Push-Pull Technology in Climate-Smart Agriculture: A Strategy for Sustainable Agriculture

Dennis Kimoso Mulupi, Esther Ng'ong'a, Cosmas Kiprono, Winnie Oliech, Fredrick Aila, Benjamin Ombok, George Odhiambo

Abstract

The SSA region is bearing the brunt effect of climate change as a result of over-reliance on agriculture, poor farming practices such as deforestation, and intensive use of agrochemicals in production. As the outcome, the land is degraded, and natural resources are depleted instigating a decline in soil fertility, low rainfall, high temperature, and low crop production. As mitigation, several strategies have been mooted including organic farming, conservation agriculture, and regenerative agriculture. These are the sustainable agricultural practices or climate-smart agricultural strategies as they are eco-system friendly. UPSCALE project to promote sustainable farming is upscaling PPT technology as an IPM, and organic system. It integrates the cereal or vegetable crop with a forage crop such as desmodium which repels pests such as stem borer and fall armyworm and it also suppresses Striga weed germination while brachiaria attracts stem borer moth from the crop. The technology has a great impact on crop productivity, allows fodder production for livestock, conserves the soil, and improves soil moisture content among others. The technology reduces external commercial inputs use, therefore, it is affordable for smallholder farmers. Despite the technology being a climate-smart strategy, it faces challenges such as scarcity of the desmodium seed in upscaling, weak government policies to support PPT, and poor information dissemination. Therefore, it is recommended that different stakeholders need to be engaged in transdisciplinary research to support the adoption of PPT as a climate-smart agricultural strategy in the region.

Keywords;

Push-Pull technology (PPT), Climate Smart Agriculture, Climate change, UPSCALE project, agroecology, Organic Farming, Regenerative Agriculture, Sub-Saharan Africa, Multi-actor community (MACs)

Introduction

Over the years, Sub-Saharan Africa (SSA) has encountered the most challenging economic, social, and political environment. This region is vulnerable to the effect of most global pandemics. As a result, the prices of energy, as well as food products, have constantly remained on a steady rise. The region is experiencing one of the highest population growth globally which has increased the rate of unemployment forcing many of the population to rely on the agricultural sector as a source of livelihood in attaining food security, employment, and economic growth (African Development Bank, 2019). Due to the declining land holding, the use of intensive farming systems and poor farming practices such as deforestation to increase food production have instigated land degradation resulting in climate change in the region (UN-OHRLLS, 2015). This has accelerated the decline in soil fertility through erosion and caused low crops, and animal feeds production leaving over 67 percent of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 861998.

the population in the region food insecure. This has increased hunger and malnutrition cases among children and left most households poor (Gitz et al., 2016).

The region is dependent on rain-fed agriculture, and the prolonged drought has caused water scarcity making most countries import food (Makurira, 2011). To counter this, sustainable farming systems are key for the resources to be protected for the current and future generations. These sustainable farming techniques are what have been collectively known as climate-smart agriculture(OECD, 2021). They include all the eco-friendly farming systems such as organic farming, agro-forestry, conservation farming, and regenerative farming technologies. In promoting the sustainable farming system in East Africa, the UPSCALE project is one of the leading partners to ensure farmers are adopting agroecological farming systems (icipe, 2015).

The UPSCALE project team is a combination of transdisciplinary experts that inspire Multi-actor community integration in addressing the problems affecting small-scale farmers, especially on weed and pest management, addressing the issues of soil fertility, environmental conservation, curbing climatic change attacks and low crop production to attain household food security (Nyang'au et al., 2018). It is reported that weeds and pests are capable of reducing annual cereal crops such as maize production by up to 60 percent in the region. The most dominant and dangerous biotic stressors in the region affecting cereal production are the Striga weed, stem borer, and Fall Army Worm (FAW) pests. Elimination of weeds and pests will positively impact the quality and quantity of output. The project is promoting a farming technique called push-pull technology (PPT) among small-scale farmers in East Africa. PPT is an Integrated Pest Management (IPM) farming technology that controls Striga weed, FAW, and stem borer, improves soil fertility, controls soil erosion, conserves soil moisture content, increases crop yields, and crop diversification, and integrates crop-forage production as animal feeds (Tadele, 2017).

Push-pull technology is a cropping system, where cereal crops are inter-cropped with Desmodium legume and the plot is surrounded by Napier, Sudan grass, or Brachiaria as a border crop for controlling Striga weed, Stem borers, and Fall Army Worm pests (Pickett et al., 2014)(Pickett et al., 2014b). Desmodium a leguminous fodder planted between the rows of cereal crops, repel the pests (push) and control the parasitic Striga weed, while the border grasses attract (pull) the stem bores moth to lay their eggs, however, they do not support larval development hence the manage the pest population naturally below economic injury level (Khan et al., 2007). Initially, the technology was integrated into maize production but it has been expanded to high-value short-season vegetables to enable farmers to increase household income.

