Promoting Conservation Agriculture through Push-Pull Technology as an Agroecological Transition

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Abstract

Low soil fertility, weeds, pests, and climatic change severely threaten crop productivity and agricultural sustainability, especially in SSA. Despite decades of research finding adequate technical solutions for most situations of food systems, the problem of low food productivity has persisted. In an effort to counter this, intensive agricultural systems have been mooted including the high application of agrochemicals to control weeds, and pests and increase production. However, these initiatives have not lasted beyond the project cycle and they have instigated land degradation through unsustainable practices. As a solution, conservation agricultural practices have been promoted among small-scale farmers. These practices focus on minimizing soil disturbance, crop diversification, and cover cropping. Push-pull technology is an aspect of conservation agriculture where intercropping a cereal crop with a repellent plant, such as desmodium and planting an attractive trap plant, such as brachiaria or Napier grass as a border crop around this intercrop. This paper aimed at reviewing existing literature to establish the linkage between conservation agriculture components, push-pull technology, and a sustainable agroecological transition. A list of questions directed the discussion where push-pull technology has been proven to be an aspect that promotes conservation agriculture. It has been able to increase crop yields, reduced tillage, established a cover crop on the farm, and further, PPT has a regenerative aspect through the integration of livestock husbandry providing organic manure that and together with the nitrogen fixation ability of the grass, improve soil fertility, conserved soil moisture, and reduce erosion. This reduces the use of inorganic input, and machinery making farming economical for small-holder farmers.

Keywords

Conservation Agriculture, Push-Pull Technology, Agroecological Transition, UPSCALE, PrAEctiCe

Introduction

Sub-Saharan Africa (SSA) has faced numerous challenges in an attempt to attain food security. Despite other developing regions such as Asian countries increasing food production by an estimated 30 percent, there has been a continuous annual decline of an average of 3 percent in per capita food production in SSA since 1990 (World Bank, 2008). Among the dominant causes of this decline are poor soil fertility, pests, and weeds on farms, and climate change (Raimi et al., 2017). The infection from pests and weeds has attributed to about 50 percent loss in production which has been exacerbated by the low rainfall and low soil fertility prevalent in the region (Khan et al., 2011; Tadele, 2017). In an effort to increase crop productivity in this region, intensive farming systems such as the use of agrochemicals including pesticides, herbicides, and the huge application of inorganic fertilizer in production and machines have been advocated (Makurira, 2011; Mohammed-Saleem, 1995).

Although this modern intensive agriculture has been highly successful when viewed through the lens of productivity, it has repeatedly failed to account for externalities including impacts on water, soil, biodiversity, and society (Novikova, 2014; TOHA science, 2021). In response, various "alternative" agricultures have developed, with the largest uptake occurring for those which are otherwise compatible with an industrial scale and approach to agriculture, such as organic and conservation agriculture (FAO, 2018a).

Initially, agricultural knowledge and innovation systems have been thought of from an academic perspective as moving from centralized diffusion of specialized research to trans-disciplinary, holistic development of knowledge with practitioners/farmers as co-designers (Darnhofer et al., 2012). These innovations have tended to focus on above-ground production and ignored the potential impacts of different root structures and soil-plant interactions, which can be highly important for soil structure (Clemensen et al., 2020).

Therefore, alternative agricultural movements have largely been founded and led by practitioners rather than researchers, often as a response to the centralized model of innovation and to perceived and real failures to take values other than productivity into account (Faure et al., 2018). Some, such as conservation agriculture, address specific problems such as the degradation of soil (Hobbs et al., 2008). The three principles of conservation agriculture are minimizing soil disturbance, maintaining plant cover at all times, and maximizing crop diversity (Palm et al., 2014).

Conservation agriculture is a farming system that creates a suitable soil environment for growing crops and that conserves soil, water, and energy resources mainly through the reduction in the intensity of tillage, and retention of plant residues (Jat et al., 2014). Push-pull technology has been instigated to promote the principles of conservation agriculture. It is a strategy for controlling agricultural pests by using repellent ('push') and trap ('pull') crops. Currently, the UPSCALE project aims at scaling up the understanding and applicability of this technology from individual fields to regional farms and from cereal crops to forage production (Khan et al., 2011). Besides the role, push-pull technology has many other benefits to the farmers and the environment at large (Mirti, 2019).

Conservation of the resources is an important concept in today's agriculture since the human will not want to compromise the ability of its future offspring to produce their food needs by damaging the natural resources used to feed the population today (Gitz et al., 2016). This therefore, is key in attainment of sustainable of agricultural intensification for the farmers and the region.

