

INFORMING RECONSIDERATION OF NEW BREEDING TECHNIQUE (NBT) REGULATION IN SOUTH AFRICA

NEED FOR A MODERNISED
REGULATORY APPROACH

A RESEARCH REPORT BY

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Key findings

- South Africa's GMO regulatory framework has long provided an important and credible biosafety foundation, and scientific advances now present an opportunity to evolve this system proportionately to accommodate emerging breeding technologies.
- South Africa's current regulatory framework for New Breeding Techniques (NBTs) applies requirements originally developed for transgenic technologies to a broader range of newer techniques, including some products that may be comparable to conventionally bred outcomes. While no NBT applications have yet been submitted, the current regulatory approach raises questions about proportionality, potential innovation impacts, and alignment with international regulatory developments.
- International NBT regulatory approaches are evolving, with many key trading partners and African countries adopting or considering more risk-proportionate, product-focused systems. South Africa's continued reliance on a process-based framework may increasingly affect domestic innovation and create future trade and competitiveness challenges.
- Most NBT products, site-directed nuclease (SDN-1 and SDN-2), do not contain foreign DNA and resemble conventionally bred outcomes. Regulating these products as GMOs is likely to limit South Africa's ability to participate fully in the next generation of mainstream breeding technologies and emerging global innovation pipelines.
- The current GMO regulatory pathway is often costly, complex, and time-consuming, particularly for lower-risk NBT applications. This restricts participation by universities, public research institutions, and SMEs, concentrating innovation within large multinational firms and increasing reliance on externally developed technologies.
- Delays in adopting a more risk-appropriate NBT framework could carry measurable economic costs. Scenario modelling indicates that by around 2035, South Africa could face widening productivity gaps, with potential maize and soybean export losses of about R5 billion and additional wheat import expenditure approaching R6.5 billion annually relative to a more enabling scenario.
- Food security and affordability could be adversely affected over time. Scenario analysis suggests that access to NBTs could improve productivity and efficiency, potentially lowering maize meal prices by around 21% over time, with meaningful benefits for low-income households.
- The evidence presented in this report suggests that a more risk-appropriate, product-based framework warrants serious consideration. Regulatory focus should move from the breeding process to the characteristics and risk profile of the final product, distinguishing genuinely novel biosafety risks from changes achievable through conventional breeding.
- Practical reform options are available. A product-based trigger, clear criteria for lower- and higher-risk applications, and a streamlined pre-assessment or notification process would improve clarity and reduce unnecessary barriers.
- Reform can be implemented without compromising biosafety. Clarifying definitions, guidance, and procedures within the existing GMO framework can maintain robust oversight, provided NBT regulation remains embedded in broader food safety, environmental, plant health, and consumer protection systems.
- Aligning any future NBT reform with national priorities will be important. Embedding regulatory reform within South Africa's agricultural innovation and food security agenda could support domestic R&D, strengthen farmer competitiveness, enhance food security, and improve the long-term resilience of the food system.

1. Background

South Africa's Current Regulatory Stance on NBTs

Over the past three decades, advances in biotechnology have transformed the way scientists are able to modify plants, animals, and microorganisms. Earlier forms of genetic engineering relied primarily on the transfer of genetic material between organisms. More recent gene-editing technologies, however, have enabled precise changes to an organism's own genetic material, including small deletions or alterations that may be indistinguishable from naturally occurring mutations or those produced through conventional breeding. These scientific advances have prompted regulators around the world to reconsider how biotechnology products and techniques should be defined and regulated.

South Africa currently regulates these New Breeding Techniques (NBTs) under the Genetically Modified Organisms Act 15 of 1997 (DoA, 2021). This Act was developed at a time when genetic modification was largely defined by transgenesis, i.e., the introduction of foreign DNA across species boundaries. As a result, the Act's definitions are intentionally broad, classifying any organism altered through 'genetic modification by non-natural means' as a GMO (Groenewald et al., forthcoming). When enacted, the Act provided a strong and precautionary foundation, supporting the responsible introduction of transgenic crops while establishing a comprehensive national biosafety framework. The framework reflected both the scientific understanding and the biosafety priorities prevailing internationally at the time, and it has contributed meaningfully to regulatory oversight and public confidence in biotechnology applications.

With the advent of highly precise gene-editing tools such as Clustered Regularly Interspaced Short Palindromic Repeats/ CRISPR-associated protein 9 (CRISPR/Cas9) in the 2010s, regulators were presented with technological developments that had not been anticipated when the Act was drafted. In decisions communicated in 2021 and reaffirmed in 2023, the GMO Act's statutory decision-making body, the Executive Council, elected to apply the Act's existing language to encompass products derived from NBTs, including all forms of genome editing (GE) (DoA, 2021). This interpretation means that even targeted edits involving small deletions without the introduction of foreign DNA (SDN-1 edits), which result in organisms indistinguishable from those arising through conventional breeding or natural mutation, are assessed within the same regulatory framework as traditional transgenic organisms.

Taken together, these regulatory and technological developments suggest that South Africa's current process-based approach is increasingly out of step with global regulatory trends. As major trading partners and leading agricultural economies continue to adopt more risk-proportionate frameworks for precision-bred crops and animals, South Africa's current interpretation of the Act differs from a growing number of international regulatory approaches that distinguish between transgenic GMOs and certain precision-bred products. South Africa therefore faces the risk of becoming increasingly misaligned with international breeding innovation trends, which could constrain its ability to fully leverage its domestic research base. A formal review of how the Genetically Modified Organisms Act of 1997 is applied to NBTs would therefore provide an opportunity to ensure that the country's regulatory framework remains scientifically robust, internationally relevant, and supportive of long-term agricultural competitiveness and resilience.

Recent consultations with regulators have suggested an emerging recognition that the regulatory treatment of NBTs may warrant further consideration in light of scientific advances and evolving international practice. According to the Registrar for GMOs, *"South Africa is actively exploring options to ensure that the country's regulatory framework remains scientifically robust, internationally relevant, and supportive of long-term agricultural competitiveness and resilience. Discussions and consultations on the regulation of New Breeding Techniques under the Genetically Modified Organisms Act framework have been initiated, with the aim of developing a risk-based classification system, profiling New Breeding Techniques according to their risk and potentially exempting certain low-risk New Breeding Techniques products from a detailed risk assessment as well as a possible regulatory oversight with compressed assessment timeframes"* (Pers. Comm. Sept 2026, GMO Registrar).

While no specific reforms have yet been adopted, the indicated discussions are both encouraging and timely given the potential innovation, competitiveness, trade and food security implications highlighted in this report.

2. The Evolution of Breeding Techniques and Their Products

Plant breeding is a story of continuous innovation, moving from simple observation to remarkable precision (Acquaah, 2012). Understanding this evolution reveals why treating all NBTs like early GMOs is a regulatory mismatch that overlooks centuries of scientific progress, whose main milestones include:

- **Selection and Seed Saving (c. 10,000 BCE):** For millennia, farmers improved crops by simply saving seeds from the most desirable plants (e.g., largest fruit, highest yield, drought survival). This was phenotypic selection with no understanding of genetics, yet it formed the foundation of agriculture (Gepts, 2004).
- **Mendelian Era and Hybridisation (1800s-1900s):** The discovery of genetics allowed for scientific crossbreeding. Breeders could systematically combine desirable traits from two parents to create superior offspring. This led to the development of high-yielding hybrid maize, which revolutionised productivity through the principle of hybrid vigour (Crow, 1998).
- **The Green Revolution and Mutation Breeding (1950s):** To accelerate genetic variation, scientists began inducing random mutations using chemicals (mutagens) or radiation (e.g. gamma rays). This process, while powerful, was a game of chance, a scattergun approach creating thousands of random genetic changes in the hope of finding a single beneficial outcome (Ahloowalia & Maluszynski, 2001). Critically, products from this less precise method are not regulated as GMOs in South Africa.
- **First-Generation Genetic Modification or Transgenesis (1990s):** The 1990s brought transgenic technology, allowing scientists to insert foreign DNA (e.g., from a bacterium) into a plant to introduce a novel trait, such as insect resistance (e.g. Bt maize) (Vasil, 2008). This was the technology the 1997 GMO Act was specifically designed to regulate.
- **New Breeding Techniques (NBTs) and Genome Editing (2010s):** Today, tools like CRISPR/Cas9 allow for the precise, targeted modification of a plant's own genome, often without introducing any foreign DNA. This is akin to using a word processor's 'find and

replace' function to correct a single letter in a vast book, rather than inserting a page from another novel (Jaganathan et al., 2021).

This journey towards precision does not render conventional breeding obsolete; rather, it reinforces its foundational importance. Traditional methods of crossing and selection remain the primary engine for creating the vital genetic diversity upon which NBTs depend. While new techniques offer a powerful scalpel for targeted refinements, they are most effective when applied to the robust, field-tested varieties developed through conventional breeding. Ultimately, these advanced tools enhance, rather than replace, the essential work of identifying and combining the complex, multi-gene traits that underpin agricultural productivity.

Regulating the most precise tools (NBTs) more strictly than the least precise ones (e.g. random mutation breeding) represents a significant scientific inconsistency in the current regulatory approach, and comes at a cost to society, as explained later.

What are NBTs and Genome Editing?

NBTs encompass a range of modern breeding tools. The most prominent are genome editing (GEd) techniques using Site-Directed Nucleases (SDNs) like CRISPR/Cas9, Transcription Activator-Like Effector Nucleases (TALENs), or Zinc Finger Nucleases (ZFNs). These act like molecular scissors that can be programmed with guide RNA to cut DNA at a very specific location. The cell's natural repair mechanisms then fix the cut, which could lead to a small change in the targeted DNA sequence (Schaart et al., 2016).

SDN applications can be divided into three categories:

- **SDN-1:** These GEd tools make a cut in the target DNA sequence, which the cell's own repair mechanism fixes through non-homologous end-joining (NHEJ). NHEJ often introduces small inserts or deletions (indels) at the site, which could lead to the loss of gene function. The final product contains no foreign DNA, and the intended mutation falls within the range of changes that can arise through natural mutation or conventional mutation breeding (Euroseeds, 2024; Schaart et al., 2016).
- **SDN-2:** These tools make a cut while a short, homologous DNA template is provided to allow homology-directed repair (HDR), resulting in the introduction of specific, minor mutations that may modulate gene function. Again, the final product contains no foreign DNA (Schaart et al., 2016).
- **SDN-3:** These applications use a donor DNA template to insert larger DNA sequences at a targeted genomic site via SDN-induced double-strand breaks. The inserted sequences may be derived from the same or cross-compatible species (cisgenesis or intragenesis) or from non-crossable species (transgenesis). In the first two cases, the resulting plants can, in principle, contain no DNA originating from outside the breeder's gene pool in the final product, whereas the latter is molecularly equivalent to conventional transgenic GMOs. It is often argued that SDN-3 events involving transgenic insertions should remain under GMO regulation in revised regulatory frameworks (Schaart et al., 2016).

The central argument for regulatory reform is that SDN-1 and SDN-2 products are indistinguishable from those developed via natural or unregulated processes, and that they are fundamentally different from transgenic organisms. A product-based system acknowledges this distinction, while a process-based system does not.

Comparing Breeding Methodologies

The landscape of plant breeding has evolved from traditional, non-specific techniques to highly precise molecular interventions. Understanding these nuances is critical for effective regulatory policy, particularly where current frameworks are often applied with a ‘blanket’ approach despite significant technical differences in the final products.