Methodology

This is a reflection on ongoing discussions at transdisciplinary multi-actor communities (MACs) of practice constituted under the UPSCALE project in East Africa where reports from many actors including researchers, farmers, agro-dealers, and NGOs are involved. A reflection is also drawn heavily from the first East Africa agroecology conference on climate change, an extensive review of existing literature from the national and international reports on climate change, scholarly work, and the experience of the authors over time. Through the articles review and the stakeholder meetings, climate change has negatively affected the agricultural sector in the SSA region. Therefore, the need to promote an eco-friendly farming system of urgent to mitigate the effect of climate change that is causing low food production and depletion of natural resources. There is a need to produce more food organically, protect the environment, and reverse the effect of climate change. This can be done with reduced or no chemical use in weeds, and pests control through the PPT farming system as a climate-smart strategy. The main question of focus in the review is how beneficial is PPT as a climate-smart agriculture strategy to farmers in terms of soil protection, weed and pest control, crop and productivity, and mitigation of climate change.

Results and Discussions

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 861998.

Principles of Climate-Smart Agriculture

Climate-smart agriculture is the practice that will move the agricultural sector forward to achieve sustainable development economically, socially, and environmentally while addressing the issues of food security. It is based on three principles which are sustainably increasing agricultural productivity and income, adapting and enhancing resilience to climate change, and, reducing and removing greenhouse gas from the atmosphere (Verhagen et al., 2014). PPT has been reported as an eco-friendly farming system with the ability to protect the current agricultural resources to remain economically viable for future production. It has economic, social, and environmental benefits across the soil, the farmer, and the ecosystem. Besides increasing crop productivity, PPT promotes climate-smart agriculture in different ways as it helps to mitigate the effects of climate change experienced in SSA.

PPT as an IPM strategy

Push-pull technology advocates for the minimum to zero application of external inputs in a production system. This means that inorganic fertilizers and the agrochemicals used in controlling weeds and pests are not required. PPT control the weeds and pest organically through the repellent nature of desmodium and the trapping mechanism of brachiaria (Khan et al., 2016). Desmodium also produces allele chemicals that suppress the manifestation of the Striga seed bank in the soil (Awaad & El-Naggar, 2019; Zahran, 1999). Although Pests and weeds are not necessarily eradicated, they are maintained at a level where they cannot result in yield loss as they are part of the ecosystem (Damalas, 2009). The reduction in farm chemical use reduces household green gas emissions which mitigates climate change as a climate-smart farming strategy (Perrin, 2015).

Land/soil conservation

PPT is an integration of cereal or vegetable crops with forages such as Napier or Brachiaria at the border and Desmodium within the crop. The forages are cover crops that are key in controlling splash and water erosion carrying away topsoil from the farm (ICIPE, 2011). This reduces land degradation and maintains soil fertility. The cover crop also improves soil water management as the soil is not exposed (Lemessa & Wakjira, 2015). This helps the plant to benefit from the moisture during the dry season maintaining higher productivity. Desmodium also as a leguminous fodder helps in the fixation of atmospheric nitrate into nitrates in the soil for plant uptake hence improving soil fertility (Tadele, 2017).

Crop diversification

Push-pull technology promotes the diversification of crops and forages on a farm. Cereal crops, vegetables, and forages can be integrated to intensify productivity. This allows the breakdown of survival and multiplication cycles of pests, diseases, and weeds and improves soil fertility (Ratnadass et al., 2012). This also enhances farming households to spread production and economic risk over a broader range of crops hence reducing the financial risk associated with unfavorable weather or market shocks.

Fodder production

Desmodium, brachiaria, and Napier grass are good sources of livestock feed, they are nutritious enhancing good growth with high milks yields in livestock (Mutimura et al., 2020). Push-Pull crops are perennials that are resistant to variation in climate change hence they provide feeds for the livestock year all round (Altieri et al., 2012). A good forage-based feeding system reduces green gas emissions which mitigates climate change

Despite the achievements, PPT upscaling is experiencing various challenges to promote climate-smart agriculture. The challenges include a lack of awareness of the technology among farmers and other stakeholders,

UPSCALE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 861998.

low adoption of the technology, seed certification issues, scarcity of desmodium seeds on the market, desmodium seed being expensive, poor policies to support PPT farming in the country, small land holdings, and lack of government support in form of incentives, awareness and inputs for a technology to be adopted.

The UPSCALE project team through the MACs ensures the promotion and adoption of new/existing technologies to transform the agricultural sector that provides benefits in terms of food production, health, and economic growth (Medina-García et al., 2022). Moreover, MACs engagement determines how agricultural technologies are disseminated and adopted because productivity depends on the quality and type of inputs made by different actors and how best they collaborate, coordinate, and interact among themselves to promote a technology (Nyangau et al., 2018) provide opportunities for publicizing information and knowledge from on-farm testing and research observations and for obtaining feedback for improving future research programs and interventions.

