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The State of Soybean in Africa: Evaluating the Benefits of Implementing Soy-Maize Crop Rotations in Sub-Saharan Africa

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USAID's Feed the Future Lab for Soybean Value Chain Research, aka the Soybean Innovation Lab (SIL), is a research for development project begun in 2013. The team of 45 US researchers work in 17 countries, most of which are in Sub-Saharan Africa. The University of Illinois is the lead institution, accompanied by the University of Missouri and Mississippi State University. Recently, farmdoc asked SIL to provide a series of articles describing the state of soybean development in Sub-Saharan Africa. This series of articles describes the current state of soybean in Africa from the multiple disciplines that comprise the Soybean Innovation Lab. Peter Goldsmith is the Principal Investigator at the Soybean Innovation Lab. Feel free to reach out to Amy Karagiannakis at the Soybean Innovation Lab at soybeaninnovationlab@illinois.edu for more information on any of the topics, or if you would like to collaborate with the team.

A list of all articles published in the series can be found at: https://farmdocdaily.illinois.edu/category/areas/other/soybean-africa-series

Maize is one of the most important crops on the African subcontinent, accounting for over half of daily caloric intake in some regions. However, continuous cropping of maize has led to extensive degradation of soil and decreased crop productivity. The cultivation of soybean holds great promise in improving agricultural systems in sub-Saharan Africa. Introducing soy into rotation with maize is a method to diversify diets and better nutritional status, reduce abiotic and biotic stresses, and improve soil fertility, all the while enhancing crop productivity and generating more income for farmers.

There is great opportunity to improve crop productivity in SSA through the implementation of soy-maize rotations as a form of agricultural intensification. Maize is an important staple crop and is widely cultivated in many regions of SSA (Badu-Apraku and Fakorede, 2017; Ekpa et al., 2018). The combination of legume and cereal crops creates a stable system that can help protect soil fertility and reduce abiotic and biotic pressures, while also producing high yields (Agyare et al., 2006; Nyagumbo et al., 2016; Franke et al., 2018; Uzoh et al., 2019). Indeed, yields in maize are higher when subsequently planted after soybean when compared to continuous cereal cultivation (Agyare et al., 2006; Nyagumbo et al., 2016; Frank et al., 2018; Uzoh et al., 2019). Additionally, soy-maize rotations have been very successful in other tropical parts of the world, offering great promise to intensify agricultural production in SSA (Oliveira Duarte et al., 2007; Duarte and Kappes, 2015; Goldsmith and Montesdeoca, 2018; Adie and Krisnawati, 2018).

Several agronomic benefits are associated with the use of soy-maize rotations in the tropics, including increased soil fertility, decreased biotic pressure, and increased maize and soy yields (Agyare et al., 2006; Frank et al., 2018; Uzoh et al., 2019). Indeed, soy-maize rotations are a widely accepted system to improve crop productivity, increasing SSA cereal yields by an average of 437.17 lbs/ac or more in fields planted after a legume when compared to cereals in continuous cultivation (Baijukya et al., 2016; One Acre Fund, 2016; Franke et al., 2018).

Soy-maize rotations are widely considered a sustainable method for nutrient management in farming systems, as soy can contribute to the nitrogen economy of the soil (Kohjely et al., 2018; Franke et al., 2018; Uzoh et al., 2019). Soybean provides high-quality residues that are high in nitrogen and have a low carbon to nitrogen ratio. Rotations that include soybean decrease the need for chemical fertilizer inputs by adding available soil nitrogen (between 39- 268 lbs. ac^{-1}/year) while sometimes making less-labile forms of phosphorus more accessible to cereal crops (Khojely et al., 2018; Richardson et al., 2009).

The additional nitrogen fixed by soybeans has been found to significantly increase maize yields subsequently planted after soy (Franke et al., 2018). These results are also sustainable over long periods of time, indicating the stability of this rotation system (Agyare et al., 2006; Frank et al., 2018). For example, a long-term study in the Guinea Savannah Zone of Northern Ghana found that implementing a soybean-maize rotation helped to sustain higher maize yields over the period of 11 years when compared to other maize rotation strategies in the same region (Agyare et al., 2006). Furthermore, soybean-maize rotations provide the most total energy value and protein yield produced when compared to other rotation approaches (Agyare et al., 2006; Goldsmith and Montesdeoca, 2018). Finally, it was found that rotating between maize and legumes was more successful at increasing maize yields than traditional intercropping with both crops (Agyare et al., 2006). Additionally, legumes can improve maize's phosphorus acquisition by changing the chemical and biological properties of the soil (Frank et al., 2018).