Table 1 outlines the key technical differences between conventional breeding methods, traditional transgenesis, and the various tiers of SDN technology. Understanding these categories is essential for identifying which methods yield products that are indistinguishable from natural variations versus those that introduce novel genetic material.

Table 1: A comparisons of breeding methods

Attribute	Mutation Breeding (Traditional)	Transgenic GMOs	GE _d (SDN-1)	GE _d (SDN-2)	GE _d (SDN-3)
Precision	Very Low (Random)	Low-Medium (Random insertion)	Very High (Targeted indel)	Very High (Targeted edit)	Very High (Targeted insertion)
Speed (to desired trait)	Slow (Extensive screening)	Moderate	Fast (Direct and predictable)	Fast (Direct and predictable)	Moderate to Fast
Foreign DNA in Final Product	No	Yes	No	No	Yes (usually but not always, e.g., cisgenesis)
Outcome vs. Nature	Indistinguishable from natural mutation	Novel combination (known transgene / foreign DNA)	Indistinguishable from natural or mutation breeding	Indistinguishable from natural or mutation breeding	Novel Insertion

3. International regulation of NBTs

The Shifting International Context

Global regulation of NBTs has matured significantly over the past ten years. A clear international trend has emerged, moving away from a rigid process-based approach towards risk-proportionate, product-based frameworks.

Product-based systems focus on the final characteristics and risk profile of the product itself, not the techniques employed to create it. The core principle is that if an organism could have been developed through conventional or mutational breeding or natural processes, i.e., it doesn’t contain foreign DNA, it should not be subjected to heightened regulation (Kuzma & Kokotovich, 2020). This approach fosters innovation by aligning regulation with scientific risk. On the other

hand, regulation based on process-based frameworks are based on the breeding technique. If a process is considered genetic modification (e.g., genome editing), the product is regulated as a GMO, regardless of its final genetic makeup. This was the model initially adopted by the European Union and New Zealand, and later South Africa. However, it is increasingly viewed as scientifically outdated and a barrier to innovation (Groenewald, 2021).

Major agricultural producers and trading partners of South Africa have moved toward risk-proportionate, product-based regulation:

- **Africa:** Several African nations, including Kenya, Nigeria, Ghana, and Ethiopia, are developing or have implemented enabling frameworks for NBTs to address pressing food security and climate challenges. Nigeria led the way, amending its biosafety laws in 2019 to specifically regulate genome editing, issuing detailed guidelines in 2020 that distinguish between products based on the presence of novel genetic combinations (USDA, 2024a). Kenya published its guidelines in 2022, and Ghana followed in 2023, establishing science-based, case-by-case regulatory systems to facilitate research and development into resilient crops like drought-tolerant maize and disease-resistant cowpea (Alliance for Science, 2024; USDA, 2024b). Ethiopia published its own guidelines for genome-edited products in 2024, aiming to accelerate research on staple crops such as teff and sorghum (GAIN, 2025).
- **The Americas:** Countries like the United States (under its SECURE rule), Brazil (CTNBio Resolution 16), Argentina, and Canada have established that NBT products without foreign DNA, and which are indistinguishable from those that could be obtained through conventional breeding, are not regulated as traditional GMOs (Genetic Literacy Project, 2023). Argentina, a global pioneer in this regulatory space, established its framework in 2015, which relies on a case-by-case evaluation by its National Advisory Commission on Agricultural Biotechnology. This process determines if a product is free of foreign DNA and the resulting modification is equivalent to one that could have been obtained through conventional breeding, thereby exempting it from GMO regulations (Whelan & Lema, 2015). Following a similar logic, Brazil's influential Normative Resolution 16 of 2018 grants its National Technical Biosafety Commission the authority to make a similar determination. This product-based regulatory approach has been pivotal in fostering local innovation in these countries by providing regulatory clarity and reducing the development timelines for new and improved crop varieties (ISAAA, 2024a).
- In the **Asia-Pacific region**, countries such as Australia and Japan have adopted proportionate, product-focused regulatory approaches for NBTs that reflect the precision and limited risk of certain genome-editing applications. Australia amended its Gene Technology Regulations in 2019 to clarify that SDN-1 genome-edited organisms are not regulated as GMOs. This determination, overseen by the Office of the Gene Technology Regulator, is based on the assessment that such products are indistinguishable from those developed through conventional breeding, providing regulatory certainty and supporting agricultural innovation (OGTR, 2019; USDA, 2023). Japan has implemented a comparable approach through a notification-based system established in 2019 by its health and agriculture Ministries. Under this framework, genome-edited foods without foreign DNA are not subject to full GMO

approval but must be disclosed to regulators. This system has enabled early commercialisation of genome-edited products, while maintaining transparency and oversight (MHLW, 2019; ISAAA, 2024a). In late 2024, New Zealand introduced the Gene Technology Bill to replace its 30-year-old restrictive framework with a risk-proportionate, product-based model. As of March 2026, the Bill has passed its Select Committee stage but remains subject to political negotiation. The proposed framework establishes a ‘Gene Technology Regulator’ and a tiered risk system that explicitly allows exemptions for low-risk NBTs (SDN-1) that are indistinguishable from conventional breeding. Although the final operational date has been delayed due to coalition deliberations regarding environmental release, the legislative intent marks a definitive shift away from New Zealand’s historical, overly ‘precautionary’ stance toward alignment with the Australian and Japanese models.

- **The United Kingdom:** Following withdrawal from the European Union, England has begun to diverge from the EU GMO framework in its regulation of certain gene-edited organisms. This process culminated in the Genetic Technology (Precision Breeding) Act 2023 and subsequent implementing regulations, which establish a distinct, streamlined regulatory pathway for ‘precision-bred organisms’ whose genetic changes could have occurred naturally or through traditional breeding. The Act distinguishes such precision-bred organisms from traditional GMOs, subjecting them to a proportionate, science-based notification and authorisation process rather than the full GMO risk-assessment regime, while GMOs remain under stricter controls. By aligning regulatory oversight with the final product’s risk profile, the English framework aims to accelerate innovation in agriculture, support climate-resilient and sustainable food systems, and enhance competitiveness in agri-biotechnology research and commercialisation (Rothamsted Research, 2025). In contrast, **Scotland, Wales and Northern Ireland** currently continue to apply the (old) EU-derived GMO model (Gene Literacy Project, 2023).
- **European Union:** As a major agricultural trade partner to South Africa and historically a bastion of precautionary, process-based regulation, the European Union reached a landmark political agreement in late 2025 to create a streamlined category (NGT1) for New Genomic Technique products deemed equivalent to conventional varieties (Council of the European Union, 2025; Euroseeds, 2024). This decision marks a definitive shift toward a risk-proportionate framework driven by a ‘triple imperative’ of climate resilience, geopolitical competitiveness, and scientific proportionality (European Commission, 2025; Council of the European Union, 2025).

Under this revised framework, NGT plants classified as Category 1 (NGT1) will be regulated similarly to conventional plants and therefore exempted from the stringent requirements of the EU’s existing GMO legislation (European Parliament, 2026). This key exemption means that NGT1 products - defined by the ‘20/20 rule’ as having no more than 20 genetic modifications of 20 nucleotides or fewer - will not be subject to the same rigorous authorisation processes, mandatory risk assessments, or GMO labelling requirements, significantly easing their path to market (European Commission, 2021; 2023).

Several critical factors underpinned this policy shift by the EU:

- **Scientific Equivalence and Mutational Logic:** Central to the EU's decision was the scientific conclusion by the European Food Safety Authority that NGT1 plants are 'mutational equivalents' to those produced through conventional breeding. EFSA's 2024/2025 opinions confirmed that NGT1 modifications align with genetic variations found in nature and pose no additional hazards or risks to human health or the environment compared to traditionally bred crops (EFSA, 2024). This shift acknowledges that the safety of an organism is determined by its specific traits and properties, rather than the precision tool used to develop it (European Commission, 2023).
- **Addressing 'Regulatory Limbo' and Innovation Barriers:** The 2025 agreement effectively moves away from the 2018 European Court of Justice ruling in Case C-528/16, which classified all genome-edited products as GMOs regardless of their risk profile. Academic legal analysis has argued that this ruling created a rigid, 'unfit-for-purpose' framework that led to significant legal uncertainty (Vives-Vallés & Collonnier, 2020; Wasmer, 2021). This academic consensus was mirrored by industry stakeholders, who maintained that the 2018 ruling acted as a 'prohibitive barrier' to European innovation, effectively stalling the development of biotech start-ups and SMEs that could not afford the costly and lengthy GMO authorisation processes (Seed World, 2025). By creating the NGT1 category, the EU has finally resolved this 'regulatory limbo,' aligning legal definitions with modern genomic realities (European Commission, 2023; Council of the European Union, 2025).
- **Climate and Food Sovereignty:** A primary driver towards the policy revision was the recognition that the EU could not meet its 'Green Deal' sustainability targets or ensure long-term food security without NGTs. These tools are seen as essential for developing crops that can withstand extreme weather while requiring fewer chemical inputs (Council of the European Union, 2025).
- **Geopolitical Alignment:** To avoid becoming a 'regulatory outlier' in a global agricultural market, the EU moved to align more closely with major trading partners who have already adopted tiered, risk-based systems (Council of the European Union, 2025; Acumen Research, 2026).

The EU formally adopted its new regulation on plants obtained through NGTs on 17 June 2026 - Regulation (EU) 2026/1388. It entered into force on 16 July 2026, but most provisions will apply only from 17 July 2028, so any material change to trade conditions will be prospective. The framework covers imported as well as EU-grown plants and distinguishes two categories: following verification, Category 1 (NGT-1) plants, those with limited genetic changes that could also arise through conventional breeding, will be treated like conventional plants, whereas Category 2 (NGT-2) plants remain subject to existing GMO rules, including risk assessment and authorisation (European Parliament, 2026). The reform signals a move towards differentiated, arguably proportionate oversight based on the characteristics of the resulting plant and its genetic changes, rather than regulation based solely on the breeding process.

4. Products from NBTs in the Global Plant Breeding Pipeline

The global pipeline for NBT-derived crops is accelerating, with gene-edited seeds for staple crops expected to reach mainstream markets within the next 2-5 years (ISAAA, 2025). This progress is driven by fit-for-purpose regulation in key regions as well as enabling technologies like speed breeding and AI-guided genomic selection that are compressing development cycles. Whereas early innovations focused on niche applications (like non-browning and disease-resistant bananas in the Philippines and Colombia, and high-GABA¹ Tomatoes in Japan), research and development efforts have increasingly shifted toward maize, soybean, and wheat (the three most significant field crops globally) with a growing number of products moving through late-stage development.

Research applying the European Union's proposed regulatory criteria to current NGT plant applications indicates that approximately 94% of products in the development pipeline would be classified as NGT1 (Bohle et al., 2024). This category includes SDN-1 and SDN-2 modifications that comply with the EU's "20/20 rule" and are therefore regarded as equivalent to conventionally bred plants (European Commission, 2023). Because the genetic changes introduced in these plants fall within the range of variation that could occur naturally or through conventional breeding, regulators increasingly consider them to pose risks comparable to those associated with conventionally bred crops (European Commission, 2023; EFSA, 2024). Assessments of breeding pipelines suggest that many anticipated agricultural innovations, including drought-tolerant maize and disease-resistant staple crops, are being developed using these techniques (Parisi & Rodríguez-Cerezo, 2021). The finding that the vast majority of current NGT applications would qualify as NGT1 highlights the potentially far-reaching implications of the proposed regulatory framework. It has also strengthened arguments that subjecting these products to conventional GMO regulatory requirements would impose a disproportionate burden on innovation, food security, and agricultural competitiveness, given their similarity to conventionally bred plants and their comparatively low-risk profile (Bohle et al., 2024; European Commission, 2023; EFSA, 2024).

