation as Zimbabwe.

**Forestry**

Zimbabwe's forests and woodlands are being deforested at an alarming rate with estimates as high as 100,000 ha./yr being cited in the Science and Technology Policy document. Pines and eucalyptus are grown on commercial plantations. These trees grow fast but have the drawback of using a lot of underground water, thus, they cannot be grown everywhere. The indigenous hardwoods, mukwa and mahogany, on the other hand, take a long time to grow. While a range of biotechnological tools are now widely available, very few of these have been applied for forestry improvement. Funding and a lack of capacity in both human resources and infrastructure are often cited as major constraints to biotechnology development in this area. The size of the industry in Zimbabwe is rather limited, while pressure from environmentalists is already mounting and gaining ground in the GMO debate. This resistance is threatening to hinder forestry certification, leaving researchers in a dilemma as to whether genetic modification, in particular, could be used to improve forestry products in Zimbabwe. However, macro- and micro-propagation have played a major role in the maintenance of both plantation and some indigenous tree species. The use of molecular DNA markers could aid in a wide variety of applications, such as in selection, crossing, and identification. Technology for conferring resistance against termites would be a useful development.

**Fisheries**

Zimbabwe has 114 indigenous fish species and 30 exotic species that have been introduced over time. The largest fishery is Lake Kariba. The country produces about 25,000 tons/yr and less than a thousand tons is exported. Aquaculture is also present on a limited scale, with commercial fish farming occurring in tanks and ponds to produce trout, bream, carp, and prawns. Previously, the tremendous success of the beef industry meant that fish only played a minor role in export, or indeed as an industry that could have more resources devoted to it.

In terms of research, however, most of the effort has been devoted to fish nutrition, disease control, fish recruitment, and fish ecology. Seven research stations have been established in
the country, and these fall under the Ministry of Environment and Tourism, although some of the research on aquaculture of Tilapia is also ongoing at Henderson Research Station, which falls under the Ministry of Agriculture. Future research needs have been identified in the areas of pathology, species selection and pond ecology. These are areas that could be addressed using biotechnological tools such as marker-assisted selection, that is, the use of molecular markers to study genetic diversity and species identification. The country could explore the possibility of disseminating aquaculture much more widely, and needs to develop bioremediation strategies to address pollution in water bodies. In recent times, one of the major concerns in this sector has been the use of antibiotics in stockfeeds that are now having an impact on the development of antimicrobial resistance (Barson 2016).

The Future: Advancing Agricultural Biotechnology in Zimbabwe

The basic policy and legislation framework on biotechnology is now in place, although further refinements will be necessary as discussed above. The stage is now set for rapid growth in research and development in biotechnology for agriculture. However, policy makers need to be aware of the advantages biotechnology could bring increase in agricultural productivity. Consequently, any decision that they make must recognize the contribution that biotechnology is likely to bring. In other words, risks and benefits of modern biotechnology must be evaluated.

Genomics

One of the key biotechnology areas for the future is the area of genomics. This technology is now driving the design and development of new crop varieties with improved growth, pest-resistant properties, and superior nutritional characteristics. It is expanding our knowledge of human, plant, and livestock genomes, such that new genes become available that could not have been isolated before. This technology, together with bioinformatics and the use of microarrays, are expected to speed up the development of new crop varieties, livestock, and diagnostic and detection procedures. Because of the high cost and infrastructure required for these new technologies, Zimbabwean scientists would benefit from collaboration with scientists in advanced laboratories elsewhere. In the meanwhile, and as a step in the right direction, Zimbabwe has set up the High Performance Computer Centre at the University of Zimbabwe. It is one of three such infrastructures in Africa, with one in South Africa and another in Ghana. The HPC will aid in gene discovery and handling of big data coming out of sequencing whole genomes.

Metabolic engineering

Another area for the future is metabolic engineering, metabolomics, which involves the use of recombinant DNA technology to enhance the activities of a cell by manipulating its metabolic pathways. The goal of metabolic engineering in plants is to produce transgenic crops in which the range, scope, or nature of a plant’s existing natural products is modified to provide economically important attributes. To fully exploit this technology, scientists in Zimbabwe will need to develop an improved understanding of cell metabolism and its complexity. There will be a need for considerable investments in Zimbabwe for human capital and infrastructure for research and development.
**Genome editing technologies**

As the GM debate rages on, it is interesting to note that the technology has developed so rapidly that it is quite conceivable that only genome-edited crops could be on the market in the future. It would be interesting to see how Zimbabwe responds to this. Are these products going to be regulated by the NBA? How is this field going to play out? In the United States and Europe, already decisions have been made that genome-edited crops are not going to be regulated as products of GM technology. Perhaps this is where Zimbabwe could actually catch up on lost time given that in the 1990s it was one of the leaders on the continent in this area.
3. Biotechnology R&D in Selected Sub-Saharan Countries

New initiatives that apply evidence-based policy and decision making will inform the Zimbabwean agricultural development rather than a rendition of R & D activities alone. Thus, this section focuses on the status of biotechnology R & D issues in selected countries, namely, South Africa and Malawi. It also highlights relevant activities in selected sub-Saharan countries, namely Burkina Faso, Ghana, Kenya, Malawi, Nigeria, South Africa and Uganda (see Table 1). Moreover, the role of the Network of African Science Academies (NASAC) is also spotlighted, discussing the Network’s attempts to re-engage African governments in enabling the environment to adopt and implement agricultural biotechnology on the continent.

Why Biotechnology for Africa? A Perspective of the Network of African Science Academies

Discussions on modern biotechnology have been ongoing since the early 1990s, especially in recognition that agriculture is still the mainstay of many African economies, which unfortunately continue to be plagued by a host of production constraints. These range from biotic to abiotic stresses of various forms that could be addressed by using this technology.

The potential for technology to address some of these constraints was recognized in Agenda 21 of the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992. Subsequent to this, Africa hosted in 2002 the World Summit on Sustainable Development in Johannesburg where Africa affirmed its commitment to the full implementation of Agenda 21, the Programme for further Implementation of Agenda 21 and the commitments to the Rio Principles. African governments, under the auspices of the African Union, followed up on and initiated key Pan African program and initiatives—namely, the New Partnership for Africa’s Development (NEPAD), the High-level African Panel on Biotechnology, and the African Biosafety Network of Expertise (ABNE)—aimed at guiding the continent in harnessing the potential of biotechnology for human development, global competitiveness, and ecological management. These initiatives have been complemented by the Global Environment Facility of the United Nations Environment Programme (UNEP-GEF) and other private and civil society supported programs—and yet, we still witness ambivalence in adoption of this technology across the continent.

To this end, the Network of African Science Academies (NASAC), in collaboration with the European Academies Science Advisory Council (EASAC), the German National Academy of Sciences (Leopoldina), the United Nations Economic Commission for Africa (UNECA), and the African Union Commission (AUC), jointly organized an expert workshop on agricultural biotechnology with funding from the German Federal Ministry of Education and Research in Addis Ababa, Ethiopia, on February 25–26, 2014. Following this workshop, NASAC continued the collaboration with Leopoldina to facilitate the development of an agricultural biotechnology policy makers’ booklet to present to African governments and business leaders as a source of scientific evidence to help them in policy and decision making. The booklet was launched at a communication event in Addis Ababa, Ethiopia, in April, 2016, with five keys messages for policy makers, shown in the figure below.
South Africa: Commercialization of Biotechnology

South Africa continues to be a lead country in the commercialization of biotechnology in Africa. The country first commercialized insect-resistant (Bt) cotton in 1997, and in subsequent years, six other crop-trait combinations were commercialized: Insect-resistant, Bt maize in 1998; Roundup Ready (RR) soybean and RR cotton both in 2000; herbicide tolerant (HT) maize in 2002; the stacked-trait HT/Bt cotton in 2005; and, HT/Bt maize in 2007.

An account of how crops in South Africa were first commercialized to the present day and the challenges this country is facing with adoption is thoroughly documented by Morris and Thomson (2014). First, they highlight the issue of the funding mechanism, where previously following a recommendation from the National Biotechnology Strategy of 2001, Biotechnology Innovation Centres were formed, and within the BICs, Plant Bio was responsible for funding agricultural biotechnology. In 2010 the Department of Science and Technology incorporated the Centres into the Technology Innovation Agency, which was charged with promoting commercialization of all technologies including biotechnology.
move was unfortunate in that biotechnology was now being viewed as being too long term and risky as an investment, thus creating a challenge in funding for biotechnology. The aforementioned Department also created Biosafety SA in 2008, as a service platform within the national biotech innovation system designed to provide regulatory support for GM product development in academia and companies. Biosafety SA was under the original Plant Bio, but when Plant Bio was incorporated into the Technology Innovation Agency, Biosafety SA also moved into this agency although this arrangement is likely to change.

Meanwhile, other confounding factors influence the debate, namely: (1) there are few projects in the pipeline requiring this kind of regulatory support, (2) projects in academia are in their early stages, (3) more advanced projects are arising through public-private partnerships involving multinational companies that usually have in-house regulatory support, and lastly, (4) the local industry is not willing to accept the market risk associated with a GM product. It has always been recognized that the adoption and commercialization of biotechnology in South Africa largely relied on products developed elsewhere, and now the developments described above paint a gloomy picture for agricultural biotechnology development and adoption in South Africa going forward.

**Malawi: Status of GM Crops**

Within SADC, Malawi is chalking an aggressive pathway with three CFT approvals granted on Bt cotton a commodity crop, on trial since 2013, and two food crops, pod-borer resistant cowpea (Bt cowpea) and virus resistant bananas in 2015 (James 2015). Malawi completed the first stage towards releasing its first GM crop on 12 April 2016 when the Environmental Affairs Department (EAD) deregulated insect resistant GM cotton after three years of confined field trials (CFT). On that date following the deregulation, Monsanto the technology developer, was issued with a licence to conduct open field trials of the Bacillus thuringiensis (Bt) cotton at government research stations. The deregulation is a major milestone in itself, however, there is still a lot of work to be done by the technology provider and the seed company. During this period the Bt cotton is grown in open field trials at government research stations, not in confinement, and plant breeders will monitor its efficacy and adaptability prior to varietal release for commercialisation.

In terms of the crop seeds varietal release regulations, new varieties should undergo open field trials over two years before an application for commercial release. The open field trials of Bt cotton are set to commence during the cropping season beginning 1 September 2016. Therefore, if the open field trials are successful, Malawian farmers may begin to grow GM cotton by the cropping season beginning 1 September 2018. In the outlook, two crops are undergoing CFTs: GM cowpeas and bananas (James, 2015). In 2016, EAD approved an application to commence CFTs on bananas, itself a major food crop. This followed an outbreak of the bunchy top virus, a major viral disease that affects bananas in southern Malawi.

**Other**

In other African countries, experience with GM crops varies. Three countries have approved the commercial cultivation of GM crops—and although these still represent a small number of countries in Africa, this represents a welcome improvement on previous years, as the spread now covers all regional blocks on the continent and could result in viable synergies. For the first time in 2009, each block had a regional lead country, Egypt to the north, Burkina
Faso to the west, and South Africa to the east and south. Interestingly in the same region to the north, Egypt has withdrawn commercialization of GM crops, but has now been replaced by Sudan. The signing into law of the Biosafety Bill in Kenya in 2009, as well as the fact that Kenya already has a number of GM crops in the testing pipeline, clearly places Kenya in the position to take the lead in the east. However, Uganda is another interesting case, with eight confined field trials (CFTs) approved in just two years using existing legislation, while the Biosafety Bill undergoes review by the cabinet. Mozambique has also given approval for CFTs for double-stacked drought tolerant- and insect-resistant maize under the Water Efficient Maize for Africa (WEMA) Project. WEMA products are also undergoing trials in Kenya, Uganda, and South Africa. All in all, in 2015 there were eight CFTs conducted on pro-poor crops in African countries.

Table 3.1 below highlights the status of advanced GM trials in sub-Saharan African countries. The Biotechnology R & D activities in select sub-Saharan countries, namely Burkina Faso, Egypt, Ghana, Kenya, Malawi, Nigeria, South Africa and Uganda.

Table 3.1. Status of Advanced GM Technologies in Africa, 2016

<table>
<thead>
<tr>
<th>Country</th>
<th>Crop</th>
<th>Trait under Testing</th>
<th>Stage</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burkina Faso</td>
<td>Cowpea</td>
<td>Insect resistance</td>
<td>CFT</td>
<td>AATF, CSIR, IITA, Monsanto, NGICA</td>
</tr>
<tr>
<td>Egypt</td>
<td>Maize (Zea mays)</td>
<td>Insect resistance</td>
<td>CFT</td>
<td>AGERI, Pioneer</td>
</tr>
<tr>
<td>Egypt</td>
<td>Cotton (Gossypium barbadense)</td>
<td>Insect resistance</td>
<td>CFT</td>
<td>ARC</td>
</tr>
<tr>
<td>Egypt</td>
<td>Wheat (Triticum durum L.)</td>
<td>Drought tolerance</td>
<td>CFT</td>
<td>AGERI</td>
</tr>
<tr>
<td>Egypt</td>
<td>Wheat (Triticum durum L.)</td>
<td>Fungal resistance</td>
<td>CFT</td>
<td>AGERI</td>
</tr>
<tr>
<td>Egypt</td>
<td>Wheat (Triticum durum L.)</td>
<td>Fungal resistance</td>
<td>CFT</td>
<td>AGERI</td>
</tr>
<tr>
<td>Egypt</td>
<td>Potato (Solanum</td>
<td>Viral resistance</td>
<td>CFT</td>
<td>AGERI</td>
</tr>
</tbody>
</table>

1 Note: AATF = African Agricultural Technology Foundation; AGERI = Agricultural Genetic Engineering Research Institute; ARC = Agriculture Research Council, South Africa; CFT = confined field trials; CSIR= Council for Science and industrial Research, Ghana; IITA = International Institute of Tropical Agriculture; INERA = Institute of Environment and Agricultural Research; KARI=Kenya Agricultural Research Institute; MSU = Michigan State University; NARO = National Agricultural Research Organization; NGICA =Network for the Genetic Improvement for Africa
<table>
<thead>
<tr>
<th>Country</th>
<th>Crop</th>
<th>Trait</th>
<th>Season</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>Cowpea (<em>Vigna unguiculata</em> L.)</td>
<td>Insect resistance</td>
<td>CFT, 3rd season</td>
<td>AATF, CSIR, DFID, IAR, IITA, INERA, Kirkhouse Trust, Monsanto, NGICA, Purdue University, RF, USAID</td>
</tr>
<tr>
<td>Ghana</td>
<td>Bt cotton</td>
<td>Insect resistance</td>
<td>MLT</td>
<td></td>
</tr>
<tr>
<td>Ghana</td>
<td>Newest rice</td>
<td>NU, WU, ST</td>
<td>CFT</td>
<td>CSIR</td>
</tr>
<tr>
<td>Kenya</td>
<td>Maize (<em>Zea mays</em>)</td>
<td>Insect resistance (insect-resistant maize for Africa against stem borers)</td>
<td>CFT</td>
<td>KARI, CIMMYT, Monsanto, SFSD University of Ottawa,</td>
</tr>
<tr>
<td>Kenya</td>
<td>Maize (<em>Zea mays</em>)</td>
<td>Drought tolerance (WEMA)</td>
<td>CFT, 2nd season</td>
<td>AATF, BMGF &amp; HGBF, CIMMYT, KARI, Monsanto,</td>
</tr>
<tr>
<td>Kenya</td>
<td>Cotton (<em>Gossypium hirsutum</em> L.)</td>
<td>Insect resistance (bollworms)</td>
<td>CFT, completed</td>
<td>KARI/Monsanto</td>
</tr>
<tr>
<td>Kenya</td>
<td>Cassava (<em>Manihot esculenta</em>)</td>
<td>Disease resistance (cassava mosaic viral disease)</td>
<td>CFT, 1st season</td>
<td>DDPSC, KARI</td>
</tr>
<tr>
<td>Kenya</td>
<td>BioCassava Plus</td>
<td>Bio-Cassava Plus, enhanced levels of iron and zinc, protein, Vitamins A and E</td>
<td>CFT, 1st season</td>
<td>CIAT, DDPSC, IITA, KARI</td>
</tr>
<tr>
<td>Malawi</td>
<td>Cowpea (<em>Vigna unguiculata</em>)</td>
<td>Insect resistance</td>
<td>CFT, 3rd season</td>
<td>AATF, CSIR, DFID, IAR, IITA, INERA, Kirkhouse Trust, LUANAR, Monsanto, NGICA, Purdue University, RF, USAID</td>
</tr>
<tr>
<td>Malawi</td>
<td>Cotton</td>
<td>Bollworm resistance and herbicide tolerance</td>
<td>CFT, 3rd season</td>
<td>JUANAR</td>
</tr>
<tr>
<td>Malawi</td>
<td>Banana</td>
<td>Virus resistance</td>
<td>CFT</td>
<td>DARS</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Cassava (<em>Manihot esculenta</em>)</td>
<td>Increased level of beta-carotene (Pro-vitamin A)</td>
<td>CFT, 3rd season</td>
<td>DDPSC, NRCRI</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Cassava (<em>Manihot esculenta</em>)</td>
<td>Nutrition enhancement for increase in iron level</td>
<td>CFT, 2nd season</td>
<td>DDPSC, NRCRI</td>
</tr>
<tr>
<td>Country</td>
<td>Crop</td>
<td>Trait</td>
<td>Season</td>
<td>Collaborators</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------</td>
<td>--------------------------------------------</td>
<td>--------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Cowpea (Vigna unguiculata)</td>
<td>Insect resistance</td>
<td>CFT, 3rd season</td>
<td>AATF, CSIR, DFID, IAR, IITA, INERA, Kirkhouse Trust, Monsanto, NGICA, Purdue University, RF, USAID</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Sorghum (Sorghum bicolor)</td>
<td>Bioavailability of iron, zinc, protein, vitamin A</td>
<td>CFT</td>
<td>AATF, Africa Harvest, ARC, CSIR, FARA, ICRISAT, Pioneer Hi-Bred International, University of Pretoria</td>
</tr>
<tr>
<td>South Africa</td>
<td>Maize (Zea mays)</td>
<td>Drought tolerance</td>
<td>n/a</td>
<td>AATF, ARC, BMGF &amp; HGBF, Monsanto</td>
</tr>
<tr>
<td>South Africa</td>
<td>Cassava (Manihot esculenta)</td>
<td>Bio-fortified and modified starch</td>
<td>n/a</td>
<td>HarvestPlus</td>
</tr>
<tr>
<td>South Africa</td>
<td>Sugarcane</td>
<td>Virus resistance, increased yields, alternative products</td>
<td>n/a</td>
<td>South Africa</td>
</tr>
<tr>
<td>South Africa</td>
<td>Maize (Zea mays)</td>
<td>Maize IR resistant to MSV</td>
<td>n/a</td>
<td>University of Cape Town, Pannar Seed Co.</td>
</tr>
<tr>
<td>South Africa</td>
<td>Potatoes</td>
<td>Insect resistance</td>
<td>n/a</td>
<td>ARC/MSU</td>
</tr>
<tr>
<td>Uganda</td>
<td>Maize (Zea mays)</td>
<td>Drought tolerance</td>
<td>CFT, 2nd season</td>
<td>AATF, BMGF &amp; HGBF, Monsanto, NARO</td>
</tr>
<tr>
<td>Uganda</td>
<td>Banana</td>
<td>Bacterial wilt resistance</td>
<td>CFT</td>
<td>AATF, IITA, NARO</td>
</tr>
<tr>
<td>Uganda</td>
<td>Banana</td>
<td>Nutritional enhancement (Fe and Pro-Vitamin A)</td>
<td>CFT</td>
<td>NARO, QUT</td>
</tr>
<tr>
<td>Uganda</td>
<td>Cassava (Manihot esculenta)</td>
<td>Virus resistance</td>
<td>CFT, 2nd season</td>
<td>DDPSC, IITA, NARO</td>
</tr>
<tr>
<td>Uganda</td>
<td>Cotton</td>
<td>Bollworm resistance and herbicide tolerance</td>
<td>CFT, 3rd season</td>
<td>NARO</td>
</tr>
</tbody>
</table>

While modern biotechnology holds promise in delivering benefits to the people and economy of Africa, the two major drawbacks lie in Africa’s unfavourable biotechnology development policies as well as its stringent biosafety regulations against a backdrop of limited human-, infrastructure- and, institutional capacity for biotechnology product development and biosafety regulation. The Network of African Science Academies (NASAC), in collaboration with the German National Academy of Sciences (Leopoldina) facilitated the development of an agricultural biotechnology policymakers’ booklet to present to African governments and business leaders a source of scientific evidence to help them in policy and decision making. The booklet was launched at a communication event in Addis Ababa, Ethiopia in April, 2016 and concludes with four recommendations for African governments, which are paraphrased here:

African countries need to re-think biotechnology development policy and biosafety regulatory regime to create an enabling political environment for the development, adoption, and deployment of modern agricultural biotechnology. To achieve this, the continent will have to embrace evidence-based decision making by harnessing the technical capacity of the rich network of African academies of science as a source of credible evidence-based advice to policy.

