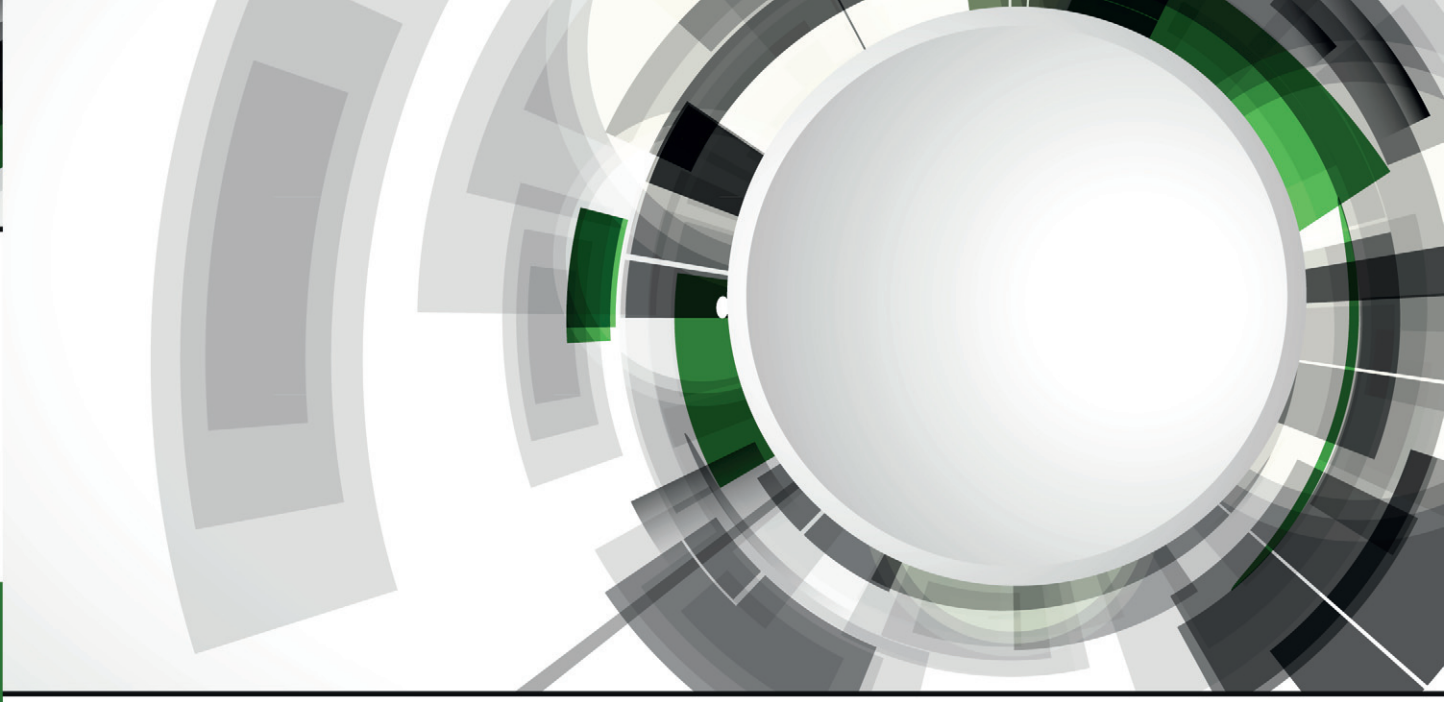

# Genetically Modified and Irradiated Food

## Controversial Issues: Facts versus Perceptions

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CHAPTER

# Genetically modified (GM) food in South Africa

# 6.1

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## Contextualizing the two-decades-old debate on GM foods

Generally speaking, members of the public and scientists have very different perceptions regarding the utility, safety, and desirability of genetic modification (GM) technology and the genetically modified organisms (GMOs) that result from it. In fact, in the United States, the science-related issue with the greatest difference in opinion between the public and scientists (37 vs. 88%) is that of the safety of GM foods (Funk and Rainie, 2015). This divide and resulting publicly accessible debate is almost exclusively focused on GM foods/crops, while GM-based medicines and industrial applications of GM technology are rarely discussed or considered to be controversial. The reasons for this state of affairs are varied, complex, interdependent, and context specific, but three, broad thematic contributing factors have crystallized over the past 2 decades since GM crops were first commercialized:

1. *The specialized nature of GM-related topics*: The specialized nature of genetics, GM technology, risk analysis, etc. places these subjects well outside the frame of reference of the general public. In addition, the average person's limited exposure to GMOs, including exposure to the direct benefits they offer, has also limited the value of heuristic decision-making. As a consequence, much uncertainty exists and many have no other option than to base their personal opinion and risk-benefit judgments on the limited, oversimplified and often intentionally inaccurately framed information, which is publicly accessible.
2. *Inaccurate risk-benefit perceptions*: Internationally, the predominant GM crops are commodity products, e.g., maize, soybeans, and cotton, with GM traits that improve their agricultural input characteristics, e.g., insect resistance, and herbicide tolerance. The direct benefits associated with such GM traits, e.g., reduced agricultural input costs and higher yields, are therefore experienced by the farmers, rather than the consumer who ends up buying a final product, which is mostly indistinguishable from the conventional one. In addition, consumers are exposed to claims of increased risks via the public debate on GMOs—personal risk-benefit perceptions regarding GM foods are therefore strongly

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prejudiced. Two different experiences gained since GM products were first commercialized support this strong link between positive risk-benefit perceptions and the acceptance of GM products. Firstly, farmers from around the world have enthusiastically accepted GM crops and those who do not yet have access to them, continue to petition their availability. Secondly, GM-based medicines, where the benefits to the individual patient are clear and direct, are accepted without apparent objection.

3. *Food's social context*: Food is not a purely functional object but also represents a magnitude of societal, cultural, and emotional values. Many of the criticisms leveled against GM food relate to these broader social issues, rather than any of the inherent characteristics of the crops or derived foods themselves. The association of many of the currently available GM crops with multinational companies, intellectual property, industrial-scale farming, a commodity nature, etc. has seemingly placed GM crops in conflict with some of these evolving societal values.

In combination, these factors have resulted in the GM debate evolving into a value-based, rather than a purely fact-based discussion. The use of GM technology, particularly in food crops, has therefore become controversial, not because of any tangible, well-definable, or quantifiable inherent characteristics of GMOs, but rather because it represents a watershed between different value systems—ostensibly placing "technological advancement" and a "nature ideology" in direct conflict. Exacerbated by the fact that it is a technology that is applied to living organisms, i.e., nature itself. GMOs have therefore developed into one of the quintessential examples dividing these apparently contrasting value systems.

In addition, identity-protective cognition theory suggests that science-based arguments alone will not bring an end to such value-based debates, because facts alone do not change value perceptions (Kahan, 2010). People's value systems divert them from using their reasoning to identify and recognize what the facts are and instead redirect them to conform to beliefs that predominate their value system (Kahan, 2017). This value-based, cognitive bias is the reason why data are always disputed and areas of uncertainty ever expanded in scope and detail. In fact, one of the most noticeable characteristics of the anti-GMO narrative over the past 2 decades is that the arguments against the use of GM technology have evolved continually to exploit new areas of apparent uncertainty, in support of personal value systems, when preceding doubts have been addressed successfully through research.

Distinguishing between "science" and "value" conversations is critically important to make sense of the "GMO debate". Although a final decision regarding "acceptance" will always remain a personal choice, influenced by values, emotion, and dogma, these should be kept out of science-based discussions of GMOs, as not to dilute fact and/or unduly impact access for those with different, personal value choices.

*Opposition based on emotion and dogma contradicted by data must be stopped. How many poor people in the world must die before we consider this a crime against humanity?*

**From: Open letter to Greenpeace, the UN and Governments around the world signed by 107 Nobel Laureates in medicine, chemistry, physics and economics, June 2016.**

# Genetically modified organism science

## Genetics and genetic modification

Genetic modification relates to the deliberate design, editing, and/or assembly of genetic sequences using recombinant DNA technologies and is aimed at changing the genetic characteristics of a living organism. GM technology is not constrained by sexual reproduction and allows researchers to transfer a specific genetic sequence (a particular gene or genetic trait) to any another organism to generate novel individuals, i.e., GMOs, with novel trait combinations. In other words, a GMO is a living organism identical to its conventional counterpart except for the addition of one or two extra genetic traits, e.g., insect resistance and herbicide tolerance, which were transferred to the organism using GM techniques.