International wheat cultivar development pipeline

Despite its complex hexaploid genome (or because of it), wheat is seeing rapid NBT advancements, and commercial seeds could be available by 2026–2028. Key developments include:

- **Quality and Health Traits:** GEd-wheat with low asparagine content (which reduces the formation of carcinogenic acrylamide when toasted) is in late-stage trials in the UK (Rothamsted Research, 2023). Researchers have also used CRISPR/Cas9 to precisely edit the alpha-gliadin gene family to produce low-gluten, celiac-safe wheat (Sanchez-Leon, et al., 2018). Further advancements include 'waxy' wheat varieties developed by knocking out the starch-branching enzyme (SBEIIa) gene to increase amylopectin content, which provides superior properties for industrial food processing and starch stability.

¹ Gamma-Aminobutyric Acid (GABA), which is the primary inhibitory neurotransmitter in the brain. At the correct levels, it can assist in stress reduction.

- **Disease Resistance:** China has approved its first gene-edited wheat variety with resistance to powdery mildew, achieved by knocking out the Mildew Locus o (MLO) susceptibility genes (Reuters, 2024), reducing the need for fungicide applications. In the US, the introduction of new germplasm targeting the Fhb1 locus offers significant resistance to Fusarium head blight (FHB), a major cause of grain quality degradation and mycotoxin contamination (USDA ARS, 2026).
- **Climate Resilience and Stress Tolerance:** Gene-edited lines with enhanced tolerance to heat and drought are advancing towards commercial release. By targeting the Dehydration-Responsive Element-Binding (DREB) and Trehalose phosphate phosphatase (TPP) gene families, researchers have improved water-use efficiency and thermal stability, allowing for yield preservation in high-temperature environments without the ‘yield drag’ common in traditional transgenic crops (Bioceres, 2024)
- **Yield:** Scientists have successfully used CRISPR/Cas9 to edit genes that act as negative regulators of grain development. By deactivating specific genes such as Triticum aestivum E3 ligase Grain width and weight2 (TaGW2) and Triticum aestivum Grain Size 5-A1 (TaGS5-A1), researchers have managed to increase grain width, length, and overall thousand-kernel weight, providing a pathway for stable productivity increases (Wang, et al., 2018; Chachar, et al., 2024).
- **Herbicide Tolerance:** Researchers have created wheat varieties that are tolerant to specific herbicides by making precise (SDN-2) edits to the Acetolactate Synthase (ALS) gene. Editing this gene confers tolerance to multiple classes of herbicides, including imidazolines and sulfonylureas, facilitating more efficient weed management with lower chemical application rates (Zhang, et al., 2019).

International soybean cultivar development pipeline

Gene-edited soybeans are at the forefront of NBT commercialisation. Products with SDN-1 edits have already been approved in the US, Brazil, and Japan, with commercial seeds expected in 2026. The pipeline includes:

- **Tailored Oil Profiles:** The first gene-edited food product on the US market was Calyxt’s Calyno™ high-oleic soybean oil. Developed using TALENs, this variety offers a healthier fat profile with zero trans fats and a longer shelf life (ISAAA, 2019).
- **High-Protein Soy:** Amfora, Inc. is developing soybeans with a protein increase of at least 10% by modulating the expression of native genes. This trait targets the growing specialty markets for aquaculture feed and plant-based meat alternatives, reducing the need for intensive protein concentration processing (Amfora, Inc., 2024).
- **Abiotic Stress Tolerance:** Researchers are using CRISPR/Cas9 to ‘knock out’ negative regulator genes, such as Glycine max ABA-Induced Transcription Repressors (GmA1TR), to significantly enhance salt and drought tolerance. Recent field trials have confirmed that these lines maintain stable yield potential under high-salinity conditions that typically compromise conventional crops (Wang, et al., 2021).
- **Enhanced Yield Soybeans:** Inari has developed the gene-edited soybean variety VPM-0007, which uses precise deletions to increase both the number and physical size of seeds. In January 2026, the U.S. Food and Drug Administration completed its safety consultation, clearing the variety for use in food and animal feed and paving the way for full commercial deployment (USFDA, 2026).

- **Photoperiod Adaptation:** Leveraging CRISPR-Cas12a technology, Syngenta has developed soybean varieties with truncated flowering and maturity cycles. By editing the genes governing the plant's internal clock, these varieties can produce high yields in temperate or high-latitude regions where traditional soybeans often fail to mature before the first frost (ISAAA, 2024b).

New soybean seed technologies that are near commercialisation but that will need to be regulated as GMOs because they are transgenic, include:

- **Pest and Disease Defence:** The Nemasphere™ trait, scheduled for the 2026 planting season, provides a novel biotechnological solution to Soybean Cyst Nematode, a leading cause of global yield loss. By utilising a unique Cry14 protein, this technology offers the first transgenic (GMO) mode of action specifically engineered to protect root systems from nematode-induced damage (BASF, 2024).
- **Multi-Herbicide Tolerance:** Bayer's upcoming 'Vyconic' technology (formerly HT4) is designed to provide robust tolerance to five distinct herbicide classes: dicamba, glufosinate, mesotrione, 2,4-D, and glyphosate. This five-way stack allows for unprecedented flexibility in weed management, enabling growers to combat increasingly resistant weed populations through more diversified chemical applications (Bayer, 2025).

International maize cultivar development pipeline

Commercialisation of gene-edited maize is projected for 2026–2028, with wider adoption by 2030. The pipeline is focused on traits crucial for food security and farmer profitability in regions like Southern Africa:

- **Yield Enhancement:** Recent studies have demonstrated that knocking out the Kernel Row Number 2 (KRN2) gene, a negative regulator of grain productivity, can increase maize yields by approximately 8–10% without compromising other agronomic traits. This SDN-1 approach allows for the development of high-performing hybrids that are indistinguishable from those produced via conventional breeding (Chen, et al., 2022).
- **Disease Resistance:** A critical priority for African food security is the development of resistance to Maize Lethal Necrosis (MLN) disease. A public-private partnership between CIMMYT and Corteva Agriscience is using CRISPR/Cas9 to develop MLN-resistant hybrids, with commercial availability anticipated following regulatory clearance (CIMMYT, 2023). Additionally, genome editing of susceptibility genes such as ZmLOX3 (a Zea mays lipoxygenase gene), Zea mays Rab GDP dissociation inhibitor alpha (ZmGDIα), and Zea mays CORONATINE INSENSITIVE 1a (ZmCOIa) has successfully enhanced resistance to destructive fungal pathogens (*Ustilago maydis*, *Fusarium graminearum*) and viral threats such as Maize Rough Dwarf Virus (Yang, et al., 2022).
- **Improved Feed and Industrial Quality:** Genome-edited maize with reduced lignin content is currently undergoing field trials in Europe to improve digestibility for the livestock sector. This modification enhances feed conversion efficiency and significantly lowers the energy requirements for the bioethanol and paper industries by facilitating easier breakdown of plant cell walls (VIB, 2024).
- **Climate Resilience:** Multi-institutional programmes are leveraging CRISPR to enhance drought tolerance and nitrogen-use efficiency. By precisely modulating the expression of genes involved in the plant's stress-response pathways, researchers have developed maize lines capable of maintaining productivity under extreme heat and water scarcity.

(Chen et al., 2024; Sheoran et al., 2022) - core challenges for South Africa's summer rainfall regions responsible for most of the country's maize production.

- **Endogenous Herbicide Tolerance:** Unlike traditional GMOs that rely on bacterial genes, GEd is being applied to maize to develop herbicide-tolerant varieties by making precise (SDN-2) modifications to endogenous genes such as EPSPS and ALS. This creates resistance to broad-spectrum herbicides without the introduction of foreign DNA, potentially allowing these varieties to be regulated as conventional products in modernised frameworks (Kaul, et al., 2024).

The rapid advancement of these cultivar development pipelines underscores a fundamental shift in global agricultural innovation. While the maize and soybean sectors are moving from broad-spectrum transgenic traits toward high-precision enhancements, the wheat pipeline represents a historic pivot, as NBTs provide the first commercially viable pathway for biotechnology in a crop traditionally restricted to conventional breeding. As these NBT-derived varieties, particularly those categorised as SDN-1 and SDN-2, enter commercial markets in the first-adopting larger agricultural economies and expand into other regions as conventional seeds, they establish a new global benchmark for yield, climate resilience, and nutritional density.

5. Implications of the Current South African Approach NBTs

South Africa's current regulatory classification of all products derived from NBTs as GMOs creates a fundamental disconnect between national policy and scientific reality. Maintaining this approach poses three critical strategic risks:

- **The Stifling of Domestic Innovation:** The prohibitive cost of a full GMO dossier (often exceeding USD 10–30 million) and the decade-long approval timeline, effectively exclude public institutions such as the Agricultural Research Council (ARC) and national universities, as well as local SMEs, from the biotechnology sector. This transforms agricultural innovation from a national capability into a privilege reserved for large multinational corporations (Groenewald et al., forthcoming; Lassoued et al., 2025).
- **Imminent Trade Friction:** As NBT-derived crops become global commodity standards, South Africa's process-based regulatory system will create technical barriers to trade. This threatens the stability of both essential imports (e.g., wheat) and high-value exports, as our regulatory framework fails to recognise the equivalence of these products to their conventional counterparts.
- **Erosion of Farmer Competitiveness:** By denying timely access to SDN-1 and SDN-2 seed technologies, the current framework forces South African farmers to operate with a 'technology gap'. While global competitors adopt varieties with superior yield, heat resilience, and reduced input costs, South African producers remain tethered to outdated genetics, compromising their long-term economic viability and limiting their ability to adapt to climate change.

Maintaining the current approach could have significant implications for South Africa's food security and agricultural competitiveness. The impact will transition from a hidden innovation cost today to a visible, systemic market crisis by 2030.

The 'Innovation Chill' - Stifling Domestic Research and Development

Perhaps the most insidious cost of the current regulatory environment is the 'innovation chill' it imposes on the domestic scientific community. By treating precision-edited crops as traditional transgenics, the regulatory framework imposes a compliance burden that local innovators simply cannot bear (Groenewald et al., forthcoming). This creates a direct conflict with the South African Bio-economy Strategy (2013) and the Agricultural Bioeconomy Innovation Partnership Programme (ABIPP), which explicitly mandate the use of biotechnology to improve crop resilience and address climate change in support of food security; support and expedite the development of indigenous crops; and enhance the productivity of smallholder and emerging farmers through drought- and heat-resilient maize (DST, 2013; DSI, n.d.).

The current regulatory approach is also at odds with the Department of Agriculture's Agriculture and Agro-Processing Master Plan (AAMP), which identifies innovation, climate resilience and inclusive, export-oriented growth as core priorities for the sector (DALRRD, 2022). It constrains ambitions to leverage South Africa's scientific capacity and bio-innovation ecosystem to strengthen food security, agricultural competitiveness, and rural livelihoods, as envisaged in the AAMP's implementation pillars. In practice, the regulatory 'innovation chill' risks weakening precisely those channels - technology adoption, value-chain upgrading and smallholder integration, that the Master Plan seeks to accelerate.

