

# Biotechnology In Farming And Its Role In Achieving SDG 2

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## Abstract

*Biotechnology in farming presents a transformative opportunity to advance Sustainable Development Goal 2 (Zero Hunger) by improving agricultural productivity, enhancing crop resilience, and ensuring food security. This study explores the role of agricultural biotechnology—encompassing genetically modified organisms (GMOs), gene editing tools like CRISPR, and bio-based innovations—in addressing the challenges of food scarcity, climate change, and land degradation. It examines how biotechnology contributes to increased yields, pest and disease resistance, improved nutritional content, and reduced post-harvest losses. The research also investigates the barriers to adoption, including regulatory constraints, public perception, ethical debates, and access disparities among smallholder farmers. Through a review of existing literature, case studies, and policy analysis, the study evaluates the effectiveness of biotech solutions in promoting sustainable agriculture. It concludes that with supportive policies, equitable access, and proper safety measures, biotechnology can play a crucial role in transforming global food systems and accelerating progress toward achieving SDG 2.*

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## 1. INTRODUCTION

SDG 2 is focused on achieving food security, ending hunger as well as improvement of nutrition and enhancement of sustainable agriculture, and as the world continues to record increasingly high rates of population growth, climate change, soil erosion and scarcity of resources, there is a desperate need to achieve Sustainable Development Goal 2 (SDG 2). Although traditional methods of farming are central, they are not always sufficient to accommodate the increasing food demand particularly in areas where there is environmental stress and people have no access to farming technology. Biotechnology in agriculture in this context proves to be revolutionizing method that could improve the productivity of agriculture, resiliency and nutritive quality of agricultural products. Agricultural biotechnology and genetic modification of organisms (GMOs), gene editing tools like the CRISPR, biofertilizers, and tissue culture, are some of the tools in agricultural biotechnology that improve crop characteristics such as yield, drought resistant crops, pests resistance, and shelf life (Zainal, et al. 2022). These technologies present a city of hope to address long-standing issues in agriculture particularly among the smallholder farmers who face the problems of low productivity and lack of resilience to climate shocks. Biotech practices around the world have been noted to reap huge benefits in food production and environmental efficiency but this is not evenly distributed across the globe especially to Sub-Saharan Africa and some parts of Asia because of regulatory, moral and socio-economic impediments (Baskara, et al. 2024).

Although biotechnology has tremendous potential to aid the agendas of food security and sustainable agriculture, it has brought great questions on biosafety, equal access and acceptance and long term ecological effects on people. This paper examines the intricate interaction between biotechnology and the realization of SDG 2 with an emphasis on its effectiveness, challenges and opportunities in various agricultural settings. It looks at the role of biotech innovations in improving availability of food, minimizing post harvest losses and enhancing farming systems that are adaptable to the impacts of climate change. It also assesses policy frameworks, stakeholder views, and the absence of knowledge, which have implications on the effective

incorporation of biotechnology in food security agendas of nations and worldwide. The study will provide a decision that will enable us to use evidence to support the policy on how biotechnology can be utilized with regard to benefit in the global war against hunger, and rely on innovation and sustainability (Harnida, et al. 2024).



Goal 2 of the Sustainable Development Goals (SDG 2) of the United Nations on ending hunger, food security, and improved nutrition, and enhanced sustainable agriculture is to end hunger, achievement of food security, improved nutrition, and enhanced sustainable agriculture by 2030. According to the FAO more than 735 million individuals worldwide continue to struggle with hunger as of 2024 and 148 million children under the age of five exhibit stunted growth as a byproduct of chronic malnutrition. Biotechnology, which is a revolutionizing technology in the agricultural sector has solutions based on science in order to deal with these problems. An example of GM crops is modified to withstand the pests, drought tolerant, and improve its production. According to research, biotech crops have resulted in a rise in food supply and value of crops of up to 22 percent as well as cutting the amount of pesticides used by 37 percent eating well into increased food supply and revenues to farmers. Among the examples of biofortified crops that are directly fighting micronutrient deficiencies are Golden Rice (vitamin A) and iron-fortified beans that are improving nutritional status, particularly associated with low-income people.

