Agricultural Systems 124 (2014) 21–31

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Productivity and efficiency analysis of maize under conservation agriculture in Zimbabwe

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ARTICLE INFO

Article history:
Received 9 March 2013
Received in revised form 8 October 2013
Accepted 21 October 2013
Available online 22 November 2013

Keywords:
Conservation agriculture
Productivity
Technical change
Efficiency
Fixed effects regression
Stochastic frontier analysis

ABSTRACT

This study assesses the productivity and efficiency of maize production under conservation agriculture (CA). The analysis is based on a three year (2008–2010) panel sample of small holder farming households across 15 rural districts in Zimbabwe. We make a comparison of CA with alternative conventional farming methods. Our empirical strategy consists of two methods. First, using a fixed effects model, we estimate maize production functions and derive technical change estimates under CA and conventional farming. Second, we estimate a joint stochastic production frontier to compare productivity and technical efficiency between CA and conventional farming. Under CA, technical progress has been land-saving but seed and fertilizer-using, while it has been land-using but seed-saving in conventional farming. Lastly, the results of the efficiency analysis show that that farmers produce 39% more in CA compared with conventional farming, but technical efficiency levels are essentially equal in both technologies. Overall, the results show significant yield gains in CA practices and significant contributions to food production. CA is land-saving, and this is an important issue for land constrained farmers because they can still have viable food production on smaller area. However, high labor and fertilizer demands in CA present some problems in adoption amongst resource-constrained farmers.

1. Introduction

An important challenge in Zimbabwe's smallholder agricultural sector is to raise the productivity of food crop production. In the last decade, the productivity of important staples has declined amongst rural households. For example, maize yields have significantly declined over the years, from about 1500 kg/ha in the early 1990s to around 500 kg/ha after 2000 (Government of Zimbabwe, 2002). Similar to most parts of sub-Saharan Africa, agricultural productivity levels in Zimbabwe have fallen partly due to land degradation as a result of many years of erosive cultivation, and declining soil fertility (Mano, 2006). Increasing frequency of droughts due to growing variability in the climate also presents formidable challenges for crop productivity and overall food security amongst rural households (Mazvimavi, 2011).

A response to declining food production in Zimbabwe has been the wide-scale relief distribution of agricultural inputs to small-scale farmers (Rohrbach et al., 2005; DFID, 2009). As part of these agricultural relief and recovery programs, dissemination of new agricultural technologies has been seen as a strategy to complement input provision and sustain farmers' productivity. Conservation agriculture (CA) is one such technology that has been introduced to small-scale farmers as a more sustainable and productive way of farming. CA is a set of technology principles whose aim is to improve and stabilize crop yields while preserving soil and water, and minimizing the use of some inputs through precision application methods. The three basic principles of CA are: minimum soil disturbance, permanent soil cover, and diversification of crops through rotations (Twomlow et al., 2008; Thierfelder and Wall, 2010).

There have been major investments and a concerted policy drive supporting CA as a way of improving crop productivity in Zimbabwe. According to Andersson and Giller (2012), a significant number of funding agencies, international research and development agencies, and non-governmental organisations (NGOs) have taken a keen interest in promoting CA; not only in Zimbabwe but in other countries in Southern Africa. This growing focus on CA as a policy option for smallholder farmers has also stimulated research interest in evaluating the impact of CA. Specifically, does the use of CA lead to productivity gains and contribute significantly to household food security?

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0308-521X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.agsy.2013.10.004

There is a fast growing empirical literature on the impacts of CA as a technology option in resource-constrained environments in Zimbabwe and other countries in Africa. However, empirical studies have turned in mixed results. Studies by Oduol et al. (2011) and Musara et al. (2012) report that the adoption of CA practices pushes smallholder farmers closer to their production frontier. They also find that an improvement in human capital variables, such as improved access to extension and education, can significantly reduce inefficiencies in production. On the other hand, Giller et al. (2009) report that empirical evidence on CA contributions to yield gains is not clear and inconsistent. Gowing and Palmer (2008), and Nkala et al. (2011) also note that CA may not be an appropriate option for resource-poor farmers due to its high demand for external inputs such as fertilizer and herbicides.

Empirical studies that have been carried out to assess CA impacts in Zimbabwe use different methods and analytical approaches, ranging from on-station and on-farm agronomic experiments to broader socio-economic household surveys (Nyagumbo, 1999; Nkala et al., 2011; Musara et al., 2012). However, most of these studies tend to use cross-sectional data, and do not have a longitudinal dimension. Studies that do use longitudinal data do tend to focus on agronomic impacts such as yield and soil properties, but generally fail to control for household level covariates that may have important interactions in the production process. These data limitations present a challenge in drawing correct inferences and conclusions on the actual contributions of CA. In addition, little is known empirically about the nature of economic relationships, such as technical change, factor productivity, and efficiency under CA technology. For example, higher yields achieved under CA may simply be due to higher input usage but this does not necessarily translate to higher technical efficiency levels (Wouterse, 2010). An analysis of these economic relationships should generate important insights on the effectiveness of CA.