The current approach constrains progress toward several stated national policy objectives in the areas of agricultural innovation, food security, transformation, and scientific development:

- **Prohibitive Regulatory Barriers:** A standard GMO regulatory pathway involves timelines of 10–15+ years. For public institutions such as the ARC, as well as local companies, this is economically and operationally unfeasible. As a result, promising 'public-good' traits, such as locally adapted pest resistance, drought tolerance, and biofortified indigenous crops, remain confined to laboratories, unable to reach the farmers they were designed to serve. The high costs, uncertainty, and risk associated with navigating this regulatory pathway further discourage commercialisation, often resulting in projects not progressing beyond early development stages, and limiting local IP generation, product development, and investment.
- **The Exclusion of Local Breeders:** NBTs were originally heralded for their ability to 'democratise' plant breeding. Unlike traditional genetic modification, which requires massive infrastructure, gene editing allows smaller, agile local seed companies to develop niche, locally adapted varieties. According to the South African National Seed Organization (SANSOR), it costs approximately R200 million (about \$12.5 mil) to commercialise a GMO locally, of which over 50% goes towards meeting regulatory requirements (AgbioInvestor, 2022; Cilliers, 2023). South Africa's current regulatory approach effectively destroys this opportunity for local SMEs.
- **The Erosion of National Scientific Capacity:** The absence of a viable commercial deployment pathway for NBTs creates a 'brain drain'. Young scientists and biotechnology graduates are discouraged from pursuing careers in a field with no domestic future. Potential collaborators shy away from partnerships with South African researchers, and international and local funding agencies are increasingly hesitant to invest in South African research, as the regulatory hurdles are viewed as insurmountable.
- **Surrender of Regional Leadership:** Historically, South Africa was the continent's leader in biotechnology adoption. However, by maintaining an outdated stance on NBTs, the

nation is surrendering its position as a regional R&D hub and as an attractive entry point into the African seed market. Countries like Kenya, Nigeria, and Ethiopia are moving rapidly to establish enabling, risk-proportionate frameworks, attracting the research investment and scientific talent that would historically have flowed to South Africa.

- **Risks to Food Security:** Taken together, these barriers create a structural risk to South Africa's food security. By preventing locally developed, stress-tolerant and nutrient-enhanced varieties from reaching farmers, the current framework slows productivity growth, weakens the adaptive capacity of smallholder and commercial systems to climate and market shocks, and deepens dependence on a narrow set of imported technologies and germplasm. This undermines core national policy objectives to secure stable, affordable food supplies, reduce vulnerability to external disruptions, and build a resilient, domestically anchored agricultural innovation system.

Although research on transgenic crops has been ongoing in South Africa since the 1980s (James & Krattiger, 1996), no locally produced GMO has been commercialised to date. Twenty-eight years since the first commercial GMO was released onto the South African market (Bt cotton), over 1 300 permits for import, export, trial release, commodity clearance and general release of 82 transgenic events have been issued (DoA, 2026). These events were all developed outside South Africa, primarily by large multinationals, reflecting how local regulatory barriers have constrained the translation of local research into commercial products. Maintaining the current GMO status of products developed using NBTs will yield the same result. By retaining the existing regulatory approach, the state is not merely slowing down access to technology; it is actively preventing the creation and deployment of home-grown solutions tailored to South Africa's unique environmental and social challenges.

Erosion of Farmer Competitiveness - Maize and Soybeans

South African agriculture has historically maintained its global edge through the rapid adoption of world-leading seed genetics. This technological agility is precisely what allows the sector to remain a net exporter and provide affordable staples to domestic consumers, even amidst the extreme volatility of international commodity markets and geopolitical turmoil. However, the current NBT policy places this competitive foundation at direct and imminent risk.

- **The Emergence of a 'Structural Yield Gap':** As competitors in the first-adopting larger agricultural economies (notably Brazil and Argentina) integrate SDN-1 and SDN-2 maize and soybeans into their portfolios, their productivity frontiers will shift. These varieties, with improved germplasm and featuring precision-edited traits for drought tolerance, nitrogen-use efficiency, and enhanced pest resistance, will accelerate global yield trends. South African farmers, restricted to legacy transgenic or conventional technologies, will face a widening productivity gap that cannot be closed through traditional management alone.
- **A Systematic Technology Access Blockage:** The current regulatory environment creates a 'market failure' for new genetics. Both domestic and multinational seed companies are unlikely to undertake the multi-million-rand, scientifically redundant GMO registration process for NBT varieties that are treated as conventional elsewhere. Consequently, the latest, most efficient germplasm will simply bypass the South African market, leaving local producers with a diminishing pool of competitive seed choices.

- **The Input Cost Disadvantage:** Global NBT trends are increasingly focused on ‘input-replacement traits’ - seeds that require significantly less synthetic fertiliser, water, and chemical intervention to achieve optimal yields. Without access to these efficiencies, South African farmers will be burdened with higher production costs per tonne. In a global commodity market where profit margins are thin, this cost disparity will erode the profitability of local farming operations and compromise their ability to compete in regional and global export markets.
- **Contradicting Environmental and Health Mandates:** South Africa has made firm international and domestic commitments to phase out certain hazardous agricultural remedies. However, the current NBT policy creates a regulatory conflict: it restricts the very tools (crops resistant to viruses, fungi, and insect pests) that would allow farmers to reduce their chemical footprint. By delaying access to these ‘built-in’ biological defences, the current framework inadvertently forces a continued reliance on older, more hazardous chemicals, undermining the nation’s broader environmental and public health objectives.

The current ability of South African farmers to act as a buffer against global food inflation is not guaranteed; it reflects decades of sustained access to advancing agricultural technologies. Maintaining the current NBT regulatory framework risks eroding this capacity, potentially undermining domestic food affordability and export-driven economic growth.

Imminent Trade Friction and Food Security Risks

South Africa is a net importer of wheat, sourcing approximately 40–55% of its annual requirement from the global market. While the prospect of a systemic collapse in this supply chain may currently seem an unlikely or alarmist scenario, it is the structural and inevitable trajectory enforced by the current regulatory treatment of NBTs. By maintaining a process-based framework that categorises precision-edited traits as traditional GMOs, South Africa is drifting toward a state of ‘Regulatory Isolation.’ The following predictable sequence of events, though hypothetical in the present moment, represents the unavoidable operational reality that will eventually compromise national food security:

1. **The Proliferation of ‘Lead Adopters’:** By 2028–2030, NBT wheat varieties will be commercially dominant in South Africa’s primary import hubs, specifically Australia, the United States, and Argentina. As these exporters and other major producers like Canada and Brazil, and eventually the Black Sea region prioritise climate resilience and yield competitiveness, the availability of conventionally bred wheat will rapidly diminish.
2. **The Collapse of ‘non-NBT’ Wheat Sources:** Crucially, South Africa’s traditional European suppliers (notably Lithuania and Poland) are no longer ‘non-biotech’ sanctuaries. Following the EU’s 2025 adoption of a risk-proportionate NGT framework, these Baltic sources are transitioning toward NBT varieties that are exempt from GMO oversight. Consequently, South Africa may increasingly struggle to source wheat from major export regions that do not utilise NBTs (Council of the European Union, 2025).
3. **The Commingled Supply Chain Reality:** In global grain logistics, wheat is handled as a bulk commodity. Because NBT wheat is regulated as conventional in the countries of origin, it will not be segregated or labelled. Without a mandatory (and prohibitively expensive) ‘closed loop’ identity preservation system, NBT wheat will be naturally and invisibly blended into the global bulk supply (Turnbull et al., 2021).

4. **The Scientific Detection Gap:** Under current South African law, this wheat would be classified as an unapproved GMO. However, detecting SDN-1 edits in bulk shipments is practically impossible. As there is no foreign DNA signature, these edits are practically indistinguishable from natural mutations (Grohmann et al., 2019). This creates an enforcement paradox, as authorities would have to reject shipments based on ‘administrative suspicion’ rather than scientific proof.
5. **Private Sector Risk and Withdrawal:** The threat of having entire shipments seized or rejected based on unverifiable suspicion creates an unquantifiable financial liability for grain importers, millers, and processors. Faced with the risk of ‘administrative forfeiture’ at South African ports, private actors may be forced to withdraw from traditional markets, destabilising the domestic wheat supply.
6. **The Economic Burden of Non-NBT Sourcing:** As NBT wheat becomes the global standard, conventionally bred wheat will transition into a niche, luxury product. This creates a dual economic risk: first, South Africa would be forced to pay a significant ‘anti-technology tax’ (a traceability premium) for verified non-NBT grain. Second, because conventional wheat would command a higher price, there would be a massive incentive for global suppliers to mislabel NBT-blended wheat as conventional to capture the premium - a fraud that South Africa cannot scientifically detect or verify (Turnbull et al., 2021).
7. **The Dossier Deadlock:** If the state requires full GMO-style safety dossiers for every new NBT cultivar developed globally, the sheer volume of new releases, which NBTs allow to happen much faster than traditional GM, will overwhelm domestic regulatory capacity. This creates an ‘asynchronous approval’ backlog that could block bulk imports for years.

To avoid this external dependency, South Africa would be forced to achieve near-total self-sufficiency in wheat. This would require an immediate and radical expansion of domestic production, bringing an estimated 500,000 additional hectares under cultivation, primarily in the marginal, summer-rainfall regions of the Free State.

This strategy faces two insurmountable hurdles:

- **Historical Context:** South Africa last produced wheat on this scale in the 1990s, a period sustained by massive government intervention and market support that no longer exists.
- **The Policy Irony:** Reclaiming half a million hectares in these marginal, heat-stressed areas would require exactly the ‘climate-smart’ traits (drought and heat tolerance) that NBTs provide. By restricting NBTs, the current policy simultaneously creates the need for domestic expansion while banning the very tools required to make that expansion viable.

The inevitable outcome is a substantial increase in the price of wheat and wheat products. The costs of regulatory friction, premium sourcing, or failed domestic expansion will largely be passed to the consumer. This transforms a technical biotechnology debate into a direct threat to the price of bread and staples, disproportionately affecting low-income households and threatening national food security.

6. Quantifying the Impact: A Forward-Looking Analysis

This section evaluates the projected erosion of South Africa’s agricultural competitiveness and food security resulting from the current regulatory treatment of NBTs.

South Africa’s agricultural resilience, which sustains affordable food prices despite extreme volatility in international commodity markets, is driven by the rapid, agile adoption of world-class seed genetics and technological innovations (BFAP, 2023; Kgatle, 2025). Comparative data indicates that local yields have successfully tracked the trajectories of major agricultural powers like the USA, Brazil, and Argentina, often while operating under more challenging climatic conditions (BFAP, 2023). For maize, this long-term advancement has seen an average annual yield growth rate of 3.8% between 1990 and 2024 - a performance surpassing that of many other nations (Figure 1).