Utilization of soy-maize rotations presents the opportunity for farmers to diversify their agricultural production systems and build resilience against devastating biotic factors. One of the largest threats to maize production in SSA is Striga (*Striga hermonthica*), a parasitic weed that can cause yield losses in maize of up to 80% (Kim et al., 2002; Kanampiu, 2018). Consequently, Striga is the most important species affecting cereal production in sub-Saharan Africa and has been credited to producing $7 billion USD in losses (Gethi et al., 2005; Kim et al., 2002). However, soybean does not act as a host for Striga and can help to reduce the prevalence of the parasitic weed. Soybeans exudate strigolactones from their roots, which induce the germination of Striga seeds (Bouwmeester et al., 2007, Odhiambo et al., 2011). This induction of suicidal germination by soybean can aid in drastically decreasing Striga weed seedbanks in the soil, consequently reducing weed pressure in later maize rotations and increasing yields (Carsky et al., 2000; Frank et al., 2018). One study found that maize yields increased by 90% when planted after a soybean rotation in Striga infested fields (Carsky et al., 2000). Additionally, planting soybean is preferable to leaving fields fallow as may native grasses can act as a host to Striga, increasing Striga seed bank and negatively affecting maize production (Frank et al., 2018).

The ability to reduce pest pressure with soy-maize rotations is less clear with nematodes, stem borers, and the fall armyworm. For example, soybeans are not effective at controlling nematode populations as they can also act as a host, causing buildups of nematode populations in the field. In a study in Cameroon, it was found that stem borer attacks increased in response to soy-maize rotations, likely due to the increased nutritional status of maize due to the soy rotation (Chabi-Olaye et al., 2005; Frank et al., 2018).

Currently, maize yields in SSA are being devastated by the arrival of the fall armyworm. Throughout sub-Saharan Africa estimated maize yield losses to fall armyworm range from 20-50% and cost up to $6.2 billion USD annually (FAO, 2018, Early et al., 2018). Although fall armyworm can affect soybean, it typically acts as a secondary pest, preferring C_4 grasses (Sosa-Gomez et al., 2017; Hardke et al., 2015). Yet, soybean can become completely defoliated by fall armyworms in circumstances where severe infestations of a typical host, such as maize, precedes the planting of soy (Sosa-Gomez et al., 2017). At the moment, little information is available about whether the inclusion of a soy rotation would help to diminish pressure from fall armyworm in SSA.

Continuous maize cultivation is believed to fuel a lack of diet diversity throughout SSA (Mango et al., 2017). Correspondingly, many studies and policy recommendations have called for increased diet diversification in SSA, beginning with diversifying agricultural production (Mango et al., 2017). Crop diversification is known to play an essential role in improving household food and nutritional security (Mango et al., 2017). Soybean is a good source of protein, which can supplement a carbohydrate-heavy diet and provide essential amino acids not found in maize (OECD/FAO 2016).

To effectively implement soy-maize rotations, it is important to acknowledge the tremendous amount of diversity present economically, politically, culturally, and ecologically in SSA. Soil types, rainfall, and climate patterns all vary greatly both within countries and across the entire continent affecting how soy-maize rotation can be applied. Sometimes these factors can act as an inhibitor or limitation to the adoption of new agricultural techniques and technologies (OECD/FAO, 2016). Consequently, there is no one singular way to increase agricultural intensification through soy-maize rotations and approaches need to be tailored to the needs of specific regions. Additionally, many of the limitations that affect soy-maize rotation efficacy are the same issues that generally affect agricultural production in SSA such as poor infrastructure, inadequate farmer extension services, limited access to agricultural resources and inputs, limited access to markets, climate change, and political instability or civil strife (Byamugisha, 2013; OECD/FAO, 2016; Tadele, 2017).

Finally, one of the biggest inhibitors to the adoption of soy-maize adoption is the initial lack of access to agricultural inputs (ex. high-quality seeds, fertilizers, and pesticides) and extension services. Accessing agricultural resources has been a persistent problem to smallholder farmers in SSA (Tadele, 2017; Goldsmith, 2018). While soy-maize rotations should reduce the need for some inputs, such as fertilizer or herbicides, and raise income through the production of higher yields, there may still be issues with farmers accessing agricultural services that could improve productivity.

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