Although GM technology is relatively young (~40 years) and for the first time allows the routine transfer of genetic material between unrelated species, the exact same underlying genetic principles still apply to GM genes and GMOs. GM genes do not behave differently or are not "unique" or "unnatural" as a matter of principle. GM technology is only the directed application of what has been learned from nature (and happens in nature; Kyndt et al., 2015) and is a natural continuation of age old genetic design technologies such as selective breeding, hybrid development, polyploidy, mutation, breeding, etc. GM genes can, however, change the phenotypic traits of the resulting GMO in a novel way and are for this reason subject to regulation, which requires confirmation that the new GM trait(s) does not introduce any biosafety (food/feed/health or environmental safety) concerns, before the GMO can be commercialized.

## Why do we want to use GM technology?

GM technology is a very powerful tool with which the genetic traits of organisms can be changed in very particular and useful ways. It is:

- **specific**, allows the addition/removal/change of a particular gene(s),
- **accurate**, only the targeted genes are impacted at the level of intervention, and
- **unrestrictive** in terms of transferring genetic trait between organisms.

It can therefore be used as a powerful research tool to elucidate biological research questions or as an innovation tool with which to develop novel, useful biotech products.

When these GM products are developed within a framework that ensures their sustainability, they can effectively address social, environmental, and technical challenges associated with biological systems in, for example, the health, agriculture, and manufacturing sectors. The unique potential benefits of GM technology are especially important within the context of responsible economic and social development, accessible healthcare, sustainable agriculture aimed at feeding a growing world population using limited natural resources, and climate change.

## Genetically modified organism regulation and sustainable use in South Africa

### Why are genetically modified organisms regulated?

GMOs are potentially novel, living organisms with a genetic trait that may not have been associated with the particular organism previously, and this new trait may impact the way the organism interacts with its environment—e.g., grow, propagate, or ability to act as a food source for other organisms. A GMO's potential impact on human/animal health and the environment therefore has to be assessed scientifically to ensure it is safe before it is released and consumed.

The assessment and management of these potential risks are the reason for and objective of all GMO regulations, in the same way road safety regulations, for example, govern the risks associated with driving a vehicle on a public road. However, keeping the analogy in mind, it is critically important that regulatory requirements remain proportional to the possible risks they govern, to ensure they do not unintentionally inhibit appropriate application and the loss of all associated benefits.

### How are genetically modified organisms regulated in South Africa?

Although some binding international agreements regarding GMOs are in place, e.g., the Cartagena Protocol on Biosafety and the CODEX Alimentarius, it is important to realise that GMOs are primarily governed based on national legislation. Every country or territory therefore has the right and ability to decide exactly how they would like to use and regulate GMOs. The "regulatory unit" (the entity that receives approval) of all GMO regulatory systems around the world is the "GM event"—a genetically unique GM *individual*. In the case of GM crops, this individual is subsequently used in breeding programs to propagate the GM trait in its progeny to yield the various varieties farmers plant. Every GM event must be approved by every national regulatory authority where it may be imported or cultivated. Typically, the GMO events that have been commercialized in South Africa have therefore been subjected to the regulatory requirements and scrutiny of various other countries as well.

*All* activities with GMOs in South Africa are primarily regulated under the GMO Act (Act 15 of 1997). This includes research and development, import/export, production, consumption, and other uses of GMOs and their products. The GMO Act

establishes minimum standards to ensure the food/feed (health) and environmental safety, as well as the socioeconomic viability of all activities involving GMOs (see the "GMO sustainability" section below for more details on these parameters).

