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Maize in 2034: A Decade of Growth, Innovation, and Sustainability in Crop Production

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ABSTRACT

Maize (Zea mays L.) is a major world cereal grain and an important food, feed and raw material crop. This review looks at the changing role of maize in the world's agriculture, but with an emphasis on the challenges and opportunities that it will likely face in the future. Increased demand for maize (due to population growth, dietary change and expansion of bioenergy production) requires intensified effort to boost productivity while maintaining sustainability and resilience. Increased drought, heat stress, and outbreaks of pests all threaten maize production, and especially in vulnerable regions, climate change is largely seen as an issue. Yet advances in genomics, biotechnology and agronomy hold promise to erase these constraints. These traits are crucial for stabilizing yields: stress tolerant and nutrient efficient maize varieties; precision agriculture and integrated pest management. Crop's future is also shaped by socioeconomic factors such as technology access, infrastructure development and favourable policy frameworks. Therefore, this review points to the need to focus on the inclusive innovation and equitable distribution of agricultural resources for smallholder farmers in developing countries. It also underscores the importance of environmentally sound maize systems for their long term viability. This review synthesizes current knowledge and identifies strategic priorities by which researchers, policymakers and other stakeholders can improve the contribution of maize to global food systems. Scientific progress alone will not ensure the future of maize; rather it is a matter of collective action towards sustainability, equity, and resilience in agricultural development.

INTRODUCTION

Maize is a major crop of the world cultivated extensively for its production for food, feed, and industrial uses (Serna Saldivar, 2023; Revilla et al., 2022). In many countries it is a staple crop and an essential commodity for global food security. Maize is the largest crop in terms of production volume in the U.S. and is an important component of the economy (Erenstein, Jaleta, Sonder, Mottaleb, & Prasanna, 2022; Prakash & Venkataramana, 2023). Maize is one of the most consumed food crop throughout the world, particularly in areas like Sub Saharan Africa, Latin America, and some regions of Asia (Amanjyoti et al., 2024; Krishna et al., 2023). Maize is a staple food for millions of people in many developing countries, with calories and essential nutrients being the primary source of calories in their diet (Anwar, Borbi, & Rakha, 2024; Kaushal et al., 2023). Maize is a cultural and dietary staple in Mexico, and the basis of many traditional dishes like tortillas, tamales, and tacos (Choudhary, Grover, & Singh, 2021). At the same time the crop is also a major food crop in countries like Ghana, Greece, Nigeria, and South Africa (Goredema-Matongera et al., 2021; Odjo et al., 2022). Maize significantly contributes to food security, especially in regions that other crops like wheat and rice are not so well matched locally (Soto-Gómez et al., 2022; Farooq et al., 2023). Smallholder farmers in Sub-Saharan Africa often grow maize as a source of income generation as well as food (Amede, Konde, Muhinda et al., 2023; Otsuka, Jayne, Mano, & Takahashi, 2024). Due to its adaptability to a variety of climates & soils, it is an important crop for those areas that suffer environmental challenges, i.e. droughts & floods. Maize is also a source of high energy carbohydrates, an essential part of the diet that is limited nutritionally (low in essential amino acids), usually making it reliant on complementary food sources such as beans and vegetables (Petrikova, Bhattacharjee, & Fraser, 2023). Apart from being an important food crop, maize is vitally important to meet global livestock and poultry production (Erenstein et al., 2022; Birhanu, Osei-Amponsah, Yeboah Obese, & Dessie, 2023). Plant food used primarily to feed cattle, poultry, and swine, included maize. This feeds into the animals as an energy rich source, with the carbohydrates required for growth, weight gain and milk production. As demand for meat, milk and eggs in the emerging economies of China and India grows, maize consumption as animal feed has risen (Zhu, Wang, & Zhu, 2023; Zhang et al., 2024). Some 40 percent of global maize production is used as dietary feed for animals. Maize demand in this sector, particularly in the countries with large agricultural industries like the U.S., Brazil and China is a major driver of maize demand. Due to rising demand for animal-based protein, especially in developing nations, driven by the increasing global population and incomes, the need to produce maize as one of the key ingredients of feed also increases (Ogutu et al., 2024). It is particularly noteworthy in the context of intensifying livestock farming systems, where farming is being conducted on scale with high yields and low cost feed grain such as maize.