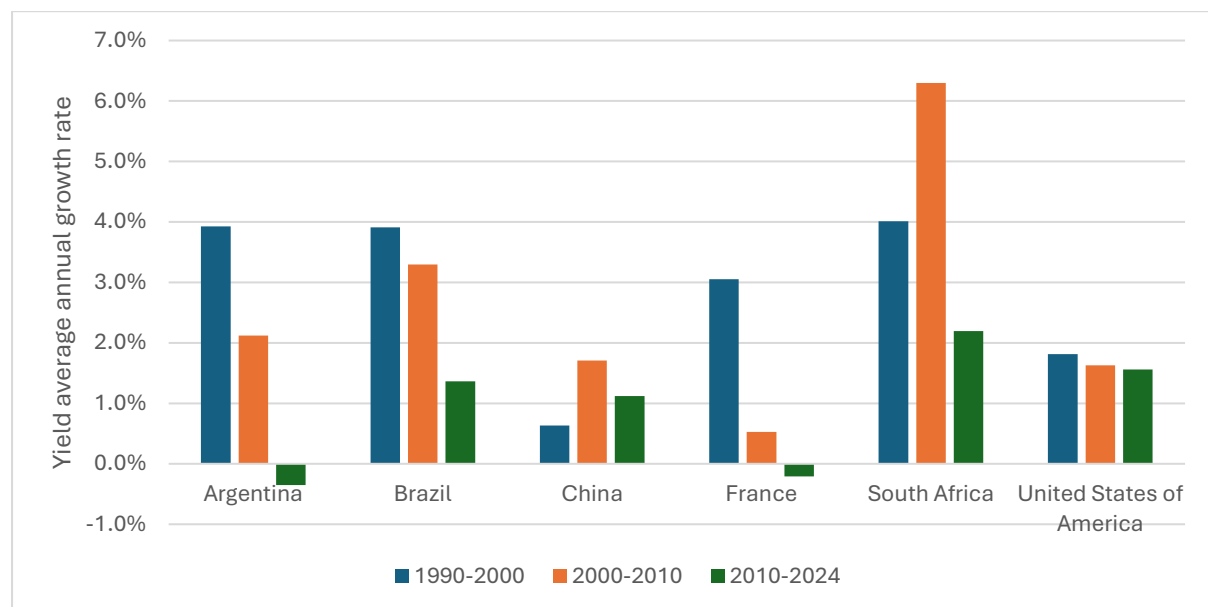


Figure 1: Maize yield growth rates (average annual increase for the indicated periods).

This trajectory is rooted in distinct historical phases: competitive performance in the 1990s was followed by a period of robust acceleration between 2000 and 2010, with annual yield increases exceeding 6%. This rapid growth was driven not by the adoption of genetically modified (GM) maize varieties alone, but by their synergistic integration with significantly improved farming practices (Kgatle, 2025). While the pace of yield growth has since moderated to approximately 2.2% per annum for the 2010–2024 period, South Africa has maintained its competitive position as a leading maize producer among its international peers (BFAP, 2025). This sustained productivity is further bolstered by ongoing improvements in agricultural practices, such as conservation tillage, precision fertiliser application, and integrated pest management, all of which remain central to ensuring the long-term sustainability of the grain industry and its ability to meet growing population demands (Pramanick et al., 2022; Kgatle, 2025; BFAP, 2025).

The South African soybean industry has undergone a remarkable transformation, evolving from a reliance on imports to becoming a pivotal component of the domestic oilseed market. This structural shift, largely unfolding over the past two decades, was primarily driven by increasing demand for soybean oilcake within the domestic animal feed and poultry industries, which prompted strategic investments in local processing capacity (BFAP, 2021).

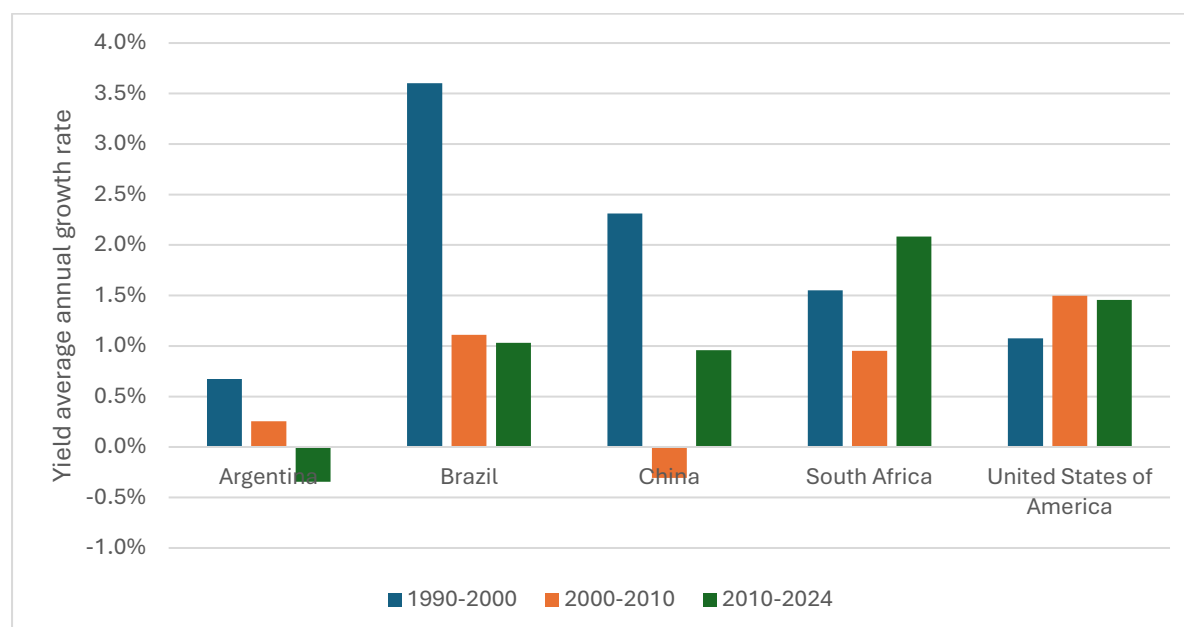


Figure 2: Soybean yield growth rates (average annual increase for the indicated periods).

Technological advancement remains the cornerstone of this success. The widespread adoption of GM seeds, which now account for approximately 95% of total soybean plantings, has been critical to protecting yield potential and ensuring economic viability (BFAP, 2023). Furthermore, the industry has achieved remarkable productivity gains since the early 1990s, with yields doubling over this period - a particularly impressive feat given that the area under production has expanded more than ten-fold over the past three decades (BFAP, 2021). Between 2010 and 2024, South Africa's soybean yield increases have led that of international counterparts like Brazil and the USA (Figure 2), with these gains driven by the implementation of improved seed cultivars, precision farming, and enhanced agricultural management practices - themes consistently highlighted in BFAP's agricultural outlooks and in research regarding fertiliser trends and on-farm seeding trials (BFAP, 2023; Truter et al., 2025).

Despite persistent challenges such as climatic volatility and infrastructure constraints, the soybean sector's ongoing integration of advanced farming techniques and its role in import substitution underscore its pivotal contribution to South Africa's food security and long-term agricultural competitiveness (BFAP, 2023).

However, the transition from legacy GM technologies to the NBT era presents a critical pivot point. The following analysis quantifies the potential 'productivity gap' - contrasting the continuation of SA's historical performance against the stagnation expected under a regulatory approach that precludes NBT adoption.

Methodology and Assumptions

The Bureau for Food and Agricultural Policy (BFAP) employs a sophisticated multi-market Partial Equilibrium (PE) model, refined over more than fifteen years, to analyse agricultural market dynamics across a broad spectrum of commodities and countries. This framework operates on fundamental balance sheet principles, ensuring that total supply (comprising production, imports, and stocks) consistently equates to total demand (encompassing consumption, exports, and ending stocks). The model's robustness stems from its dynamic, recursive architecture, which integrates complex policy details, market elasticities, and key macroeconomic indicators - sourced from organisations such as the OECD, the IMF, and the Bureau for Economic Research (BER) - to generate reliable baseline projections. By basing price determinations on a nexus of import/export parity and domestic supply-demand interactions, the model can effectively simulate the impacts of alternative scenarios and dynamic responses over time. Crucially, the system links relevant agricultural sectors through competition for resources and input-output relationships (such as feed-livestock dependencies), allowing for nuanced scenario analysis and robust sustainability assessments.

Analysis and Findings

Yield Assumptions

To evaluate the economic impact of potential access to NBT's in South Africa, BFAP's partial equilibrium market model was used for a scenario-based assessment. Two different scenarios were simulated for the coming decade, based on different yield assumptions associated with NBT access. In the scenario where South African producers are unable to access NBT seed, yield projections are based on USDA (2025) and World Bank (2025) which point to a compounding productivity gap of 5-10% for soybeans and 6-8% for maize in countries that are unable to utilise NBT products over the coming decade. Practically, this was introduced as a yield lag relative to global projections from the OECD-FAO (2025). In each of the commodities, yield growth at global level by 2035 was compared to an average of the past 5 years. Consideration of a 5-year base period removes the impact of climate fluctuations that may result in projecting growth from an above or below average level if only the last year is considered. South African projections are then based on attaining 10% less growth than the world average by 2035 for maize and 8% less growth than the world average by 2035 for soybeans. The stagnation in yields in South Africa relative to global growth is assumed to occur mainly in the latter half of the outlook, as the share of new varieties based on NBTs is assumed to increase over time, leaving limited new options to producers unable to access NBT based varieties.

As an alternative scenario that considers a world where South African producers are able to access NBT varieties, these yield projections are adjusted based on findings from Qaim (2020), Riccroch et al. (2022) and OECD-FAO (2019) that point to additional yield potential from NBT varieties of 10%-20% on average for maize and wheat, along with a 5%-15% gain on average for soybeans over a 10-15 year horizon. With the current forward looking assessment considering impacts by 2035, a midpoint was used, adding 15% above the non-NBT scenario by 2035 for maize and wheat, and 10% above the non-NBT scenario by 2035 for soybeans. The acceleration is particularly evident in the second half of the outlook, as more options become available and adoption rates increase. A visual representation of the implied yield assumptions is provided in Figure 3, Figure 4 and Figure 5.

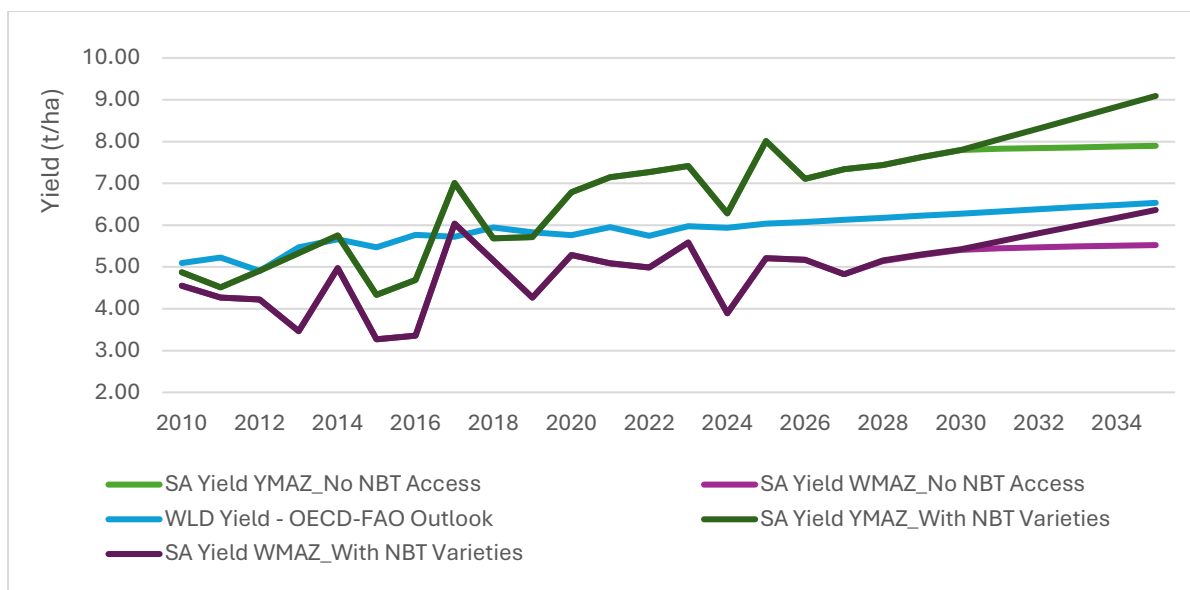


Figure 3: Maize yield outcomes under different scenarios with and without access to NBT varieties.