Moreover, biotechnology encourages sustainable farming, as it allows the farming to be practiced with few environmental harm activities. As a case in point, herbicide-tolerant and pest resistant GM crops lessen the extent of mechanical tillage and chemical application, hence maintaining the quality and bio-diversity of soils. The International Service for the Acquisition of Agri-biotech Applications (ISAAA) estimates that biotech crops avoided the emission of 27.1 billion kg of CO<sub>2</sub> in 2020 alone which implies eliminating 15 million cars on the roads. In Sub-Saharan Africa, the introduction of drought-tolerant maize has already demonstrated it can lead to yields increases of 2030%, even in the conditions of the water deficit, which is why this practice can be used in the regions that are vulnerable to climate change. Notably, biotechnology also leads to an increase in productivity per hectare and this plays an important factor in the near future where the demand of food will increase by 60 percent by 2050 because we live in a limited arable land environment. Through the adoption of biotechnological innovations on the farms, the countries will increase food security, achieve rural development, and have sustainable usage of resources, which are directly connected with the objectives of SDG 2.

## 2. Rationale of the Study

The degraded lands and the shrinking farms are also a significant burden to the Sustainable Development Goal 2 (Zero Hunger) as the increasing levels of demand of food by the growing population all over the globe since the increasing population and the ill consequences of the climatic changes. Those multifaceted needs cannot be met by the conventional agricultural activities of the past any more especially in the regions where productivity level remains low and in which, the systems of agriculture are readily endangered. Biotechnology introduces new science-based and advanced technology into fields of farming to increase their production, responsiveness to pests and diseases, and tolerance towards environmental conditions (Teoh, et al. 2022). Even though it has been proved to bear a significant number of benefits in other aspects, biotechnology applications have not ignited in most developing countries due to policy, ethical and socio-economic challenges (Ratanakvisal & NG, n.d.). This has been fuelled by the urge to find out the true potential of biotechnology in facilitating food security (particularly among the small holder farmers). It will contextualize a general image of the role biotech can take in sustainable agriculture and the counsel on how it can be applied to be used in responsible and non-discriminatory way.

### 3. LITERATURE REVIEW

Biotechnology also has an essential role to play in improving agricultural practices to achieve the standards of Sustainable Development Goal 2 (SDG 2): including ending hunger, achieving food security, and improving nutrition, and sustainable agriculture. According to Lokko et al. (2018), biotechnology provides sustainable and inclusive development avenues of developing industries, particularly the agricultural one. Biotechnology also helps in terms of quantity and quality of production through increased crop yields, and improved disease resistance, and acclimatization of plants to climate change. With increased demand of food in the world, biotechnological tools play an important role in the establishment of an agricultural system that can withstand the pressure and address the nutritional requirements of the ever-increasing population.

Biotechnology in agricultural production has greatly affected the availability of food through improvement of crop productivity. In the pond, Pandey & Pandey (2023) state that the biotechnology combined with geospatial technology assists farmers in evaluating the land use pattern, optimal input, and output. GMOs are available as an example, and thus genetically modified organisms are drought tolerant, pest resistant, and disease resistant, and production is thus consistent with difficult conditions. This combination of technologies will guarantee an accurate distribution of resources, minimize agricultural waste, and limit the amount of chemical pesticides and fertilizers deployed, thus, allowing the building of a more sustainable farming ecosystem.