African countries should support and fully participate in the ongoing regional initiatives (COMESA, ECOWAS, EAC, and SADC) working toward the harmonization of biotechnology development policies and biosafety regulations to ensure that Africa becomes a key participant in the global biotechnology enterprise.

African countries should enhance the level of public awareness, education, and engagement in matters of biotechnology development and biosafety regulations in Africa. This will eliminate deliberate distortion of facts and a nonscientific basis of risk perception. It will also make it easy for Africa to exploit economic and other opportunities offered by modern agricultural biotechnology.

African countries must invest in building human, infrastructure, and institutional capacity for biotechnology development and biosafety regulation by allocating financial resources and leveraging on global partnerships and collaborations within the South-South and North-South frameworks. As a starting point, Africa should position herself to reap maximum benefit from current collaborative initiatives with developed countries for Science, Technology and Innovation (ST&I) in general and modern agricultural biotechnology research in particular. To this end, NASAC (1) is uniquely positioned as a strong base for partnerships with governments on matters of science and (2) should take the lead in initiating dialogue with African government leaders on matters of science and technology generally and modern biotechnology specifically.
4. Policy and Regulatory Framework

The Zimbabwe Biosafety Framework

The National Biotechnology Authority (NBA) is a strategic arm of the government of Zimbabwe, established through the National Biotechnology Authority Act [Chap. 14:31] of 2006. It is the National Competent Authority for all biotechnology, biosafety, and biosecurity matters including GMOs. It is also the national focal point of the Cartagena Protocol on Biosafety. In 1998 the Research Act amended to provide for the management of potentially harmful technologies and undertakings, then the Biosafety Board was formed. In 2005 Zimbabwe ratified the Cartagena Protocol on Biosafety and the National Biotechnology Policy was developed with support from UNEP-GEF, which was influential in the improvement of the National Biosafety Framework. In 2006 the National Biotechnology Authority of Zimbabwe (NBA) Act [Chap.14:31] of 2006 was gazetted, giving rise to the National Biotechnology Authority. The NBA’s mandate is further emphasised in 2nd Science Technology and Innovation Policy of 2012. The scope of the NBA Act includes biosafety regulation of related technologies such as nanotechnology, synthetic biology, metabolic engineering, proteomics, metabolomics, DNA-chip technology, and bioinformatics.

The Zimbabwe Biosafety Framework is given in Table 4.1 below:

Table 4.1 The Zimbabwe Biosafety Framework

The Zimbabwe Biosafety Framework comprises of:

- National Biotechnology Policy;
- An Act of Parliament - the NBA Act;
- Institutional arrangements - NBA & Institutional Biosafety Committees (IBCs);
- Mechanisms for risk assessment (reviews); mechanisms for decision making (NBA); mechanisms for public consultation; mechanisms for monitoring and enforcement (Biosafety Inspectorate); supporting guidelines and standards.
- All research activities involved in development, importation, exportation and use of biotechnological processes; import, export, contained use, release of any product of biotech that is likely to have adverse effect on human health, environment, economy, national security or social norms and values.

In accordance with the NBA Act, the functions of the National Biotechnology Authority are to:

- Advise the Minister on all aspects concerning the development, production, use, application, and release of products of biotechnology.
- Regulate biotechnology research, development, production, use, application, movement, and release of such products.
- Provide program on public awareness and understanding of biotech and biosafety.
- Provide infrastructural capacity and human capital development.
- Administer the Biotech Fund on behalf of the Minister.

The NBA has four functions, namely, to offer Regulatory, Research Support Services, Public Awareness and Education, and Advisory Services. They are also charged with administering
the Biotechnology Fund (yet to be realized), conducting operational research, and overseeing an as yet to be constructed National Biosafety Reference Lab with biosafety levels BSL1-BSL4. Public awareness, exhibitions, outreach programs for farmers, students, and so forth.

Their regulatory function, includes issuance of permits and certificates, pre- and post-shipment inspections of imports and exports, monitoring imports and exports at ports, registration of biotechnology facilities, biosafety policy development, assessment of potential release of GMOs into the environment (GMO surveillance and testing), supervision of contained use, and trials and general release of biotechnology products.

Registration of facilities has been controversial given the steep cost of US$2,000 annually per laboratory; as such, many laboratories are not registered. The NBA registers and issues permits to operate facilities that are used for biotechnology work to contain health and safety risks. The registration is in accordance with Part III (Control and Monitoring of Biotechnology) of the NBA Act of 2006 [Chap.14.31].

Section 22: specifies that the Authority’s biosafety guidelines and standards of practice and procedure shall be binding to users of the products of biotechnology. Section 23: provides for the establishment of a register of biotechnology facilities by the Authority. Section 24: prohibits the ownership or use of unregistered facilities.

Zimbabwe has not yet approved the commercialization of GM crops or animals. However, Confined field trials for Bt maize and cotton were conducted from 2001 to 2005. It is hoped that research on GMOs will be authorized in the future as currently no officially approved research is on going.

The NBA monitors all of the border posts with staff posted at these sites, manning them 24/7. Their team of inspectors includes agents for SPS regulatory, plant quarantine, and Port Health. They also work hand in hand with the Environemental Management Authority (EMA), Medicine Control Council of Zimbabwe (MCAZ), Medical Research Council (MRCZ), and the Research Council of Zimbabwe (RCZ).

**Regional Biosafety Initiatives**

**SADC’s Advisory Committee on Biotechnology**

The SADC Advisory Committee on Biotechnology was formed by the Council of Minister’s directive of 2003 in response to the food aid crisis of 2002. The Committee’s focus was to consider a regional harmonization effort focusing on policies related to the handling and transboundary movement of food aid, biosafety policies and regulations, and capacity building and public awareness. The recommendations developed for biosafety were highly precautionary and guided by the African model law. Unfortunately, this Committee has since ceased to exist.

**COMESA’s Regional Approach to Biotechnology and Biosafety in Eastern and Southern Africa**

The idea for a regional harmonization of biosafety policies was mooted in 2001 at a COMESA Ministers of Agriculture Conference. It was initiated to address the inevitable
transboundary movements of GMOs and the potential impact posed on trade and the delivery of emergency food aid. The Regional Approach to Biotechnology and Biosafety in Eastern and Southern Africa (RABESA) initiative commenced in 2004 led by the COMESA Secretariat, Lusaka, Zambia. The main focus of RABESA was the development of regional biosafety policies and guidelines to inform decision making on the handling of GMOs in the COMESA region. The Implementing partners were the COMESA/ACTESA, ISAAA, Association for the Strengthening of Agricultural Research in East and Central Africa, and the Program for Biosafety Systems (PBS). This project lasted for years and encompassed two phases, RABESA phase I and II. Activities included (1) Policy research and analysis component, (2) National and regional workshops, (3) Drafting and review process of regional policies and guidelines, (4) Regular reporting and feedback from COMESA Ministerial meetings, and (5) Dissemination of information on progress through monographs, policy briefs and journal articles, workshops and conferences.

The Minister’s areas for harmonization, identified in 2006 and endorsed in 2007, are shown in the table below.

<table>
<thead>
<tr>
<th>Area of focus</th>
<th>Appropriate option/recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial planting of GM crops</td>
<td>Centralized regional assessment, national decision making</td>
</tr>
<tr>
<td>Commercial trade policy in GM products</td>
<td>Advice/information from a central regional clearing house, national decision making</td>
</tr>
<tr>
<td>Emergency food aid policy on GM products</td>
<td>Guidelines developed at regional level, decision taken at country level on case by case basis</td>
</tr>
</tbody>
</table>

The objectives of the COMESA Policy on GMOs were stated as follows:

- To provide COMESA Member States with a mechanism for independent scientific regional risk assessment of GMOs
- To provide a technical opinion about the biosafety of GMOs seeking commercial status in the COMESA region that can be used by individual countries to make approval decisions
- To provide a harmonized mechanism for decision-making involving trade in GMOs & food aid with GM content
- To assist COMESA Member States share and build capacity in order to conduct scientific risk assessment and management.
- To establish interactive regional information sharing mechanism on biosafety and biotechnology issues

Included in these were the exemptions of the Policy as follows:

- Socioeconomic, cultural, liability and redress, labelling, and other country-specific considerations regarding GMOs would be handled at the national level in accordance with national laws and biosafety frameworks.
• Activities conducted with GMOs in the laboratories and confined field trials, leading up to commercial planting, would be handled at the national level.

The general provisions on the structure and procedures of the Policy were as follows:
• The COMESA Secretariat would establish a regional biosafety risk assessment desk.
• The COMESA Panel of Experts (PoE) would be the main guiding body to formulate a risk assessment “Opinion” on applications submitted by Member States.

GMO risk assessment sub-committees (GRASCOM) would be constituted by PoE to conduct RA on a case-by-case basis

The final decision to approve or reject a GMO for commercial planting, trade or food aid would rest on the sovereignty of the individual COMESA Member State.

Provisions on Commercial Planting of GMOs

Applicants intending to commercially plant a GMO in any COMESA Member State would apply to the NCAs of the recipient Member State.

An application with full dossiers would be forwarded to the COMESA Secretariat by the Member State for consideration by the Panel of Experts (PoE) under the regional risk assessment mechanism.

An opinion from the PoE would be communicated back to the submitting country to inform decision-making at the national level.

COMESA Opinion would be communicated to other member states.

Provisions on Trade in GMOs

Seed

For GM seed that has NOT been approved in a COMESA Member State, an application would be made to the importing country. The importing country would transmit the risk assessment dossier to the COMESA secretariat which would constitute GRASCOM to conduct the risk assessment and provide an Opinion.

For a GM seed APPROVED in a COMESA Member State and which is traded to another COMESA Member State where the originating and receiving environments are similar, approval should be granted without the need for another PoE risk assessment and opinion.

Criteria for determining whether an environment is similar to another receiving environment would be established by the PoE referencing national seed policies and variety release procedures. The importing country would make the final decision.

GMOs for Food, Feed and Processing

For a GMO approved in a COMESA Member State which is traded to another COMESA Member State intended for Food, Feed, and Processing (FFP) approval should be given upon application and sharing of risk assessment reports or approval decision documents.
For a GMO-FFP approved in a non-COMESA country and which is traded for the first time in a COMESA Member State, an application would be made, through COMESA Secretariat for an independent risk assessment by the PoE and GRASCOM.

**GMOs in Transit**

For a GMO approved in one COMESA Member State transiting through another COMESA Member State, expedited approval of transit would be given provided transboundary movement requirements of the Cartagena Protocol on Biosafety are observed. In the event of an objection to transit for a GMO approved in a non-COMESA country transiting through a COMESA Member State, the matter would be referred to the PoE for a scientific opinion on whether there are any risks of such transit.

**Applications for Emergency Food Aid with GM Content**

All applications to introduce food aid with GM content must be submitted to the NCA in the recipient or transit country. When transferring food aid with GM content from one COMESA Member State to another and the GM food has already been approved for public consumption in a COMESA Member State, a statement by the applicant that the GM food aid is already approved in a COMESA Member State shall be submitted. In cases where food aid with GM content has NOT been approved in a COMESA Member State, an application would be submitted by the exporter to the recipient country. Transit COMESA Member States would facilitate and expedite transportation of emergency food aid. The importer would be expected to comply with biosafety requirements for transportation in the transit and destination countries.

Throughout this exercise there were lessons learnt, namely that national sovereignty was to be respected, that Regional harmonization was both a technical and political process, and that process had to be transparent, consultative and inclusive to secure buy-in from member states. A number of observations have been made regarding the ECOWAS process namely; the approval process for LMOs/FFP and the duration taken to reach a decision is about 75 days, which presents a challenge when delivering emergency food. Furthermore, the pros and cons of including products thereof need to be carefully analyzed as these could present a challenge as well. The requirement (Article 12) that LMOs or products thereof should not have adverse effects on socioeconomic environment calls for realistic and reasonable parameters to be set otherwise very little progress would be made. Similarly, Article 40, should be balanced and focus on assessment of both socioeconomic risks and benefits.

**Table 4.3 COMESA and ECOWAS Similarities & Differences**

<table>
<thead>
<tr>
<th>Similarities</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Both processes recognize transboundary challenges posed by LMOs/GMOs</td>
</tr>
<tr>
<td>• The principle of mutual recognition encouraged</td>
</tr>
<tr>
<td>• Similar institutional arrangements at the regional level proposed &amp; use of existing structures at the national level</td>
</tr>
<tr>
<td>• Public/stakeholder consultation recognized</td>
</tr>
<tr>
<td>• Capacity building support for member states</td>
</tr>
<tr>
<td>• The need for public awareness and information sharing mechanisms emphasized</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
- COMESA focuses on policies & guidelines and ECOWAS regulation
- COMESA framework provides an *opinion* while ECOWAS a *decision* at the regional level
- COMESA has exemptions which distinguish national & regional obligations
- ECOWAS framework covers *products thereof* and COMESA does not
- Final validation regional workshop organized by COMESA in May 2012 in Lusaka
- Biosafety policies and guidelines finalized and endorsed by member states for submission to COMESA policy organs in 2013
- COMESA regional biotechnology and biosafety policy implementation plan (COMPIP) was validated in a regional workshop held in Addis Ababa, Ethiopia, on Diff March 11-13, 2015. The overall goal of the plan is to support Member States to realize their aspirations of becoming active participants in the global biotechnology enterprise (James 2015).

**African Biosafety Network of Expertise**

The African Biosafety Network of Expertise (ABNE) was born out of a partnership between NEPAD and Michigan State University. The partnership is funded by the Bill and Melinda Gates Foundation and was initially funded for $1.5 million. The network was established to “help regulators access the most up-to-date training, data and resources needed to properly regulate biotechnologies, ensuring countries are able to take full advantage of advances while safeguarding consumers and the environment.” ABNE was set up in Ouagadougou, in Burkina Faso, as well as Kampala in Uganda. More recently they have set-up an office in Dakar, Senegal. Over the years ABNE in collaboration with other Biosafety Initiatives on the continent (PBS, AfricaBio, Crop Life, ISAAA, OFAB, Africa Harvest, International Center for Genetic Engineering and Biotechnology, SABIMA) (Table 4.4) have been coordinating activities to bring a meaningful participation/intervention in biosafety in several African countries.

**Table 4.4 Key Biosafety Capacity Building Programs in Africa**

<table>
<thead>
<tr>
<th>Initiative</th>
<th>Key Player</th>
<th>Activity/Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNEP/GEF</td>
<td>All African countries</td>
<td>Biosafety in conformity with the Cartagena Protocol on Biosafety</td>
</tr>
<tr>
<td>ICGEB</td>
<td>Sub-Saharan African countries</td>
<td>Strengthening and expanding biosafety systems</td>
</tr>
<tr>
<td>PBS</td>
<td>COMESA, Ghana, Kenya, Malawi, Nigeria, Tanzania</td>
<td>Integrated practical technical, legal, and</td>
</tr>
</tbody>
</table>
Program for Biosafety Systems

Program for Biosafety Systems (PBS) is one of the long serving initiatives aimed at building capacity in Africa. Managed by IFPRI and funded by USAID. PBS is a global consortium of biosafety expertise working in both Africa and Asia. Their focus it to empower African countries to develop, implement, and manage their own systems by providing training, technical and legal advice, and independent policy research for decision makers. Its approach provides a constant, in-country presence with an ability to directly interface with African governments. PBS helped establish the early operational frameworks and field trials in Kenya, Uganda and Malawi and is now assisting in Tanzania. In Africa, PBS works with in-country personnel in Ghana, Nigeria, Malawi Kenya and Uganda and Tanzania (Chambers 2013).

Africa’s Participation at the COP/MOP

Historically the participation of developing countries, small islands and countries with economies in transition participation in COP/MOP activities has been less than satisfactory leading to the following observation by the CBD secretariat: “The COP/MOP secretariat notes with concern the number of project and low amount of funding requested by parties from the GEF to support implementation of the Protocol during the GEF-5 period”. To this end the International Service of Acquisition of Agribiotech Applications (ISAAA) Afri-Center together with ABNE and other like-minded partners have coordinated the participation of Africa party states through national, sub-regional and regional workshops for the last three consecutive COP/MOP sessions (5, 6, &7). These interventions have shown
remarkable improvement in the participation of the African group in COP/MOOP workshops, shared responsibilities in the two working groups at the MPOs, prior development of country positions; and a deeper understanding of the issues in general (Karembu et al. 2015).

Policy Options for Agricultural Biotechnology

Policy decisions must be made in the following areas when considering the regulation of GMOs, their products, or both:

- Intellectual property rights (IPRs)
- Biosafety
- Trade
- Food safety and consumer choice
- Public research and investment
- Transboundary movement of living modified organisms (LMOs)

Most of these are covered by existing regulation, but IPR and biosafety are the two policy areas that are most likely to require new legislation. Options of these policies are detailed in Table 4.5 and Zimbabwe’s current approaches to each aspect of GM policy are highlighted and in bold.

Table 4.5: Policy Options for GM Crops

<table>
<thead>
<tr>
<th></th>
<th>Promotional</th>
<th>Permissive</th>
<th>Precautionary(^3)</th>
<th>Preventative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intellectual property rights</td>
<td>Full patent protection, plus plant breeders’ rights under UPOV 1991</td>
<td>PBRs under UPOV 1991</td>
<td>PBRs under UPOV 1978, which preserves farmers’ privilege</td>
<td>No IPR for plants or animals, or IPRs on paper that are not enforced</td>
</tr>
<tr>
<td>Biosafety</td>
<td>No careful screening; only token screening or approval based on approvals in other countries</td>
<td>Case-by-case screening for demonstrated risk depending on intended use of product</td>
<td>Case-by-case screening also for scientific uncertainties owing to novelty of GM product</td>
<td>No careful case-by-case screening; risk assumed because of GM process</td>
</tr>
<tr>
<td>Trade</td>
<td>GM crops promoted to lower commodity production costs and boosts exports; no restrictions on imports of GM seeds or plant materials</td>
<td>GM crops neither promoted nor prevented imports of GM commodities in limited in same way as non-GM in accordance with science-based WTO standards</td>
<td>Imports of GM seeds and materials screened or restrained separately and more tightly than non-GM labelling requirements imposed on imports of GM foods or commodities</td>
<td>GM seed and plant imports blocked; GM-free status maintained in hopes of capturing export market premiums</td>
</tr>
<tr>
<td>Food safety and consumer</td>
<td><strong>No regulatory distinction drawn</strong></td>
<td>Distinction made between GM and</td>
<td>Comprehensive positive labelling</td>
<td>GM food sales banned or warning</td>
</tr>
</tbody>
</table>

\(^3\) IFPRI did not distinguish between cautionary and precautionary policies in their framework, but this distinction is important as highlighted in the recommendations.
choice between GM and non-GM foods when testing or labelling for food safety

| Public research and investment | Treasury resources spent on both development and local adaptation of GM crop technologies | Treasury resources spent on local adaptations of GM crop technologies, but not on development of new transgenes | No significant Treasury resources spent on GM crop research or adaptation; donors allowed to finance local adaptation of GM crops technologies | Neither treasury nor donor funds spent on any adaptation or development of GM crop technology |

Sources: IFPRI, Paarlberg,( 2000); Kitch, Koch and Sithole-Niang (2002).

Intellectual property rights

This is a new and challenging area for many developing countries. Any company wishing to make investments in R&D is compelled to do so by existing IPR regulations. It is a way of recovering costs on investments made on the R & D, and applies to patents, copyrights and breeder’s rights, and so forth.