Each actor in the MAC brings unique expertise and experience to catalyze PPT adoption and mutually benefit other actors in the value chain. For this to happen, the economic benefits of the technology should be established to serve as a foundation for upscaling PPT, alongside other sustainable agricultural intensification technologies. Direct involvement of farmers in all steps of development and implementation of the pathway to success through collaborative workshops and farmer field days would essentially promote PPT implementation and adoption within eastern Africa.

The changing ecological conditions in the world and Africa in particular require a commitment to scientific research in finding solutions that will improve agro-productivity, and enhance food security and sovereignty. A study by (Khan et al., 2020) suggested that lack of strong national extension support, lack of information, and shortage of inputs are some of the challenges affecting agricultural technologies. Therefore, different actors need to be engaged in promoting PPT to curb climate change.

Opportunities in PPT farming

The scarcity of desmodium seeds is an opportunity for women and youths to engage in PPT to fill the market demand gap. The seeds when certified can be sold through agro-dealers, seedlings of the desmodium crop can be sold to farmers, the feeds can be sold to farmers, and as hey as silage through agro-dealers. This will enhance income generation for the farmers (Amudavi et al., 2009).

Conclusion and Recommendation

PPT is the key strategy for promoting climate-smart agriculture in the attainment of food security and quality feeds. A significant increase in productivity in maize farms and integrated livestock production has been reported. This is a result of improved soil fertility and the availability of quality forage for dairy cattle. In addition, farming become affordable as the use of expensive commercial inputs such as agrochemicals, animal feeds, and fertilizer is reduced. Moreover, the system is eco-friendly as fewer chemicals are sprayed into the atmosphere, soil erosion is reduced and less fertilizer applies to the soil, and good animal feeding is adopted. This reduces green gas emissions mitigating climate change.

However, establishing a PPT farm might be expensive for the first seasons as a result of the inputs required and the labor intensity, however, it progressively reduces and in the long run, it becomes affordable for small-scale farming. The major challenge in the adoption of the technology is the scarcity and the high prices of the desmodium seeds, the lack of certification of the seed on the market, the desmodium crop failing to flower in some agroecological zones, and poor policies to support PPT.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 861998.

Upscaling of PPT will increase productivity and mitigate climate change as well as provide other gains. Therefore, it is recommended that different stakeholders need to be engaged in transdisciplinary research to support the adoption of PPT in the region, governments should ensure documentation of policies that address issues about PPT as an agroecological technology and subsidize the desmodium seeds for the farmers to afford, certification of the seeds to be accelerated, and extension systems need to be strengthened and empowered to help in dissemination and sensitization of farmers, agro-dealers and all stakeholders involved to upscale the adoption of the technology sustainably.

References

African Development Bank. (2019). *African Economic Outlook 2019: Macroeconomic performance and prospects Jobs, growth, and firm dynamism Integration; Integration for Africa's economic prosperity*. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/2019AEO/AEO_2019-EN.pdf

Altieri, M. A., Ponti, L., & Nicholls, C. I. (2012). Soil Fertility, Biodiversity, and Pest Management. *Biodiversity and Insect Pests: Key Issues for Sustainable Management*, *May*, 72–84. https://doi.org/10.1002/9781118231838.ch5

Amudavi, D. M., Khan, Z. R., Wanyama, J. M., Midega, C. A. O., Pittchar, J., Nyangau, I. M., Hassanali, A., & Pickett, J. A. (2009). Assessment of technical efficiency of farmer teachers in the uptake and dissemination of push-pull technology in Western Kenya. *Crop Protection*, *28*(11), 987–996. https://doi.org/10.1016/j.cropro.2009.04.010

Awaad, H., & El-Naggar, N. (2019). Potential role of intercropping in maintaining and facilitating environmental sustainability. *Sustainability of Agricultural Environment in Egypt: Part I: Soil-Water-Food Nexus*, 81–100.

Damalas, C. A. (2009). Understanding benefits and risks of pesticide use. *Scientific Research and Essays*, *4*(10), 945–949.

Gitz, V., Meybeck, A., Lipper, L., Young, C., & Braatz, S. (2016). Climate change and food security: Risks and responses. In *Food and Agriculture Organization of the United Nations*. https://doi.org/10.1080/14767058.2017.1347921

icipe. (2015). The ' Push – Pull ' Farming System : Climate-smart, sustainable agriculture for Africa. In *The 'Push–Pull' Farming System: Climate-smart, sustainable agriculture for Africa*. http://www.push-pull.net/planting_for_prosperity.pdf

ICIPE. (2011). Climate-smart push–pull: resilient, adaptable conservation agriculture for the future. *International Centre of Insect Physiology and Ecology*, 1–8.