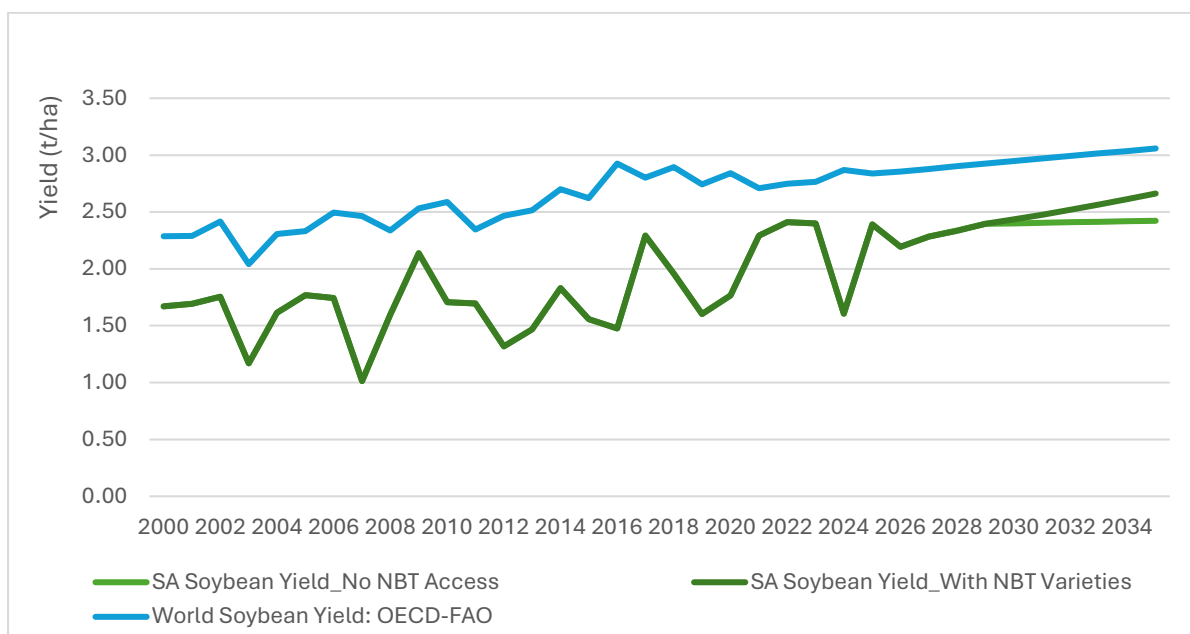


Figure 4: Soybean yield outcomes under different scenarios with and without access to NBT varieties.

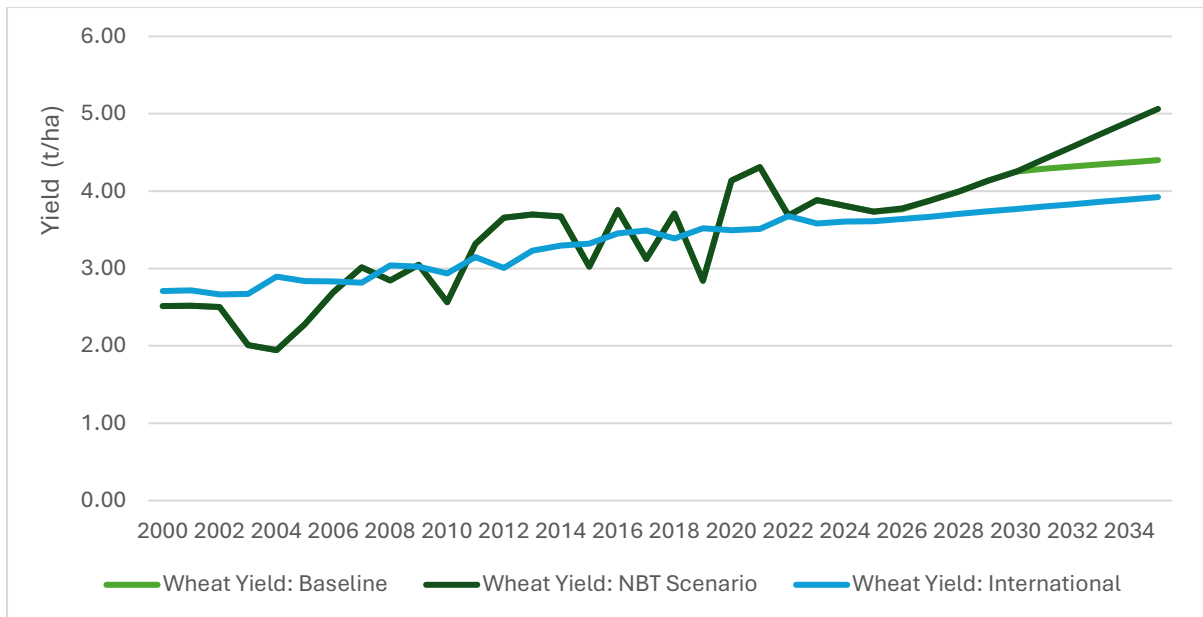


Figure 5: Wheat yield outcomes under different scenarios with and without access to NBT varieties.

Price Impacts

To consider the impacts of the ability to adopt NBT varieties, different outcomes from the two scenarios can be compared. The first important outcome is price effects, given its influence on food prices, particularly for basic staples such as maize and wheat. The impact varies across different products, based on core differences in price formation dynamics. South Africa is a surplus producer of maize and prices typically tend toward export parity levels, but this depends on the size of the crop. In years with a strong surplus, prices tend to trade at export-parity levels and even slightly below during peak harvest time, in order to facilitate large-scale exports, particularly of yellow maize into the world market. White maize is more frequently exported into the Southern African region, where South Africa has become a reliable supplier to Mozambique, Botswana and Namibia. These markets rely on South African supply and have almost become an extension of the domestic market, with exports typically flowing in most years, regardless of the size of South Africa's surplus. Exports to further markets, such as Zimbabwe, are more intermittent, depending on the relative prices in South Africa and Zambia, as well as Zambia's export policy, which has imposed discretionary export bans fairly frequently in the past. In years when supply in the region is abundant, white maize prices typically fall below yellow maize to enable its use in the animal feed market, with yellow maize being exported into the global market instead. In extreme drought years when imports are required to supplement domestic production, prices can spike rapidly to import-parity levels. In years when South Africa's surplus is small, the price tends to trade between export and import parity depending on how tight the expected supply and demand balance is. In average climatic years, when South Africa produces a surplus of around 2.5 million tonnes, annual average prices normally trade marginally higher than export parity. Typically, prices would fall closer to export parity through peak harvest, but given that a smaller share of the total crop is exported, this is more in line with parity levels calculated from KwaZulu-Natal and the Eastern Free State, which is higher than the Randfontein-based export parity owing to closer travel distance to the Durban port. Once exports have shipped, prices tend to recover, trading slightly above export parity levels.

Conversely, South Africa imports around half of its total wheat requirements in any given year, and so wheat prices tend to trade in line with import parity levels, regardless of the size of the domestic crop. In good years the share of imports in total consumption declines, but not to the extent that the price formation mechanism changes. In the case of soybeans, prices are also typically dependent on the derived price from processed products such as soybean meal and soybean oil. With South Africa having shifted in recent years to a surplus position for soybeans and soybean meal, prices tend to fluctuate between export parity and the derived price of the processed products, depending on the size of the expected surplus.

Price formation mechanisms suggest that maize prices would be by far the most sensitive to differences in total production expectations over the outlook that result from divergence in yield paths. Figure 6 illustrates the divergence in maize prices under the different scenarios. When yields stagnate due to lack of access to NBT varieties, South Africa's projected maize production is 15.9 million tonnes by 2035 in a normal climatic year. This leaves an exportable surplus of 2.1 million tonnes, of which 1.5 million tonnes is white maize destined for neighbouring markets. As such, annual average equilibrium prices drift upward from export parity levels. Conversely, in a scenario where NBT access is enabled, the total crop projected by 2035 increases to 17.4 million tonnes, with an exportable surplus of 3.3 million tonnes, leaving prices trading at export parity levels, some 35% below the levels associated with the no-NBT scenario. In the case of white maize, prices fall further (37%) than yellow maize (33%), due to the size of the surplus and the need to either absorb product in feed markets or ship it to more distant regional markets. Maize price dynamics have an important bearing on maize meal prices, with Louw et al. (2017) estimating a long-run price transmission elasticity of 0.63. This suggests that, in a world with NBT access, where South Africa's white maize prices are 37% lower compared to a non-NBT world, maize meal would be 21% cheaper. Considering the dependence of lower-income consumers on maize meal as a core staple, this is a significant outcome with respect to food security.

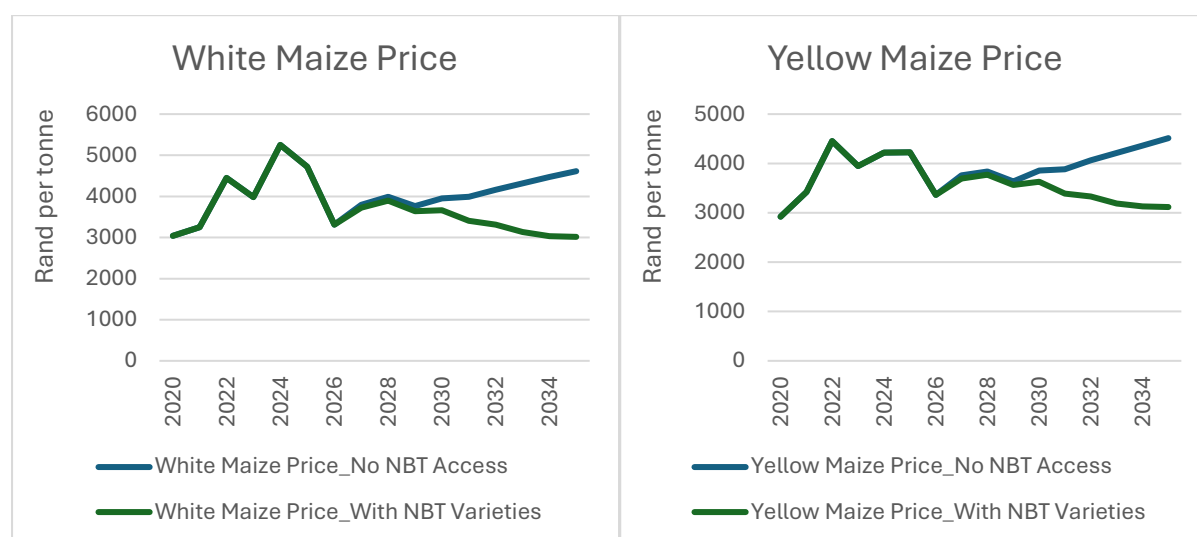


Figure 6: Maize price projections under different NBT access scenarios.

