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Multi-model approach for assessing the sunflower food value chain in Tanzania

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ABSTRACT

Sunflower is one of the major oilseeds produced in Tanzania, but due to insufficient domestic production more than half of the country's demand is imported. The improvement of the sunflower food value chain (FVC) understanding is important to ensure an increase in the production, availability, and quality of edible oil. In order to analyse causes and propose solutions to increase the production of sunflower oil, a conceptual framework that proposes the combined use of different models to provide insights about the sunflower FVC was developed. This research focus on the identification of agricultural models that can provide a better understanding of the sunflower FVC in Tanzania, especially within the context of food security improvement. A FVC scheme was designed considering the main steps of sunflower production. Thereafter, relevant models were selected and placed along each step of the FVC. As result, the sunflower FVC model in Tanzania is organized in five steps, namely (1) natural resources; (2) crop production; (3) oil processing; (4) trade; and (5) consumption. Step 1 uses environmental indicators to analyse soil parameters on soil-water models (SWAT, LPJmL, APSIM or CroSyst), with outputs providing data for step 2 of the FVC. In the production step, data from step 1, together with other inputs, is used to run crop models (DSSAT, HERMES, MONICA, STICS, EPIC or AquaCrop) that analyse the impact on sunflower yields. Thereafter, outputs from crop models serve as input for bio-economic farm models (FSSIM or MODAM) to estimate production costs and farm income by optimizing resource allocation planning for step 2. In addition, outputs from crop models are used as inputs for macro-economic models (GTAP, MAGNET or MagPie) by adjusting supply functions and environmental impacts within steps 3, 4, and 5. These models simulate supply and demand, including the processing of products to determine prices and trade volumes at market equilibrium. In turn, these data is used by bio-economic farm models to assess sunflower returns for different farm types and agro-environmental conditions. Due to the large variety of models, it is possible to assess significant parts of the FVC, reducing the need to make assumptions, while improving the understanding of the FVC.

1. Introduction

Sunflower (*Helianthus annuus* L.) is an annual plant, native from temperate North America, which is one of the four most important oil seeds in the world. Due to its high drought tolerance and adaptation to a great variety of soils, the sunflower is suitable for to be cultivation in many regions of the world. Because of sunflower oil's high quality and the resulting high demand, the cultivation of sunflower is spreading to countries in Asia and Africa (Jocic et al., 2015).

In Tanzania, sunflower corresponds to 36% of national oilseed production, accounting for production of 350,000 tons of seeds in 2008, resulting in about 90,000 tons of edible oil (RDLC, 2008). For 2013, according to the FAO (Food and Agriculture Organization of the United Nations), sunflower seed production reached close to 1 million tons, with the potential to increase in the future (United Republic of Tanzania, 2016). This near three fold increment in production from 2008 to 2013 can be attributed to an increase in cultivation area, as well as to a higher demand from the domestic market. The current market for edible oil is mainly for local consumption (contributing to about 40% of national edible oil requirement), but due to insufficient domestic production, Tanzania import more than half of the edible oil consumed in the country (RDLC, 2008; United Republic of Tanzania, 2016).

Sustainable improvement of agricultural systems requires integration of productivity enhancements, natural resource management, and institutional innovation (Schut et al., 2016). Therefore,

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interdisciplinary research concerning the improvement and innovation of the sunflower food value chain (FVC) is important for ensuring an increase in production, availability, and quality of edible oil in Tanzania. Agricultural simulation models can contribute to understanding if there is a gap between actual on-farm yields and theoretical, potential yields. They can help to improve resource allocation within farms and identify, for example, bottlenecks in processing and trade via the market models as well as investigate different interventions through scenario runs. Therefore, due to the wide range of models, from crop models to farm-level and economic models, it is possible to assess different aspects of the sunflower oil production in order to better understand all the steps along its food value chain.

Since it aggregates specialized research groups working with different agricultural models, the MACSUR (Modelling European Agriculture with Climate Change for Food Security) knowledge hub is an excellent source of models and tools that might be used to analyse the sunflower FVC. The project is divided into three themes focused (1) on agricultural modelling for crop production (CropM); (2) on livestock and grassland production as well as farm-level aspects of production (LiveM); and (3) on the assessment of socio-economic impacts (TradeM) (MACSUR, 2015). Overall, the MACSUR project seeks to benefit European policymakers, public institutions, farmers, consumers, and extension services by improving their capacity to respond to the challenges of food security and climate change. Lately, the MACSUR project is seeking to assist countries outside Europe.