This paper, therefore, will deliver comprehensive information on the linkage between conservation agriculture components, push-pull technology and a sustainable agroecological transition through a narrative review of peer-reviewed research papers. It will promote push-pull technology as a modern conservational agricultural practice that can enable farmers in many parts of the world to achieve the goal of sustainable agricultural production. The paper will first discuss the principles of conservation agriculture and how push-pull technology conform these principles, how can push-pull technology be promoted, the challenges, and the achievements that farmers have attained through the technology. Throughout the review, the main question leading the discussion were;

I. What are the principles of conservation agriculture?
II. Does push-pull technology as a strategy meet the conditions of conservation agriculture?
III. What are the achievements of push-pull technology as a strategy promoting conservation agriculture in terms of food security and climate change?
IV. What are the challenges facing push-pull technology adoption as strategy promoting conservation agriculture?
V. What are the gaps that exist in the push-pull technology as a strategy for promoting conservation agriculture?
VI. How can push-pull be promoted as a strategy of conservation agriculture?

Discussion

Reasons for Conservation Agriculture

The agricultural conservation practices are set to prevent accelerated soil erosion by reducing anthropogenic impact, increasing ground resistance to destruction by wind and water, stimulating soil restoration, and increasing the fertility of eroded lands (FAO, 2018b; Oyeogbe, 2018). Good incorporation of the conservation practices on the farm can increase the ability of carbon restoration in the soil, improve the resistance of the ground top layer to the emission of harmful particles in the air and wind erosion, facilitates moisture penetration into the soil, reduces the leaching of nutrients due to the preservation of a large amount of organic matter, and lowers the moisture evaporation from the ground (Bouwman et al., 2021; Palm et al., 2014). This practices are done through three principles that is minimum soil disturbance, maintaining plant cover at all times and maximizing crop diversity (Fuentes et al., 2020). To realize the full potential of conservation agriculture, all three principles have to be applied concurrently.

Minimizing Soil Disturbance

Over time, tillage has been a major component of cultivation and agricultural management practices since invention of farming as a way of livelihood by human 3000 BC in Mesopotamia (Jarvis & Woolford, 2017; Lal et al., 2007). However, the system has undergone transition in tillage from the use of simple materials such as sticks and with the industrial revolution, mechanical power and tractors became available to undertake tillage operations (Brockington, 1986). Tillage was majorly done to soften the soil in preparation for planting that allow seed to be planted suitable depth into moist soil, removing the weeds from crop field, it helped release soil nutrients needed for crop growth through mineralization and oxidation after exposure of soil organic matter to air, tillage was determined to be a critical management practice for controlling soil-borne diseases and some insects, and it gave temporary relief from compaction using implements that could shatter belowground compaction layers formed in the soil (Mukherjee, 2022).

However, lately, the resechers are highly against tillage as a management practice. They claim that human interventions in soil management through ploughing leads to unsustainable agricultural systems. They have claimed that rather than tillage allowing organic matter to be worked into the soil by worms and other burrowing animals, instead buries this valuable material under the subsoil where it remains like a wad of undigested food from a heavy meal in the human stomach. The researchers have advocated for planting directly without hoeing or ploughing and reducing tillage only to ripping planting lines or making holes for planting.

Maintaining Plant Cover at all Times

Mulch, special cover crops and/or crop residues left on the field protect the soil from erosion and limit weed growth throughout the year, mostly these crops are not food crop but could be grass (Iqbal et al., 2020). This is opposed to conventional farming practices, whereby farmers remove, burn crop residues or mixes them into the soil with a plough or hoe (ACT, 2020). As a consequence, the soil is left bare, so it is easily washed away by rain, or is blown away by the wind. Cover crops manage soil erosion, soil fertility, soil quality, water, weeds, pests, diseases, and biodiversity in an agro ecosystem (Clark, 2015).

Maximizing Crop Diversity

By planting the right mix of crops in the same field, and rotating crops from season to season is a way of conserving the soil as opposed to conventional farming where the same crop is planted each season. This allows a breakdown of survival and multiplication cycles of pests, diseases and weeds resulting in higher yields and maintenance of soil fertility (Altieri et al., 2012).

Push–Pull Technology in the Promotion of the Principles of Conservation Agriculture.

