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Challenges and Sustainable Strategies for Enhancing Maize Production: A Comprehensive Review.

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ABSTRACT

This study includes a comprehensive review of 20 articles published in 10 peer-reviewed journals between 2015 and 2022 on sustainable strategies for enhancing maize production. Two reasons justify this analysis. First, policymakers, such as Uganda's Ministry of Agriculture, Animal and fisheries and the Ministry of Finance, recognize the importance of enhancing maize production to help people have stable food and income in order to fight hunger and poverty. Any policy response requires a thorough understanding of the underlying factors. Second, the availability of data on maize production, allows researchers to conduct more advanced studies. I summarize the literature based on two broads, albeit overlapping, themes of sustainable strategies for maize production. The literature was meticulously evaluated into seven subcategories using an open coding process. Although the sustainability element in maize production is revealed and further empirical research is still needed, the results show that there is a significant relationship between challenges, sustainable strategies and maize production.

Key words: Maize production, Sustainable strategies

Introduction

Maize production is influenced by several factors that are beyond the control of smallholder farmers. These factors include climate change, agronomy, genetics, politics, and political stability (Hill et.al. 2021). Increasing corn production requires strategies that go beyond expanding area (Li et.al. 2020). Adoption of new technologies is uneven, with female farmers having lower adoption rates than male farmers. To achieve sustainable corn production, four key challenges must be overcome. These challenges include improving the nutrient density of corn, increasing the introduction of new varieties, increasing fertilizer use, and addressing gender challenges in adoption (Yang, Zhilong & Chai, 2018). In particular, gender challenges need to be addressed to achieve the desired effects of new technologies. Fertilizers can help increase maize production, but the low and variable return on investment can limit fertilizer adoption. Increasing maize production requires sustainable strategies that include a portfolio of complementary technologies and policies. It is important to note that he needs to triple maize production in sub-Saharan Africa to meet the needs of future generations (Benson, 2021). Good agronomic management practices, such as increasing input usage and leveraging genotype-environment-management interactions, can reduce yield gaps and sustainably improve maize productivity is essential. Improved maize varieties alone cannot achieve significant increases in productivity; crop rotation and diversification, and the use of organic matter are important elements of good agricultural management practices (Asante, Temoso, Addai & Villano, 2019). However, it is important to consider the environmental sustainability of corn cultivation and stay within planetary boundaries. Therefore, demand-side interventions such as reducing animal foods can help improve the environmental sustainability of maize production. Additionally, care should be taken not to overextend maize, as other dry grains may offer more resilient options in semi-arid environments. Finally, the environmental footprint of food miles and the impact of international trade in the context of agricultural exports depends on scale, including both European corn exporters and non-exporting countries. International trade can either alleviate or exacerbate the environmental impacts associated with corn production. Research and development investments to make maize production more environmentally sustainable and resilient while adapting to climate change are seen as a way to increase maize production in the Global South.

A major challenge in growing maize (Zea mays) is to achieve high grain yield (lower yields) while improving resource efficiency. Using a dataset consisting of 83 peer-reviewed articles, this study first investigated the effects of water and/or nitrogen (N) supply on maize yield, water productivity (WP) and plant performance. and assessed the effects of plant density, environmental factors (temperature, soil texture) and management factors (water and/or nitrogen input). Water supplies increased maize yield, WP and NUE only when supply was less than 314, 709 and 311 mm, respectively; N application increased maize yield, WP and NUE until inputs exceeded 250, 128 and 196 kg ha^{-1}, respectively (Cerrudo et.al. 2017). In addition, the results of the mixed-effects model and random forest analysis indicated that annual mean temperature (AMT) was the most important factor in reducing the gap (between the actual and the potential variable, called the treatment-control ratio) of yield (RRY), WP (RRWP) and NUE (RRNUE), respectively. Specifically, RRY, RRWP, or RRNUE were negatively correlated with MAT when MAT was higher than 15 °C (Kogo, Kumar, Koech & Kariyawasam, 2019). Furthermore, the structural equation model showed that water consumption and RRWP with the highest coefficient were more important than N and RRNUE inputs in improving RRY (Andrea, Boote, Sentelhas & Romanelli, 2018). These findings provide new insights into the drivers and constraints of global maize production and provide some guidance for water and/or nitrogen management.