Biosafety

Again, this is a new policy area for many developing countries especially those in Africa, although they signed and ratified the Cartagena Protocol on Biosafety. Upon signature, a country is compelled to implement biosafety regulations in line with the requirements of the Protocol—namely, to have a mechanism for evaluating the environmental and food safety associated with GMOs. Zimbabwe has signed and ratified the protocol, and yet, there is now a moratorium on GMOs in the country. This is in direct contravention with those obligations.

Trade

Biosafety regulations are well established under the WTO to encourage trade, eliminate unfair protection, and exclusions; as such, the Zimbabwean industry cannot prevent import of cooking oil from South Africa because South Africa grows GM soybean. Meanwhile, the European Union also imports stock feed from Brazil and Argentina, countries that are well known for producing GM soybeans.

Food safety and consumer choice

Regulations on food safety and labeling already exist in countries to inform on the nutritional status and presence of allergens. These follow the Codex Alimentarius, which represents internationally recognized standards and guidelines for foods, food production, and food safety.

Footnote

4 Currently no regulations in place which require compulsory labelling of GM foods.
Public research and investment

The traits present in existing GM crops often need to be introgressed into locally preferred germplasm and tested under local conditions. In Zimbabwe, part of the argument with Monsanto on GM cotton back in 1997 was the ownership of the improved germplasm. The Ministry of Agriculture wanted to own 51 percent of the GM cotton; however, Monsanto was offering royalties of 5 percent of seed sales. The question becomes, what is the normal practice globally?

Transboundary movement of living modified organisms

Interestingly, the movement of living modified organisms is already covered by existing trade and pest control regulations. However, the Cartagena Protocol on Biosafety was negotiated to ensure that GMOs are not sent to countries without their prior consent, and without the country having an opportunity to review the safety to human health and the impact on the environment. However, while this regulation already exists, as is the case in Zimbabwe, it now necessitated the country to streamline the SI 20/2000 with the Cartagena Protocol on Biosafety. This was done in 2006 when the NBA Act 2006 (Chap 14:31) was passed.
5. Zimbabwe’s Agricultural Profile in the Context of Introducing Biotechnology to Key Crops

Introduction

This chapter explores Zimbabwe’s agricultural profile in the context of potentially introducing genetically modified varieties of three important crops: cotton, soybeans, and maize. Comparisons are made of the yields achieved by smallholder farmers using empirical studies carried out in Zimbabwe and South Africa in 2015.

According to the United Nations (2015), the population of Zimbabwe will reach 30 million by 2050 from the current 15.6 million. In such a scenario, Zimbabwean farmers will need to double its current production against land resources that will remain mainly constant or even be reduced owing to land degradation and infrastructural needs (housing, roads, and so forth). As a result, the farmers will need to produce more food and fiber and to seek innovations and tools that will make it possible to achieve higher yields. However, on the backdrop of limited resources of land, labor, and capital, the cost of production and productivity determines which crops the farmers choose to grow against competing crops.

Zimbabwe has 39 million hectares of land available for farming, forestry and game, and urban development. Before the land reform of 2000, there were four land ownership structures in the farming community of Zimbabwe that were made up of a customary law tenure system (communal), the old resettlement, small-scale and large-scale commercial farms (for more information on land tenure and marketing, see Agricultural policy study entitled Land Tenure and Land Marketability in Zimbabwe). During the land reform programme, land was reallocated largely from the white large-scale commercial sector to the A1 and A2 schemes, of which A1 comprises the small scale and the A2 comprise medium-to-large scale commercial farms.

Table 5.1 shows the number of households and land area in the land ownership structure.

Table 5.1 Land Ownership Structure by Sector, 1980, 2000, and 2015

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Communal</td>
<td>1,400,000</td>
<td></td>
<td>16,400,000</td>
<td>16,400,000</td>
<td>16,400,000</td>
</tr>
<tr>
<td>Old Resettlement</td>
<td>75,000</td>
<td></td>
<td>3,500,000</td>
<td>3,500,000</td>
<td>3,500,000</td>
</tr>
<tr>
<td>Small-Scale Commercial</td>
<td>8,500</td>
<td></td>
<td>1,400,000</td>
<td>1,400,000</td>
<td>1,400,000</td>
</tr>
<tr>
<td>Large-Scale Commercial</td>
<td>4,500</td>
<td></td>
<td>15,500,000</td>
<td>11,725,000</td>
<td>648,000</td>
</tr>
<tr>
<td>A1</td>
<td>145,000</td>
<td></td>
<td>4,137,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>18,000</td>
<td></td>
<td>6,232,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td></td>
<td></td>
<td>196,000</td>
<td>250,000</td>
<td>250,000</td>
</tr>
<tr>
<td>Forest Park</td>
<td></td>
<td></td>
<td>5,074,000</td>
<td>5,074,000</td>
<td>5,074,000</td>
</tr>
<tr>
<td>State</td>
<td></td>
<td></td>
<td>500,000</td>
<td>721,000</td>
<td>721,000</td>
</tr>
<tr>
<td>Unallocated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>708,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1,651,000</td>
<td></td>
<td>39,070,000</td>
<td>39,070,000</td>
<td>39,070,000</td>
</tr>
</tbody>
</table>

Source: MAMID (2016).
The smallholder farmers constitute 98.6 percent of farming households and hold 78.6 percent of the farmland, and yet, 21.4 percent of the land is held by 18,000 A2 farmers who comprise medium-scale and large-scale commercial farmers. Farmers who were part of the large-scale commercial farms before 2000 are now part of the new land reform A2 scheme.

**Cotton**

The world produces and consumes 25 million tonnes of cotton lint per year. Of this, 70 percent of this number represents genetically modified crop (James, 2015). India, at 6.5 million tonnes, is the world leader followed by China. The Agricultural Marketing Authority (AMA 2015) noted that cotton is a major crop grown by 250,000 smallholder farmers in Zimbabwe, supporting over 1.5 million people. Indeed, under the agricultural crop category cotton, this key crop is the second largest contributor of foreign currency earnings after tobacco.

Note: This study found that in Zimbabwe only three large-scale commercial farmers grow certified planting seed cotton on special terms and conditions with the Quton Seed Company. The special case of the three farmers does not fall within the scope of this study.

The products derived from cotton are mainly the fiber (lint), cotton cake (for animal feed), and edible oil, which may be used for other purposes including cosmetics. In Zimbabwe, as is the case with most African cotton-producing countries, cotton is mainly grown by resource-poor smallholder farmers in semi-arid conditions under dry land on small pieces of land, usually one or two hectares. The cotton plants are comparatively more drought-tolerant than other crops such as maize and soybeans. As a result, farmers in areas with low rainfall potential, such as the Low Veld, Gokwe, and Muzabani, invariably prioritize cotton crop cultivation ahead of other crops.

In recent years, cotton crops suffered production setbacks as the national production of seed cotton declined progressively from a high of 352,000 tonnes during the 2012/13 season to a projected low of 100,000 tonnes during 2015/16 (Ministry of Finance, 2016). The average yield has remained low at about 700 kilograms per hectare. Among reasons attributed to falling production, chief among them are erratic rainfalls, insufficient inputs, and declining world lint price, which to a large extent determines the price that farmers are paid for their harvest. However, farmers' income is a function of the price of cotton and the volume sold against the costs of production. In this section, we explore the costs of production and factors that influence the yield that the farmers may achieve. According to the AMA (2015), when the farmers were paid 85 cents per kilogram of seed cotton in 2010, they responded in 2011 increasing production, with national crop production at 330,000 tonnes.

In Zimbabwe, resource-poor smallholder farmers are heavily dependent on contract farming for input supply. Thus, cotton is grown mainly under contract farming whereby ginning companies provide inputs to farmers. The contracts are usually entered into between farmers and contract farming companies, or contractors, that own gins who assure the farmers of an output market. The contractors supply the farmers with planting seed, crop protection chemicals, and sometimes fertilizers on credit. At harvest time, the farmers deliver seed cotton to the contractors and the farmers get paid after deducting the cost of inputs.

The advantages of contract farming enjoyed by farmers include access to inputs without the need to raise cash upfront. In addition, the farmers are assured of an output market for their
crop. However, the disadvantages include a limited choice of the buyer because farmers are obliged to sell to the contractor regardless of the price offered. The challenges of contract farming arise when the farmers side market their crops to avoid payment of debts owed to the ginning companies (Dowd-Uribe 2013). Contractor inputs are thus invariably inadequate because the contractors manage their costs to account for potential side marketing.

In recent times, the government has intervened in contract farming by providing inputs (seeds, fertilizers, and chemicals). To revive the cotton sector, the government has been expected to intervene for three years, that is, 2015, 2016, and 2017. During this period, the government will be providing direct subsidies to cotton farmers (Ministry of Finance, 2016). For cropping season 2015/16, the Agricultural Marketing Authority (AMA 2015), which regulates the cotton sector, approved the input package for one hectare: 20 kilograms certified planting seed and 2 bags [of 50 kilograms each] fertilizer and insecticide chemicals. The inputs are recoverable by the contractors at harvest when the farmers sell seed cotton. According to Agricultural Extension Services, the seeding rate for cotton is 20 kilograms per hectare and basal fertilizer application ranges from 250 to 300 kilograms per hectare, depending on soil type. Also, the application of ammonium nitrate is 200 to 300 kilograms per hectare. Although seed provided by the contractors is adequate, the fertilizer volume is only 20 percent of what is required to achieve optimum yields (AMA, 2015).

Cotton production budgets

A number of stakeholders in the cotton sector prepare budget models for cotton farmers, including farmer unions, the Ministry of Agriculture, and the Cotton Ginners Association (CGA). Budgetary analysis presented by these stakeholders generally present a similar trend, that is, cotton farmers are not achieving reasonable profit margins, and in most cases, the farmers are experiencing losses owing mainly to variables such as crop yields, production costs, and the market price of seed cotton.

However, the budget model of the varying stakeholders varies according to their business interest. For instance, the CGA is an association of companies that supply inputs to farmers; they want to manage the production costs so that, during price negotiation, the price remains as low as possible. In this regard, the model of crop input costs developed by the CGA may be biased downward. In comparison, the farmer union’s model represents farmers' interests. In response to a question whether smallholder farmers who use family labor should charge commercial rates on the budget model, a senior national farmer leader of the Zimbabwe Farmers Union said, “I do not like this question that seems to suggest that smallscale farmers do not incur labor costs.” He then charged, “Haven’t you heard the word maricho? Where do you think it came from? Workers in Harare send money to their parents in the communal lands to pay for labor!” So the farmer union’s position is that smallholder farmers incur labor costs regardless of whether they formally employ workers. In addition, the union argues that there is no difference in production costs for a smallholder farmer and a medium-to-large-scale commercial farmer because “they buy from the same shops at the same prices.”

This study uses the production model for cotton growers prepared annually by the Ministry of Agriculture. The researcher compared the model with those of CGA and ZFU and made some adjustments in consultation with all stakeholders.

Table 5.2 presents this production budget for smallholder farms.
Table 5.2 Smallholder Farms: Abridged Cotton Production Budget (per Hectare) for 2015 cropping season.

<table>
<thead>
<tr>
<th>Variable Cost</th>
<th>Quantity</th>
<th>Cost per ha. ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed (kg)</td>
<td>15</td>
<td>29</td>
</tr>
<tr>
<td>Land preparation</td>
<td>n/a</td>
<td>105</td>
</tr>
<tr>
<td><strong>Labor days</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting and crop establishment</td>
<td>15</td>
<td>38</td>
</tr>
<tr>
<td>Weeding</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>Spraying</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>Harvesting</td>
<td>37</td>
<td>92</td>
</tr>
<tr>
<td><strong>Fertilizer (kg)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compound L</td>
<td>50</td>
<td>36</td>
</tr>
<tr>
<td>AN</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td><strong>Pesticides</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spraying chemicals (ltrs)</td>
<td>5</td>
<td>51</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport, baling, consumables</td>
<td></td>
<td>41</td>
</tr>
<tr>
<td><strong>Insurance</strong></td>
<td></td>
<td>11</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
<td>28</td>
</tr>
<tr>
<td><strong>Total Variable Costs</strong></td>
<td></td>
<td>587</td>
</tr>
<tr>
<td><strong>Yield</strong></td>
<td>Estimated yield (kg/ha.)</td>
<td>700</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td>Selling price ($0.45/kg)</td>
<td>315</td>
</tr>
<tr>
<td><strong>Profit</strong></td>
<td>Gross Margin</td>
<td>(272)</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture (2016). (See Appendix E for details.)

The budget presented above shows that a farmer that embarked on cotton production in the 2015 cropping season and harvested 700 kilograms of the crop per hectare in 2016 incurred a loss of $272.19 per hectare if familial labor were valued at $2.50/day. Clearly, the above budget shows that a farmer that grows cotton in Zimbabwe in 2015 does so at a loss. This is one of the reasons why cotton farmers are abandoning cotton production in preference for higher paying crops and in 2016 production of raw cotton was less than 32,000 tonnes against 350,000 tonnes delivered in 2012 (Ministry of Finance, 2016)

**Cotton crop breeding and new technologies in Zimbabwe**

Zimbabwe boasts world class crop-breeding capabilities in both public and private institutions. In 1952 the first hybrid seed maize, SR52, was released under the government crop breeding program (Rusike and Eicher 1997). Subsequently, the rapid adoption of hybrid seed maize followed, and currently, the over 90 percent of maize grown in Zimbabwe is hybrid seed. Regarding the cotton crop, the country grows certified improved varieties bred by public and private breeders. The Cotton Research Institute (in Kadoma) is a government cotton breeding facility that has released conventional varieties that have performed beyond customer expectations within and outside Zimbabwe. Based in Zimbabwe, Quton Seed Company is an international seed business, itself a subsidiary of the Maharashtra Hybrid
Seeds Company (Mahyco) of India. Quton is involved in the breeding and distribution of certified cotton planting seeds.

In their breeding programs, cotton plant breeders must consider the demands of three distinct markets, the farmers, textile processors, and cottonseed end users, markets with conflicting requirements that cannot be addressed at the same time (Roupakias and Mavromatis, 2010). Oil processors may require cottonseed that has a high oil content, while textile processors demand parameters such as fiber length, strength, fineness, color, and lack of foreign matter. A critical stakeholder, farmers demand varieties that give increased yields, drought, and disease tolerance. A recent technology that addresses some of the production challenges of the farmers and is now available to farmers is genetically modified (GM) crops.

**Economic and social benefits of GM cotton**

The first generation of GM crops was developed specifically to bring direct benefits to farmers (WHO 2014). The traits are selected on the basis of their desirability in order to serve a specific purpose, for example, herbicide tolerance, insect resistance, and drought tolerance (Gong and Wang 2013). Table 5.2 establishes that during the cropping season (for 40 days, and each day being 6 hours long), farmers work in cotton fields removing weeds. Weeds compete with crops for nutrients, and if not eliminated, they adversely affect crop yields. An herbicide-tolerant GM crop means that a farmer can spray herbicide chemical, and although the weeds will be eliminated yet the crop thrives. The ability to insert the desired genes from foreign species into the genome of a crop, according to Halford (2012), is one of the major advantages of the GMO technology as compared to conventional plant breeding. Other than weeds, the boll worm, which devours tender cotton bolls if not controlled, causes heavy losses in yields of cotton crop.

A non-GMO cotton plant in Zimbabwe produces bolls that weigh on average between 5 and 7 grams, depending on the position of boll on the plant, the top boll being the lightest, the middle boll heavier, and bottom the heaviest. One plant can carry up to 100 bolls, and one hectare may hold over 20,000 plants depending on plant spacing (Mhandu, 2016). Table 5.3 illustrates the yields that can be achieved of seed cotton, depending on the plants established, number of bolls retained by a plant, and the weight of the bolls.

**Table 5.3 Seed Cotton Potential Yields (per Hectare)**

<table>
<thead>
<tr>
<th>Seed cotton plants per hectare</th>
<th>Bolls per plant</th>
<th>Average boll weight (grams)</th>
<th>Yield per hectare (kilograms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>33,000</td>
<td>5</td>
<td>5</td>
<td>825</td>
</tr>
<tr>
<td>33,000</td>
<td>10</td>
<td>5</td>
<td>1 650</td>
</tr>
<tr>
<td>33,000</td>
<td>20</td>
<td>5</td>
<td>3 300</td>
</tr>
<tr>
<td>33,000</td>
<td>30</td>
<td>5</td>
<td>4 950</td>
</tr>
</tbody>
</table>

Source: Mhandu (2016)

It is obvious that the greater the number of bolls retained on the plant, the higher the yield that a farmer can achieve—doubling the number of bolls leads to roughly double the number of kilograms produced per hectare. However, one of the major causes of loss of yield in cotton farming is the bollworm, a caterpillar that feeds on the tender boll. Farmers spray pesticides to protect the bolls against the bollworm; however, not all sprays are effective.
Among many reasons farmers fail to control the pests effectively: There may be errors in the calibration and mixing of the chemicals and water, or the active ingredient of the chemical may have expired. A heavy downpour of rain may happen soon after the farmer will have sprayed the chemical, and the pesticide may have been washed away. Still, owing to repeated applications, the pest may have developed resistance against the pesticide in use.

The insect-resistant GM cotton was developed to address this problem. Its advantage is that the pesticide is inbuilt in the plant. Thus, the need for spraying insecticide is reduced because the bollworm dies soon after taking a bite of the plant. The reduction in number of sprays translates into a reduction in walking distances for the farmers. Invariably smallholder farmers are resource poor, and unlike commercial farmers, they lack mechanical tractor-drawn boom sprayers and use, instead, manual knapsack sprayers. Because of this, farmers walk long distances to complete one round of spray on one hectare of land. A one-hectare piece of land is equivalent to 10,000 square meters (100 m x 100 m), and during spraying, the distance covered is 10 kilometers because the knapsack covers one swath which is one meter.

The table below shows the average net income for smallholder farmers in non-GMO (Zimbabwe) versus GMO producing countries (South Africa), 2013/2014 Season.

<table>
<thead>
<tr>
<th></th>
<th>Zimbabwe Non-GM</th>
<th>South Africa GM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of sprays</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Yield of seed cotton (kilogram/hectare)</td>
<td>819</td>
<td>1,012</td>
</tr>
<tr>
<td>Price for seed cotton (US cents/kilogram)</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>Income (US$/ha.)</td>
<td>459</td>
<td>567</td>
</tr>
<tr>
<td>Cost of production (US$/ha.)</td>
<td>359</td>
<td>306</td>
</tr>
<tr>
<td>Net income (US$/ha.)</td>
<td>100</td>
<td>261</td>
</tr>
</tbody>
</table>

Source: Mhandu (2016).

Table 7.4 shows the results of a study in 2015 of 72 smallholder farmers in Gokwe, Sanyati, and Chinhoyi in Zimbabwe and of 42 farmers in Makhathini Flats and KwaZulu-Natal in South Africa. It was established that the number of sprays by South Africa farmers that produce GM cotton is 2; therefore, the South African farmers would walk 20 kilometers per hectare, carrying a 16 liter knapsack sprayer. In contrast, the Zimbabwean farmers would walk 80 kilometers. Furthermore, the South African smallholder farmers achieved a 193 kilogram higher yield per hectare than their Zimbabwean counterparts. Even though the price of cotton seed was the same at 56 cents per kilogram, the South African farmers had lower costs of production of $306 as compared to $359 incurred by the Zimbabwean farmers. Thus, net income per hectare for South African smallholder farmers was 2.61 times greater than that of the Zimbabwean smallholder farmers.

For purposes of comparison, if Zimbabwe were to adopt GM cotton, it is assumed that all 400,000 hectares available for cotton production would be cultivated and the average yield would increase to 1,012 kilograms per hectare, other things remaining equal. Thus, it would mean that the national incremental benefit of adoption of GM cotton would be (193 x 400,000 x 0.56) $43 million, based on the findings of the aforementioned study. The
incremental benefit for a smallholder farmer would be $108 per hectare. However, the varieties sold in Zimbabwe have a potential yield of 4,000 kilograms per hectare under high input management with the potential of 2,000 kilograms per hectare under dry land conditions. It is proven that farmers that adopt GM cotton achieve higher yields and more economic benefits. There are also social benefits that accrue as a result of use of GM cotton.