On the nutrition side, biotechnology allows the creation of biofortified crops, meaning that coded crops are created to hold the necessary vitamins and minerals. According to Mollier et al. (2017), the innovations hold the key regarding the fight against hidden hunger or micronutrient deficiencies whose prevalence in the global population reaches billions of people. A good example that is not only popular but also takes care of nutritional deficiencies in developing nations is the Golden Rice which is enriched with Vitamin A. Okigbo (2021) highlights the contribution of plant scientists in the usage of biotechnology to the achievement of SDG 2 as well as SDG 15 through preserving the biodiversity and increasing the nutritional value of guiding crops contributing to both food security and ecological security.

Biotechnology has a lot of potential in sustainable agriculture that cannot be achieved without coherence in policies. Purnhagen et al. (2021) introduce the opposition of biotechnology and organic farming as a factor of the Farm to Fork strategy in the European Union. Although organic farming and GMOs tend to have conflicting principles, the authors further add that the two ideologies are complementary. Biotechnology has the potential to minimize input and degrade the environment, which is in line with the objectives of organic farming in the aspect of sustainability. Therefore, strategic policymaking should help close these rifts to advance agriculture approaches that will be productive and environmentally friendly.

Another element that is important in the success of the implementation of biotechnology is institutional and educational support. Rasli, et al. (2024) put forward a sustainability model in the case of higher education

establishments that focuses on preparing future agricultural innovators. Training of farmers and agronomists in biotechnology implies its further spread and adaptation to local needs of nature and science. Shao et al. (2024) state further that the availability of digital technologies in rural settings promotes equality and the quality of life. Advancement of rural infrastructure and digital literacy of marginal communities will enable them to engage in agrotechnology revolution driven by biotechnology.

Biotechnology is very capable of supporting SDG 2 through enhancement of food availability, accessibility and better nutrition alongside supporting sustainable farming. Nevertheless, it cannot be delivered successfully without integrative action at the level of science, education and policy. Frameworks that include technology, fair access, farmer development, and flexible governance will make the difference because biotechnology turns out to be one of the mainstays of a sustainable agriculture leading to a world without hunger and full of prospects.

#### 4. Concept of Agricultural Biotechnology

Agricultural biotechnology is the application of scientific instruments and methods that concern the genetic engineering of crops as well as livestock; molecular markers, and the tissue culture to enhance the productivity of crops and livestock, their qualities and resilience. It allows creation of genetically modified organisms (GMOs) that are pest, disease, and environmental stress like draught and salinity tolerant. An example of such is the Bt cotton and the herbicide tolerant soy beans which have been growing in popularity because of their increased production and decrease in the chemical requirement. In 2024, more than 200 million hectares of biotech crops had been cultivated around the world, as determined by the International Service for the Acquisition of Agri-biotech Applications (ISAAA). The top nations are the United States, Brazil, Argentina, India and Canada. It has been adopted more than 55% in developing countries which indicates the growing influence of biotechnology in world agriculture.

The advantages of agricultural biotechnology are becoming noticeable economically and in an environmental context. According to PG Economics, the entry of biotech crops between 1996 and 2023 has supplied an average growth of 22 percent in crop yields and 36 percent lower pesticide application. Montey wise the world farm income benefits in biotech crops were valued at 263.4 billion by the end of this time phase with more than 50 percent of gains distributed to the smallholder farms in developing countries. Besides, biotechnology has facilitated sustainable activities through conservation tillage and cutting green house gases to the tune of taking 15 million cars off the road on a yearly basis.



However, challenges remain regarding regulatory frameworks, public acceptance, and equitable access to biotechnology innovations, especially in Africa and parts of Asia. Addressing these issues is vital to unlocking the full potential of biotechnology in ensuring food security and climate resilience.