Khan, R.Z., Muyekho, N.F., Njuguna, E., Pickett, A.J., Wadhams, J.L., Pittchar, J., Ndiege, A., Genga, G., Nyagol, D. and Lusweti, C. (2007). A Primer on Planting and Managing ' Push - Pull ' Fields for Stemborer and Striga Weed Control in Maize A Step-by-Step Guide for Farmers and Extension Staff. *Icipe*, *2*, 1–39.

Khan, Z., Midega, C. A. O., Hooper, A., & Pickett, J. (2016). Push-Pull: Chemical Ecology-Based Integrated Pest Management Technology. *Journal of Chemical Ecology*, *42*(7), 689–697. https://doi.org/10.1007/s10886-016-0730-y

Khan, Z. R., Midega, C. A. O., Pittchar, J. O., Murage, A. W., Birkett, M. A., Bruce, T. J. A., & Pickett, J. A. (2020). *Achieving food security for one million sub-Saharan African poor through push–pull innovation by 2020*. *April 2014*. https://doi.org/10.1098/rstb.2012.0284

Lemessa, F., & Wakjira, M. (2015). Cover crops as a means of ecological weed management in agroecosystems. *Journal of Crop Science and Biotechnology*, *18*(2), 133–145. https://doi.org/10.1007/s12892-014-0085-2

Makurira, H. (2011). Rainfed Agriculture in Sub-Saharan Africa. *Water Productivity in Rainfed Agriculture*, *181*(November 1947), 35–48. https://doi.org/10.1201/b10823-9

Medina-García, C., Nagarajan, S., Castillo-Vysokolan, L., Béatse, E., & Van den Broeck, P. (2022). Innovative Multi-Actor Collaborations as Collective Actors and Institutionalized Spaces. The Case of Food Governance Transformation in Leuven (Belgium). *Frontiers in Sustainable Food Systems*, *5*. https://doi.org/10.3389/fsufs.2021.788934

Mutimura, M., Resources, A., Board, D., & Ghimire, S. (2020). Handbook of Climate Change Management. *Handbook of Climate Change Management*, *May*. https://doi.org/10.1007/978-3-030-22759-3

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 861998.

Nyang'au, I. M., Kelboro, G., Hornidge, A. K., Midega, C. A. O., & Borgemeister, C. (2018). Transdisciplinary research: Collaborative leadership and empowerment towards sustainability of push-pull technology. *Sustainability (Switzerland)*, *10*(7). https://doi.org/10.3390/su10072378

Nyangau, I. M., Kelboro, G., Hornidge, A., & Midega, C. A. O. (2018). *Stakeholders Interaction and Social Learning : The Case of Push-Pull Technology Implementation for Stemborer Pest Control in Ethiopia*. *October*. https://doi.org/10.20944/preprints201810.0480.v1

OECD. (2021). Adoption of Technologies for Sustainable Farming Systems. *Wageningen Workshop Proceedings*, 149.

Perrin, A. (2015). Climate-smart agriculture. *Spore*, *2015*(SpecialIssue), 18–21. https://doi.org/10.4324/9781315621579-4

Pickett, J. A., Woodcock, C. M., Midega, C. A. O., & Khan, Z. R. (2014a). Push-pull farming systems. *Current Opinion in Biotechnology*, *26*, 125–132. https://doi.org/10.1016/j.copbio.2013.12.006

Pickett, J. A., Woodcock, C. M., Midega, C. A. O., & Khan, Z. R. (2014b). Push–pull farming systems. *Current Opinion in Biotechnology*, *26*, 125–132.

Ratnadass, A., Fernandes, P., Avelino, J., & Habib, R. (2012). Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review. *Agronomy for Sustainable Development*, *32*, 273–303.

Tadele, Z. (2017). Raising crop productivity in Africa through intensification. *Agronomy*, *7*(1), 1–30. https://doi.org/10.3390/agronomy7010022

UN-OHRLLS. (2015). *The Impact of Climate Change, Desertification and Land Degradation on the Development Prospects of Landlocked Developing Countries*. http://unohrlls.org/custom-content/uploads/2015/11/Impact_Climate_Change_2015.pdf

Verhagen, A., Schaap, B. F., Pulleman, M. M., Hengsdijk, H., & Achterbosch, T. J. (2014). Climate-smart agriculture as a guiding principle for agricultural transformation. *The Food Puzzle: Pathways to Securing Food for All*, *Verhagen*, 55–57.

Zahran, H. H. (1999). Rhizobium-legume symbiosis and nitrogen fixation under severe conditions and in an arid climate. *Microbiology and Molecular Biology Reviews*, *63*(4), 968–989.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 861998.