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Use of Integrated Soil Fertility Management Technologies in Malawi: Impact of Dry Spells Exposure

Samson P. Katengeza[a,*], Stein T. Holden[a], Monica Fisher[b]

[a] School of Economics and Business, Norwegian University of Life Sciences, P.O. Box 5003, 1432 Ås, Norway
[b] International Center for Insect Physiology and Ecology, P.O. Box 30772-00100, Nairobi, Kenya

1. Introduction

Droughts in many parts of sub-Saharan Africa (SSA) are frequent and severe with devastating impacts especially on agriculture and food security (Benson and Clay, 1998). One way to identify a drought is when average seasonal rainfall is below 75% of the normal. In addition, dry spells within a rainfall season turn into a drought if they last for more than three months (Chabvungma et al., 2015). Coupled with poor soil fertility and poor water retention capacity of the soils, 60% of SSA is vulnerable and 30% extremely vulnerable to drought (Benson and Clay, 1998). For the past four decades, SSA countries have faced a risk of failed cropping season with 10–40% probability due to drought. In the mid-1980s for example, drought resulted in the worst famine in Africa, affecting 20 countries and endangering the lives of 35 million people. The most affected regions were eastern and southern Africa, particularly the countries of Ethiopia, Kenya, Malawi, Mozambique and Zimbabwe (Shiferaw et al., 2014).

In Malawi, a country heavily dependent on rain-fed agriculture (Government of Malawi, 2011b), frequent and prolonged dry spells and low levels of nitrogen use are major causes of low crop productivity resulting in persistent food insecurity (Weber et al., 2012). Another problem faced by Malawi's agricultural sector is over-dependence on maize as a staple crop (Smale, 1995). Maize production is highly vulnerable to drought; maize productivity can be reduced by up to half when a severe drought occurs, especially during grain filling phase (CIMMYT, 2013). Over the past two decades, Malawi's maize production has been significantly low in drought years such as 1991/92, 2001/02 and 2004/05 (Denning et al., 2009; Msowoya et al., 2016; Nangoma, 2007).

Efforts to enhance maize productivity through increased drought resilience, nutrient application and nutrient maintenance are thus important to achieve sustainable food security. Such efforts require complementary investments in organic and inorganic integrated soil fertility management (ISFM) technologies and high yielding and drought tolerant crop varieties. ISFM technologies increase nutrient intake, protect the soils against degradation and minimize nutrient depletion through enhanced soil organic matter and biological activity (Vanlauwe et al., 2015; Weidmann and Kilcher, 2011). ISFM ensures nutrient balance and efficient management of soil fertility through combinations of inorganic fertilizer, organic resources, soil and water conservation technologies and crop diversification. Over time, ISFM technologies increase crop yields and yield stability.

In this paper, we use a four-wave panel dataset for Central and Southern Malawi to examine use and use intensity of two ISFM technologies – organic manure and maize-legume intercropping – and how exposure to dry spells influences their use. Organic manure and maize-legume intercropping are not new technologies to Malawian smallholders, and our longitudinal data enable an improved understanding of how the technologies have been used for a period of close to 10 years. We examine the degree to which farmers' use of organic manure and maize-legume intercropping is associated with previous experiences of dry spells, holding constant other key factors. This issue has been largely unexplored in the literature. It is reported that conservation agriculture practices can minimize the drought sensitivity of crop yields in “normal” rainfall years (Kilcher, 2007; Makate et al., 2017a; Makate et al., 2017b; Muzari et al., 2012) but may also reduce crop yield in years of high or low rainfall (Corbeels et al., 2014).