METHODOLOGY

In this review paper a comprehensive and integrative methodology is applied to examine the role projected for maize by 2034, analyzing current advancements, challenges and sustainability practices in the global maize production. The study is designed as a qualitative synthesis of secondary data with the use of systematic literature review techniques and thematic analysis. The methodology is centered on collecting, organizing, and critically reading through findings of relevant peer-reviewed scientific journals, institutional reports, and international agricultural database to make an informed prediction on the future of maize cultivation.

Scope and Objectives

Its key objective, however, is to predict maize production over the next 10 years, focusing on innovation, sustainability and adaptation to global challenges like climate change and market volatility. Areas that are of focus are Genetical and technological improvements, environmental concerns and socio-economic factors. It focuses on both the developed and the developing regions, particularly on the regions where maize is a staple crop or its trade and food security are significant.

Data Sources and Selection Criteria

This review included sources from various databases as PubMed, Scopus, Web of Science, FAOSTAT and USDA publications and World Bank reports, to ensure comprehensive coverage. In this literature search, the years 2000 to 2023 were considered to allow capturing recent trends and technological developments relevant to maize production. Inclusion criteria for literature were:

- Peer-reviewed articles, reports, and studies focused on maize genetics, biotechnology, precision agriculture, irrigation technologies, and sustainable farming practices.
- Government and NGO data related to maize yields, trade, climate impact, and policy frameworks.
- Studies examining socioeconomic effects of maize production, especially in regions like Sub-Saharan Africa, South Asia, and Latin America.

Keywords used in the literature search included “maize production,” “genetically modified maize,” “climate change and maize,” “precision agriculture,” “biofuels,” “food security,” “drought-tolerant maize,” and “maize sustainability.” Studies not available in English or lacking sufficient data reliability were excluded.

Thematic Analysis Framework

After compiling the selected literature, a thematic analysis was applied to identify key emerging trends. This framework organized findings into thematic categories that align with the core objectives of the paper:

- Technological innovations (e.g., genetic engineering, CRISPR, and precision farming)
- Environmental impacts (e.g., climate stress, soil degradation, water use)
- Socio-economic dynamics (e.g., trade, price volatility, smallholder farmer challenges)
- Sustainability practices (e.g., conservation tillage, biofortification, agroecology)

Each theme was further sub-categorized to reflect both current developments and future projections for the year 2034.

Analytical Tools and Forecasting Approach

While this review is qualitative in nature, it incorporates basic forecasting techniques using historical production trends from FAO and USDA reports. Statistical data on global maize production, consumption, and trade were used to identify trajectories and make informed projections. These trends were interpreted in light of technological and environmental factors, such as the expected rise in demand for biofuels, genetic innovations, and the projected impacts of climate change.

The paper also employs a comparative approach by examining maize production systems in different agro-ecological zones. For example, the analysis of precision agriculture practices in the U.S. Corn Belt was compared with smallholder adaptation strategies in Sub-Saharan

Africa. This approach enabled the paper to highlight disparities, opportunities, and required interventions across regions.

Validation and Triangulation

To enhance credibility, data and findings were triangulated from multiple reputable sources. Key trends identified in peer-reviewed journals were cross-referenced with international agricultural databases (e.g., FAOSTAT, IFPRI), as well as with national agricultural reports from high-production countries such as the U.S., Brazil, China, and India. Information related to sustainability and technological interventions was further corroborated by institutional publications from CGIAR, CIMMYT, and national research organizations.

Limitations

While the review strives to be comprehensive, it is constrained by the availability of up-to-date data and the dynamic nature of agricultural technologies. Some emerging technologies, such as gene editing tools like CRISPR, are still under development and may have limited large-scale data. Moreover, projections are based on current trends and assume a linear progression, which may not account for unforeseen geopolitical, economic, or environmental disruptions.