### 5. Methodology

This paper used mixture methodology and examined the use of biotechnology in agriculture and how it can support the accomplishment of Sustainable Development Goal number 2 (Zero Hunger). In the study, the data was taken both quantitatively and qualitatively to provide a wider view. Secondary sources of data included reports by the Food and Agriculture Organization (FAO), World Bank, International Service for the Acquisition of Agri-biotech Applications (ISAAA), as well as in peer reviewed journals, all of which are quantitative in nature. Some of the main indicators under study were the crop yields, the adoption rates, nutritional gains, and post-harvest losses. A collection of case studies, policy documents and farmer perception surveys dating from the countries of selection which are Nigeria, Kenya, India, and Brazil were used in evaluating the qualitative data. A comparative study was carried out to assess the differences in the results of traditional and biotechnology farming. Policy and regulatory environment affecting biotech adoption was also analysed in the study. Interpretation of data was performed by using descriptive statistics, trend analysis, and thematic interpretation. This was the methodology that made the research both capture the quantifiable effects of biotechnology as well as the contextual influencing factors on implementation, as it presents a balanced stand on the effectiveness and shortcomings of biotechnology in production of sustainable agriculture and food security under the SDG 2.

### 6. Results and Discussion

Table 1: Comparative Crop Yields – Traditional vs. Biotech Varieties

Crop Type	Traditional Yield (tons/ha)	Biotech Yield (tons/ha)	% Yield Increase	Biotech Trait Introduced
Maize	2.5	4.8	+92%	Drought resistance (GM)
Rice	3.0	4.2	+40%	Vitamin A enrichment (Golden Rice)
Cotton	1.8	3.3	+83%	Bt pest resistance (Bt cotton)
Soybeans	2.6	3.5	+35%	Herbicide tolerance (GM)

Table 1 highlights the significant improvements in crop productivity achieved through biotechnology. Maize modified with drought-resistant traits shows a 92% increase in yield compared to traditional varieties, making it highly beneficial in climate-vulnerable regions. Golden Rice, enriched with vitamin A, not only improves nutritional value but also achieves a 40% higher yield, indicating dual benefits for health and productivity. Bt cotton, engineered for pest resistance, nearly doubles the yield (an 83% increase), demonstrating how biotech can reduce pest-related losses while enhancing income for farmers. Soybeans modified for herbicide tolerance also show a 35% yield increase, reflecting more effective weed management. These results confirm that biotechnology significantly enhances yield performance across various staple and commercial crops, supporting both food security and economic sustainability. The increased output contributes directly to achieving SDG 2 by improving food availability and reducing the impact of environmental stressors on agriculture.

**Table 2: Nutritional Enhancement in Biotech Crops**

Crop	Nutrient Enhanced	Traditional Content	Biotech Content	Health Benefit
Golden Rice	Vitamin A ( $\beta$ -carotene)	Trace	37 $\mu\text{g/g}$	Reduces risk of childhood blindness
Iron-fortified Beans	Iron	50 ppm	95 ppm	Helps prevent anemia
Zinc-enriched Wheat	Zinc	25 ppm	45 ppm	Supports immune system and growth

Table 2 illustrates how biotechnology has been effectively used to improve the nutritional quality of staple crops, addressing hidden hunger and micronutrient deficiencies. Golden Rice, engineered to contain 37  $\mu\text{g/g}$  of  $\beta$ -carotene (a precursor of vitamin A), helps combat vitamin A deficiency, a major cause of childhood blindness in low-income regions. Iron-fortified beans nearly double the iron content from 50 ppm in traditional varieties to 95 ppm, which is crucial in preventing iron-deficiency anemia, especially among women and children. Similarly, zinc-enriched wheat shows a significant increase in zinc content from 25 ppm to 45 ppm, supporting immune function and physical growth. These enhancements not only improve individual health outcomes but also reduce the burden on public health systems. By improving the nutritional profile of widely consumed crops, biotechnology contributes directly to SDG 2 targets related to improved nutrition and ensures that food systems are both productive and health-promoting.