It further establishes the necessary operational procedures and infrastructure required for the regulation of GMOs:

- The Registrar, seated within the Department of Agriculture, Forestry and Fisheries (DAFF), is responsible for administrating the Act.
- Inspectors are responsible for ensuring permit conditions are adhered to.
- The Advisory Committee (AC) is a panel of independent scientists that does a science-based evaluation of all applications.
- The Executive Council (EC) is the decision-making body and consists of 10 members representing seven different state agencies, i.e., DAFF, as well as the departments of Health (DoH), Science and Technology (DST), Environmental Affairs (DEA), Trade and Industry (dti), Labour (DoL), and Water Affairs and Sanitation (DWS).

Decisions by the EC are based on the information in the permit application, the AC's science-based recommendations, and the public's inputs and are interpreted within government's policy framework. A unanimous resolution is required for a permit to be issued, ensuring all possible perspectives from this widely representative body are critically considered.

Additional regulations, specifically pertaining to GMOs, are also contained under legislation of the DoH, e.g., food safety and labeling requirements, DEA, e.g., postrelease monitoring and triggers for environmental impact assessments (EIAs) and dti, e.g., labeling (Fig. 6.1.1).

## The top five facts about South Africa's regulatory framework for genetically modified organisms

1. The goal of the GMO Act (1997) as defined in its preamble is "*to provide for measures to promote the responsible development, production, use and application of GMOs,*" emphasizing the balanced and accountable approach of the regulatory framework. Although risk management is the primary focus of the Act, it does so within a context of recognizing the benefits associated with biotechnological innovation.
2. South Africa's regulatory framework for GMOs was one of the earliest established anywhere in the world (initiated in the late 1970s by local scientists), which allowed South Africa to be an early adopter of GM technology—resulting in South Africa now having one of the most experienced, robust, and respected regulatory systems in the world. To date, the system has processed more than 5400 individual permit applications.
3. It is widely representative and a well-balanced system, allowing direct policy interpretations from various government departments and public inputs, while maintaining a solid science basis. Examples of policy interpretations, based on

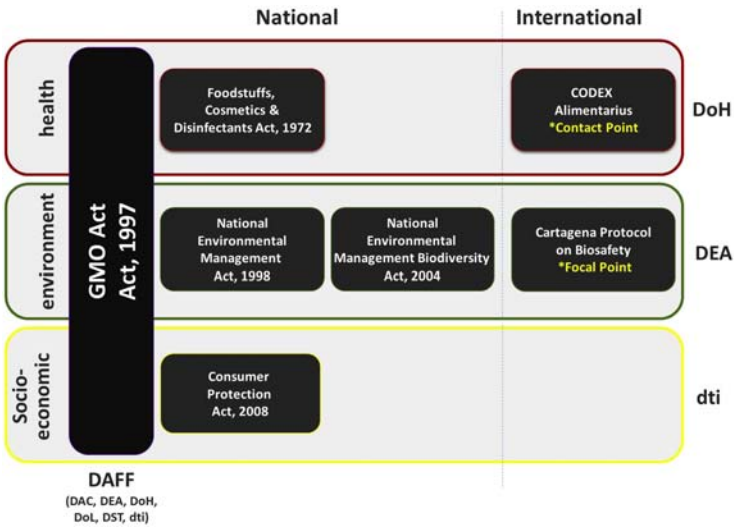


**FIGURE 6.1.1**

South Africa's regulatory framework for GMOs. National acts and international agreements directly pertaining to the regulation of GMOs, the associated government departments, and the scope of the respective legislation are indicated. *DAFF*, Department of Agriculture, Forestry and Fisheries; *DEA*, Department of Environmental Affairs; *DoH*, Department of Health; *DoL*, Department of Labour; *DST*, Department of Health Science and Technology; *dti*, Department of Trade and Industry; *GMO*, genetically modified organism.

socioeconomic impact assessments, which have been enforced over the years include safeguarding South Africa's international markets, ensuring competition within the relevant sectors and retaining minimum levels of choice for the end user. This close collaboration and wide consultation of experts underlay the fact that no confirmed negative impacts have been reported for the commercialized GMOs in the country.