The way the wheat market sets prices suggests that the impact on local wheat prices would be minimal even if NBT varieties are introduced. SA would still require imports of about 1.6 million tonnes, compared to 2.2 million in a scenario without NBT wheat cultivars. This initial

observation, however, fails to consider the dynamics in the rest of the world, which is increasingly choosing to enable NBT-use. If South Africa is required to source from countries that either do not use NBT varieties or are able to segregate the market to supply non-NBT products, it would have to pay a premium for such products, given the additional costs of segregation, identity preservation, and certification. The only reference for what such a premium could be is found in non-GM premiums for various products. This has historically ranged from R80-R150 per tonne of maize (Afgri, 2023, pers.comm.) which translates to 3-5% considering maize prices over the 5-year period preceding 2023, and 22-25% for soybeans (USDA, 2026; USSEC, 2026).

Given the extent of this range, an increasing premium was applied to imported wheat, which reaches 15% by 2035. If such a premium is applied to wheat in a non-NBT scenario, it also drives maize prices up further, as the higher wheat price causes some consumers to shift to maize meal instead, as the more affordable alternative. Figure 7 illustrates the divergent price paths of wheat and white maize under the different NBT access scenarios. Accounting for wheat price effects leaves white maize prices in a world without access to NBT varieties at 4.4% higher compared to the same scenario without accounting for the increase in wheat prices. In the case of wheat, higher prices would also drive bread prices higher. Louw et al. (2017) suggest that the transmission to bread prices is more complete with a long-term transmission elasticity of 0.98. This suggests that the 15% increase in wheat prices in a non-NBT scenario would translate into a 14.7% increase in bread prices for consumers.

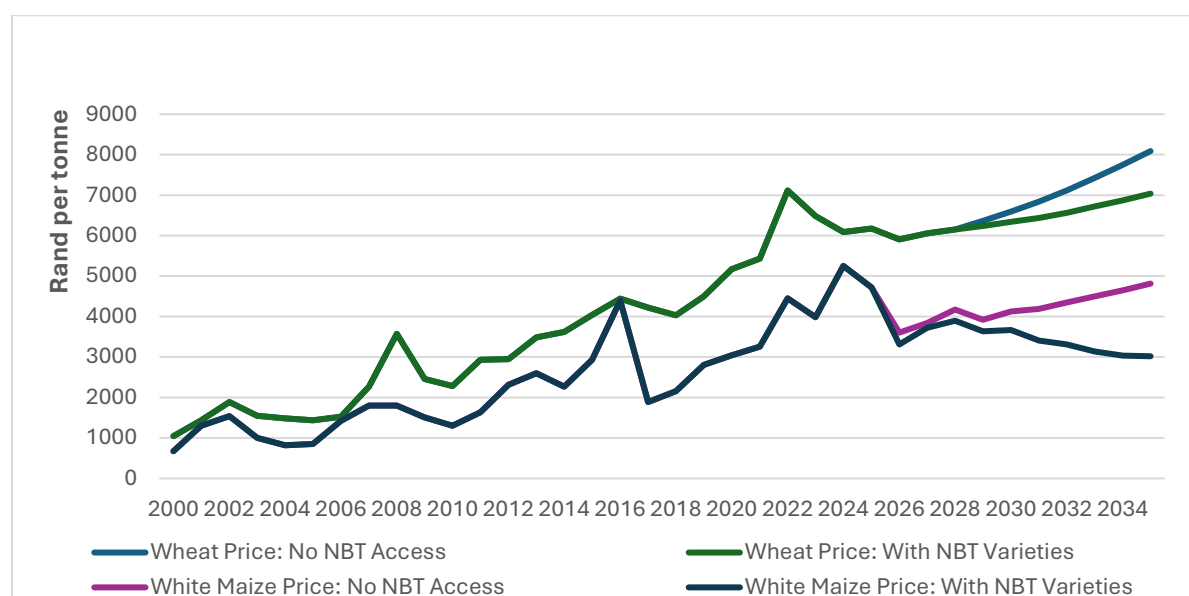


Figure 7: Wheat and White Maize price projections under different NBT access scenarios.

Figure 8 presents a summary of price gaps by 2035 across the various products. Given that NBT access is not being facilitated under current regulations, the price gaps are expressed as a percentage decline in a scenario where NBTs are enabled, relative to a scenario where there is no adoption of the technology in South Africa. It's worth noting that the soybean price effect is comparatively small, given that South Africa remains a surplus producer in both outcomes. Hence, prices remain a function of both export parity and the derived price from processed products in both scenarios. There is, however, a substantial difference in the size of the surplus and consequently the export revenue generating potential.

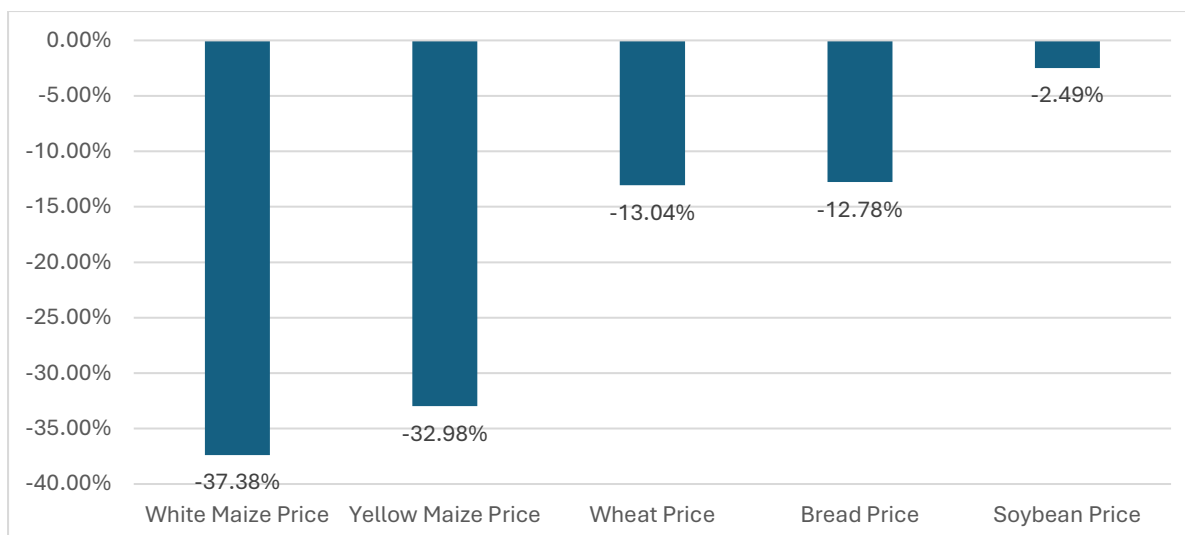


Figure 8: Commodity price reduction in a scenario where NBT seed adoption is enabled.

Trade

Further to the price effects, it is worth considering the potential impact of NBT technology adoption on foreign revenue. Agriculture is a consistent net exporting sector, with significant contributions from maize and, more recently, also from soybeans. At the same time, wheat ranks amongst the leading contributors to South Africa's food import bill, suggesting that enabling the adoption of NBT varieties can significantly bolster South Africa's agricultural trade surplus. Figures 9 and 10 relate the relevant shifts in the trade balance to volumes and revenue, illustrating that maize and soybeans alone can provide almost R5 billion in additional export revenue by 2035 if the adoption of NBT varieties is enabled. Similarly, the wheat import bill can be reduced by R6.5 billion per annum in a scenario where the adoption of NBT varieties is enabled.

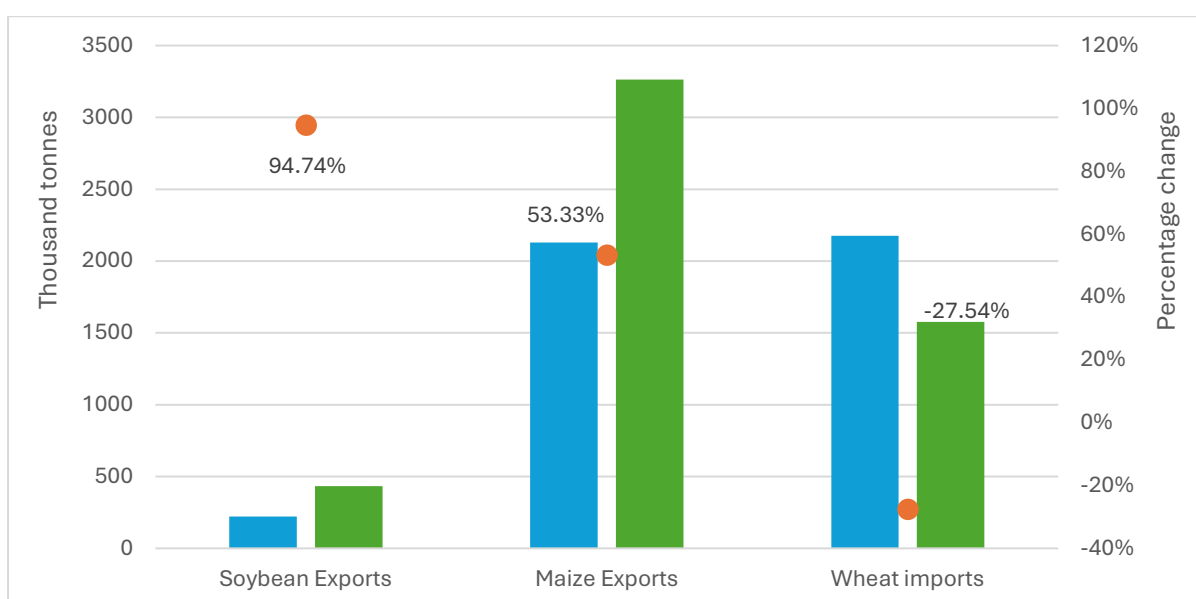


Figure 9: Differences in exportable surplus for soybeans and maize and import shortfall for wheat under different NBT adoption scenarios by 2035 (blue = no NBT and green = NBT).

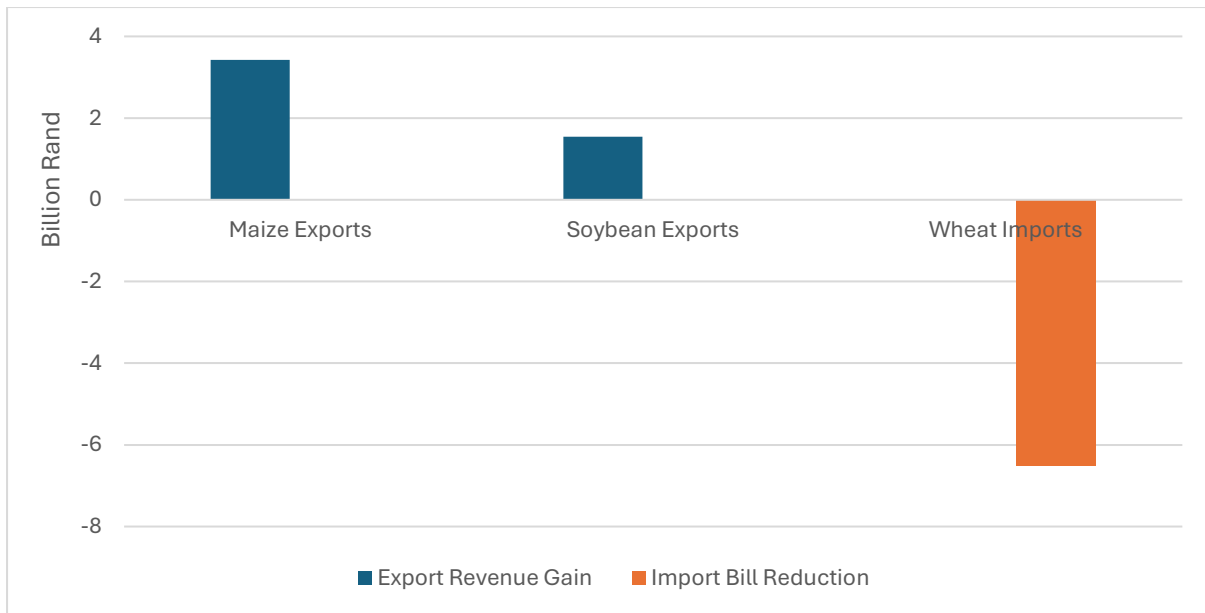


Figure 10: Differences in export revenue and import expenditure when NBT variety adoption is enabled relative to a scenario where NBTs are not adopted.

