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Perspective

Maize seed choice and perceptions of climate variability among smallholder farmers

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ABSTRACT

Despite decades of research and interventions, crop yields for smallholder farmers across sub-Saharan Africa are dramatically lower than in developed countries. Attempts to address low yields of staple crops in Africa since the Green Revolution through policies and investments in advanced seed cultivars have had mixed results. Numerous countries have heartily embraced and promoted hybrid cultivars through government subsidy programs and investments in research and seed multiplication. One possible explanation for why these programs have not resulted in more significant yield improvements is the challenge faced by farmers to select cultivars that are suited to their local environmental conditions. The question of what seeds farmers choose is exceptionally complex as it is often affected by local seed availability, the availability of information on seed performance, and the transfer of that information to farmers. At the foundation of this choice are farmers' perceptions of different seed varieties coupled with their perceptions of climate variability. We examine seed choice in Zambia, a country with decades of hybrid maize seed development and supporting policies. We demonstrate how input subsidy programs and seed market liberalization have led to choice overload and a discontinuity in information exchange between farmers and seed companies. The decision making environment is further complicated by the heterogeneity in growing conditions and its variable impact on seed performance, which complicates characterization of seed duration at the farm level. Perceptions and biases related to climate variability effect seed choice, and potentially lead farmers to make risk averse decisions, which ultimately depress maize yields.

1. Introduction: hybrid maize, input subsidies, and climate variability in Africa

The Green Revolution in Asia during the 1960s was based on the development of high-yielding varieties of staple crops (Evenson and Golin, 2003). During this period, average yields of rice and wheat doubled as a result of the improved germplasm and widespread use of fertilizer, particularly in areas with high rainfall or irrigation access. In sub-Saharan Africa (SSA), where maize is grown by the vast majority of households on rainfed agricultural land, the story is somewhat different (McCann, 2009). Despite the proliferation of hybrid varieties of maize and fertilizer across SSA, African farmers are still struggling to achieve a revolution in grain production similar to other parts of the world (Smale and Jayne, 2003). While many SSA countries like Kenya and Zimbabwe experienced significant gains in maize production since the 1960's, a substantial gap remains between actual and potential maize yields (van Ittersum et al., 2016).

Numerous countries in SSA including Ethiopia, Ghana, Kenya, Malawi, Nigeria, Tanzania, and Zambia have all implemented input subsidy programs at substantial cost to government and donor budgets (Mason and Ricker-Gilbert, 2013). The majority of these programs focus on providing inorganic fertilizer to small farmers at subsidized prices and increasingly on providing subsidized seeds, particularly hybrid maize seeds. These costly and ambitious hybrid crop and fertilizer subsidy programs have been met with limited success (Denning et al., 2009; Mason et al., 2013). While the majority of countries experienced a decrease in absolute maize production during the 1990s, others (such as Malawi) experienced an increase due to input support programs (Smale and Jayne, 2003). There are however, limits to solving the pervasive SSA yield gap through inputs, given the biophysical limitations posed by poor soil fertility and the constraints this places on improvements in crop genetics (Tittonell and Giller, 2013).

Another reason crop yields remain low is changing weather patterns and increasing frequency and intensity of weather events in SSA (Kotir, 2011; Field and Intergovernmental Panel on Climate Change, 2012; Campbell et al., 2016). Climate variability disproportionately impacts

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poorer nations and poorer, agrarian households within those nations who rely on rainfall for agriculture (Jarvis et al., 2011). The impact of climate variability on crop production is expected to constitute a significant threat to food security, particularly with crops like maize in more marginal parts of SSA in this century (Lobell et al., 2008; Rippke et al., 2016). Approximately 40% of Africa's maize growing area faces occasional drought stress resulting in yield losses of 10–25% and one quarter of the maize crop is impacted by drought with losses up to 50% of the harvest (CIMMYT, 2013).

The development of crops that are adaptable to changing weather patterns has the potential to improve food security in rainfed agricultural areas of Africa. In addition to doubling or tripling the yield of local open pollinating varieties (OPVs), some hybrid maize varieties are more adaptable to climate variability (Cairns et al., 2013). One major advance in SSA are varieties that can reach physiological maturity in three to four months as opposed to six months which is more common with OPVs. Hybrid varieties with different maturation periods have the potential to mitigate the effects of increasingly erratic growing seasons and facilitate adaptation to climate variability by maximizing the growing period (Tambo and Abdoulaye, 2012). Early maturity hybrids are more appropriate for areas with either a short rainy season (about three months) or that frequently experience dryspells or drought (Cooper et al., 2008). Additionally, early maturing varieties, can be planted later in any region if the rains begin later and still reach physiological maturity by the end of the growing season (Smale et al., 2015). Medium maturing varieties are appropriate for zones that reliably get four to five months of rains and late maturing varieties are most advantageous in higher rainfall zones that can support a six to seven month growing season. There is a tradeoff with maturity though since generally speaking, a longer maturation period translates into higher potential yield.