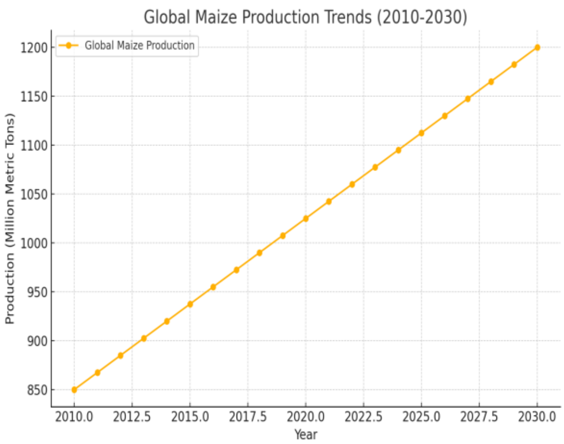
Ethical Considerations

As a literature-based study, this review did not involve human or animal subjects. Ethical considerations were centered on proper citation and acknowledgment of all referenced sources to avoid plagiarism and to maintain academic integrity.

RESULTS

The findings of this review reveal a multifaceted outlook on the future of maize production, highlighting key advancements, ongoing challenges, and the anticipated transformation of global maize systems by 2034. The results are categorized under major thematic areas: technological innovations, environmental impacts, socio-economic dynamics, and sustainability practices.

Figure 1



Technological Innovations in Maize Production

The review indicates a significant acceleration in the development and adoption of genetic and technological innovations in maize cultivation:

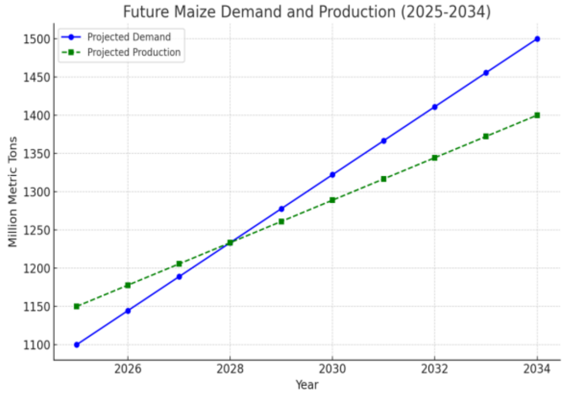
Genetically Modified (GM) Varieties: Bt maize and herbicide-tolerant varieties have shown increased adoption across major maize-producing countries. Studies show yield improvements ranging from 20–50% in pest-prone areas due to GM crop use, along with reduced reliance on chemical pesticides.

Drought-Tolerant Maize: The implementation of drought-tolerant varieties in Sub-Saharan Africa and South Asia has demonstrated yield stability during water stress conditions. Projects like WEMA have already released over 100 drought-tolerant varieties in African countries.

CRISPR and Gene Editing: Emerging gene-editing technologies are being increasingly explored for traits such as pest resistance, improved nutrient profiles, and stress tolerance. Although large-scale commercial deployment is still in early stages, trials indicate strong potential for improved productivity and resilience.

Precision Agriculture: Satellite imaging, drone surveillance, and variable rate application technologies are widely adopted in countries like the U.S. and Brazil. These tools have contributed to a 10–30% increase in resource use efficiency, especially in fertilizer and irrigation management.

Figure 2



Climate Change and Environmental Impacts

Temperature and Water Stress: Yield reductions of 5–8% per 1°C increase in growing season temperature were consistently reported, especially during flowering and grain-filling stages. Drought and irregular rainfall patterns are already affecting maize productivity in Asia, Latin America, and Africa.

Extreme Weather Events: Heatwaves like the 2019 heatwave in the U.S. Midwest and frequent flooding have resulted in a significant loss of yield due to disruptions to planting and harvesting schedules. Though very vulnerable in flood and drought prone areas, maize persists.

Mycotoxin Contamination and Crop Losses: Heat has expanded the range of pests like fall armyworms and pathogens like Fusarium spp., incrementing losses in crops and contaminating mycotoxins. These threats are reported to intensify under warming conditions in Africa, India, and South America.