The significant social benefits of GM cotton include the reduction in chemicals that are stored in homes and are released into water bodies. Resource poor smallholder farmers do not use adequate protective apparel when applying the chemicals (Kouser and Qaim 2011). Also, the farmers are mainly illiterate and unable to read and understand chemical dosage instructions on leaflets or container labels. In a study of smallholder cotton farmers in Zimbabwe, Maumbe and Swinton (2003) found that the growers lost significant amounts of money each year owing to pesticide-related health effects. Various ailments, including nausea and vomiting, skin rash, and itching eyes, affected the farmers. Kouser and Qaim (2011) pointed out that adopters of Bt cotton experienced 1.8 fewer cases of pesticide poisoning per season compared to non-adopters. However, symptoms of itching eyes and sneezing are common in people with allergies. In China, Pray et al. (2001) found that after adoption of GM cotton, there were significant reductions in the number of pesticide sprays from 30 to 3 times in some cases, while some farmers reduced sprays from 12 to 2 times.

Thirtle et al. (2003) noted health and environmental benefits in the Makhathini Flats, in South Africa as a result of the adoption of Bt cotton. Before adoption of the technology, cleaning and disposal of chemical waste were done haphazardly in fields and household refuse pits. There was a marked improvement with the introduction of Bt cotton because a reduced number of chemicals were used. Critics of GMOs argue that the claims of reduced pesticide use are unfounded because the insects develop resistance over time, and the farmers will gradually revert to use of pesticides (Antoniou, Robinson, and Fagan 2012). To manage pest resistance of GM cotton, farmers are encouraged to plant a refuge of non-Bt cotton alongside Bt cotton. For instance, in Australia, high doses of pesticides and refugia have been used to manage pest resistance to Bt cotton (Downe and Mahon 2012).

Atherton (2002) argues that proteins in the food consumed will not cause serious health problems in humans because almost all proteins that are ingested are eliminated in the digestive system by proteases. In support, Batista and Oliveira (2009) argue that although genetic engineering is a recent technology, studies carried out so far on GMO food have not provided evidence of adverse effects on human health. Thus, it is assumed the proteins contained in the oil extracted from Bt cottonseed likewise will be destroyed.

The findings above clearly show why Zimbabwean farmers are shunning production of cotton ahead of other crops. The adoption of GM cotton is not a panacea for the falling national production of cotton, but it will certainly help. The GM cotton is just but one tool available in the toolkit of farmers. GM technology does not replace, but compliments other agronomic practices, such as the use of integrated pest management systems, the use of lime and fertilizers, and in the case of rain-fed farming, complimentary water and so forth.

Impacts of feeding GM cotton products to domestic animals

The issue regarding the concern about the safety of insect-resistant GM products has been documented in various studies. The retracted Seralini et al. (2012) study about rats that developed tumors after having been fed Monsanto’s herbicide-tolerant (Roundup™ Ready)
GM maize consistently for 90 days, raised a lot of doubt in the minds of many people about the safety of GMOs (Adenle, Morris, and Parayil 2013). Even the Kenyan government banned GM crops after the publication of the Seralini paper (DeRosier et al. 2015).

However, all GM crops are subject to safety evaluation of the genes before the product is released commercially. The issue regarding the safety of the insect resistant GM crops was dealt with by Christou and Twyman (2004); they explained how although the insects are killed by the genes, yet it is safe for other animals and human beings to eat the protein. They stated, “The Bacillus thuringiensis (Bt) is a spore-forming bacterium that produces insecticidal toxins during the sporulation process.” The toxins are activated by proteinases in the highly alkaline environment of the insect gut. Christou and Twyman explain that the guts of human beings and those of the little insects, for example, the bollworm that are killed by the Bt protein are biologically different; hence, the unlikeyhood of any adverse effects on the health of people that eat food from insect-resistant GM products.

A more recent paper by Thomson (2015) explains that “the toxin, which is protein, binds to specific cells in the lining of the guts of the susceptible larvae, punctures them, and leads to the death of the larvae.” Furthermore, a study by Walsh et al. (2012) on the effect of insect-resistant GM maize proved that the transgenic crop had the same effect as its isogenic equivalent. Walsh et al. (2012) found no adverse effects in the vital organs of the pigs after feeding them for 110 days with a Monsanto insect-resistant GM maize variety.

Another aspect to consider is the risk of allergies to humans that consume GM products because all crops, whether transgenic or conventional have the potential to be allergenic (Key, Ma, and Drake 2008). According to Wang and Sampson (2011), food allergies are caused by food proteins, and some of the sources of food allergens are mammalian milk, fish, soybeans, peanuts, and rice. Halford (2012) notes that food allergens have been noted long before the advent of GM crops. In addition, Key, Ma, and Drake (2008) argue that GM crops undergo more stringent safety evaluations than their counterparts, the conventional varieties. The evaluation of transgenic crops against allergies uses a special bioinformatics computerized software, and according to Ladics et al. (2011), the biotech industry has successfully used bioinformatics to screen transgenic crops against potential allergenicity.

**Organic cotton**

This section examines whether organic cotton is a viable option to conventional and GM cotton in Zimbabwe. Proponents of organic farming claim that it brings beneficial impacts to the environment as compared to conventional agriculture. In this study, we use the definition of organic agriculture as given by the Institute of Science in Society (2007) and attributed to the Food and Agriculture Organisation of the United Nations (FAO), that is, “a holistic production management system that avoids the use of synthetic fertilizers and pesticides, and genetically modified organisms, minimizes pollution of air, soil and water, and optimises the health and productivity of plants, animals and people.”

The major issue with cotton production has been established, it is pest control. Farmers may grow organic cotton if organic pesticides are available at costs that are affordable to farmers. In addition, the market for organic cotton needs to compensate growers sufficiently to enable them to produce organic cotton at a profit. When asked what challenges organic cotton growers may face, an entomologist responded, “in this country the crop isn’t fed properly and that makes it even more susceptible to pest attack and disease.” In addition, when ginning the
cotton, the farmers must produce sufficient volumes to dedicate the gin to the ginning of organic cotton, a challenge that may not be addressed easily.

It was noted earlier that cotton is mainly grown in Zimbabwe under contract. An expert from the Cotton Ginters Association of Zimbabwe (CGA) noted that two ginning companies that have been involved in producing “organic cotton” in Zimbabwe have not been strictly working on “pure organic cotton” because the parameters, as defined by FAO, may not have been followed. However, there may be confusion between what constitutes conventional cotton and organic cotton. Seed companies that breed, propagate, and distribute cotton planting seed, apply fungicides and pesticides to protect foundation seed and the scarce, valuable, and expensive breeder seed usually available in small quantities. The growers of organic cotton may not access this type of seed if they follow the strict no pesticide requirement. A senior official of the Zimbabwe Farmers Union (ZFU) summed it up, “given the priorities of wanting to achieve higher yields, the farmers may not embrace the organic cotton unless the returns per hectare are higher than conventional cotton, but as of now organic cotton is not our priority.”

**Soybeans**

Soybean is a source of protein, and its products include edible oil and soybean cake for stock feeds. The national demand is estimated at 300,000 tonnes, but the market has perennial shortages (MAMID, 2016). The soya meal is also used for a variety of products that include confectionery, protein meal, and many more products. In Zimbabwe, the soybean crop is produced on about 100,000 hectares, mainly by A2 medium- and large-scale commercial farmers. However, there are some A1 small-scale farmers located in medium-to-high rainfall potential areas that are involved in soybean growing (Authors data).

The conventional varieties available from seed companies have a yield potential of 4–5 tonnes per hectare, yet the actual national average yield achieved in 2014/15 was a disappointing 1.2 tonnes per hectare (MAMID, 2016). The crop thrives in fertile soils and requires water of 500mm-600mm during the season. Some farmers grow the crop under rain-fed conditions, but the yield is enhanced if supplementary water in the form of irrigation is available. Ideally, combine machine harvesting is required when grown on large pieces of land. In this regard, the crop is mainly grown by commercial farmers that are highly mechanized and have access to irrigation facilities.

Rural farmers that grow GM herbicide-tolerant (HT) soybeans under dry-land in South Africa achieve higher yields (2 tonnes per hectare) (DAFF, 2016) than their Zimbabwean counterparts who achieve 1.5 tonnes using non-GM varieties (MAMID, 2016). This is attributable mainly to weed control because the South African farmers are able to keep their fields clean of weeds during the plant’s vegetative stages. Therefore, the South African crops get adequate nutrients and, as a result, achieve optimum yields.

**Maize**

Maize is the main staple food for 14 million people in Zimbabwe (Rukuni et al., 2006). However, perennial food shortages have dogged the country since the introduction of the land reform in 2000. Again, drought, erratic rainfall, poor distribution of farming inputs, such as seed and fertilizer, are attributed as the major causes of falling national productivity.
The improvement of maize crop varieties started in 1932 at the government research station in what was then Salisbury. The release of the first hybrid seed maize, SR 52, occurred in 1960 (McCann 2005). Zimbabwean maize farmers are renowned for taking the lead in the world on adoption of hybrid technology, and the current take-up of hybrid seed maize is over 80 percent. According to Seed Co Limited (1999), 80 percent of maize seed sales were in the communal sector. This important market was confirmed by McCann (2005) who reported that as early as 1967 small-scale and communal farmers had discovered the yield potential of hybrid seed maize, the SR52.

The yield potential of some of the hybrids currently available on the market is about 15 tonnes per hectare under high management regimes. Yet, in comparison, productivity is a far cry from potential. The Ministry of Agriculture, Mechanisation and Irrigation Development (MAMID 2015) reported that during the cropping season 2014/15, the national average yield had been below 500 kilograms per hectare. Further, MAMID reported that in the 2013/14 cropping season, maize was grown on 1,655,000 hectares by A1 farmers, A2 farmers, and old resettlement farmers with national production at 1,456,000 tonnes.

Unlike cotton where losses in yield are mainly caused by pests, in maize production, the lack of fertilizers including lime is the major cause. In addition, weed control, stem borer caterpillar, and the lack of sufficient moisture adds to the challenges that maize farmers face. In this regard, a stacked gene GM maize that has both insect-resistant and herbicide-tolerant (HT) traits can help deal with the challenges of stem borer and weed control.

In the smallholder farming sector, conservation farming has been encouraged by extension workers for a long time. It was found by Gouse et al. (2016) that in South Africa smallholder farmers who use minimum tillage had higher adoption rates of HT GM maize. They found that the farmers’ decisions were influenced by the reduction of weeding. In this regard, the farmers spray herbicides on their HT GM maize crop and allocate their free time to other activities. In Zimbabwe, the main raw material for cattle feed is maize, ginned seed cotton, and soybean. Because of the shortages in the country, milling companies have had to import raw materials from neighbouring countries, mainly South Africa. About 70 percent of maize produced in South Africa is GM. When asked whether they have used any raw material that is GM, a senior manager of a milling company explained that the Ministry of Agriculture did not issue specific import licences for GM products for stock feed. An official at the Ministry of Agriculture said that government policy is to protect the export market for Zimbabwean products because the European Union does not like GMOs. However, this argument is not feasible because the EU imports GM soya meal from the USA as well as South America. Despite any objections to the effects of GMO products on human health, Zimbabwean consumers are already eating GM maize imported from South Africa, in effect, supporting the South African maize industry at the expense of Zimbabwe’s maize farmers.

Lost Opportunities for Zimbabwe

Stockfeed supply and demand

The Ministry of Agriculture estimates national demand for stockfeed at 400,000 tonnes (350,000 MT). According to MAMID (2015), the broilers are consuming 70 percent of the total feed produced by the animal feed industry. This volume is allocated between broilers, pigs, and cattle for dairy and beef. Because of perennial low harvest of field crops, stockfeed shortages of stockfeeds in Zimbabwe have led to imports. However, the Ministry of
Agriculture does not allow imports of stockfeeds that contain GM products into the country because the government would like to protect the country’s exports to the countries that do not accept GMOs. This is against the backdrop that South Africa, Zimbabwe’s main trading partner, grows three GM crops that provide the bulk of stockfeeds: maize, soybeans, and cotton. According to the Livestock & Meat Advisory Council (Commercial Farmers Union, 2015), the imports of GM-free soybean have been difficult because most major soybean-producing countries grow GM soybeans.

During the year ending December 31, 2014, the stockfeed supply industry produced 440,000 tonnes of stockfeed, yet it operated at 29 percent capacity (Commercial Farmers Union 2015). This shows that the industry can produce over 1.3 million tonnes if operating at full capacity. However, this may not be achievable unless the country improves farm productivity. Productivity can be enhanced if farmers adopt new farming technologies that include biotechnology.

**Beef and dairy cattle farming**

The national herd of beef cattle is estimated at 5.5 million, of which over 90 percent is held by smallholder farmers (MAMID 2015). Thus, about 500,000 cattle are in the hands of commercial farmers who have larger pieces of land and may afford to buy supplementary animal feed in the event of drought and during the dry period when pasturage is depleted. The main constraints affecting cattle production include drought and diseases. The recurrent droughts caused massive de-stocking in the main cattle-producing regions of Matabeleland and Midlands provinces. Cattle have succumbed to foot-and-mouth disease, and its control is a priority of government and farmers.

High-protein animal feeds are fed to beef cattle for pen feeding and supplementary feeding during the dry period when pasturage is depleted of grass. In pen feeding, the cattle are put on intensive feeding for 90 days, using nutritious stock feeds to enhance the finishing of the cattle to achieve the maximum price offered by the market. The soya meal is preferred because of its high protein content. However, because of shortages of soya beans, maize meal is generally used.

**Pigs**

During the 2015/16 farming period, the number of pigs produced increased by 23 percent from 345,249 in the previous year to 425,540. The major constraint on pig production is the shortages of maize meal, which is the main raw material in the pig feed. Small-scale producers rely on their own maize production.

**Imported chicken**

In 2014, Zimbabwe imported 3,988 tonnes of chicken from South Africa (SA Poultry Association, 2015). Most likely, the chicken had been produced using mainly GM-based stockfeed because 70 percent of maize, 95 percent soya bean, and 95 percent cotton produced in South Africa is GM. The total exports of poultry from South Africa to regional countries were 66,355 tonnes.
6. Recommendations and Paths Ahead

Achieving farmer profitability through transgenic crops

The stark reality of perennial challenges that agriculture faces are prices and the weather, both of which farmers cannot control. The profit that smallholder farmers can achieve is determined by the volume produced, price of all inputs, and costs of marketing. Farmers can achieve higher income if yields are increased, costs of production are lowered, and market access is eased. Owing to the fact that the higher the volume, the lower the unit cost, to increase farmer income, yields must be increased. Experience from farmers around the world shows that by growing Bt cotton, an insect-resistant transgenic crop, they achieved higher yields and profits in comparison to their counterparts that grow conventional varieties.

Developing practical, scientifically valid regulatory policies to commercialize GM crops

In light of the above, there is a case to be made for adoption of Bt cotton in Zimbabwe, despite perceived risks of losing access to markets, effects on human health, and giving control of ownership to multinational companies. Owing to various controversies surrounding GM crops around the world, there is a need to develop practical and yet scientifically valid regulatory policies to facilitate field testing and the commercialization of GM crops in Zimbabwe. Thus, political will, the scientific regulatory framework for CFTs, commercialization, and stakeholder communication must all be considered before Bt cotton is introduced, as discussed below.

Ensuring political will to create enabling environments for biotech R&D

The most important factor in the adoption of Bt cotton is political will. Zimbabwe is a signatory of the Cartagena Biotechnology Protocol, has implemented the legal framework for biotechnology, and established the National Biotechnology Authority (NBA). Because biosafety regulations are in place, and the NBA has the capacity to handle GMO-related issues, including safety evaluation, an environment should be created that allows for biotechnology research and development. This would involve CFTs and making the products, if found safe, available to the farmers. The government of Zimbabwe must take a bold decision to functionalize its established regulatory authority and move forward with the introduction of biotech crops into the country’s agriculture. Zimbabwe has no time to lose on this point.

Protecting national seed varieties against sovereignty concerns

A point of controversy often debated by policy makers and other stakeholders is the control of national seed assets by “foreign” multinationals—what is really a seed sovereignty concern. In response to these concerns, Zimbabwe can resort to many available schemes: the country can apply national seed laws to establish the ownership of seeds or the subsequent introgression of new biotech traits into local varieties that farmers prefer. International laws protecting the rights of plant genetic resources confer such rights to countries. Zimbabwe already has national seed banks that have authentic scientific information about its seeds to ward-off any poaching of seeds.
Bolstering regulatory framework safe deployment of GM crops

In the early 2000s, Confined Field Trials (CFTs) were conducted on Bt cotton in Kadoma, Zimbabwe. Results of the trials were not made public, and CFTs were shut down without any explanation. Since then, purveyors of biotech crops have released an impressive array of new biotech crops that could enormously help Zimbabwean farmers. Zimbabwe lagged behind building its regulatory oversight capacity in the interim, and farmers saw no benefit from the new technology. It is important to evaluate the new technology at research stations under the supervision of the NBA. It is critical to have a functional, consistent, and reliable regulatory framework to realize the safe deployment of GM crops into the country’s agriculture. The regulatory framework must be able to speedily and effectively move forward CFTs and large-scale unconfined field trials so that GM cotton can be delivered to farmers as soon as possible. Zimbabwe must take advantage of the combined global expertise and experience, knowledge, and skills that have accrued in the past twenty years of growing GM crops—and hasten their deployment in Zimbabwean agriculture.

The Cartagena Protocol on Biosafety lays out clear ways by which signatory countries can apply the expertise available to set up a sound regulatory framework for biotech crops, and that option must be exercised by Zimbabwe immediately.

Zimbabwe must embrace science-based regulatory policies that by default is cautionary in its approach but opposed to the way the European Union (EU) interprets the precautionary principle—an approach that grinds everything to halt for want of absolute proof that nothing negative happens. It is difficult to design an experiment to prove a negative thing does not ever happen.

Zimbabwe can easily rely upon the scientific views and opinions of leading scientific academies and regulatory authorities of the world to make its decisions on GM crops. Zimbabwe can take a lot of comfort on the singular fact that in almost 20 years of GM crops cultivation around the world, not a single harm to the environment or other life forms have been reported. Zimbabwe has nothing to fear but fear itself to go ahead with GM crop technology.

There is a real concern regarding the socioeconomic benefits of GM crops for which Zimbabwe can conduct ex-ante analysis under the provisions of the Cartagena Protocol on Biosafety. This concern alone should not be the reason for delaying the implementation of agricultural biotechnology in agriculture. The path ahead for Zimbabwe is clear, and that is to facilitate the immediate safe deployment of biotech crops under a proficiently functioning regulatory authority.

Addressing fear of loss of export markets via lessons from abroad

Zimbabwe can learn lessons from South Africa, a country that has commercialized GM crops since 1997 and has never lost an export market for its beef and poultry that is fed on GM stockfeed. Indeed, Denmark has not lost a single market for its lucrative Danish ham from pigs fed on GM stockfeed and traded globally.

Reviving public awareness and participation in biotechnology issues
Zimbabwe should resuscitate previous efforts at building public awareness and participation on agricultural biotechnology issues.

**Summary of recommendations**

- The government should lift the ban on GM stockfeeds.
- Government must create an enabling environment that resuscitates agriculture, using GM technologies where appropriate.
- Government must set up a science-based regulatory framework and functionalize the existing regulatory authority.
- Zimbabwe can avail itself of the services of existing biosafety initiatives to build its capacity for biosafety review.
- Government should immediately permit CFTs of GM cotton and other GM crops.
- Regulatory authorities, in addition to assessing socioeconomic impacts of GM crops, must also carry out risk-benefit analysis.
- Government should align National Biosafety Framework to international best practices.
- Zimbabwe should take a cautionary approach to regulate GM crops as opposed to the precautionary principle that will completely halt progress.
- Regulatory authorities must develop protocols for continuous monitoring of GM crops post-commercialization and inspect for regulatory compliance by the technology purveyors.
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Appendices

Appendix A: History and Status of Biotechnology: International

United States Agricultural Biotechnology Policy

The U.S. Department of State’s Office of Agricultural Policy supports and advances American agricultural interests, which are integral to the State Department’s critical global trade and food security goals. The Office also addresses trade barriers to open markets for American farm products. In Fiscal Year 2015, the United States exported US$133 billion in agricultural products and had a trade surplus of $19 billion for the agricultural sector. The United States contributes to the development of effective food aid policies, promotes rural development and increasing agricultural productivity through biotechnology, and handles commodity issues within the State Department such as cotton and coffee. Through this Office, the State Department also works to ensure the health and well-being of U.S. consumers by monitoring food safety, animal health, and plant health. Regarding food security, the United States brings stakeholders and policymakers together to address the needs of small-scale farmers. Additionally, the Office of Agricultural Policy leads new agricultural technologies outreach to promote transparent, predictable, and science-based regulatory frameworks.