There is a growing literature documenting that farmers in developing countries are aware of trends in precipitation variability and employ a range of coping and adaptation strategies (Thomas et al., 2007; Mertz et al., 2008). A number of studies document various ex-ante agricultural strategies smallholder farmers use to cope with the effects of climatic variability including selecting new seed varieties (for example: Eakin, 2000; Smit and Skinner, 2002; Jarvis et al., 2011; Mercer et al., 2012). Most of the literature concerning climate adaptation focuses on demographic and economic explanations (for example: Below et al., 2012; Bryan et al., 2009; Deressa et al., 2009), and to a much lesser extent psychological and behavioral factors (for example, Jain et al., 2015). There is a growing literature regarding the importance of smallholder perceptions of climate change (Grothmann and Patt 2005; Mertz et al., 2008; Nyanga et al., 2011).

There are a number of cognitive factors that can influence farmer's perceptions of climate variability and adaptation. People rely on heuristics for judging probabilities and this can cause them to assign greater weight to more recent or extreme events (Tversky and Kahneman, 1973), which has been found to be true with farmers experiencing shocks and disturbances (Morton, 2007; Marx et al., 2007; Hertwig and Todd, 2003). There is also evidence that historical preferences or "path dependency" can influence perceptions and hinder adoption of climate adaptation technologies (Wise et al., 2014). The efficacy of one's beliefs about coping with drought is also an important predictor of an individual's propensity to adopt and maintain new behaviors (Truelove et al., 2015).

Another factor which may impact an adaptation activity such as a farmer's seed choice is their ability to evaluate multiple competing varieties of seeds. Farmers need to process many factors related to seed selection as well as to navigate the decision landscape under conditions of environmental uncertainty. Past research has found that poverty, common among smallholder farmers in SSA, impedes cognitive function (Mani et al., 2013). The choice of what seed to plant is cognitively challenging given the vast array of seed attributes and varieties a farmer must both understand and evaluate. Each farmer has unique experiences with seed varieties, unique farm conditions, and faces a different set of choices constrained by local seed availability, all of which dictate what variety they seek in a given year. In other words, farmers make seed choices based on many factors and it is unclear how important climate-related factors are relative to other factors.

With a generally weak presence of agricultural extension in SSA and an influx of seed varieties from private seed companies and non-governmental agencies, farmers are inundated with numerous yet similar choices of cultivars. Previous research has investigated farmer perceptions of seed cultivars (Gibson, 2009) and adoption of maize varieties (Fisher et al., 2015) but not unpacked the behavioral complexity inherent in the selection of hybrid maize seed cultivars by farmers given the diversity in farmers' perceptions of climate variability. We explore seed choice and misinformation by examining the following research questions: (1) How do farmers' perceptions of hybrid maize seed attributes differ from information provided by seed companies? (2) Is there a mismatch between farmers' seed choices and the timing of planting within the context of inter-annual climate variability? (3) What factors drive the choice of maize cultivars and to what extent do farmers' perceptions of climate variability matter?

We explore these research question in the context of southern Zambia, a region with relatively low rainfall conditions in a country where maize cultivation is prevalent, and hybrid maize adoption is high. While we explore these research questions in a specific context, the decision-making is similar across maize producing areas of SSA despite the high physiological and socioeconomic variability. In countries where maize production dominates, there are diverse seed types available, generally low information exchange about different cultivars, and heterogeneity of farmers' perceptions of weather events and climate trends even within a small geographic area.

2. Introduction of hybrid maize seed in Zambia

The maize seed industry in Zambia was formalized with the establishment of the parastatal Zambian Seed Company (Zamseed) in 1981 (Morris, 1998; Smale et al., 2015). Zamseed was largely organized to replicate maize seed varieties, developed by the National Agricultural Research Service (NARS), which was responsible for the establishment of shorter-season hybrid varieties. The government of Zambia also provided farmers with subsidized fertilizer and seed on credit and purchased their harvest through the parastatal National Agricultural Marketing Board (NAMBOARD) (Smale and Jayne, 2003). These new varieties combined with subsidized credit for seed and fertilizer led to a doubling of maize area in Zambia during the 1970s and 1980s (Smale et al., 2015). The establishment of similar institutions and similar investments made during the colonial period in various African countries had similar benefits for small farmers post-independence (Smale and Jayne, 2003).

As a result of pressure from the International Monetary Fund and the World Bank through the Structural Adjustment Program, the government of Zambia liberalized the seed market in the 1990s. During this process, Zamseed was privatized, and new regional and international seed companies entered the market. The number of hybrids and improved OPVs doubled between 1992 and 1996 (Howard and Mungoma, 1997). Since then, hundreds of new varieties have been released in Zambia by 14 different companies and research institutions, and the rights of almost all these varieties are held by private seed companies (Smale et al., 2015). The International Maize and Wheat Improvement Center alone released 160 drought tolerant maize varieties between 2007 and 2013 in 13 African countries (Fisher et al., 2015). Many of these new hybrid varieties were released by multinational companies on a regional scale and so many of the varieties are the same across SSA countries.

After liberalization the government abandoned NAMBOARD due to its high operational costs but found it politically infeasible to stop subsidies (Smale and Jayne, 2003). The Fertilizer Credit Program (FCP),