Figure 3

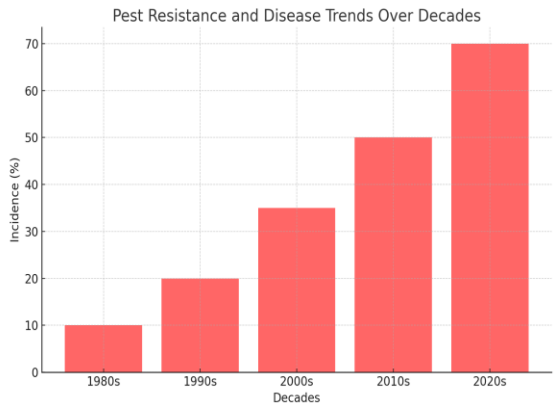
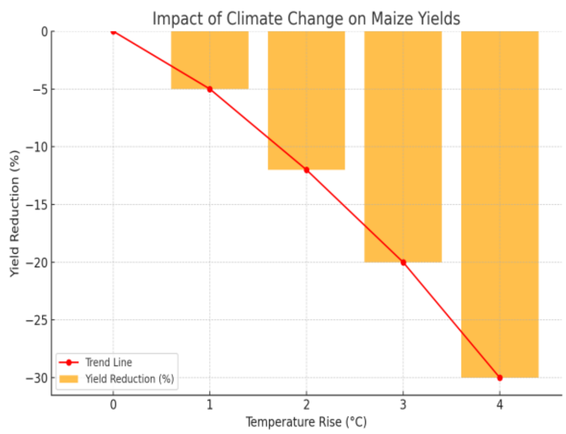


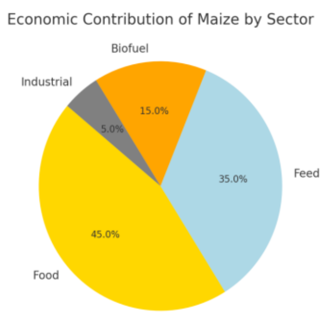
Figure 4



Socio-Economic Dynamics and Market Trends

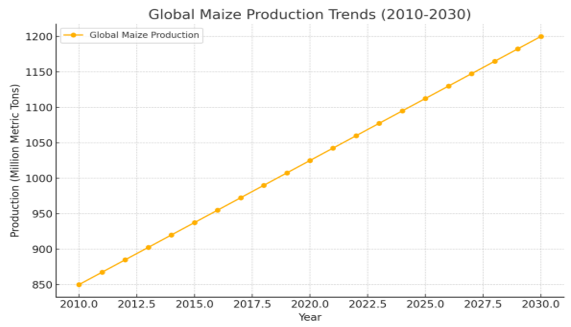
Rising Global Demand: Maize demand is expected to increase by 30–40 per cent by 2034, from population growth, increase in livestock feed demands and biofuel mandates.

Figure 5



This trend is especially prominent in emerging markets such as China, India, and parts of Africa.

Figure 6

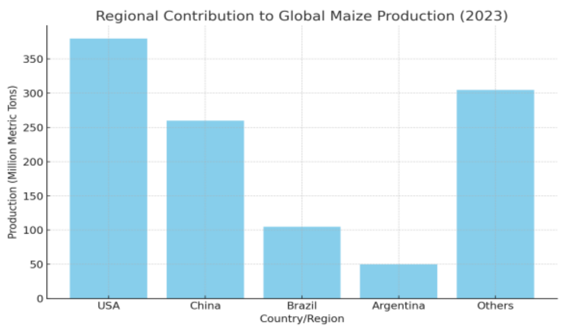


Biofuel Expansion: In the U.S., over 40% of maize is used for ethanol production. Trends are similar in Brazil. Biofuels provide economic opportunities but also present food security issues in maize importing nations.

Climate Events: Maize prices have more fluctuated due to climate events, trade policies, and global demand shifts. The external shocks—including the 2008 food crisis and the 2012 U.S. drought—impact maize markets and food access.