President Obama recently signed the Global Food Security Act of 2016 to ensure global farm development. This act specifically promotes the use of GM crops development and the export of GM crops as a part of food aid from the United States.

Advances in science, many resulting from research findings of scientists at the U.S. Department of Agriculture (USDA) or through USDA-funded research, have opened up new options for farmers by responding to market needs and environmental challenges. Many new plant varieties being developed or grown by farmers have been produced, using genetic engineering, which involves manipulating the plant's genes through techniques of modern molecular biology (often referred to as recombinant DNA technology). These techniques are included in what is often referred to as biotechnology or modern biotechnology.

The USDA supports the safe, appropriate use of science and technology, including biotechnology, to help meet agricultural challenges and consumer needs of the 21st century. The USDA plays a key role in assuring that biotechnology plants and the products derived from these plants are safe to be grown and used in the United States. Once these plants and products enter commerce, the USDA supports the export of these and other products to the worldwide marketplace.

Government Responsibility for the Safety of Agricultural Biotechnology

Under the rubric of the Federal Coordinated Regulatory Oversight on Biotechnology (1986), three federal agencies are involved in ensuring that plants produced using biotechnology and

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5 For more information on the State Department’s Office of Agricultural Policy's goals and activities, visit http://www.state.gov/e/eb/tpp/agp/index.htm.
the many products derived from them are safe for farmers to use, for humans and animals to consume, and for the environment to ensure sustainable development. These three agencies are USDA's Animal and Plant Health Inspection Service (APHIS), the U.S. Department of Health and Human Services' Food and Drug Administration (FDA), and the United States Environmental Protection Agency (EPA). These three agencies regulate these products based on the characteristics of the actual products and their intended uses. They operate under the existing laws passed by the U.S. Congress to ensure the safety of plants and pesticides used in agriculture, and the safety of foods and feed consumed by humans and animals. In addition, many other USDA agencies have roles in the development, use, and marketing of these products as well.

At present, the USDA-APHIS is engaged in an exercise to revise its biotech regulations. Both houses of the U.S. Congress have passed a new GMO labeling bill in July 2016 to override any other state- or county-passed bills on the labeling of GM foods.

Farmer Adoption of Agricultural Biotechnology-Derived Crops

Since the first successful commercialization of a biotechnology-derived crop in the 1996, many new crop varieties have been developed and made available to farmers in the United States and worldwide. According to the latest report of the USDA-Economic Research Service (ERS), U.S. farmers have rapidly adopted many of these new GE varieties, so that in 2016, 92 percent of the corn, 93 percent of the cotton, and 94 percent of the soybeans planted in the U.S. were varieties produced through genetic engineering. A large proportion of the production of other crops, such as alfalfa, papaya, and sugar beet, is biotech-derived. As of 2016, the United States has 40 percent of the global acreage of genetically engineered plants planted.

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Biotechnology Policy Development

Essentially, the history and the status of biotechnology in the United States reflects the timeline of modern biotechnology around the world. The U.S. biotechnology industry’s rapid growth is largely a result of intellectual property laws following the U.S. Supreme Court’s landmark decision on modified living organisms in 1970 and ensuing regulatory policies. The Court’s decision was key since private investment in modern agriculture flowed only once there was guarantee that processes and products developed by companies are not appropriated by others. Contrasting that with the developing countries clearly shows that without proper intellectually property rights, no investment in modern biotechnology invention or innovation occurs. Even, the transfer of technology has been hampered by regulations that are mainly designed to stall technology implementation. As a result, most developing countries have not benefitted from the modern biotech crops even after 30 years after their commercial debut. What benefited the U.S. agricultural biotechnology is the alacrity with which it put together a sensible, science-based regulatory oversight mechanism that has undergone appropriate improvements and modifications to facilitate the safe transfer of technology to the farmers as early as mid-1980s. That helped catapult the United States to become a leading nation in the field of modern agricultural biotechnology. In fact, even multinational companies pursued their agribusiness interests involving modern biotechnology in the U.S. market, leaving the European Union (EU) far behind solely for want of facilitative regulatory policies that are currently being confounded by anti-tech activism.

The increasing use of biotechnology in agriculture has changed, and will continue to change, farming and the work of the USDA in the long term. To help understand and address these changes, the USDA established the Advisory Committee on Biotechnology and 21st Century Agriculture (AC21). AC 21 was originally established in 2003 and was chartered to examine the long-term impacts of biotechnology on U.S. agriculture and provide policy guidance to the USDA to chalk out a roadmap for the development of modern agricultural biotechnology.

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for the betterment of U.S. agriculture. One critical area where the committee has recently focused its attention is on how farmers who produce different crops intended for different customers—biotechnology derived, conventional, or organic—can best co-exist and produce the crops that meet their customers' needs. Essentially, the position of the United States is that GM and organic crops can co-exist without compromising each other’s integrity and fidelity. Herbicide-tolerant (HT) crops, developed to survive application of specific herbicides that previously would have destroyed the crop along with the targeted weeds, provide farmers with a broader variety of options for effective weed control. Based on USDA survey data (Fernandez-Cornejo et al. 2014), HT soybeans went from 17 percent of U.S. soybean acreage in 1997 to 68 percent in 2001 and 94 percent in 2014 and 2015. Plantings of HT cotton expanded from about 10 percent of U.S. acreage in 1997 to 56 percent in 2001, 91 percent in 2014, but declined to 84 percent in 2015. The adoption of HT maize, which had been slower in previous years, has accelerated, reaching 89 percent of U.S. corn acreage in 2014 and in 2015.

Insect-resistant crops containing the gene from the soil bacterium Bt (Bacillus thuringiensis) have been available for maize and cotton since 1996. These bacteria produce a protein that is toxic to specific insects, protecting the plant over its entire life. Plantings of Bt maize grew from about 8 percent of U.S. corn acreage in 1997 to 19 percent in 2000 and 2001, before climbing to 29 percent in 2003 and 81 percent in 2015. The increases in acreage share in recent years may be largely due to the commercial introduction of new Bt maize varieties resistant to the corn rootworm and the corn earworm, in addition to the European corn borer, which was previously the only pest targeted by Bt maize. Plantings of Bt cotton also expanded rapidly, from 15 percent of U.S. cotton acreage in 1997 to 37 percent in 2001 and 84 percent in 2014 and in 2015 (ibid.).

Use of Bt maize will likely continue to fluctuate over time, based on expected infestation levels of European corn borer, and the corn rootworm, which are the main pests targeted by Bt maize. Similarly, the adoption of Bt cotton depends on the expected infestation of Bt target pests, such as the tobacco budworm, the bollworm, and the pink bollworm. Adoption appears to have reached a plateau, as adoption has already occurred on acreage where Bt protection is needed most. Insect-resistant varieties have not been developed for soybeans.

These figures include adoption of "stacked" varieties of cotton and corn, which have both HT and Bt traits. The adoption of stacked varieties has accelerated in recent years. Stacked cotton reached 79 percent of cotton plantings in 2015. Plantings of stacked corn made up 77 percent of corn acres in 2015.

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10 The AC21 has provided a report to USDA, with recommendations, on this subject; for more information, visit http://www.usda.gov/wps/portal/usda/usdahome?navid=BIOTECH.
Number of releases approved by APHIS by GE trait (includes permits and notifications)*

- Bacterial resistance, 224
- Fungal resistance, 1,191
- Virus resistance, 1,425
- Marker gene, 1,892
- Other, 1,986
- Agronomic properties, 5,190
- Herbicide tolerance, 6,772
- Nematode resistance (NR), 149
- Insect resistance, 4,809
- Product quality, 4,896

*As of September 24, 2013.
Authorizations for field releases of GE plant varieties are issued by USDA’s Animal and Plant Health Inspection Service (APHIS) to allow technology providers to pursue field testing. Counts refer to the actual number of approved release locations per phenotype category. http://www.aphis.usda.gov/biotechnology/status.shtml

Number of releases approved by APHIS: Top 10 crops (includes permits and notifications)*

- Corn: 7,778
- Soybeans: 2,225
- Cotton: 1,104
- Potato: 904
- Tomato: 688
- Wheat: 485
- Alfalfa: 452
- Tobacco: 427
- Rapeseed: 310
- Rice: 294

*As of September 24, 2013.
Authorizations for field releases of GE plant varieties are issued by USDA’s Animal and Plant Health Inspection Service (APHIS) to allow technology providers to pursue field testing.
Adoption of genetically engineered corn: growth of stacked traits, 2000-2013

Percent of acres planted

Bt crops have insect-resistant traits; HT crops have herbicide tolerance traits.

Figure 10
Adoption of genetically engineered cotton: growth of stacked traits, 2000-2013

Percent of acres planted

Bt crops have insect-resistant traits; HT crops have herbicide tolerance traits.
The adoption of all genetically engineered cotton, taking into account the acreage with HT or Bt traits, or both, reached 94 percent of cotton acreage in 2015. Genetically engineered soybean adoption rates reached 94 percent in 2015 (soybeans have only HT varieties how about high oleic soybeans). Adoption of all genetically engineered maize accounted for 92 percent of maize acreage in 2015.

Most U.S. acres planted with GE crops have traits that provide Herbicide Tolerance (HT) or Insect Resistance (IR), or both. These seeds became commercially available in 1996. Several second-generation GE crops have been approved by APHIS: high-lysine maize, reduced-nicotine tobacco, high oleic acid soybean oil, stearidonic acid-producing soybeans, improved fatty acid–profile soybeans, altered-flower color roses (blue), oil profile-altered canola, and alpha amylase maize. Overall, nearly 20 percent of the approvals for deregulation (as of September 2013) were second-generation crops (Genetically Engineered Crops in the United States, ERR-162 Economic Research Service (ERS)/USDA). More than 15 years after commercial introduction, adoption of first-generation GE crop varieties by U.S. farmers has reached about 90 percent of the planted acres of maize, soybeans, and cotton. U.S. consumers eat many products derived from these crops—including maize meal, oils, and sugars—largely unaware of their GE origins. Despite the rapid increase in adoption rates for GE maize, soybean, and cotton varieties by U.S. farmers, some continue to raise questions regarding the potential benefits and risks of GE crops (Fernandez-Cornejo et al. 2014).

National Academies Report on Policy and Regulatory Framework

A new report issued in May 2016 by the National Academies of Science (Genetically Engineered Crops: Experiences and Prospects) new technologies in genetic engineering and conventional breeding are blurring the once clear distinctions between these two crop-improvement approaches. While recognizing the inherent difficulty of detecting subtle or long-term effects in health or the environment, the study committee found no substantiated evidence of a difference in risks to human health between currently commercialized GE crops and conventionally bred crops, nor did it find conclusive cause-and-effect evidence of environmental problems from the GE crops. GE crops have generally had favorable economic outcomes for producers in early years of adoption, but enduring and widespread gains will depend on institutional support and access to profitable local and global markets, especially for resource-poor farmers.

The following are the main conclusions presented in the report about various effects of Bt crops based on available data:

- **Bt Crop Yield.** Bt in maize and cotton from 1996 to 2015 contributed to a reduction in crop losses (closing the gap between actual yield and potential yield) under circumstances where targeted insect pests caused substantial damage to non-Bt varieties and synthetic chemicals could not provide practical control.

- **Abundance and diversity of insects.** In areas of the United States and China where adoption of either Bt maize or Bt cotton is high, some insect-pest populations have been reduced regionally, benefiting both adopters and nonadopters of Bt crops. Some secondary (nontargeted) insect pests have increased in abundance, but there are only a few cases in which the increase has posed an agronomic problem. Planting Bt crops

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11 For a report in brief or a downloadable PDF of the full report, visit http://nas-sites.org/ge-crops/.
tended to result in higher insect biodiversity than planting similar varieties without the $Bt$ trait and using synthetic insecticides.

- **Insecticide use.** Application of synthetic insecticides to maize and cotton has decreased following the switch from non-$Bt$ varieties to $Bt$ varieties, and in some cases, the use of $Bt$ crops has been associated with lower use of insecticides in non-$Bt$ varieties of the crop and other crops in the same area.

- **Insect resistance.** Target insects have been slow to evolve resistance to $Bt$ proteins when crops produced a high-enough dose of $Bt$ protein to kill insects with partial genetic resistance to the toxin, and there were refuges where susceptible insects survived. Where resistance-management strategies were not followed, damaging levels of resistance evolved in some target insects.

- **Herbicide resistance** allows a crop to survive the application of an herbicide that would otherwise kill it. Most herbicide-resistant GE crops are engineered to be resistant to glyphosate, commonly known as RoundUp®. Conclusions based on the available evidence include the following:

- **Herbicide-resistant crop yield.** Studies indicate that herbicide-resistant crops contribute to greater yield where weed control is improved because of the specific herbicides that can be used in conjunction with the herbicide-resistant crop.

- **Herbicide use.** Total kilograms of all types of herbicide applied per hectare of crop per year declined when herbicide-resistant crops were first adopted, but the decreases have not generally been sustained. However, total kilograms of herbicide applied per hectare is an uninformative metric for assessing changes in risks to the environment or to human health owing to GE crops; because the environmental and health hazards of different herbicides vary, the relationship of kilograms of herbicide applied per hectare and risk is poor.

- **Weed-species distribution.** In locations where glyphosate is used extensively, weed species that are naturally less susceptible to that herbicide may populate a field. The Committee found little evidence that agronomic harm had resulted from such shifts in weed species.

- **Weed resistance.** In many locations, some weeds have evolved resistance to glyphosate. Integrated weed-management approaches can be used to delay resistance, especially in cropping systems not yet exposed to continuous glyphosate applications. Further research is needed to improve strategies for management of resistance in weeds.

Overall, the Committee found no conclusive evidence of cause-and-effect relationships between GE crops and environmental problems. However, the complex nature of assessing long-term environmental changes often made it difficult to reach definitive conclusions.

**Comparisons with conventional breeding**

The Committee assessed detailed surveys and experiments comparing GE to non-GE crop yields and examined changes over time in overall yield per hectare of maize, soybean, and cotton reported by the U.S. Department of Agriculture (USDA) before, during, and after the switch from conventionally bred to GE varieties of these crops. Although the sum of experimental evidence indicates that GE herbicide resistance and insect resistance are contributing to actual yield increases, there is no evidence from USDA data that the average historical rate of increase in U.S. yields of cotton, maize, and soybean has changed.
Human Health Effects

GE crops and foods derived from them are tested in three ways: animal testing, compositional analysis, and allergenicity testing and prediction. Although the design and analysis of many animal-feeding studies were not optimal, the many available animal experimental studies taken together provided reasonable evidence that animals were not harmed by eating foods derived from GE crops. Data on the nutrient and chemical composition of a GE plant compared to a similar non-GE variety of the crop sometimes show statistically significant differences in nutrient and chemical composition, but the differences have been considered to fall within the range of naturally occurring variation found in currently available non-GE crops.

Many people are concerned that GE food consumption may lead to higher incidence of specific health problems including cancer, obesity, gastrointestinal tract illnesses, kidney disease, and disorders such as autism spectrum disorder and allergies. In the absence of long-term, case-controlled studies to examine some hypotheses, the committee examined epidemiological datasets over time from the United States and Canada, where GE food has been consumed since the late 1990s, and similar datasets from the United Kingdom and Western Europe, where GE food is not widely consumed. No pattern of differences was found among countries in specific health problems after the introduction of GE foods in the 1990s.

Social and Economic Effects

At the farm level, soybean, cotton, and maize with GE herbicide-resistant or insect-resistant traits (or both) have generally had favorable economic outcomes for producers who have adopted these crops, but there is high heterogeneity in outcomes. The utility of a GE variety to a specific farm system depends on the fit of the GE characteristic and the genetics of the variety to the farm environment and the quality and cost of the GE seeds. In some situations, in which farmers have adopted GE crops without identifiable economic benefits, increases in management flexibility and other considerations may be driving adoption of GE crops, especially those with herbicide resistance.

The cost of GE seed may limit the adoption of GE crops by resource-poor smallholders. In most situations, the differential cost between GE and non-GE seed is a small fraction of total costs of production, although it may constitute a financial constraint because of limited access to credit. In addition, small-scale farmers may face greater financial risk when purchasing more expensive GE seed if the crop fails.

The committee heard diverse opinions on the ability of GE crops to affect food security in the future. GE crops, like other technological advances in agriculture, are not able by themselves to address fully the wide variety of complex challenges that face smallholders. Such issues as soil fertility, integrated pest management, market development, storage, and extension services all need to be addressed to improve crop productivity, decrease post-harvest losses, and increase food security. Even if a GE crop may improve productivity or nutritional quality, its ability to benefit intended stakeholders will depend on the social and economic contexts in which the technology is developed and diffused.

In regards to Bt cotton, a 10 percent increase in productivity accompanied by 2.3 percent increase in returns was observed in 2012 (Table 6). Essentially, Bt maize and Bt cotton have
returned higher productivity and increased net farm income in the years they have been cultivated by the U.S. farmers. In case of HT seeds, producers paid higher seed prices, but gained by reducing the costs of weed control and weed scouting costs. HT crop adopters lowered the pesticide costs. However, HT seeds showed mixed results on net returns (Fernandez-Cornejo et al. 2014). One of the rationales for the adoption of HT crops can be the non-monetary gains like freeing up time, enterprise and other off-farm income generating activities that are hard to quantify. USDA-ERS research shows HT adoption is associated with higher off-farm household income by HT soybean farmers.

**Bt crops reduces the use of insecticides:** In the case of Bt corn, farms showed decrease in the consumption of overall insecticide use since 1995, the year of Bt corn adoption. In 2010, U.S. corn farmers applied insecticides only 9 percent of the times (Fernandez-Cornejo et al. 2014).

**PROSPECTS FOR GENETIC ENGINEERING OF CROPS**

Emerging genetic-engineering technologies such as CRISPR/Cas9 promise to increase the precision with which changes can be made to plant genomes and expand the array of characteristics that can be changed or introduced, such as improved tolerance to drought and thermal extremes; increased efficiency in photosynthesis and nitrogen use; and improved nutrient content. Insect and disease resistance are likely to be introduced into more crop species and the number of pests targeted will also likely increase. If deployed appropriately, such characteristics will almost certainly increase harvestable yields and decrease the probability of crop losses to major insect or disease outbreaks. However, it is too early to know whether complex genetic changes that substantially improve photosynthesis, increase nutrient-use efficiency, and increase maximum yield will be successfully deployed. Therefore, the NAS committee recommended balanced public investment in emerging genetic-engineering technologies and other approaches to address food security.

**Regulation should focus on novel characteristics and hazards, and not on the process by which they are made**

All technologies for improving plant genetics—whether GE or conventional—can change foods in ways that could raise safety issues. Therefore, it is the product that should be regulated, and not the process (i.e., genetic-engineering or conventional-breeding techniques). New plant varieties should undergo safety testing if they have intended or unintended novel characteristics with potential hazards (House of Commons-UK Science and Technology Committee Report of the Session 2014-15).
Proposed Strategy for Evaluating Crops Using -Omics Technologies. New -omics technologies could be used to determine the extent to which the novel characteristics of the plant variety are likely to pose a risk to human health or the environment, regardless of whether the plant was developed using genetic-engineering or conventional-breeding processes.¹²

Thanks to the dynamic regulatory system of the United States, the biotech crops moved rapidly from the laboratory to the field and then on to commercialization within a span of ten years. Encouraged by the regulatory facilitations, the private industry invested heavily in crop biotech research and development (R&D) and considerable number of new biotech crops are in the commercial pipeline. As recently as 2016, USDA and the German Risk Assessment Authority (https://www.gene2drug.com/dashboards/genome-editing-the-benefits-and-the-ethics/) have declared that the genetically engineered crops derived from gene editing technology are not GMOs and as such it is expected that most of biotech industry might use genome edited crops technology by totally circumventing the existing regulations. This is an example of how technology development can bypass regulations with innovation. The irony is that when most developing countries that badly need the best science and technology to improve their agriculture are struggling to establish their own regulations for GMOs, a first generation technology crops, the science has overtaken them with a brand new invention in

¹² http://dels.nas.edu/banrDownload
genome edited crops. Obviously private sector will invest heavily to develop products using the genome edited technology to bypass regulatory complications and costs.