Previous research in Malawi suggests that use of organic manure increases with inorganic fertilizer use and fertilizer price (Holden and Lunduka, 2012), tenure security (Kassie et al., 2015), knowledge of manure making (Kilcher, 2007; Mustafa-Msukwa et al., 2011) and household labor availability (Chatsika, 2016; Mustafa-Msukwa et al., 2011; Snapp et al., 2002). The probability of using maize-legume intercropping has been shown to be limited by the yield advantage of maize over legumes, pest susceptibility, and a lack of appropriate legume genotypes (Kerr et al., 2007; Ortega et al., 2016). Other factors shown to influence maize-legume intercropping are market access, output prices, availability and cost of improved legume seeds, farm size and exposure to weather shocks (Asfaw et al., 2014; Kassie et al., 2015; Kerr et al., 2007; Kilcher, 2007; Ortega et al., 2016). Silberg et al. (2017) also reported that use of maize-legume intercropping increases with previous sales of legumes and noted that technologies such as organic manure and inorganic fertilizer are likely to be applied on plots where intercropping is practiced.

* Corresponding author.
E-mail addresses: samson.pilanazo.katengeza@nmbu.no (S.P. Katengeza), stein.holden@nmbu.no (S.T. Holden), mfisher@icipe.org (M. Fisher).

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We test two related hypotheses in this paper: one, exposure to early-season and late-season dry spells increases the likelihood of using organic manure; two, exposure to early-season and late-season dry spells increases the likelihood of using maize-legume intercropping. We combine household panel survey data from 2006 to 2015 and daily rainfall data from 2003 to 2015 from the Malawi's Department of Climate Change and Meteorological Services (DCCMS). We use the daily rainfall data from DCCMS to generate dry spell and rainfall distribution variables. While farmers' perception/memory of recent dry spells is an option to capture a dry spell exposure variable, this perception variable may be subjective (Duinen et al., 2015) and therefore biased. As such, we construct objective dry spell variables using daily rainfall data to minimize biased estimates. On the other hand, farmers' perceptions regarding the drought conditions on their own farm may be more accurate and take into account local heterogeneity in weather and soil conditions. Indeed, Holden and Quiggin (2017) failed to find evidence of endogeneity of farmer perception variables using data from 2012 for the sample of farmers studied herein. As such, we have estimated additional models controlling for farmer perceptions of dry spell, using data that excludes the year 2006 because of data unavailability.

In this study, dry spells are measured as the number of consecutive days (at least five) with a total precipitation below 20 mm after the onset of the rainy season.[1] We then identified the longest early-season and late-season dry spell in each of the previous three seasons of a survey year and these are the dry spell variables included in the regression analysis. Dry spells are common during Malawi's rainfall season and local meteorologists consider a dry spell as drought if their duration is three-to-four months or longer (Chabvungma et al., 2015).

Severity of dry spells has been increasing in Malawi and other parts of SSA in recent years and the use of drought-resilient technologies can help farmers adapt. For example, estimates from EM-DAT (2018) show that in 2005 the country experienced a drought that was described by local meteorologists as one of the worst in 60 years (Chabvunguma and Munthali, 2008). Approximately 30% of the country's population (over 4 million people) was affected by a subsequent hunger crisis and needed emergency food aid (Denning et al., 2009). There were also reported extensive droughts in 2008 and 2012 that affected many people. In 2015, the country reported early-season floods and late-season droughts. The early-season floods affected approximately 1.1 million people, 230,000 were displaced, and 176 and 172 people were reportedly killed and missing, respectively (Government of Malawi, 2015). The late-season drought was responsible for the poor maize harvest in 2015, estimated at 25–30% lower than the previous five-year average (FEWS NET, 2015).

2. Background

2.1. Major Weather Patterns in Malawi

Malawi has a sub-tropical climate with three major seasons. First is a cool, dry winter season between May and August before a hot, dry season from September to October. The hot, dry season is followed by the warm-wet season from November to April during which about 95% of the annual rainfall takes place. On average, the country receives 725 mm to 2500 mm of rainfall (DCCMS, 2006). Climate variability is high and weather extremes such as droughts, mid-season dry spells and floods represent severe threats to livelihoods (Chabvungma et al., 2015). The severity has increased in recent times because of climate change, population growth, urbanization and environmental degradation (FAO, 2012). Focusing on the nine-year period of our surveys, we show in Fig. 1 the average annual rainfall and maize production across the country. Annual rainfall was lowest in 2015 with an average of 918 mm while the highest was reported in 2008. It is, however, surprising that the higher rainfall in 2008 resulted in low maize production which was 19.4% less than the previous season (2007) (Government of Malawi, 2009).