Still Smallholder Vulnerability: Smallholder farmers in Africa and South Asia still experience vulnerability to yield and income instability because they do not have access to irrigation, improved seed varieties, and market infrastructure.

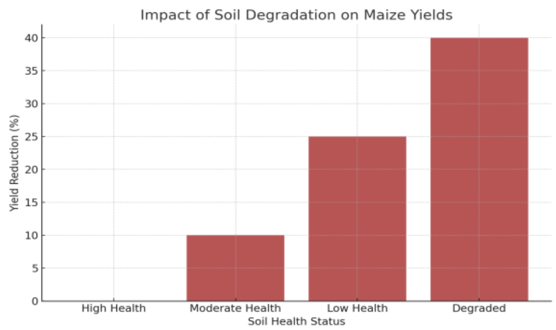
Figure 7



Sustainability and Environmental Practices

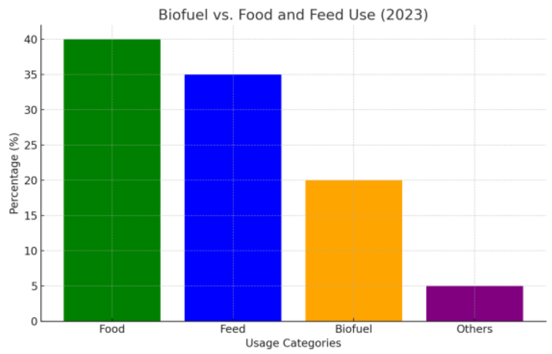
Growth in Adoption of conservation tillage and crop rotation practice. Such methods have been applied in Latin America and parts of the U.S., improving soil structure and water retention and cutting erosion by as much as 60 percent.

Figure 8



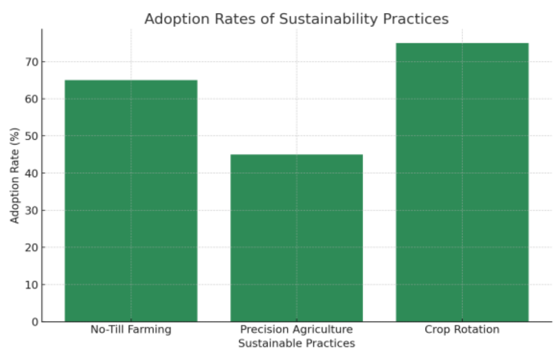
Water Management: But drip irrigation and sensor based smart irrigation systems have greatly improved the water use efficiency. These innovations saved up to 40% water and produced better maize in Israel and India.
There has been the deployment of biofortified maize varieties enriched with Vitamin A and iron in African countries. Reduced micronutrients deficiencies, especially in children and women, are being attributed to these interventions.

Figure 9



Agroecological Transition: Agroecological practices like organic amendments and intercropping are gaining interest. But best, these approaches are also ways to help reduce chemical dependency, bolster soil fertility in the long term, and enhance resilience to climate stress.