Push-pull is a technology that involve **intercropping** maize or any other cereal crop with a repellent plant, such as desmodium, and planting an attractive trap plant, such as brachiaria or Napier grass as a border crop around this intercrop (ICIPE, 2011). Gravid stem borer females are repelled by desmodium from the maize or cereal crop (push) by stimuli that mask the host crop while they are attracted (pull) to the trap crop where after the eggs hatch, the larvae get trapped by a sticky substance produced by the grass, leaving the target crop protected (Gohole, 2003). In addition, desmodium produces root exudates some of which stimulate the germination of Striga seeds and others inhibit their growth after germination and over time, it reduces the Striga seed bank in the soil (ICIPE, 1998). Since it is **a perennial** and drought-tolerant crop, it is able to exert its Striga control effect even when the host crop is out of season. This reduces the number of **tillage and soil disturbance** as the weeds are organically controlled which enhances arthropod abundance and diversity and improves soil organic matter.

Achievements of Push-Pull Technology as a Strategy Promoting Conservation Agriculture

Push-pull technology has been able to increase crop yields on the farms (icipe, 2015). Reducing tillage has proven to be economically advantageous for farmers (Jarvis & Woolford, 2017). Minimizing machinery passes over the field reduces labor and saves time, limits machinery wear, and conserves fuel.

Through covering the soil, desmodium is able to control the weeds again which reduces the number of tillage, conserves soil moisture, and prevents soil erosion. Retaining crop residue on the soil surface provides a cover that reduces wind and water erosion, runoff, or particulate matter and nutrient loss, resulting in benefits for water and air quality (Cárceles Rodríguez et al., 2022). It also fixes nitrogen to the soil improving fertility. This enables cropping systems to be more resilient and adaptable to climate change while providing essential environmental services and promoting the sustainability of the farming systems.

Through the integration of crops and forage in push-pull technology, drought-tolerant desmodium, and brachiaria are able to feed the livestock throughout the year (Mutimura et al., 2020). This integration of livestock husbandry has been highly promoted increasing milk production and boosting household nutritional value (icipe, 2015). Moreover, this has diversified the majority of the mixed crop-livestock households' sources of income motivating agribusiness among small producers. In return, livestock wastes are used as organic fertilizer improving soil fertility and increasing productivity without the use of inorganic fertilizer.

Challenges Facing Push-Pull Technology Adoption as Strategy Promoting Conservation Agriculture

Despite an increase in production, a big gap still exists between the potential production and the actual output. There is no linkage between the farmers and the researchers in the implementation of push-pull technology, therefore, low adoption of the technology. The soils are less fertile, a need for short-term solution from the farmers is a necessity in push-pull technology to realize increased production which is expensive for small-holder farmers. Push-pull technology is limited to a few areas and information dissemination is not effective. There are no policies to expand push-pull technology as a way of conserving the soils. The desmodium seeds to implement the technology are not readily available for the farmers. It is expensive to produce the seeds as they have low market attraction. Low partnership levels with other organization promoting organic farming. Use of small plots by farmers who have adopted the technology does not give room for commercialization and realization of the potential returns. The technology is labour intensive compared to other system discouraging farmers from implementing. No established legal frameworks to protect push-pull plots against intruders and destruction. Low rainfall and change of wheather patterns has limited the implementation of sustainable agricultural practices especially in degraded areas of SSA region.

Other Gaps in the Push-Pull Technology as a Strategy for Promoting Conservation Agriculture

Lack of well-established policy implementation on push-pull technology in the region, the PPT technology is still concentrated in few agroecological zones, need for transform push-pull technology from the theoretical implementation to practical experiments, need to produce more desmodium seeds, need to make push-pull a complementarity and a malt-functionality to in cooperate other benefits in other sectors, Instigate a program where farmers teach other farmers on push-pull technology.

Promoting Push-Pull as a Strategy of Conservation Agriculture

Providing financial and material support to farmers such as desmodium seeds which are expensive and not readily available. Partner with the agro-dealers to disseminate the information and products of PPT to the farmers. Make PPT a molt-functionality to promote the integration and the benefits of desmodium to other sectors such as poultry. Expand the project to the garden farming system to produce high value nutrients. Team up with other organic farming promoting organization to upscale the PPT. Improve the extension system through engagement of all stakeholders including the researchers, farmers, women and the youths.

Conclusions

PPT technology meet the conditions of conservation agriculture as it conforms and support minimum soil disturbance, maintaining plant cover and maximizing crop diversity. PPT is key in promoting conservation agriculture, maintain soil fertility in effort to attain food security and maintain the environmental health.

Recommendations

PPT is a good and important initiative to small scale farmers. Farmers have reported improved yield as compared to before adopting the technology. PPT is a good solution to improve environmental and soil health in the region. Therefore, upscaling of the PPT should be accelerated to all agroecological zones especially where Striga weed is a problem as it has the potential to reduce the effect of weeds, pests, and low soil fertility. However, it should not be a sole solution to low food productivity, other short-term solutions are necessary. Inputs should be offered to farmers in order to make PPT successful in promoting conservation agriculture.

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