**Current Status of GMOs in the European Union**

The three decade old history of GMOs in the European Union has been beset with stormy discussions and debates that are still ongoing. Almost 60 percent of the EU citizens still consider GMOs a threat to human health and environmental well-being (Lucht 2015). Notwithstanding the prevailing scientific consensus on the safety and utility of GMOs, many of the European activists and citizens believe that GM crops are linked to bee colony collapse, rise of super weeds, infertility, allergies and cancer. Many of the private sector ag-biotech companies have moved their ag-biotech R&D to the United States to avoid the hostile public and regulatory conundrum that has been created in the European Union by the anti-technology activists. The extent of anti-GM sentiment is best exemplified by the fact that the British media alone published over 700 stories about the dangers of GM crops technology that fuels the public ire against the technology and its products (Lucht 2015). World Trade Organization (WTO) declared that the European Union moratorium on GMOs illegal in 2006. The European Union lifted the moratorium, but left to member states to decide the fate of GMOs in their territories. EU issued a regulation No. 1829/2003 of the European Parliament and of the Council of September 22, 2003 on genetically modified food, followed by Implementing Regulation No. 503/2013 issued on April 3, 2013 on the authorization of genetically modified food and feed in accordance with regulation No. 1829/2003 of the European Parliament and of the Council and amending Commission Regulations (EC) No. 641/2004 and (EC) No. 1981/2006. Recently, EU issued a new directive (EU) 2015/412 on March 11, 2015 allowing the member states to restrict or prohibit the cultivation of genetically modified organisms (GMO) in their territories. EU has approved many GM crops, but it is up to individual members to allow or restrict both cultivation and consumption of GM products, according to the law passed by EU in 2011. Austria, Hungary, Italy, France, Greece, Germany, Poland, Luxemburg, Romania and Switzerland have banned GMO cultivation. Slovenia, Croatia, 198 regions and 235 municipalities and 30,000 farmers declared themselves GMO free. Spain is the only country where GMO is cultivated. However, EU’s zero tolerance policy still allows millions of tonnes of GM corn for animal feed to EU from USA (Onusic 2012).

**The United States and Europe**

A survey conducted on the college and university campuses regarding the acceptance of GMOs in Japan, Norway, Taiwan, and the United States concluded that Americans were more willing to consume foods containing GMOs than their international counterparts. Most preferred mandatory labelling of GMOs and were willing to pay extra for non-GMO food (Wang, 2016). President Obama signed a new bill on GMO labelling in July 2016. The bill nullifies mandatory labelling of GMOs at the state or local level. Anecdotally, Americans have been demanding mandatory labelling of GM foods for decades. Whereas in EU, the GMO labelling is mandatory if the contents just exceed 0.9 percent. The U.S. label bill allows for voluntary labelling of GMOs. It is also true that many food manufacturers have shown strong interest in non-GMO labelling that supposedly comes close to naturalness linked with GMO-free certification. U.S. Food and Drug Administration (FDA) policy on voluntary labelling on GMOs is consistent with many surveys that support the public policy. The U.S. regulations are science and market based and use just the existing legislative authorities to regulate agricultural biotechnology. The United States used a principled
precautionary approach to provide the regulatory oversight. Even though their federal agencies, USDA-APHIS, US-FDA and US-EPA provide regulatory cover to agricultural biotechnology products, they do so under the rubric of Coordinated Framework of Biotechnology Regulatory Policies (Office of Science and Technology Policy, 51 FR 23302, June 26, 1986).

The EU uses the precautionary principle demanding a pre-market authorization for any GMO to enter the market and a post-market environmental monitoring. It demands that the purveyors of the technology products prove that there is absolutely no harm to the environment and public health beyond doubt before allowing them for commercialization. It demands a liability be tagged on to the purveyors of the technology for any environmental damage it might cause anytime in the future. Both the European Food Safety Authority (EFSA) and the member states prepare risk assessments. This assessment must show that the food or feed is safe for human and animal health and the environment "under its intended conditions of use". As of 2010, the EU treats all genetically modified crops (GMO crops), along with irradiated food as "new food". They are subject to extensive, case-by-case, science-based food evaluation by the European Food Safety Authority (EFSA). This agency reports to the European Commission, which then drafts proposals for granting or refusing authorization. Each proposal is submitted to the "Section on GM Food and Feed of the Standing Committee on the Food Chain and Animal Health". If accepted, it is either adopted by the EC or passed on to the Council of Agricultural Ministers. The Council has three months to reach a qualified majority for or against the proposal. If no majority is reached, the proposal is passed back to the EC, which then adopts the proposal.[1]

As of September 2014, 49 GMO crops, consisting of eight GM cottons, 28 GM maize’, three GM oilseed rapes, seven GM soybeans, one GM sugar beet, one GM bacterial biomass, and one GM yeast biomass have been authorized.[3]

As of 2014 Spain has been the largest producer of GM crops in Europe with 137,000 hectares (340,000 acres) of GM maize planted in 2013 equaling 20 percent of Spain's maize production. Smaller amounts were produced in the Czech Republic, Slovakia, Portugal, Romania and Poland. France and Germany are the major opponents of genetically modified food in Europe, although Germany has approved Amflora, a potato modified with higher levels of starch for industrial purposes. In addition to France and Germany, other European countries that placed bans on the cultivation and sale of GMOs include Austria, Hungary, Greece, and Luxembourg. Poland has also tried to institute a ban, with backlash from the European Commission. Bulgaria effectively banned cultivation of genetically modified organisms on March 18, 2010.

In 2010, Austria, Bulgaria, Cyprus, Hungary, Ireland, Latvia, Lithuania, Malta, Slovenia and the Netherlands wrote a joint paper requesting that individual countries should have the right to decide whether to cultivate GM crops. By the year 2010, the only GMO food crop with approval for cultivation in Europe was MON 810, a Bt expressing maize conferring resistance to the European corn borer that gained approval in 1998. Unlike in the United States, a major exporter of GM foods, EU regulates GM foods at two different levels: The European Commission (EC) and European Food Safety Authority (EFSA) issued harmonized regulations. EU member states have individual rules on their own. Businesses that want to sell GM foods need to apply to the country authority first for permission, and if approved, the company must notify other member countries via the EC. Recently, EU has issued a new directive where, EC will give general approval for GM foods first, and then leave it to individual states to approve or deny permission. If there is objection by a member state, then
additional review is conducted submitted to EC for vote once again. If vetoed, the application must be resubmitted all over again for another round of EC approval. This whole process of regulatory clearances in EU is hinged on the ‘precautionary principle’ sensu-stricto whereas United States’ interpretation of it is to proceed with caution.

EU’s precautionary principle is due to various societal, economic and political reasons, and not based in sound science. By limiting GMOs, EU expects to protect its domestic agricultural industry by setting up a non-scientific trade barrier. EU policies on the environment and GMOs have been largely influenced by the environmental activists also known as greens. The high decibel campaign by natural and organic food supporters has resulted in EU public’s revulsion to GMOs that is not considered natural. Politicians speak very gingerly about GMOs as their constituents and constituencies don’t like GMOs, and therefore do not support any GMO promoting policies. This has resulted food prices increasing in the EU and also the development of modern biotechnology itself. This situation has forced food exporting countries of Asia and Africa from supporting pro-GMO policies purely for business reasons. It has become a very difficult situation for food exporting countries to EU to take any technology positive positions on GMOs for the fear of losing their export market.

China

According to International Service of Acquisition of Agribiotech Applications (ISAAA) (www.isaaa.org), China in 2014 grew 3.9 million hectares of biotech crops: ~3.9 million hectares of Bt cotton, ~8,000 hectares of virus resistant papaya, and ~543 hectares of Bt poplar. Bt cotton was planted by an estimated 7.1 million small, resource-poor farmers in China. The total biotech cotton plantings in China in 2014 were estimated at ~3.9 million hectares, which is ~93 percent of its total national cotton area. The adoption rate of Bt cotton in China was estimated at 93 percent in 2014, compared to 90 percent in 2013. Virus-resistant biotech papaya plantings increased by ~50 percent from 5,800 hectares in 2013 to ~8,000 hectares in 2014. Papaya growing regions Guangdong province and Hunan Island were joined by Guangxi province in 2014. Bt poplar has been planted in China since 2003. By 2014, 543 hectares of poplar has been planted. The economic benefit to China from biotech cotton for the period 1997 to 2013 is US$16.2 billion and US$1.6 billion for 2013 alone.

Bt cotton China belongs to the “six founder biotech crop countries” having first commercialized Bt cotton in 1996, the first year of global commercial planting of biotech crops. China increased their income by approximately US$220 per hectare (equivalent to approximately US$1 billion nationally) due, on average, to a 10 percent increase in yield, and a 60 percent reduction in insecticides, both of which contribute to a more sustainable agriculture and the prosperity of small, resource-poor farmers.

Biotech phytase maize and Bt rice approved for biosafety on 27 November 2009, are undergoing extensive and rigorous field trials. The biosafety certificates are up for renewal in 2015. A study led by KM Wu in 2008 suggested that the potential number of small farmers actually benefiting indirectly from Bt cotton in China might be 10 million more, which was confirmed by a separate study led by WD Hutchinson in 2010. The research estimated that the 10 million beneficiary farmers are those cultivating 22 million hectares of crops other than cotton, which also host cotton bollworm, but where infestations have decreased to up to 10-fold,
Thus, the actual number of beneficiary farmers of biotech Bt cotton in China may well exceed 17.5 million. A study on the adoption and uptake pathways of Bt cotton by small-scale farmers in China and the changes these have brought to farmers’ lives was conducted by the Centre for Chinese Agricultural Policy. The study was conducted in the provinces of Hebei, Shandong, Anhui and Henan provinces where Bt cotton is widely cultivated, also referred to as China’s Huang-HuaiHai cotton production zone. The adoption rate of Bt cotton is highest in Hebei province at 100 percent. The most promising benefit that the farmers derived from Bt cotton adoption is the reduction of pesticide use, which was evident in all of the four provinces. In Hebei, the farmers now spray pesticide only 4 times compared to more than 25 times before adopting Bt cotton. Majority of farmers also reported that planting Bt cotton enabled them to use less labour input, but higher yield with good cotton quality. This reduced their farming cost compared to the conventional cotton. Recently, the Swiss Agri-biotech giant was purchased by China Chemical Corporation for $43 billion, thus making China the home to one of the ag-biotech giants.

In September 2006, China’s National Biosafety Committee recommended for commercialization a locally developed biotech papaya resistant to papaya ring spot virus (PRSV). The technology features the viral replicase gene and was developed by South China Agricultural University; the biotech papaya is highly resistant to all the local strains of PRSV. In Guangdong province, the main province for papaya production in China, 95 percent of the 4,500 hectares of papaya is now biotech, equivalent to 4,275 hectares. Hainan Island planted biotech papaya for the first time in 2012, and in 2014, 60 percent of the 4,000 hectares of papaya grown in the area was biotech. Guangxi province planted their first biotech papaya in 2014 with an initial 90 percent adoption of the 2,000 hectares of papaya in the province. Thus, a total of 8,475 hectares of biotech papaya was planted in China in 2014, a 46 percent increase from 5,800 hectares in 2013.

Academy of Agricultural Sciences are developing a high yielding salt tolerant rice variety. The initial results showed that the biotech rice could produce 6 tons per hectare. The harvest in October 2013 also showed one variety has similar output as those varieties grown in normal farmlands.

China passed an updated Food Safety Law I October 2015 that will have strict labelling laws. No details of the labelling requirements have been announced so far. Chinese public are not averse to buying GMO foods even though their awareness is not rated very high. China’s regulations on GMOs since 1990s required pre-market testing. China has approved more than 75 percent of almost 500 applications for the biosafety review of GMOs. Since 2002, China has seriously implemented its GMO laws that require strict biosafety review and labelling. Its 2015 law on GMOs implementation remains still uncertain. Presently, China has 3.7 million hectares under GM crops cultivation which include GM Canola, maize, soybean and sugar beet (ISAAA 2016).


Argentina
Argentina maintained its ranking as the third largest producer of biotech crops in the world in 2014, occupying 13 percent of 181.5 million hectares of global biotech crop hectarage. A total of 24.3 million hectares were planted in Argentina in 2014, practically the same as the 2013 area at 24.4 million hectares. Of the 24.3 million hectares, 20.8 million hectares were biotech soybean, 3 million hectares were biotech maize, and 0.5 million hectares were biotech cotton. The 20.8 million hectares of biotech soybean is equivalent to 100 percent adoption in Argentina in 2014. Of the total maize hectarage of 3.75 million hectares in Argentina in 2014, 80 percent, or 3 million hectares were biotech, composed of 1.98 million hectares Bt/HT, 780,000 hectares Bt, and 240,000 hectares HT. Biotech cotton hectarage in Argentina increased to 530,000 hectares in 2014, a 100 percent adoption composed of 457,000 hectares Bt/HT, 45,000 hectares HT, and 28,000 hectares Bt. Argentina’s benefits from biotech crops from 1996 to 2013 is estimated at US$17.5 billion, and the benefits for 2013 alone is estimated at US$1.9 billion. There are 37 biotech crop products approved for commercial planting in Argentina from 1996 to 2014: 29 maize events, 5 soybeans, and 3 cotton events. Seven maize events were approved in 2014. The 20.8 million hectares of biotech soybean is equivalent to 100 percent of national soybean crop. The increase in soybean plantings in 2014 over 2013 is mainly due to farmers planting significantly more soybean and less maize.

**Benefits from Biotech Crops in Argentina**

Benefits from biotech crops alone for the first 15 years (1996–2010) were estimated at US$72.36 billion and the creation of 1.82 million jobs. Economic Benefits by Crops from glyphosate-tolerant soybean, benefits of US$65,153 million is broken down into US$3,231 million from reduction in production costs and US$61,917 million due to the expansion of the planted area; distributed to farmers 72.3 percent, 21.3 percent to the National Government and 6.5 percent to technology providers (seeds and herbicides). Insect resistance and herbicide tolerance technologies gave benefits of US$5,375 million, distributed as: 68.2 percent to growers, 11.4 percent to the National Government, and 20.4 percent to technology providers (mainly seeds). Total benefits from insect-resistant and herbicide-tolerant cotton, reached US$1,834 million that went mainly to farmers (96 percent), with only 4 percent going to technology providers (seeds and herbicides). More benefits include the reduction in global price. The total benefit for 1996-2012 was estimated at about US$89 billion. If this adoption process had not occurred, the international price of soybean in 2011 would have been 14 percent higher than it actually was. The potential benefits estimate that could be generated by a stacked herbicide tolerant and insect resistant soybean and a drought-resistant wheat, under three different price and adoption scenarios, from the next growing season, in the following 10 years could be US$9,131 million to US$26,073 million for soybean and US$526 million to US$1,923 million for wheat.

The stacked gene Bt/HT maize occupied about 66 percent of the total biotech maize area, and is expected to retain this premier position as there is positive trade discussions to export Argentinean biotech maize to China. Argentina has achieved a marked improvement in its promotion of biotech crops and has pursued their timely regulation aggressively. National Advisory Committee on Ag Biotech (CONABIA) now has an impressive stable of products for evaluation from both the public and private sector. Argentina’s Agriculture Ministry launched a comprehensive regulatory framework for the assessment and approval of biotech crops in March 23, 2013. This ends the multi-year regulatory streamlining process and it is expected to boost the process of evaluating the risks and benefits of adopting new biotech crops in Argentina.
Argentinian scientists have developed a drought tolerant biotech sugarcane and are exploring cooperation to further develop this product with Brazil. The product from this joint program could be approved for production by 2017 and would allow Argentina to increase sugarcane hectarage from the current 350,000 hectares to 5 million hectares in the future.

Argentinian scientists have transferred a drought tolerant gene from sunflower to maize, soybean and wheat. BioCeres, an Argentinian company, has been granted a license for this gene and has a joint venture named Verdeca, with Arcadia Biosciences from the United States. Field trials with the new seeds have increased yield by 15 percent or more. CONABIA is currently evaluating biotech potatoes resistant to viruses Y and PLRV (which cause significant losses in Argentina), as well as herbicide tolerance.


India

In 2014, India became the top cotton producing country in the world, planting more than China and the United States. India has the world’s largest hectarage of cotton, and accounts for 46 percent of the total biotech cotton area planted globally. In the 13- year period 2002 to 2014, India has tripled cotton production from 13 million bales to 40 million bales. In 2014, Bt cotton was planted in 11.6 million hectares in India, 600,000 more than the 11 million hectares planted in 2013. The 11.6 million hectares of Bt cotton is 95 percent of the total 12.25 million hectares of cotton in India. A total of 7.7 million farmers farming on average ~1.5 hectares planted 600,000 hectares more Bt cotton than in 2013. A cumulative 54 million small farmers in India have benefited from planting Bt cotton repeatedly year-after-year during the 13-year period 2002 to 2014. Commercialization of Bt cotton increased 230-fold at 11.6 million hectares in 2014 from 50,000 hectares in 2002. India doubled its market share of global cotton production from 12 percent in 2002 to 25 percent in 2014, representing a quarter of the total global cotton production. India was estimated to have enhanced farm income from Bt cotton by US$16.7 billion in the 12-year period 2002 to 2013, and US$2.1 billion in 2013 alone.

Biotech crop approval in 2014, the Genetic Engineering Appraisal Committee (GEAC) of the Ministry of Environment and Forest (MOEF) released an additional 70 Bt cotton hybrids for a total of around 1,167 Bt cotton hybrids to farmers across 10 cotton growing states in India. The GEAC deregulated 6 events of Bt cotton incorporating single and double genes belonging to public and private sector institutions during 2002 to 2014. Out of the 6 approved events, 4 events were backcrossed with a large number of superior cotton genotypes and released for commercial plantings from 2002 to 2014. The significant increase in area under hybrid cotton cultivation in India is due to the introduction of Bt technology which spurred hybridization of cotton from 3 hybrids in 2002 to 1,167 in 2014. In 2014, the GEAC resumed regular meetings, and approved the field trials of GM mustard, Bt chickpea, NUE rice, and Bt brinjal. Benefits from Bt cotton Aside from boosting cotton production in India in the last 13 years, Bt cotton has made a substantial contribution to cutting the production cost due to reduced insecticide applications. Farmers lessened spraying insecticides from 24 sprays to only 2-3 sprays per season. A steep decline in insecticide usage particularly on Helicoverpa armigera was observed from 71 percent in 2001 to 3 percent in 2011. Five new cotton events
are under biosafety assessment, contained field trial and open field testing for new and stacked traits which will be considered for commercial approval in India between 2013 and 2015.

The World Bank (http://www.worldbank.org/) registered a steep decline from 33 percent in 2001 to 11 percent in 2011 at a time when total pesticides market in the country increased significantly during the same period. Savings in insecticides between 2004 and 2014 coincided with the large scale adoption of Bt cotton from half a million hectares in 2004 to 11.6 million hectares in 2014-15, equivalent to 95 percent of the total cotton crop in 2014-15. Bt cotton ensured the sustained supply of raw cotton to meet the growing demand of the domestic textile industry, which earned US$39 billion from export of textile in 2013-14 (PIB, 2014). Bt cotton transformed India from a net importer to a net exporter of cotton. India’s cotton export registered a sharp increase from 0.05 million bales in 2001-02 to 11.4 million bales in 2013-14 (CAB, 2014). India is the world’s largest cotton exporting country with recorded cotton export ranging between 8 to 12 million bales over last few years (PIB, 2013). Drought and salinity tolerance, disease resistance, sucking insect resistance, leaf curl virus resistance and other traits related to cotton fiber quality. Timely approval and deployment of these new biotech cotton traits will provide the technological continuity necessary for developing increasingly improved biotech cotton and generate the momentum for growth. This will ensure prosperity for small cotton farmers in India with the expectation that the country will achieve a national production of 40 million bales by 2015 and a target of 100 million bales by 2030. India has recently passed a new rule in which the biotech seed prices and technology trait fee will be fixed by the government, which is bound to hamper future technology transfer, investment and innovation in the Indian agriculture.