Producer profitability and resilience

While lower prices in the scenario where NBT adoption is enabled are a clear win for consumers, one might question the impact on producer profitability. In this respect, yield gains are critical to offset lower prices, a factor that has underpinned the long-term decline in real agricultural price levels for many years. Table 2 presents a summary of current implications for prices, yields and revenue per hectare, showing the percentage change in a scenario where NBT adoption is enabled relative to a scenario with no access to NBT varieties. In the case of wheat, the lower price is offset by higher yields, leaving producers in a similar position under both scenarios, but with a clear consumer benefit. In the case of soybeans, the yield gain is more than the price decline, leaving producers 7% better off in the scenario where NBTs are enabled. In the case of maize, the current yield gain assumptions are insufficient to offset the full loss of lower prices, which results in some 120 000 fewer maize hectares planted in the NBT scenario relative to the no-NBT world. It should be noted, however, that by 2035, prices reach export parity levels, whereas in the no-NBT scenario, they trade well above export parity levels. Given that yield gain assumptions are still conservative, it is likely that prices will not fall much further if yield gains are higher than current projections, having already reached a level where large-scale exports into the global market can occur. As such, any additional yield gains above current assumptions would directly improve producer revenue. The lower area planted, where 120 000 hectares of more marginal land is not planted under the NBT scenario, should already enable higher average yield outcomes relative to the assumptions. This frees up additional area for other purposes, enabling greater diversification. It should also be noted that Table 2 presents revenue only, which is one side of the coin. Adoption of NBT varieties could also yield additional cost reductions through input traits like insect or fungus resistance or herbicide tolerance. The last column of the table illustrates that revenue in the NBT access scenario still outperforms 2026 expectations in 2035.

Table 2: Percentage change in prices, yields and revenue implications under current assumption by 2035

	% change in revenue: NBT access vs no access	% change in price: NBT access vs no access	% change in yield: NBT access vs no access	% change in revenue: NBT access outcome vs 2026 expected
White Maize	-27.9%	-37.4%	15%	12.0%
Yellow Maize	-22.9%	-33.0%	15%	18.6%
Soybeans	7.2%	-2.5%	10%	33.4%
Wheat	0.0%	-13.0%	15%	60.4%

The yields and price levels presented to date reflect long-term average weather outcomes and therefore relate to expectations under stable weather conditions. There will be significant volatility around these projected trends, likely even more so than in the past, given that climate change is expected to increase the frequency of extreme weather events. In this respect, access to the latest technology, particularly varieties better able to cope with extreme conditions, is critical to producer sustainability. In this respect, an additional scenario was tested, where drought conditions are imposed – both in the scenario where producers adopt NBT varieties and the scenario where they are unable to do so. To simulate drought impact in 2035, yields were reduced by 20% from 2034 to 2035, a similar year-on-year decline observed in previous drought years such as 2016 and 2024. In a scenario where producers have access to the latest NBT varieties, the yields under drought conditions are higher relative to a no-NBT scenario (Figure 11).

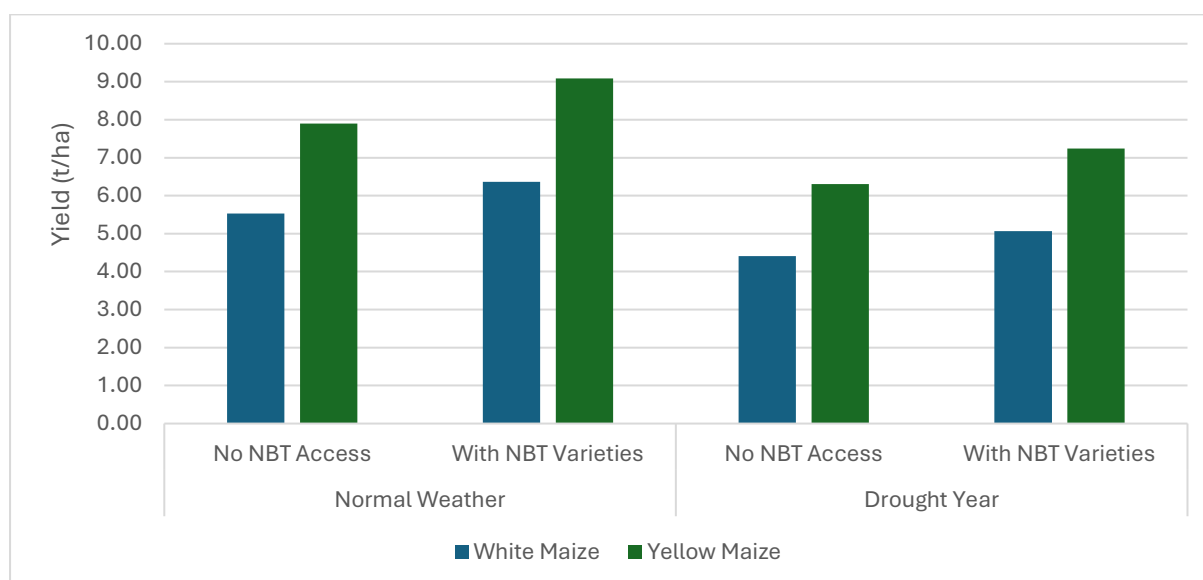


Figure 11: Maize yield scenarios by 2035 under drought conditions

The drought event is severe enough to induce a switch to import parity-based pricing in yellow maize. South Africa is not a large enough importer or exporter to move global price levels for yellow maize, but white maize is more complex, owing to limited surplus producers globally. Typically, when South Africa switches from a surplus to a deficit scenario, world reference prices

for white maize rise due to a shift in the global supply and demand balance. Consequently, white maize prices rise further in a drought scenario when there is no access to NBTs, owing to the bigger production shortfall. Figure 12 illustrates the price outcomes under normal and drought conditions by 2035 under different NBT access scenarios. From Figure 11 and Figure 12, it is clear that producers will be far more resilient through drought years and therefore able to contribute continually to longer-term surpluses if they have access to the latest seed technology underpinned by NBTs. From a producer perspective, the NBT product adoption scenario yields 6.5% more revenue from white maize and 14.9% more revenue from yellow maize in a drought year relative to a scenario without the technology. While these outcomes will differ in magnitude depending on the severity of the drought, the benefit is clear, and in the longer term it could be decisive in ensuring producer sustainability under increasing climate volatility.

Consumers will also benefit as white maize prices in a drought year do not rise as far in a scenario where producers have access to NBT varieties. The 7.3% lower maize price in a scenario where NBT varieties are adopted equates to a 4.6% lower maize meal price for consumers.

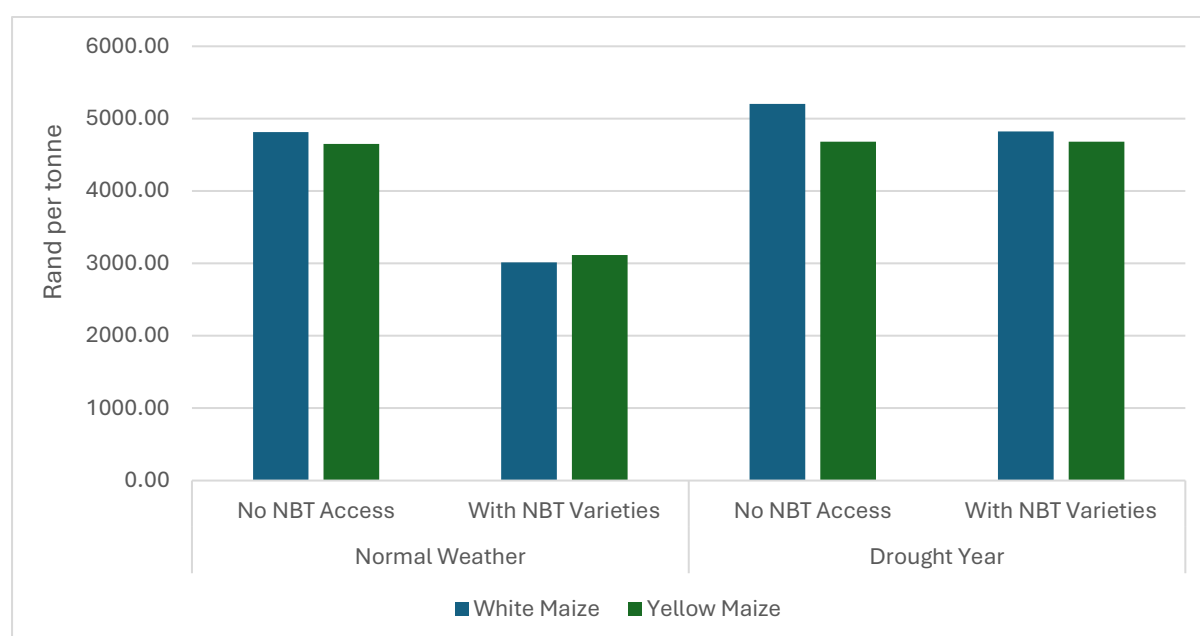


Figure 12: Maize price outcomes by 2035 under drought conditions

7. Regulatory Options for Consideration

South Africa has a significant opportunity to review its regulatory approach before the potential economic, innovation and competitiveness impacts identified in this report become more pronounced. Scientific advances, evolving international regulatory practice, and growing experience with NBTs have created conditions in which it is timely to consider whether the current framework remains fit for purpose. A key consideration is whether all NBT-derived products should continue to be treated as equivalent to first-generation transgenic GMOs, or whether

greater distinction should be made between products that pose novel biosafety risks and those that could also arise through natural processes or conventional breeding.

This report focuses primarily on the implications of maintaining the current regulatory approach, rather than on prescribing a specific model for NBT regulation. The following suggestions are therefore offered as high-level considerations.

Regulatory suggestions, largely based on the Academy of Science of South Africa's 2017 report, *The regulatory implications of new breeding techniques*, include:

- Adopt a more product-based and risk-proportionate approach, so that regulatory requirements are linked to the characteristics and risk profile of the final organism rather than the breeding technique alone.
- Formally distinguish between lower-risk NBT products, such as many SDN-1 and SDN-2 outcomes, and higher-risk products involving novel combinations of genetic material.
- Establish a simple public pre-assessment or notification system to determine, on a case-by-case basis, whether an NBT-derived product should fall within the GMO regulatory pathway or be treated similarly to a conventionally bred product.
- Update definitions, guidance documents and administrative procedures to reduce ambiguity, improve legal certainty and provide innovators with a clearer route to market.
- Ensure that any revised approach remains embedded within broader food safety, environmental, plant health and consumer protection systems, so that reform strengthens confidence in oversight rather than weakening it.
- Position NBT reform within South Africa's wider agricultural innovation and food security agenda, including support for locally relevant crop improvement, public-sector research and small and medium-sized breeders.

If implemented, such measures could help align South Africa's regulatory framework with evolving international practice, support domestic innovation, strengthen farmer competitiveness, and enhance long-term food security and agricultural resilience.

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