Figure 10



DISCUSSION

Results of this review reveal the rapidly evolving technical, environmental, and increasing global demand landscape of maize production. The food and feed production pathway to 2034 will be defined by how well producers, policymakers and researchers meet the dual challenges of sustainability and productivity in the face of the world's growing maize demand.
The development of genetic and digital technologies is, no doubt, one of the most promising findings. If genetically modified maize varieties such as Bt and drought tolerant hybrids have already demonstrated success in increased yields and reduction of pesticide dependency through widespread adoption, the results from transgenic soybeans should likewise be encouraging. Nevertheless, pest resistance and regulatory acceptance challenge remain. With the arrival of CRISPR and other gene editing tools, it becomes the new frontier for crop improvement and facilitates faster and more targeted development of climate resilient, pest resistant, nutritionally enhanced varieties.
Both precision agriculture and agricultural mechanization have been adopted as a transformative set of tools for large scale farming systems, predominantly in high income countries. Improved input efficiency and decision making are being improved through technologies like remote sensing, automated machinery and AI driven irrigation management. While these tools have not been widely adopted in regions with the majority of smallholders owing to high costs and a lack of infrastructure. Achieving equitable productivity gains will depend on bridging this technological gap.
Security of maize cultivation is threatened by the greatest challenge: climate change. Yields in major maize producing regions have already been affected by rising temperatures, changing precipitation patterns and increased frequency of extreme weather events. Maize is highly vulnerable to heat and drought stress during the flowering and grain filling stages, which underscores the importance of the need for constant breeding efforts and investment in adaptive agronomy.
The review also notes a rising threat from new pests and pathogens, which can be further enhanced by rising temperatures. The expansion of fall armyworm across Africa and Asia, along with the spread of Fusarium and other fungal diseases, signals the need for integrated pest and disease management (IPM) approaches. To be effective and sustainable, such systems must incorporate genetic resistance, biological controls and improved monitoring tools.
Maize continues to underpin food security and rural livelihoods, especially in Sub-Saharan Africa and Latin America. Yet, smallholder farmers in these regions remain highly vulnerable to climate variability, market instability, and input dependency. While technological solutions exist, their success will depend on policy support, access to finance, and local capacity building. Extension services, public-private partnerships, and inclusive agricultural programs must play a larger role in closing productivity gaps.
Global trade dynamics also affect maize availability and price stability. With increasing competition between food, feed, and fuel sectors, the debate over the allocation of maize becomes more pressing. The expansion of maize-based biofuels, while beneficial for energy goals, raises ethical and practical concerns about food security—particularly in countries that rely on maize imports for staple consumption.
Environmental sustainability has become a non-negotiable element of future maize systems. The review highlights promising practices such as conservation

tillage, crop rotation, agroforestry, and precision water management that contribute to long-term soil health and resource efficiency. Yet, the widespread implementation of these practices remains uneven.

The sustainability of input-intensive systems, particularly those reliant on synthetic fertilizers and monoculture, must be re-evaluated. Agroecological principles offer a pathway toward lower-input, biodiversity-friendly farming systems, particularly for smallholders. However, transitioning to such models requires systemic changes in policy, education, and market incentives.

Future Recommendations

By 2034, maize will continue to anchor global agriculture. But for its success to sustain, it will need to merge innovation with inclusive, climate adaptive and sustainable practices. To do this, several strategic priorities must be adopted. First, continued funding of research and development is needed to produce climate resilient, high yield maize varieties tailored to local conditions. Second, scaling up access to digital and genetic technologies is important, especially for smallholder farmers, and can be done by subsidies, training programs and strong partnerships between the public and private sector. Thirdly, strengthening policy frameworks and rural infrastructure will make maize systems more resilient and improve market access. Fourth, sustainability promoted by conservation agriculture and biofortification aligns productivity goals with environmental sustainability and nutritional needs. Thus, finally, global collaboration in, for instance, on research, technology transfer, and climate adaptation will be essential, as it is clear that maize systems across the world are subject to shared challenges and opportunities.

CONCLUSION

Maize continues to be a critical part of the global agrofood system, and its importance is expected to increase in the future as food, feed and biofuel demand continues to rise. Hence, the next stage of maize production likely depends on integrating technological innovation with climate adaptation and sustainable practices. Drought tolerant and pest resistant varieties have become more genetic and along with CRISPR and precision agriculture, these genetic advancements are providing significant gains in productivity. Nevertheless limited by their wide adoption due to access disparities especially among smallholder farmers in low income areas. Maize systems are challenged by climate change, which further intensifies vulnerabilities to heat, drought, and outbreaks of pests. The building of resilience via integrated pest management, improved agronomic practices and targeted breeding continues to be critical. This crop will impact on food security and socioeconomic factors (smallholder support, infrastructure development and stable trade policy) will influence these impacts. Conservation practices and agroecological transitions must also be prioritized for sustainability, as a means of ensuring long term viability. A coordinated action is necessary across stakeholders such as researchers, private sectors and governments to address these multifaceted challenges. At a time when maize is adapting to a changing world, those working to equalize access to the innovation, and to build inclusive policy frameworks will be critical to maintain the role of this crop as disease resistant and nutritious, while providing sustainable food security for future generations.

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