Brazil

Brazil is the second largest grower of biotech crops in the world, next to the United States, planting 42.2 million hectares of biotech crops in 2014. In 2014, the total biotech crop hectares in Brazil comprised: 29.1 million hectares of biotech soybean, 12.5 million hectares of biotech maize, and 0.6 million hectares of biotech cotton. Of the 47.3 million hectares total area planted to soybean, maize, and cotton in Brazil in 2014, 89.2 percent, or 42.2 was biotech. Biotech soybean was planted in 29.1 million hectares, up from 26.9 million hectares in 2013, equivalent to 7.9 percent growth, and 93.2 percent adoption rate. Biotech maize remained the second important crop with a total of 12.5 million hectares for both summer (4.8 million hectares) and winter (7.7 million hectares), a decrease of ~2.9 percent from 2013 due to a reduction in total maize area planted. Biotech cotton was planted in 0.6 million hectares in 2014, an increase of 25.1 percent over 2013, and 65.1 percent adoption rate. In 2011, Brazil approved a biotech bean that can resist golden bean mosaic virus. It is now completing variety registration trials and expected to be commercialized in early 2016. The economic benefit to Brazil from biotech crops for the 10-year period (2003–13) is US$11.8 billion and US$3.4 billion for 2013 alone (Brookes and Barfoot, 2015). Biotech Crop Adoption The total grain production in Brazil reached 203.3 million tons in 2014, an increase of 3.1 percent compared to the 2013/14 crop season. For the 10-year period 2005/06 to 2014/15, grain production increased by 5 percent per year.
Biotech soybean occupied 93.2 percent of the 31.2 million total soybean hectarage in Brazil in 2014. The highest adoption rate, by region, was in the South region with 94.7 percent followed by the Southeast at 94.3 percent and Midwest at 94.2 percent. Of the 6.64 million hectares of summer maize, 72.6 percent is biotech, of which 54 percent is IR/HT, 15.7 percent is IR, and 3 percent is HT alone. The highest adoption, by region, was in the Southeast at 90.2 percent, followed by the South at 89.9 percent, and Midwest at 89.7 percent. Winter maize (also referred to as “second season crop”) occupied a bigger hectarage than summer maize at 8.5 million hectares, of which 90 percent, or 7.7 million hectares is biotech. 44.7 percent of biotech winter maize is IR/HT, 40.5 percent is IR, and 4.8 percent is HT alone.

Biotech Crop approval the technical commission responsible for biosafety in Brazil, CTNBio (Brazilian National future prospects Brazil remains the principal exporter of biotech soybeans to China, and is also developing an export market for biotech maize. Brazil is developing other biotech crops, such as biotech insect Technical Commission on Biosafety), is regarded as one of the most effective commissions worldwide, with a clear federal biotech regulatory framework and functional approval processes. In the previous years, the number of approvals per year was high, but approvals for 2013 and 2014 have been low. To date, Brazil has approved a total of 37 events for planting, which includes 5 traits for soybeans, 19 for maize, and 12 for cotton and 1 for an edible virus resistant bean. Approvals by the Ministry of Agriculture (MAPA/SNRC) from 2004 to October 2014 include 959 new soybean varieties, of which 752 were genetically modified (78%) and only 207 (22%) were conventional varieties. The deployment of biotech maize in Brazil is in its seventh year. CTNBio has approved and registered 1,251 maize hybrids, of which 715 (57%) are biotech hybrids. Since 2004, Brazil has registered 97 new cotton varieties, of which 48 were biotech. Resistant sugarcane for sugar and ethanol production. Other biotech crops in the pipeline being developed include biotech eucalyptus, rice, wheat, and citrus. The successful initiative to develop resistance to BGMV in Brazil can serve as a practical model for other developing countries engaged in the development of biotech crops. This applies to both the scientific development of the product, and importantly the timely regulatory approval of the biotech bean so that producers, consumers and the country derive maximum benefits from the investment and the technology.


Bangladesh

Brinjal (eggplant/aubergine) is a very important vegetable in Bangladesh where it is grown by about 150,000 very small resource poor farmers on about 50,000 hectares, in both the winter and summer seasons. Brinjal suffers regular and heavy losses from a very destructive insect-pest called the fruit and shoot borer (FSB) which conventional insecticides cannot control effectively. However, during heavy infestation, farmers have no option except to attempt controlling it by applying insecticides, sometimes every other day, up to a total of about 80 applications per season, resulting in serious implications for producers, consumers and environment. On 30 October 2013, in a historic decision, Bangladesh approved the official release of four biotech, genetically modified, varieties of insect resistant Bt brinjal for seed production and initial commercialization. Sowing of Bt brinjal began in early 2014 in
the spring (Basanta) season. Twenty small brinjal farmers in Bangladesh received Bt brinjal seedlings on 22 January 2014, who became the first Bangladeshi farmers to plant Bt brinjal over 2.6 hectares in four representative regions of Gazipur, Jamalpur, Pabna and Rangpur where these varieties are well-adapted and carefully monitored. Bt Brinjal-1 variety, popularly known as Uttara, was planted in Rajshahi region; Bt Brinjal-2 (Kajla) in Barisal region; Bt Brinjal-3 (Nayantara) in Rangpur and Dhaka regions; and Bt Brinjal-4 variety, Iswardi/ISD006, was planted in Pabna and Chittagong regions of the country. The Bangladesh Agricultural Development Corporation (BADC) in collaboration with BARI has undertaken seed multiplication of four Bt brinjal varieties to be distributed to farmers in the forthcoming Kharif season 2014. By the next year, Bt gene will be introduced in five other popular brinjal varieties including Dohazari, Shingnath, Chaga, Islampuri and Khatkatia to meet the growing requirement of Bt brinjal seeds which will be planted in different brinjal growing areas. Notably, in the next five years, the government of Bangladesh plans to bring 20,000 hectares or approx. 40 percent of total 50,000 hectares across 20 districts under nine Bt brinjal varieties.

It is evident from the field performance of Bt brinjal that Bt technology is set to benefit farmers by mitigating economic losses and substantially increasing marketable yield, thus ensuring a bountiful harvest. For the first time, Bangladeshi consumers would have access to blemish-free brinjal fruits. Previous experimental data indicate that Bt brinjal can improve yield by at least 30 percent and reduce the number of insecticide applications by a massive 70-90 percent resulting in a net economic benefit of US$1,868 per hectare. This is a princely sum for some of the poorest farmers in the world, in a country where the annual per capita income is only US $700. At the national level, Bt brinjal is estimated to have the capacity to generate a net additional economic benefit of US$200 million per year for around 150,000 brinjal growers in Bangladesh. Consumers will benefit from a cleaner, improved and more affordable food product.


The Philippines

415,000 small, resource-poor farmers in the Philippines planted 831,000 hectares of biotech maize in 2014, the area planted to biotech maize in the Philippines increased to 831,000 hectares, up 5 percent from the 795,000 hectares planted in 2013. The area occupied in 2014 by the stacked traits of Bt/HT maize reached 761,000 hectares compared with only 721,000 hectares in 2013, with the stacked trait maize occupying 95 percent of total biotech maize hectares in 2014. The total hectarage planted to the single trait Bt maize decreased by 76 percent in 2012. In 2013 and 2014, no single trait Bt maize has been planted. Single trait herbicide tolerant (HT) maize was planted on 70,000 hectares in 2013, which is only 8.4 percent of the total biotech maize hectarage. On a percentage basis, biotech yellow maize has consistently increased by about 5 percent of the total yellow maize hectarage every single year from the Biotech maize approvals.

A total of 13 events of biotech maize have been approved for commercial planting in the Philippines since 2002: 3 single Bt, 4 single HT, 2-two Bt genes stacked, and 4 Bt/HT stacked trait. In addition, a total of 75 biotech crops and products currently approved for
direct use as food, feed and for processing in the Philippines that include alfalfa, canola, cotton, maize, potato, rice, soybean, and sugar beet. First year of commercialization was 2003, reaching the highest level of 63 percent in 2014 (up from 62 percent in 2013). The number of small resource poor farmers, growing on average 2 hectares of biotech maize in the Philippines in 2013 was estimated at 415,000 up significantly by 17,500 since 2003. The future acceptance prospects for biotech crops in the Philippines continue to look promising with new biotech crop products being developed by national and international institutions. Golden Rice (GR), is a bio-fortified rice being developed by the Philippine Rice Research Institute (PhilRice) and the International Rice Research Institute (IRRI). IRRI has reported that as of March 2014, the research, analysis, and testing of beta-carotene-enriched GR continues in collaboration with national research agencies in the Philippines, Indonesia, and Bangladesh. The fruit and shoot borer resistant Bt eggplant project is led by the Institute of Plant Breeding of the University of the Philippines Los Baños (IPB-UPLB). The proponents already completed field trials of promising hybrid varieties in the approved multi-location trial sites in Luzon and Mindanao in 2012. In May 2012, Greenpeace and other anti-biotech environmentalists and politicians lodged a petition to the Supreme Court calling for the imposition of Writ of Kalikasan and issuance of a Temporary Environmental Protection Order (TEPO) opposed to the conduct of the Bt eggplant field trials. The petition was remanded by the Supreme Court to the Court of Appeals (CA) which heard the case. After almost a year of proceedings, the CA issued a decision on May 17, 2013 granting the petition for a Writ of Kalikasan against the Bt egg-plant, directing the respondents to cease and desist from conducting field trials. Respondents filed a motion for reconsideration, but the CA reaffirmed its earlier decision. Respondents appealed the case to the Supreme Court. On July 26, 2016, the Philippines Supreme Court reversed its own ruling to stop field testing of Bt eggplants and lifted its own ban on field testing and commercialization of GM crops in the country (SEARCA.org Information Services 2016).

Biotech papaya with delayed ripening and papaya ring spot virus (PRSV) resistance, by IPB-UPLB, has already been tested in confined field trials in 2012. Bt cotton for the first time was tested in a confined field trial in 2010 and has started multi location field trials in 2012. In 2013, data to complete regulatory dossiers were collected for commercialization purposes in two years’ time. In mid-2014, the bio-efficacy of Bt cotton hybrids against the cotton bollworm were reaffirmed in another field trial. Initiatives in other crops include the development of a virus resistant sweet potato through collaborative activities between the Visayas State University (VSU) and IPB-UPLB and the initial efforts to generate transgenic lines of virus resistant abaca (Musa textilis) by the Fiber Industry Development Authority in collaboration with the University of the Philippines. The farm level economic benefit of planting biotech maize in the Philippines in the period 2003 to 2013 is estimated to have reached US$470 million. For 2013 alone, the net national impact of biotech maize on farm income was estimated at US$92 million.

The Philippine Department of Agriculture Biotechnology Program Office and the Department of Science and Technology have been very supportive of research and development activities on biotech crops and have been eager to support the public sector biotech products that will emerge in the near future.

Appendix B: International Regulations

The differences in approaches to regulation of genetically modified organisms (GMO) are most stark between the European Union and the United States, and these approaches have the potential to have a significant impact on trade both between these two governmental bodies and with third countries. Because of that, trade in agricultural biotech products has become a controversial issue within the World Trade Organization (WTO). The United States accuses the EU of using this issue as an excuse for replacing farm price-support policies, being phased down following the Uruguay Round Agreement on Agriculture, with technical barriers to trade using consumer concerns as an excuse. Reuters quoted the U.S. Agriculture Secretary as having said that it would be difficult for the United States to accept the EU's recent proposal on labelling of genetically modified foods (based on a tight system of tracing and labelling products at every step “from farm to fork”) as not trade distorting. The possibility of challenging the proposal at the WTO once again is a distinct possibility.

The resistance to GMO production and use triggered in October 1998 the imposition of a de facto moratorium on the authorization of new releases of GMOs in the European Union, pending stricter regulation in this area. The European Commission has proposed a very strict approval, traceability, and labelling policy for GMOs in 2002. Hence, the European Union is now commencing the tough job of trying to get all 15 EU members to agree to lift the three-year moratorium. By contrast, the permit procedure in the United States is far simpler and faster (see e.g., Nelson et al. 1999). With regard to genetically modified foods, the U.S. Food and Drug Administration (FDA) does not distinguish between foods produced from genetically modified crops and those from crops developed by other technologies. Thus, genetically engineered foods and food ingredients must meet the same safety standards as other food products (FDA 1995).

There are also marked differences in national labelling requirements. The U.S. Food and Drug Administration does not require labelling of GM foods per se, but only if the transgenic food is substantially different from its conventional counterpart. The European Union, by contrast, requires labelling of all foodstuffs, additives, and flavors containing 1 percent or more genetically modified material (Regulations 1139/98 and 49/2000). Individual countries within the European Union have added further requirements (OECD 2000).

Numerous non-European countries, including some developing countries, have also enacted GMO consumer legislation. Australia, Japan, and New Zealand have introduced mandatory labelling for all foods containing GMOs. Many developing countries also are beginning to develop regulations related to genetically engineered products. Operational field-testing regulations have, for example, been implemented in Argentina, Brazil, Chile, Costa Rica, Cuba, Mexico, India, the Philippines, and Thailand.

The Cartagena Protocol on Biosafety

The Cartagena Protocol on Biosafety to the Convention on Biological Diversity is designed for all people of the world to enjoy the benefits of modern biotechnology and avoid needless risks.13 The Cartagena Protocol on Biosafety was finalized in Montreal on January, 29, 2000.

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13 For more information on the Cartagena Protocol on Biosafety and online training of LMO risk assessment, visit http://bch.cbd.int/protocol.
as a part of the 1992 Convention on Biological Diversity (CBD, 2000). The Cartagena Protocol has the objective of ensuring the safe transboundary movement of living modified organisms (LMO) resulting from modern biotechnology. The Protocol stipulates that lack of scientific evidence regarding potential adverse effects of GMOs on biodiversity, taking into account also risks to human health, need not prevent a ratifying country from taking action to restrict the import of such organisms in order to reduce perceived risks. In essence, this stipulation reflects an acceptance of the guiding influence of the precautionary principle, that is, "better safe than sorry." The Protocol requires that GMOs intended for intentional introduction into the environment or for contained use must be clearly identified as LMOs; however, modified organisms intended for direct use as food or feed, or for further processing, just require a label stating that the product "may contain" such organisms. No labelling requirements for processed foods, such as cooking oil or meal, were established by the Protocol (Nielsen and Anderson 2000).

Almost 190 member governments and civil society are collaborating through the Convention on Biological Diversity to reverse the tide of devastation that humanity has inflicted on the natural world. The Convention is the first global treaty to provide a comprehensive framework that addresses all aspects of biodiversity—ecosystems, species, and genetic diversity. It also introduces a new strategy for the biodiversity crisis known as the “ecosystem approach,” which aims to reconcile the need for environmental conservation with concern for economic development. By promoting sustainable development, the Convention seeks to ensure that the earth’s renewable resources are not consumed so intensively that they cannot replenish themselves. It has three goals: the conservation of biodiversity, the sustainable use of the components of biodiversity, and the fair and equitable sharing of the benefits arising from the use of genetic resources. When crafting the Convention, governments recognized that modern biotechnology has the potential to contribute to achieving these three goals—as long as it is developed and used with adequate safety measures for the environment and human health. These governments put this conviction into action a few years later by establishing the Cartagena Protocol within the framework of the Convention (Biosafety and the Environment, CBD).  

Using the principle of Advanced Informed Agreement, parties to the convention must abide by the following principles: (1) A simplified system of regulatory review for commodities, (2) risk assessments, (3) risk management and emergency procedures, (4) export documentation, (5) << MISSING WORD? >> biosafety clearing house, (6) capacity building and finance, and (7) public awareness and participation. Other international agreements that relate to the Cartagena Protocol are the following: (1) the International Plant Protection Convention (IPPC); (2) the Codex Alimentarius Commission; (3) the World Organisation for Animal Health; and (4) the World Trade Organization (WTO). All of the provisions of these international treaties are intended to complement but not duplicate each other’s activities. The ultimate goal of all these treaties is to resolve conflicts and reconcile the legitimate interests of trade, biosafety, and other sectors of international trade and commerce.

A clear-cut roadmap for risk assessment has been envisaged based on the risk assessment experiences of the past 15 years since the commercialization of GM crops. The guidance document was drawn up by extensive consultations both on the science and the politics of

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14 For more information, also visit [https://www.cbd.int/](https://www.cbd.int/).
LMOs. The aim of the guidance document is to get it endorsed by the next meeting of the parties to the Cartagena Protocol in December 2016 (Haugitsch 2016).

**International Best Practices on Biosafety Review Standards**

Although most of the measures of the Convention on Biological Diversity (CBD) (Secretariat of the Convention on Biological Diversity 1992) focus on the conservation of ecosystems, two aspects concerning the conservation of biological diversity are relevant for biosafety—the management of risks associated with LMOs resulting from biotechnology and the management of risks associated with alien species. In the context of in situ conservation measures, the Convention requires contracting parties “... to regulate, manage or control the risks associated with the use and release of living modified organisms resulting from biotechnology which are likely to have adverse environmental impacts that could affect the conservation and sustainable use of biological diversity”. This provision goes beyond the general scope of the Convention in that it requires that risks to human health are also taken into account. Another important aspect of the protocol is that it requires a socioeconomic impact assessment of adopting GM crops, but does not talk about the missed opportunity costs in the case of GM crops are not adopted.

The Convention establishes that contracting parties have the obligation to prevent the introduction of alien species (read GMOs in this instance) and to control or to eradicate those alien species that threaten ecosystems, habitats, or species. Invasive alien species are considered as species introduced deliberately or unintentionally outside their natural habitats.
when they have the ability to establish themselves, invade or replace natives, and take over the new environment.

Risk assessment and risk management are requirements for both the Advanced Informed Agreement and Article 11 of the Protocol. The Protocol specifies general risk management measures and criteria. Any measures based on risk assessment should be proportionate to the risks identified. As such, the risk assessment also must be consistent with criteria enumerated in an annex. Moreover, in principle, risk assessment is to be carried out by competent national decision-making authorities. The exporter may be required to undertake the assessment, and the importing party may require the notifier to pay for the risk assessment. Measures to minimize the likelihood of unintentional transboundary movement of LMOs must be taken. Affected or potentially affected states must be notified when an occurrence may lead to an unintentional transboundary movement. The Protocol also contains provisions on LMO handling, packaging, and transportation (Article 18). In particular, each contracting party must take measures to require documentation that:

- For LMOs intended for direct use as food or feed, or for processing, the labelling clearly identifies that the contents “may” clearly identifies that they “may contain” LMOs and are “not intended for intentional introduction into the environment,” and a contact point for further information;
- For LMOs destined for contained use, clearly identifies them as LMOs and specifies any requirements for safe handling, storage, transport and use, and a contact point and consignee;
- For LMOs intended for intentional introduction into the environment of the party of import, clearly identifies them as LMOs and specifies the identity and the traits or characteristics, any requirements for safe handling, storage, transport and use, and a contact point, the name and address of the importer or exporter and a declaration that the movement conforms to the Protocol's requirements applicable to the exporter.

Information exchange is envisaged in the Protocol through the establishment of the Biosafety Clearing-House. The Biosafety Clearing-House is intended to facilitate the exchange of information on, and experience with, LMOs and to assist parties in implementation of the Protocol. Pursuant to Article 20, paragraph 2, it shall also provide access to other international biosafety information exchange systems. Information that parties are required to provide to the Clearing-House includes existing laws, regulations and guidelines for implementation of the Protocol; information required for the AIA; any bilateral, regional and multilateral agreements within the context of the Protocol; summaries of risk assessment and final decisions.

Public participation is specifically addressed in Article 23. Contracting parties must:

- Promote and facilitate public awareness, education and participation concerning safe transfer, handling and use of LMOs;
- Endeavour to ensure public awareness and education encompasses access to information on LMOs identified by the Protocol that may be imported; and
- Consult the public in the decision-making process regarding LMOs and make decisions available to the public in accordance with national laws and regulations. Confidential information must also be respected in those activities.