Maize is grown on over 40M ha of land in sub-Saharan Africa (SSA). Maize is the primary cereal grown in over half of the countries in SSA, and one of the top two cereals in over three-quarters of these countries (Erenstein et.al., 2022). In more than half the countries in the region, people consume more than 100 g of maize per day. The population of SSA is projected to double over the next 30 years (Prasanna et al., 2021) and demand for cereals is predicted to increase by three-fold (MADIĆ et al., 2022). Since 1961, maize production on a global scale has increased from 205 M tons to 1145 M tons (Epule, Chehbouni & Dhiba, 2022). The area under maize production increased by 187% and maize yields have increased almost three-fold. However, this figure masks important regional variation. While production increased in 64–70% of maize growing regions, there was either no improvement or a decline in production in 21–23% of maize growing regions (I VOZHEHOVA et al., 2022). Unlike other major crops (rice, wheat and soybean) where yield growth rates are similar in high- and low-income countries, there remains a large gap between the maize yield growth rates of high- and low-income countries (Erenstein, Chamberlin & Sonder, 2021). During the period 1961 to 2017, maize production in SSA increased from 14 M tons to 80 M tons (534%). In contrast to global maize trends, the increase in maize production was largely associated with an increase in area rather than yield: area under maize production increased by 275%, relative to a 191% increase in yield. The increase in area and yield during the period 1961 to 2017 in individual countries in SSA is shown in Fig. 1. Except for a few countries (Central African Republic, Côte d'Ivoire, Eswatini, Ethiopia, Lesotho, Mauritius, Somalia, South Africa and Zambia), production gains were associated with an increase in the area under maize production as highlighted by the fact most countries were above the 1:1 line. These patterns of expansion-based production growth are not sustainable in the long-run.

To meet the needs of future generations maize production must increase by 2.2% per year (Prasanna et al., 2021). Between 1981 and 2008 maize production was estimated to have increased annually by 1.7–1.8% worldwide (Iizumi et al., 2018). However, maize yields at the country level have decreased in seven countries in eastern and southern Africa (ESA) over the last 15 years where it is the main staple crop (Fig. 2). Maize yields are a function of a range of variables including genetics, climate, agronomy, policy and political stability. In southern Africa for example, the past decade (2010–2020) had six years below average rainfall with a severe El Niño-induced drought in 2016 leading to a negative yield trend in Malawi, Mozambique and Zambia. Without an increase in maize yield levels, the area of maize cultivation in SSA must increase by 184% by 2050 to meet future food security needs (Zelingher, Makowski & Brunelle, 2021).

Methodology

The researchers used two complementary search strategies: (a) A systematic database search of the scientific and grey literature, and (b) a backward literature search of the references of each study included in the review. For documents whose full text is not available in the searched databases or repositories, the research team considered all possible options by emailing the document authors and associated organizations or requesting items through two different universities. The used the following search terms in all possible combinations in each database and repository: sustainable strategies, and (b) maize production, or. A database search resulted in 156,000 potentially relevant documents. After removing duplicates, we were left with 2,000 documents whose titles we needed to investigate. After a summary review, the same team member reduced this number to 200 reports for a more comprehensive text review. This reviewer then scans the full text of each remaining article to determine whether it uses tools relevant to our review, leaving 50 documents for full text review. I left it. The researchers conducted a full-text review of these documents and identified 20 of the articles that fully met the inclusion criteria. Reviewers systematically extracted data from all included studies and saved the information in a spreadsheet created prior to data extraction. Any discrepancies that arose between reviewers and supervisors have been resolved

Results and Discussion

The infeasibility and/or unsustainability of such area expansion means that yield increases are the most feasible pathway for attaining such production increases. With a predicted maize yield gap of 80% in SSA (van Ittersum et al., 2016), the enormous deficit also suggests huge potential. To achieve this, multiple interventions will be required. There are a wide range of proven technologies, practices and institutional interventions which together can sustainability increase maize production (Hansen et al., 2019). Improved crop genetics and increased fertilizer use were key components of the Green Revolution and have been widely advocated to increase maize production. Recent investments in maize genetics in SSA are estimated to have benefited over 53 M people (Cairns and Prasanna, 2018), however more is needed and the slow speed of varietal turnover, i.e., the tendency for old varieties to dominate seeds sales despite the availability of newer varieties, has become an issue of concern and discussion (Rutsaert and Donovan, 2020a). Maize accounts for over 30% of calories in 20 countries in SSA (Goredema-Marondera et al., 2021). The average per capita consumption is over 100 kg per person per year (300 g per day) in Lesotho, Malawi, Zambia and Zimbabwe, with maize making up almost 50% of the total calorie intake per day in these countries. Given the heavily reliance on maize-based diets in many low-income rural and urban populations, there has been increasing focus to enhance the nutrient density of maize. Biofortification has been used to increase the levels of provitamin A, lysine, tryptophan and zinc (Zn) in commercial maize varieties. However, there is a growing realization that multi-nutrient trait combined with agronomic biofortification will have a greater impact on health outcomes. Despite the potential of fertilizer to substantially reduce the yield gap, annual synthetic N fertilizer use ranges from 7 kg N ha^{-1} in West Africa to 13 kg N ha^{-1} on East Africa (Leitner et al., 2020), suggesting barriers to fertilizer use. When addressing options to sustainability increase maize production in SSA it is impossible not to consider the current gender gap. As stated by Burke et al. (2019) "systemically disadvantaging half of the farming population of an agrarian society while trying to promote economic development is like trying to farm with one hand tied behind your back."