4. Public participation in regulatory decision-making is a legislated prerequisite for confined use, commodity clearance and general release permit applications. Government has also invested substantially over the past 2 decades in communication and engagement programs to inform the public about biotechnology and GMOs. First in the form of the Public Understanding of Biotechnology (PUB) Program within the South African Agency for Science and Technology Advancement (SAASTA) and subsequently via the biosafety communication and engagement program of the national biosafety service platform, Biosafety South Africa.
5. The regulatory system continues to improve and evolve as required. For example, the GMO Act was amended in 2006 to include the requirements of the Cartagena Protocol on Biosafety, to which South Africa acceded in 2003. In addition,

various guideline documents have been developed over the years to help ensure quality and compliance and to inform the public on the workings of the regulatory system. Guideline updates have been included over the years to keep them aligned with international best practice and to accommodate issues such as the management of stacked traits, new breeding techniques, low-level presents, etc.

## Genetically modified organism sustainability

### Sustainability as the minimum standard for genetically modified organism use

Broadly defined, "*being sustainable*" is the minimum requirement a GMO should adhere to before it will be considered for commercial release in South Africa. GMO sustainability can be divided into its biosafety components, i.e., food/feed (health) and environmental safety, and its viability components, i.e., sociopolitical (governance) and technoeconomic feasibility (Fig. 6.1.2).

Before continuing to discuss the sustainability of GMOs, it is critically important to appreciate the fact that these details can only be sensibly and accurately considered at the hand of a specific, individual GM product. A GM tomato containing an insecticidal protein is very different from a GM sugarcane containing a gene that makes it tolerant to a certain herbicide, when considering the respective sustainability components, e.g., food safety, environmental interactions, and potential socioeconomic benefits. Broad, generalized statements regarding the safety, utility, value, effectivity, or any other attributes of "GMOs" or "GM products" as a broad, undifferentiated group can therefore never be accurate as they fall prey to the *generalization fallacy*. Sweeping statements like "*GMOs are unsafe*" or "*GMOs increase pesticide use*" are therefore inaccurate, in the same way a statement such as "*Birds are blue*" is, as they lack context and do not recognize the possible vast differences between diverse entities, constituents, requirements, contexts, applications, etc.

The food and feed safety (health) aspects of a GMO are evaluated in terms of the organism that has been transformed (the host), the organism from which the transgene was obtained (the donor), the specific genes or genetic sequences that were used for transformation, and the final GMO event/individual. Among others, food/feed properties such as toxicity, allergenicity, and nutritional value are analyzed and evaluated. Because food safety data are transferable, these are often shared between regulatory authorities around the world.

Environmental risk assessments for GMOs consider all possible interactions between the specific GMO and its receiving environment, including aspects such as gene flow, nontarget impacts, resistance development, persistence, and associated treatments such as herbicide use.

Sociopolitical and technoeconomic assessments consider wide-ranging issues such as the existence and requirements of the national biosafety regulatory framework and its competent authority, the economic viability of the product, stakeholder,


**FIGURE 6.1.2**

Defining GMO sustainability. To be sustainable, a GMO needs to adhere to minimum health, environmental, sociopolitical, and technoeconomic standards. *GMO,* genetically modified organism.

and consumer preferences, possible market impacts, diversity and choice in the market, etc.

## Risk in context

A quick search of the internet may leave one convinced that GMOs and in particular GM crops and foods are hazardous, harmful, risky, and/or unsafe. To understand how the potential risks associated with GMOs are assessed and managed and to be able to better judge these claims for oneself, a better understanding of the vocabulary and context of risk analysis is required. Understanding the meaning of the terms most often used in GMO risk analysis is important, not only because it helps to define the context of the discipline but also because it can assist individuals in doing their own basic risks assessments.

- Hazard—is any potential source of harm (the possibility to cause harm).
- Harm—is an adverse outcome or impact.
- Risk—is the probability of a harm occurring under defined circumstances.
- Safety—is the condition of not being exposed to or being protected from harm.