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For more information on the Biosafety Clearing-House, see https://bch.cbd.int/.

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Socioeconomic considerations are allowed in decision-making. Contracting parties may account for socioeconomic considerations arising from the impact of LMOs on biodiversity conservation and sustainable use, especially with regard to the value of biodiversity to indigenous and local communities. The parties are encouraged to cooperate on research and information exchange on any socioeconomic impacts of LMOs. A process to address liability and redress for damage resulting from LMO transboundary movements must be set up by the first meeting of parties to the Protocol.

The International Plant Protection Convention (IPPC) aims to (1) secure common, effective action to prevent the spread and introduction of pests of plants and plant products and (2) promote measures for their control. Although the IPPC makes provision for trade in plants and plant products, it is not limited in this respect. Specifically, the scope of the IPPC extends to the protection of wild flora in addition to cultivated flora, and covers both direct and indirect damage from pests, including weeds. The IPPC plays an important role in the conservation of plant biodiversity and in the protection of natural resources. Hence, standards developed under the IPPC also apply to key elements of the CBD, including the prevention and mitigation of impacts of alien invasive species, and of the Cartagena Protocol on Biosafety. As a consequence, the CBD, Food and Agricultural Organization of the United Nations (FAO), and the IPPC have established a close collaborative relationship. This has, in particular, extended to the inclusion of CBD concerns in the development of new international standards for phytosanitary measures (ISPM).

ISPMs developed under the auspices of the IPPC provide countries with internationally agreed-to guidance on measures to protect plant life or human health from the introduction and spread of pests or diseases. One of the most important concept standards developed under the IPPC is ISPM No. 11, Pest Risk Analysis for Quarantine ests (FAO 2001b), adopted by the Interim Commission on Phytosanitary Measures (ICPM) at its third session in 2001. In addition, the ICPM, at its firth session in 2003, adopted a supplement to ISPM No. 11 to address risks to the environment in order to take into account CBD concerns, especially regarding invasive alien species. More recently, the IPPC has drafted another supplement to ISPM No. 11 to address pest risk analysis for LMOs.

This draft standard has undergone extensive technical discussion and consultation throughout its development. At the request of the ICPM, an open-ended expert working group was convened in September 2001 and included government-nominated experts from developed and developing countries and experts representing both plant protection and environmental concerns. The meeting’s purpose was to discuss (1) the development of this standard and (2) the need to provide detailed guidance on conducting risk analyses to address the potential plant health effects of LMOs with particular attention to the needs of developing countries.

- The working group considered that potential phytosanitary risks of LMOs that may need to be considered in a pest risk analysis, including (FAO 2002b): Changes in adaptive characteristics that may increase the potential invasiveness, including, drought tolerance of plants; herbicide tolerance of plants; alterations in reproductive biology; dispersal ability of pests; pest resistance; and pesticide resistance.
- Gene flow, including, the transfer of herbicide resistance genes to compatible species and the potential to overcome existing reproductive and recombination barriers.
- Potential to affect non-target organisms adversely, including, changes in a host range of biological control agents or organisms claimed to be beneficial and its effects on
other organisms (e.g., biological control agents, beneficial organisms, and soil microflora) that result in a phytosanitary impact (indirect effects).

- Possibility of phyto-pathogenic properties including, phytosanitary risks presented by novel traits in organisms not normally considered a phytosanitary risk; enhanced virus recombination, trans-encapsulation and synergy events related to the presence of virus sequences; and phytosanitary risks associated with nucleic acid sequences (markers, promoters, terminators, etc.) present in the insert.

Subsequently, a small working group, including CBD/Cartagena Protocol and plant protection experts prepared a draft standard that would provide general guidelines on the conduct of pest risk analysis with respect to the potential phytosanitary risks identified above. In the process of drafting this standard, the working group noted several important issues regarding the scope of the IPPC and potential phytosanitary risks of LMOs. In particular, the working group noted that whereas some types of LMOs would require pest risk analyses because they could present phytosanitary risks, many other types of LMOs (e.g., those with modified characteristics such as ripening time or storage/shelf life) do not present phytosanitary risks. Similarly, it was noted that pest risk analysis would only address the phytosanitary risks of LMOs, but that other potential risks may also need to be addressed (e.g., human health concerns for food products). It was also noted that the potential phytosanitary risks identified above could also be associated with non-LMOs or conventionally bred crops. It was acknowledged that risk analysis procedures of the IPPC are generally concerned with phenotypic characteristics rather than genotypic characteristics, noting that the latter may need to be considered when assessing the phytosanitary risks of LMOs.

Over and beyond the above considerations, the real issue regarding the Protocol is the exact technical review method or process to be used for risk assessment. There are different schools of thought: (1) the U.S. approach that is flexible, dynamic and uses the concept of familiarity and substantial equivalence and (2) the EU approach that uses the precautionary principle in a strictly narrow way. Developing countries that rely on these two schools of thought for guidance and experience are baffled as to which is the right approach. The Cartagena Protocol is not endorsed by the United States, the world’s leading agbiotech country.

**International trade agreements**

The use of genetic engineering techniques in agriculture and food production is seen as an exciting and valuable development by many who welcome the improvements in production efficiency that these techniques offer to farmers and the enhanced nutritional value envisioned to benefit consumers. Others, however, are objecting strongly, raising environmental, food safety, and ethical concerns. In fact, the emergence of genetically modified foods has generated a variety of policy reactions in different countries. A majority of consumers in Australia, Japan, and Western Europe, for example, want at least to have labels on products that contain genetically modified organisms (GMOs), while the most extreme opponents want to see genetically modified (GM) crops completely excluded from production and consumption in their country.

The most extreme view could lead to trade disputes in the World Trade Organization (WTO). Regardless whether developing countries are exporters or importers of agricultural crops, they will be affected by the biotech policies adopted in countries with which they trade—especially if international trade disputes concerning GMOs emerge. Moreover, the strong
consumer skepticism toward genetic engineering in some countries, particularly in Europe, will also define the trading environment in which developing countries must compete. For instance, China exports processed foods to the United Kingdom were restricted in 2000 because they may have contained traces of GM soybean imported by China from the United States. In turn, China placed a moratorium both on soybean imports from the United States and on the use of GM varieties by its own farmers for food and feed (but not cotton) production.

The trade of genetically modified crop varieties is currently most widespread in the maize and soybean sectors. These first-generation GM crops have improved agronomic traits such as resistance to pests and diseases, and tolerance of specific chemical herbicides. The development of plants with such attributes aims at increasing farmer profitability, typically by reducing input requirements and hence costs.

A second generation of GM crops technology is focusing on breeding for attributes desired by consumers. Although not yet commercially available, a recent example of such biotech research involves a new variety of rice, known as “Golden Rice,” which has been genetically engineered to contain a higher level of vitamin A. In contrast to the current commercial applications of biotech crops, this new rice variety aims directly at benefitting consumers rather than producers. More specifically, it aims at improving the health of poor people in developing countries that rely on rice as their main staple food.

As with the first-generation, producer-focused GM technology, the benefits over time will be shared between producers and consumers, and hence between adopting and nonadopting countries—or would be if countries remain open to international trade in these products.

**GM Regulatory Conclusions**

Developing countries need to pay special attention to the fact that crops grown with modern biotechnology techniques contribute significant societal benefits, foster food security, and promote environmental sustainability. Biotech crops have clearly shown empirical evidence for increasing agricultural production on the existing arable land; reducing crop losses owing to pests, diseases, and drought; increasing farm incomes; improving nutrition; and promoting sustainable agriculture. Also, GM crops require reduced spray of insecticides and, in turn, improved human health and environmental pollution.

Despite the wide array of biotech crops available, their adoption is restricted by stringent regulatory policies in most of the developing world. The European Union and Japan lean toward the more rigorous side for GMO regulation, whereas the United States is more utilitarian. Nonetheless, in the United States, transgenic papaya saved the industry in Hawaii, and similarly, it is hoped that biotechnology will address the citrus greening disease.

Certain developing countries that are aware of the benefits of GMOs have to balance them against the needs of their export markets (Wang 2016), rather than to avoiding the technology for the fear of losing these export markets. EU policy on GM crops defies more than two decades research, by 400 of its own research scientists, on the safety of GM crops that presented that major conclusion that “GE plants *per se* does not imply higher risks than classical breeding methods or production technologies (EC 2010, 16). After studying transgenic crop safety and potential defects on biodiversity and human health over this time
frame, it was concluded that the research has not detected any significant hazard directly connected with the use of GM crops (Nicolia et al. 1970).

Thus, it is important for developing countries to assess the risks and benefits of each biotech product on a case-by-case basis—as the United States has done since 1986. Considering the devastating negative impacts of climate change already evidenced in different parts of the world, it is critical to not exclude transgenic crops as one of the options. Notwithstanding the varying views on the risks and benefits of biotech crops, they have been in commercial cultivation for 20 years now, and not a single instance of any environmental damage or damage to any other life form has been authentically recorded. Although there is clearly a need for the continued monitoring of modern biotechnology, there is no reason to stifle either the innovation or the implementation of biotechnology techniques in world agriculture. Transgenic crops have recorded the single fastest rate of adoption in countries that facilitated their adoption, but have been lagging behind or completely absent in many developing countries that really need a scientific and technological boost to improve their agricultural productivity.

Biotech crops added US$117 billion into the global agricultural economy. It is estimated that biotech crops have saved about 123 million hectares of land to meet the needs of a growing global population. The way forward is for developing countries to quickly develop policies, regulations, and institutions to implement modern biotechnology in agriculture that accrue environmental, economic, and social benefits to their citizens. There is sufficient information, knowledge, and skills for safe deployment of GM crops in Zimbabwe, and the country must push forward with their commercialization without losing more time.
Appendix C: Glossary

Biotechnology versus modern biotechnology

The Cartagena Protocol on Biosafety defines biotechnology as (a) "in-vitro nucleic acid techniques including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles or; (b) fusion of cells beyond the taxonomic family (that overcome normal physiological reproductive or recombinant barriers and that are not techniques used in traditional breeding and selection." On the other hand, the term modern biotechnology generally implies the use of tissue culture for micro-propagation, fusion of cells beyond the taxonomic family, direct injection of nucleic acids into cells or organelles, in-vitro manipulation of nucleic acids including DNA (genetic material), and/or the use of molecular markers for breeding and fingerprinting.

Other terms in biotechnology

Tissue culture is the propagation of plant tissues and cells using defined medium. The plants are totipotent, and under defined in-vitro conditions, the technique can be used to derive whole plants. It is also used as an effective method for producing plants that are disease-free, especially viruses.

Molecular markers can be used for marker-assisted selection to speed up the process of section of a particular trait or, indeed, multiple traits governed by quantitative traits loci (QTLs). They can be used to speed up the process of introgression of a trait in a back cross program, in genetic diversity studies to derive taxonomic and phylogenetic relationships, and in tracking biological processes such as pollen movement.

Diagnostics kits have been used as a tool of biotechnology to detect plant or animal diseases at an early stage, thus averting severe crop damage or animal death. These kits tend to detect a highly specific component of the pathogen, such as the genetic material.

Genetic modification, as stated above, includes three processes: (1) conventional breeding, which involves a cross between two sexually compatible species to give rise to a progeny that can be selected for the improved or desired traits; (2) mutation breeding, which is used to increase the low level of mutation rate in a crop by employing chemical mutagens or radiation treatment; and finally (3) gene transfer, which relies mostly on genes from other species and thus outside the available gene pool to introduce them into other species.

Genetic engineering entails two key approaches that are used to transfer genes into plants: (1) the Agrobacterium-mediated system and (2) the use of the gene gun. The Agrobacterium system uses plasmids carried in the bacterium to introduce the DNA into plants. This approach has worked very well with dicotyledonous plants and has now been successfully used in monocotyledonous plants as well. The use of the gene also known as biolistics is a process that uses gold or tungsten particles coated with the foreign DNA and shot at high velocity into cells.
## Appendix D: Proposed Cotton Production Budget for Smallholder Farms, 2015/16

<table>
<thead>
<tr>
<th>Input</th>
<th>Quantity</th>
<th>Unit cost</th>
<th>Total cost per ha.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seed (kg)</strong></td>
<td>15</td>
<td>$ 1.93</td>
<td>$ 28.95</td>
</tr>
<tr>
<td><strong>Ploughing (per ha. with ox)</strong></td>
<td>1</td>
<td>$ 70.00</td>
<td>$ 70.00</td>
</tr>
<tr>
<td><strong>Discing and row marking</strong></td>
<td>1</td>
<td>$ 35.00</td>
<td>$ 35.00</td>
</tr>
<tr>
<td><strong>Labor (days)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting</td>
<td>5</td>
<td>$ 2.50</td>
<td>$ 12.50</td>
</tr>
<tr>
<td>Thinning</td>
<td>5</td>
<td>$ 2.50</td>
<td>$ 12.50</td>
</tr>
<tr>
<td>Fertilizing</td>
<td>5</td>
<td>$ 2.50</td>
<td>$ 12.50</td>
</tr>
<tr>
<td>Weeding</td>
<td>40</td>
<td>$ 2.50</td>
<td>$ 100.00</td>
</tr>
<tr>
<td>Spraying</td>
<td>8.5</td>
<td>$ 2.50</td>
<td>$ 21.25</td>
</tr>
<tr>
<td>Picking</td>
<td>28</td>
<td>$ 2.50</td>
<td>$ 70.00</td>
</tr>
<tr>
<td>Baling</td>
<td>1.8</td>
<td>$ 2.50</td>
<td>$ 4.50</td>
</tr>
<tr>
<td>Stalk destruction</td>
<td>7</td>
<td>$ 2.50</td>
<td>$ 17.50</td>
</tr>
<tr>
<td><strong>Fertilizer</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comp L (kg)</td>
<td>50</td>
<td>$ 0.73</td>
<td>$ 36.50</td>
</tr>
<tr>
<td>AN (kg)</td>
<td>50</td>
<td>$ 0.70</td>
<td>$ 35.00</td>
</tr>
<tr>
<td><strong>Pesticide</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetamark <em>(50g)</em></td>
<td>2</td>
<td>$ 1.00</td>
<td>$ 2.00</td>
</tr>
<tr>
<td>Carbaryl (kg)</td>
<td>1</td>
<td>$ 13.00</td>
<td>$ 13.00</td>
</tr>
<tr>
<td>Fernkil</td>
<td>1.5</td>
<td>$ 18.00</td>
<td>$ 27.00</td>
</tr>
<tr>
<td>Mitac</td>
<td>0.5</td>
<td>$ 18.00</td>
<td>$ 9.00</td>
</tr>
<tr>
<td>Transport</td>
<td>3.5</td>
<td>$ 4.00</td>
<td>$ 14.00</td>
</tr>
<tr>
<td>Bale hire (5 bales per tonne)</td>
<td>4</td>
<td>$ 6.00</td>
<td>$ 24.00</td>
</tr>
<tr>
<td>Twine (kg)</td>
<td>0.125</td>
<td>$ 24.00</td>
<td>$ 3.00</td>
</tr>
<tr>
<td>Insurance (% of GI)</td>
<td>3.5</td>
<td></td>
<td>$ 11.03</td>
</tr>
<tr>
<td>Miscellaneous costs (5% of TVC)</td>
<td>5</td>
<td></td>
<td>$ 27.96</td>
</tr>
<tr>
<td><strong>Total variable costs</strong></td>
<td></td>
<td></td>
<td>$ 587.19</td>
</tr>
<tr>
<td><strong>Yield</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected yield (kgs/ha.)</td>
<td>700</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selling price (45 cents/kg)</td>
<td></td>
<td>$ 0.45</td>
<td>$ 315.00</td>
</tr>
<tr>
<td><strong>Profit</strong></td>
<td></td>
<td></td>
<td>($ 272.19)</td>
</tr>
</tbody>
</table>
Note: Labor in the smallholder sector is calculated for total hours of 6 hours/day at the rate of $2.50/day.
Appendix E: Proposed Gross Margin Budget for Soyabean Production, Harvesting, and Marketing, 2015/16

GROSS MARGIN BUDGET FOR PRODUCTION (US$/ha.)

<table>
<thead>
<tr>
<th>Yield levels (t/ha.)</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated selling price ($/t)</td>
<td>550</td>
<td>550</td>
<td>550</td>
<td>550</td>
</tr>
<tr>
<td>GROSS INCOME ($/ha.)</td>
<td>825</td>
<td>1100</td>
<td>1375</td>
<td>1650</td>
</tr>
<tr>
<td>TOTAL VARIABLE COSTS ($/ha.)</td>
<td>968</td>
<td>1048</td>
<td>1084</td>
<td>1164</td>
</tr>
<tr>
<td>GROSS MARGIN ($/ha.)</td>
<td>-</td>
<td>143</td>
<td>52</td>
<td>291</td>
</tr>
</tbody>
</table>

VARIABLE COSTS ($/ha.)

A. Variable Costs Pre-Harvesting

1. Labor: 8.5 ld
   - 8.5 ld/ha. | 34 | 34 | 34 | 34 |
2. Tractor and Equipment:
   - 72.9 lit/ha. | 255 | 255 | 255 | 255 |
3. Seed: 100 kg
   - 100 kg/ha. | 120 | 120 | 120 | 120 |
   - Inoculant
     - 1 satchet/ha. | 5 | 5 | 5 | 5 |
4. Fertilizer and Lime:
   a. Compd S:
     - t/ha. | 160 | 200 | 200 | 240 |
   b. Agric Lime: .25t
     - t/ha. | 35 | 35 | 35 | 35 |
   c. Transport costs:
     - $/ha. | 23 | 25 | 25 | 28 |
5. Herbicides:
   a. Lasochlor: 3.5 lit
     - 3.5 lit/ha. | 28 | 28 | 28 | 28 |
   b. Igran: 2.2 lit
     - 2.2 lit/ha. | 24 | 24 | 24 | 24 |
6. Insecticide:
   - Endosulfan 35MO: 1 lit
     - 1 lit/ha. | 9 | 9 | 9 | 9 |
7. Fungicide
   - Shavit or Punch Xtra
     - 1.5 litres/ha. | 42 | 42 | 42 | 42 |
8. Insurance:
   - 0.57% Gross Income | 5 | 6 | 8 | 9 |

SUBTOTAL A | 740 | 784 | 785 | 829 |
Miscellaneous costs: | 15 | 16 | 16 | 17 |
TOTAL VARIABLE COST PRE-HARVESTING | 754 | 799 | 801 | 846 |
### B. Variable Costs for Harvesting and Marketing

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Cost</th>
<th>Cost</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor: .55 ld/t</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>Tractor and equipment:</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Contract combine:</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>Fuel</td>
<td>18</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Artificial drying:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Coal: 12 kg/t</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>b. Electricity: 3KWh/t</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packing materials: 20 bags/t</td>
<td>20</td>
<td>15</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>a. Lost bags: 2%</td>
<td>0.02</td>
<td>0.30</td>
<td>0.40</td>
<td>0.50</td>
</tr>
<tr>
<td>b. T2 Twine: 92g/t</td>
<td>0.092</td>
<td>0.97</td>
<td>1.29</td>
<td>1.61</td>
</tr>
<tr>
<td>Transport out:</td>
<td>75</td>
<td>100</td>
<td>125</td>
<td>150</td>
</tr>
<tr>
<td>SUBTOTAL B</td>
<td>214</td>
<td>249</td>
<td>283</td>
<td>318</td>
</tr>
<tr>
<td>Miscellaneous costs:</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>TOTAL VARIABLE COST HARVEST TO MARKET</td>
<td>214</td>
<td>249</td>
<td>283</td>
<td>318</td>
</tr>
<tr>
<td>TOTAL VARIABLE COSTS ($/ha.)</td>
<td>968</td>
<td>1048</td>
<td>1084</td>
<td>1164</td>
</tr>
</tbody>
</table>

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### Fertilizer (tonnes/ha.)

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Cost</th>
<th>Cost</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Compd S:</td>
<td>0.2</td>
<td>0.25</td>
<td>0.25</td>
<td>0.3</td>
</tr>
<tr>
<td>b. Agric Lime:</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>c. Total tonnes</td>
<td>0.45</td>
<td>0.5</td>
<td>0.5</td>
<td>0.55</td>
</tr>
</tbody>
</table>