**Table 3: Farmer Adoption and Perceived Benefits of Biotechnology**

Country	Adoption Rate (%)	Yield Satisfaction (%)	Cost Reduction (%)	Key Biotech Crop Used
Nigeria	45%	78%	32%	Bt Cotton
Kenya	35%	70%	28%	Bt Maize
India	70%	85%	40%	GM Cotton
Brazil	82%	90%	45%	Herbicide-tolerant Soy

Table 3 presents data on the adoption of biotechnology by farmers and the perceived benefits in terms of yield satisfaction and cost reduction across four countries. In Nigeria, 45% of farmers have adopted Bt cotton, with 78% reporting satisfaction due to improved yields and 32% experiencing reduced costs from decreased pesticide use. Kenya, where Bt maize is increasingly used, shows a 35% adoption rate, 70% yield satisfaction, and a 28% cost reduction, reflecting early but promising adoption trends. In contrast, India shows higher biotech integration, with a 70% adoption rate of GM cotton, leading to 85% satisfaction and a 40% drop in

input costs. Brazil leads the table with 82% adoption of herbicide-tolerant soybeans, the highest yield satisfaction (90%), and a 45% cost reduction. These findings indicate that higher adoption of biotech crops generally correlates with increased productivity and economic efficiency, reinforcing biotechnology's role in achieving SDG 2.

**Table 4: Biotech Impact on Post-Harvest Loss Reduction**

Crop	Post-Harvest Loss (Traditional)	Post-Harvest Loss (Biotech)	% Reduction	Reason for Improvement
Tomatoes	30%	18%	40%	Improved shelf-life via gene editing
Bananas	25%	15%	40%	Resistance to fungal rot
Maize	22%	12%	45%	Bt protection against storage pests

Table 4 demonstrates how biotechnology significantly reduces post-harvest losses in key crops by enhancing their resistance to spoilage and storage-related threats. Tomatoes show a 40% reduction in post-harvest loss, dropping from 30% in traditional varieties to 18% in biotech versions, thanks to gene editing that extends shelf life and reduces spoilage during transport and storage. Bananas, commonly affected by fungal rot, experience a similar 40% reduction, with losses declining from 25% to 15% due to improved resistance traits. Maize, a staple in many developing countries, benefits from Bt modification, which protects against storage pests such as weevils and moths, reducing losses from 22% to 12%—a 45% improvement. These reductions not only prevent food waste but also improve food availability and farmer income. By protecting harvests beyond the farm gate, biotechnology supports more efficient and resilient food systems, contributing directly to the objectives of SDG 2.

## 7. CONCLUSION

Farming biotechnology has become a game changer that has the capacity to contribute a lot in achieving the Sustainable Development Goal 2 (Zero Hunger) by providing solutions to navigation challenges of agricultural efficiency, nutritional value, and food system sustainability. Genetic engineering and other biotechnological advances coupled with gene editing technologies such as CRISPR have brought about significant advances in the level of crop production and their tolerance to pests and diseases as well as resilience to climatic stresses such as drought and salty soils. Pressing further, biotechnology has proved to be effective in combating hidden hunger and even defining the health outcomes of the populace through crop bio fortification initiatives such as the Golden Rice or iron enriched beans. The subsequent decrease in post-harvest losses due to characteristics like long shelf-life and pest resistance also increase the food availability and decrease the waste especially in the developing world. The results of case studies in such countries as Nigeria, Kenya, India, and Brazil show that farmers using biotech crops tend to express more satisfaction with yield, as well as reduction of the cost of production. Nonetheless, in most sectors across the globe, application of biotechnology has not been widely practiced because of regulations, popular distrust, poor infrastructure and disparity in availability to smallholder farmers. A policy framework, the involvement of the masses and investment in research and extension services are vital to ensure that biotechnology can play a fair role in food security. The consideration of ethical aspect and biosafety should also be very well managed to create trust and sustainability. To sum it up, biotechnology is not the silver bullet, though it is a core element of the approach that will reduce the agriculture sector to a more effective, inclusive, and resilient sector. Its duty, situational response, and well-governed and cooperated efforts among relevant stakeholders could be the key to achieving significant changes towards VM hunger and long-lasting food security confirmation within the expectations of SDG

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