Hazards are fairly easy to identify because many examples are part of our daily lives, e.g., a bottle of bleach under the sink. Similarly, it is easy to come up with examples of possible harms associated with a particular hazard, e.g., bleach poisoning. In contrast, it is more difficult to explain and understand the concept of risk because it is not something concrete, but rather a probability or chance of something happening. Risk is the "probability link" between hazard and harm, considering *both* the mechanisms of exposure and the extend of the harm:

$$\text{hazard} \xrightarrow{\text{exposure}} \text{harm}$$

In other words, risk defines the chance that a hazard (bleach) will result in a harm (poisoning) and implies exposure (access to and ingestion of the bleach) and a harmful result (poisoning/illness).

In formal, science-based risk assessments, the extent of a risk is estimated (or characterized) by considering both the likelihood and consequence of a harm occurring

$$\text{risk} = \text{likelihood} \times \text{consequence}$$

Reducing either of these, e.g., locking the cupboard in which the bleach is stored or only storing bleach at highly diluted concentrations, will therefore reduce the risk of bleach poisoning. Note that although both these risk management interventions have reduced the risk of bleach poising, none of them has changed the chemical structure or hazardous nature of bleach per se.

Finally, everything we do involves some level of risk and NO activity is absolutely safe. Moreover, our *perceptions* regarding specific risks are influenced by a wide array of personal factors such as familiarity (either technical knowledge or personal experience), biases, dread (or absence thereof), experienced benefits, etc., resulting in risk perceptions that are very different from the actual, technical risk. For example, millions of people get into their cars and drive on public roads every day without really contemplating the risks associated with it. We generally perceive the associated risks to be acceptable because we are familiar with them and the context in which they occur, realise, based on experience, that we can manage them well, and the risks are clearly outweighed by the benefits of high mobility. When discussing risk one should therefore always remember that:

- there is no such thing as zero risk or absolute safety,
- risk should be assessed in the relevant context,
- risks can be managed, and
- experienced benefits counteract the associated risk perceptions.

## Risk analysis as basis for sound decision-making

Sustainability as a minimum standard for the use of technology is a widely agreeable goal, but is it possible to accurately assess and obtain this for a GMO?

The answer is, YES, by subjecting potential GM products to a scientific risk analysis.

Risk analysis is by no means new or unique to GMOs, but GMO-specific risk analysis frameworks have evolved into sophisticated, robust, and powerful design and decision-making tools over the past 30 years (Johnson et al., 2007; Wolt et al., 2010). Risk analysis is in principle the contextualized, iterative integration of risk assessment, risk management, and risk communication. Although slightly different frameworks may be used by different risk assessors and although the details may vary between an environmental risk assessment and a food safety assessment, the same broad risk analysis principles are shared among the various assessments and act as the critically important science basis for all these assessments (Fig. 6.1.3).