2.2. Organic Manure

Organic manure is an organic matter-based technology (Snapp et al., 1998) whose sources include farm yard manure, compost manure, green manure, crop residues and household refuse (Chilimba et al., 2005; Government of Malawi, 2012; Holden and Lunduka, 2012; Kabuli and Phiri, 2006; Snapp et al., 1998). The advantage of this technology is that it enhances soil organic matter and essential nutrients such as nitrogen (N), phosphorus (P) and potassium (K) (NPK) (Mafongoya et al., 2006; Thierfelder et al., 2015a, 2015b). The technology also increases nutrient and water use efficiency, nutrient maintenance and soil pH (Heerink, 2005; Mafongoya et al., 2006; Nyasimi et al., 2017).

Organic manure is not a new technology to smallholder farmers in Malawi (Andersson and D'Souza, 2014). In fact, organic matter-based technologies can be traced back to indigenous knowledge as early as the 1970s (Mango et al., 2017). In the early 2000s, the government embarked on a campaign to promote the use of compost manure, farmyard manure and crop residues (Chilimba et al., 2005). At the national level, only 15.2% of maize plots used organic manure in 2002/03 and 2003/04 and 12.7% in 2008/09 and 2009/10 (Snapp et al., 2014).

There are several challenges to widespread use of organic manure. The first challenge is unguaranteed and unbalanced quality of nutrients. Different organic sources contain different quantities of nutrients with varying ranges (Chilimba et al., 2005; Mafongoya et al., 2006). Another reason for low use of organic manure in Malawi is that few households have livestock. As a result, available amounts of organic manure are often insufficient to meet nitrogen and other nutrient requirements for maize production (Mafongoya et al., 2006). The third challenge is the high labor requirement for making and transporting organic manure. Household labor availability may thus constrain adoption. Furthermore, because organic manure technology may be slow in releasing nutrients and it takes time to build soil nitrogen, crop yield response takes time to materialize (Snapp et al., 1998). A final challenge is there are trade-offs between using crop residues and household refuse for soil cover (mulching) versus using it for animal fodder or incorporating it as manure in the soil for more quick release of nutrients (Valbuena et al., 2012).

2.3. Maize-legume Intercropping

Maize-legume intercropping is a farming practice in which the maize crop is mixed with one or more leguminous crops. This technology can improve crop productivity and enhance the sustainability of maize-based cropping systems (Snapp et al., 2002). Empirical evidence has shown that these systems increase soil productivity through biological nitrogen fixation and conservation of soil nutrients (Government of Malawi, 2012; Snapp et al., 1998). Apart from the agronomic benefits, legume intercropping provides environmental benefits through reduced soil erosion, improved water infiltration and carbon sequestration; it also increases crop and food diversity by providing high protein grain and edible leaves (e.g. beans and cowpea leaves). All these benefits are achieved at a low cost and low risk for the farmer (Government of Malawi, 2012; Kamanga et al., 2010; Kerr et al., 2007; Woomer et al., 2004). In Malawi, the most common legumes that have been intercropped with maize are beans in the Central Region and pigeon peas in the Southern Region (Waddington, 1990; Waldman et al., 2017).

Maize-legume intercropping, like organic manure, is also an old technology among smallholder farmers not only in Malawi but also in Africa as a whole (Okigbo and Greenland (1976) in Silberg et al., 2017).

[1] Personal communication (February 18, 2016) with Charles L. Vanya (Principal Meteorologist with DCCMS)