Conclusion

In this review we therefore highlight four strategies: (i) increasing yields and nutritional yield alongside varietal turnover to provide increased genetic gain to farmers, (ii) solving constraints to the adoption of complementary management practices and inputs, particularly fertilizer use, (iii) Closing gender gap in maize productivity and (iv) ensuring new technologies reach smallholder farmers. We summarize the state of the literature around each of these strategies in the previous sections, after which we offered summary remarks on integrated efforts to adopt these strategies for enhancing maize production

References

Andrea, M., Boote, K., Sentelhas, P., & Romanelli, T. (2018). Variability and limitations of maize production in Brazil: Potential yield, water-limited yield and yield gaps. Agricultural Systems. https://doi.org/10.1016/J.AGSY.2018.07.004.

Asante, B., Temoso, O., Addai, K., & Villano, R. (2019). Evaluating productivity gaps in maize production across different agroecological zones in Ghana. Agricultural Systems. https://doi.org/10.1016/J.AGSY.2019.102650.

Benson, L. (2021). Factors Controlling Pre-Columbian and Early Historic Maize Productivity in the American Southwest, Part 1: The Southern Colorado Plateau and Rio Grande Regions. Journal of Archaeological Method and Theory, 18, 1-60. https://doi.org/10.1007/S10816-010-9082-Z.

Cairns, J. E., Chamberlin, J., Rutsaert, P., Voss, R. C., Ndhlela, T., & Magorokosho, C. (2021). Challenges for sustainable maize production of smallholder farmers in sub-Saharan Africa. *Journal of Cereal Science*, *101*, 103274. https://doi.org/10.1016/j.jcs.2021.103274.

Cerrudo, A., Martinez, D., Izquierdo, N., Cirilo, A., Laserna, M., Reinoso, L., Valentinuz, O., Balbi, C., & Andrade, F. (2017). Environment, Management, and Genetic Contributions to Maize Kernel Hardness and Grain Yield. Crop Science, 57, 2788-2798. https://doi.org/10.2135/CROPSCI2016.12.0997.

Epule, T. E., Chehbouni, A., & Dhiba, D. (2022). Recent patterns in maize yield and harvest area across Africa. *Agronomy*, *12*(2), 374.

Erenstein, O., Chamberlin, J., & Sonder, K. (2021). Estimating the global number and distribution of maize and wheat farms. *Global Food Security*, *30*, 100558.

Erenstein, O., Jaleta, M., Sonder, K., Mottaleb, K., & Prasanna, B. M. (2022). Global maize production, consumption and trade: Trends and R&D implications. *Food Security*, *14*(5), 1295-1319.

Hill, J., Goodkind, A., Tessum, C., Thakrar, S., Tilman, D., Polasky, S., Smith, T., Hunt, N., Mullins, K., Clark, M., & Marshall, J. (2019). Air-quality-related health damages of maize. Nature Sustainability, 2, 397-403. https://doi.org/10.1038/s41893-019-0261-y.

Kogo, B., Kumar, L., Koech, R., & Kariyawasam, C. (2019). Modelling Climate Suitability for Rainfed Maize Cultivation in Kenya Using a Maximum Entropy (MaxENT) Approach. Agronomy. https://doi.org/10.3390/agronomy9110727.

Konieczna, A., Roman, K., Roman, M., Śliwiński, D., & Roman, M. (2020). Energy Efficiency of Maize Production Technology: Evidence from Polish Farms. Energies, 14, 170. https://doi.org/10.3390/en14010170.

Li, Y., Cui, S., Zhang, Z., Zhuang, K., Wang, Z., & Zhang, Q. (2020). Determining effects of water and nitrogen input on maize (Zea mays) yield, water- and nitrogen-use efficiency: A global synthesis. Scientific Reports, 10. https://doi.org/10.1038/s41598-020-66613-6.

MADIĆ, M., ĐUROVIĆ, D., STEVOVIĆ, V., TOMIĆ, D., BIBERDŽIĆ, M., & PAUNOVIĆ, A. (2022). Grain yield in maize hybrids of different FAO maturity groups. *BOOK OF*, 254.

VOZHEHOVA, R., LAVRYNENKO, Y., MARCHENKO, T., PILIARSKA, O., SHARII, V., TYSHCHENKO, A., ... & GRABOVSKYI, M. (2022). WATER CONSUMPTION AND EFFICIENCY OF IRRIGATION OF MAIZE HYBRIDS OF DIFFERENT FAO GROUPS IN THE SOUTHERN STEPPE OF UKRAINE. *Scientific Papers. Series A. Agronomy*, *65*(1).

Yang, C., Zhilong, F., & Chai, Q. (2018). Agronomic and Economic Benefits of Pea/Maize Intercropping Systems in Relation to N Fertilizer and Maize Density. Agronomy, 8, 52. https://doi.org/10.3390/AGRONOMY8040052.

Zelingher, R., Makowski, D., & Brunelle, T. (2021). Assessing the sensitivity of global maize price to regional productions using statistical and machine learning methods. *Frontiers in Sustainable Food Systems*, *5*, 655206.