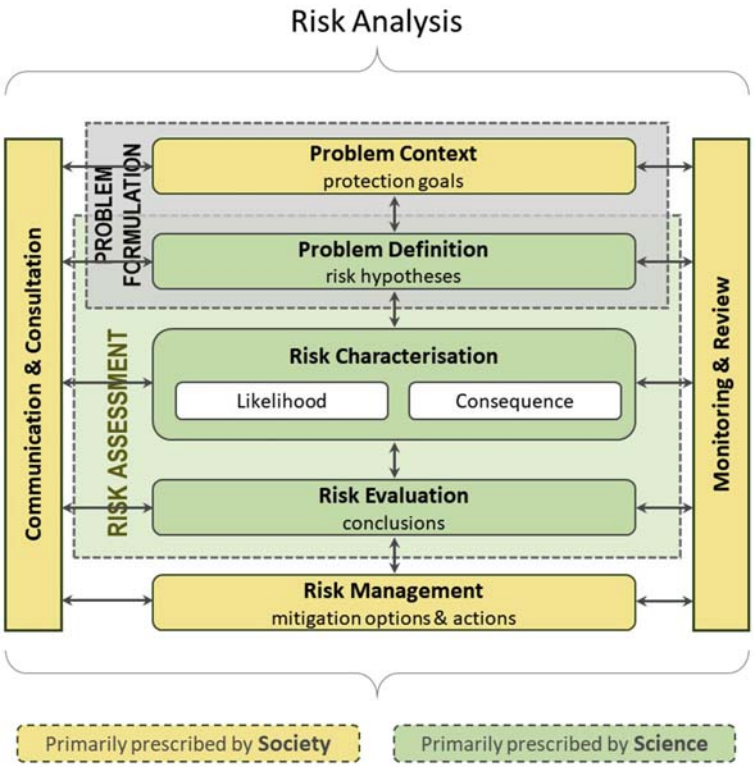


**FIGURE 6.1.3**

GMO risk analysis framework. *GMO,* genetically modified organism.

*Adapted from Johnson, K.L., Raybould, A.J., Hudson, M.D., Poppy, G.M., 2007. How does scientific risk assessment of GM crops fit within the wider risk analysis? Trends in Plant Science 12(1), 1–5 & Wolt, J.D., Keese, P., Raybould, A., Fitzpatrick, J.W., Burachik, M., Gray, A., Olin, S.S., Schiemann, J., Sears, M., Wu, F., 2010. Problem formulation in the environmental risk assessment for genetically modified plants. Transgenic Research 19, 425–436.*

The most important principles and steps of risk analysis can be summarized as follows:

- It is not a science- or scientist-only activity. Several of the activities are aimed at or fully integrated with society and/or societal values, in fact, some of the most important inputs into the process, such as the identification of protection goals, are based on societal values, not the scientific method (refer to the yellow blocks in Fig. 6.1.3).
- Generally speaking, the first step of risk analysis is to consider the context, both in terms of those tangible parameters that directly relate to the specific GMO, e.g., the host and donor organisms and receiving environment, as well as the more generic and intangible parameters such as values, e.g., what constitutes a harm, and protection goals.
- The second step, problem formulation, basically entails asking the question "*What can go wrong within the specific context?*". This is asked from all the different perspectives, which together constitute sustainability, i.e., possible health, environmental, and socioeconomic impacts, and then evaluated in terms of possible scientific risk hypotheses. To be able to develop meaningful hypotheses a clear pathway to harm must exist.
- If any of these hypotheses are found to be plausible, the next step is to characterize the associated risk in terms of the likelihood that harm may occur and the consequence thereof. If the risk is ascertained to be unacceptably high, the product will be discarded, or, if possible, risk mitigation strategies may be incorporated into its design or use to reduce the risk to acceptable levels.
- Only when the risks associated with a *specific* GMO is found to be acceptable, will it be released for commercial use, but even then, it will still be subject to postrelease monitoring. Monitoring data are fed back into the risk analysis process to continuously verify if the original risk analysis conclusions remain accurate.
- The steps of risk analysis are therefore not strictly sequential, but rather iterative, meaning that information obtained from a risk assessment can be used to inform risk management decisions and vice versa. Similarly, data generated from risk communication activities, e.g., public engagement, are used to define the outcomes of the risk analysis process.

## Local and international experience with genetically modified organism use

When discussing the sustainable or safe use of GMOs in the South African context, i.e., judging the performance of "GMOs" based on historic data, it is important to remember the following:

- GM-based medicines, generally referred to as recombinant DNA (rDNA) medicines, have also long been commercialized, but are seldom discussed or criticized (refer to "Contextualizing the two-decades-old debate on GM foods").

Public debates on "GMO use in South Africa" therefore predominantly relates to GM crops or GM foods.

- In terms of GM crops, only a few, specific GMOs, i.e., maize, cotton, and soy, each having either one or a combination of only two GM traits, i.e., insect resistance and herbicide tolerance, are relevant, as only these have been commercialized in South Africa. To be clear, no other GM crops, fruits, or vegetables are currently available on the South African market.
- One should distinguish between "a theoretical" and "the relevant" GMO discussion, i.e., the discussion should be limited to what is applicable—the few approved GMOs within the South African context. For example, in theory pollen-mediated gene flow, often, disparagingly referred to as "genetic contamination," is indeed possible and for that reason always forms part of GMO risk analysis, but within the specific context of an approved GMO within a particular environment, such broad assertions may be irrelevant at best and malevolent at worst.