By monitoring farmers who have adopted CA over time, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has constructed a panel database, which captures production and socio-economic information of farmers practising CA in 15 districts in Zimbabwe. We make use of this panel data set in this study. Our objective is to contribute to the understanding of CA impacts by utilizing a unique data set that captures maize production under CA and alternative conventional farming practices across different agro-ecological regions. We employ a productivity and efficiency analytical approach and implement econometric methods to estimate factor productivity, technical change and technical efficiency in maize production under CA and draw comparisons with conventional farming practices.

The structure of this article is as follows: in Section 2, we briefly review the literature on CA practices in Africa. Section 3 outlines a theoretical framework for productivity analysis. In Section 4, we specify the empirical models and discuss econometric strategies for estimation. Section 5 describes the data and presents some descriptive analysis. Section 6 reports the major empirical findings from the econometric estimation. We conclude and discuss policy recommendations in Section 7.

2. Literature review

In Zimbabwe, CA is largely practiced by smallholder farmers using small farm implements, such as the hand hoe, to create planting basins. CA technologies typically involve agricultural management practices that prevent the degradation of soil and water resources and thereby permit sustainable farm production without environmental degradation (ECAF, 2002; Haggblade et al., 2004). Mazvimavi (2011) provides a comprehensive review of CA practices in Zimbabwe and other Southern African countries.

Studies have been carried out to assess the effect of CA practises in several African countries. Tsegaye et al. (2008) assess the impacts of CA on land and labor productivity in Ethiopia. Their study analyzes the adoption of the different components of CA and finds that the initial decision to adopt CA is influenced by regional location, family size, access to extension, and formal education. They find a positive relationship between land productivity and the use of CA practices. Hassane et al. (2000) evaluate the impact of planting basins and the use of fertilizer and manure on millet crops in Niger. Their study finds that farmers experienced yield gains of up to 511% between 1991 and 1996. Similarly, significant yield gains are also noted in a planting basins and applied crop residues and fertilizer achieved 56% yield gains in their cotton fields and 100% yield gains in their maize fields.

While there is evidence of CA gains in the literature, there are also studies that present a sharply contrasting assessment of CA impacts. Nyagumbo (1999) reports that the performance of CA relative to existing technologies is highly variable, and dependent on site and farmer characteristics. Gowing and Palmer (2008) examine the evidence of CA benefits amongst small-scale farmers in Africa and conclude that CA does not overcome the constraints found in low external-input systems. They note that CA can deliver the productivity gains required for food security and poverty alleviation targets only if farmers have access to fertilizers and herbicides. They further assert small-scale farmers are not likely to completely adopt CA, but only as a complement to existing management practices. Giller et al. (2009) suggest that the empirical evidence is not clear and inconsistent regarding CA's contribution to yield gains. Their study highlights concerns that include decreasing yields under CA, higher labor requirements when herbicides are not used, a shift of the labor burden to women, and problems with meeting mulching requirements. They also note many cases where the adoption of CA is temporary and only lasts as long as NGOs and research institutions are present, but once the organizations leave, CA is disadopted. Nkala et al. (2011) carry out a meta-analysis of the impacts of CA in Southern Africa and find that CA is better suited for smallholder farmers who can readily access farm implements, financing, and other livelihood assets. Their study concludes that the effectiveness of CA towards improving livelihood outcomes in Southern Africa remains debatable, especially when supportive government policies are lacking. Lastly, Andersson and Giller (2012) note that the appropriateness of CA in highly diverse smallholder farming systems is unclear, and that adoption is only suitable for a limited number of farmers.

Although the studies that have been highlighted above provide key insights, little has been done in the literature to analyze productivity in CA within a longitudinal framework that assesses evidence of technical change in CA relative to conventional farming technologies. In addition, possible differences in the nature of technical progress with respect to input use under CA and conventional farming have not been explored empirically. While evidence of positive productivity impacts under CA have been reported, we do not know whether or not farmers are technically efficient under CA. This paper seeks to contribute to this literature by addressing these gaps. This article will highlight important differences in the contribution of factors of production to technical change in CA relative to conventional farming. In addition, we investigate the efficiency of CA. Together, these results will help to inform best practices and guide policy on technology adoption in small-scale agriculture.