Sunflower is cultivated throughout Tanzania, with production predominantly done by small farmers (95% of the producers) in areas between 0.4 and 1.2 ha, intercropped with maize, sorghum, and cowpeas. Additionally, there are a few medium and large farms (4% and 1% of the producers, respectively) growing sunflower as their main crop. In these farms, sunflower is grown using improved seeds, fertilizers, and a high level of mechanization. Regarding small farmers, the majority face a number of constraints resulting in poor yields and poor production quality, including, among others, the predominant use of recycled seeds from previous seasons; manual labour (mainly family labour) with hand tools and animal traction; poor agronomic practices; lack of access to inputs as fertilizer and agrochemicals; and poor extension services (RDLC, 2008; World Bank, 2016). According to FAO (2017), sunflower yields in Tanzania increased from 0.64 t/ha in the year 2000 to 1 t/ha in 2014. Compared yields between 1.2 and 1.8 t/ha in South Africa, there is still potential for improvement. In small farms, harvesting is done manually, while medium and large farmers use machinery. After harvesting, the oilseeds may be sold directly to processors, to middlemen, or to cooperatives. Small farmers typically depend on itinerant middlemen to sell their product (sunflower seeds), making small farmers vulnerable to manipulation, resulting in an unreliable business relationship (RDLC, 2008; Ugulumu, 2008; United Republic of Tanzania, 2016). Due to a lack of appropriate storage facilities, small farmers must face sell their seeds immediately after harvest in order to avoid post-harvest losses.

Most sunflower oil extraction is done in small oil mills using a manual pressing method; although some is extracted in a few large oil mills (World Bank, 2016). The main by-products generated from sunflower harvest and oil production include crop residues (as straw), sunflower hulls, and sunflower cake. Sunflower cake is already used in Tanzania as livestock feed, but as the Tanzanian livestock industry is relatively small, the cake is exported – mainly to India and Kenya – and, thus, it is the most important sunflower export product in financial value (United Republic of Tanzania, 2016). Meanwhile, straw and hulls could be used as an alternative biofuel source for cogeneration (FAO, 2012) or for biodiesel production (Antonopoulou et al., 2016). Sunflower oil can be sold as crude oil or as refined oil, the latter being suitable for human consumption. Currently, just few oil millers in Tanzania are able to produce refined sunflower oil directly or by refining crude oil received from the small millers companies without refining capacity (RDLC, 2008).

Other key players in the sunflower FVC include transporters (transporting sunflower seeds to the mills and the oil to the final consumers), wholesale, retailers, and consumers (Ugulumu, 2008). Smaller processors normally sell their products to local wholesalers or retailers, while the large mills either send their branded products to urban areas of Tanzania or export it.

Food crops, like sunflowers, are a promising renewable energy alternative, but the use of these crops for biodiesel production could threaten the amount of food available for human consumption (food security), especially in developing countries. Branca et al. (2016) suggests that the production of sunflower biodiesel in Tanzania is only profitable when produced on large farms (many of them owned by foreigner investors), thus threatening the Tanzanian agriculture that is based on poor and vulnerable small farmers, as well as the country's food security. The Bioenergy and Food Security analysis for Tanzania (FAO, 2012) indicates that sunflower biodiesel production is not currently viable in Tanzania due to a combination of high production costs, current diesel prices, and current edible oil prices. For this reason, we only assess the sunflower FVC for edible oil production.

The research question underlying this study is if combining different models can contribute to the analysis and further improvement of a FVC. In order to answer this question, the models must be linked in order to approach different components of the FVC, thus generating output that will be used in the next model. This approach is especially useful in data-poor environments because models can generate high quality data as outputs that may replace assumptions commonly used in such studies.

Therefore, the aim of this study is to propose a conceptual framework to allow the combined use of multiple models that provide insights about the sunflower FVC in Tanzania. The research focuses on identifying the models participating in the MACSUR project that can be coupled along the sunflower FVC to improve the understanding of value chain in Tanzania, especially within a context of food security improvement.

2. Methodology

In this work, the sunflower FVC was framed following the structure proposed by Reif et al. (2015). In this approach, the FVC is divided into five main components that encompass everything from the basic inputs preceding production through use by the final consumer: natural resources, production, process, trade, and consumption. In this framework, the residues generated at each step can be incorporated in other value chains, forming a food net. Therefore, in order to extend the interpretation possibilities of a sunflower FVC scheme for Tanzania, the framework was improved to show the physical matter flow (Fig. 1a) and process flow (Fig. 1b), addressing the main steps of sunflower production. Matter flow is described here as the input and output materials used and produced throughout the sunflower FVC. Meanwhile, process flow is described as the processes involved in the FVC, from natural processes that generate the biomass through its transformation into edible oil, for example.

In order to increase the understanding of the FVC components and their interactions, models from two MACSUR themes (CropM and TradeM) were evaluated according to their potential to be coupled along each step of the sunflower FVC. This was done by (1) identifying the main target/purpose of a given model; (2) accessing model requirements in terms of inputs and processes involved in the modelling phase; (3) the outcomes of such models that can be used as input for the next step; and (4) the applicability of the models for sunflower crop and also its validation in tropical countries like Tanzania. Furthermore, the application and contribution of each model to the FVC were described.