## The local perspective

South Africa approved its first GM crop, insect resistant cotton, in 1998. Since then, GM crops were widely adopted by farmers because of the value they derive from the GM traits. Currently approximately 85% of the maize, 95% of the soy, and 100% of the cotton planted in South Africa contain GM traits (ISAAA, 2017). To date, the estimated economic gains for South Africa since 1998 are ~US$ 2.1 billion; at ~US$ 237 million per annum (Brookes and Barfoot, 2017). Although the benefits may not be as apparent for the end consumer, studies have shown that GM adoption has stabilized the growth rate in maize prices, thereby reducing price risks (Abidoye and Mabaya, 2014). However, these authors continue to emphasize that direct benefits, derived from commodities such as maize, by the end consumer, are influenced much more by the off-farm part of the food system, unrelated to the fact that they are GM or not.

Seminal research regarding the possible socioeconomic benefits of GM crops for South African smallholder and subsistence farmers has been done over the past decade by Dr Marnus Gouse and coworkers of the University of Pretoria. They found that although South Africa's smallholder farmers do derive direct economic benefits from certain GM crops, they generally rate the social benefits associated with these crops in their particular context, as more important. These benefits include time and drudgery savings due to the reduced labor requirements and the elimination of the challenges associated with the application of chemical insecticides—which of course also has a safety benefit. An insect-resistant grain stored in informal systems also has lower levels of fungal/mycotoxin contamination due to the lower levels of insect damage (Gouse et al, 2004, 2005a, b, 2006, 2016; Gouse, 2012; Pray et al., 2013).

No confirmed food/feed or environmental safety issues have been raised during the 2 past decades regarding the approved GMO crops (or medicines) in South

Africa (Gouws and Groenewald, 2012). Similarly, no environmental issues have been identified (Van den Berg and Van Wyk, 2007; Van Wyk et al., 2008). Although insect resistance has developed against the first generation of Bt maize (Van Rensburg, 2007), this does not represent an environmental impact, and the potential economic impacts have been mitigated through appropriate risk management practices, including refugia compliance management and the introduction of stacked Bt genes.

### The international perspective

A recent review by the US National Academies of Sciences, Engineering, and Medicine, which represents the current seminal work on this topic, is presented as the international consensus. It is entitled "*Genetically Engineered Crops: Experiences and Prospects*" and is available at http://www.nap.edu/23395:

- More than 20 scientists worked for longer than 2 years and considered more than 900 different publications and studies on GMOs, spanning more than 20 years, and read more than 700 submissions by the public to come to the conclusion that "***no substantiated evidence that foods from GM crops were less safe than foods from non-GM crops could be found.***"
- The use of insect-resistant or herbicide-resistant crops did not reduce the overall diversity of plant and insect life on farms, in fact, sometimes insect-resistant crops resulted in increased insect diversity, the study found.
- The available evidence indicates that GM soybean, cotton, and maize have generally had favorable economic outcomes for producers who have adopted these crops, but outcomes have varied depending on pest abundance, farming practices, and agricultural infrastructure. Although GM crops have provided economic benefits to many small-scale farmers in the early years of adoption, enduring and widespread gains will depend on such farmers receiving institutional support, such as access to credit, affordable inputs such as fertilizer, extension services, and access to profitable local and global markets for the crops.

## Conclusion

GM technology is a powerful tool that has already made significant positive contributions to agricultural and industrial practice, productivity, and sustainability, as well as human healthcare around the world. It is indeed possible to develop and use GMOs sustainably, and risk analysis is an appropriate, robust, and effective design and decision-making tool to help ensure this within an appropriate sustainability framework; a framework that should also carefully consider the issues related to the social license required for the successful deployment of GM products.

South Africa has a well-established, representative, robust, and competent regulatory framework for GMOs, which has enabled it to be an early adopter of GM technology and has therefore greatly benefited from its implementation in terms of (1) human healthcare and food production, (2) the protection and justifiable, sustainable use of our environmental resources, and (3) enabling socioeconomic development and growth.

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