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The farm-level economics of conservation agriculture for resource-poor farmers

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ABSTRACT

The farm-level economics of conservation agriculture (zero tillage, mulching and crop rotation) are described, reviewed and modelled. The economics are defined broadly to include not just short-term financial benefits and costs, but also the whole-farm management context, constraints on key resources such as labour and capital, risk and uncertainty, interactions between enterprises, and time-related factors, such as interest rates and the urgency of providing for the farm family. A wealth of evidence shows that these economic factors and variables related to them have significant influences on farmers' decisions about adoption of conservation agriculture. Literature on the farm-level economics of conservation agriculture for resource-poor farmers is reviewed. There is not a large body of high-quality relevant studies. Those that have been published highlight that the economics are highly heterogeneous and need to be considered on a case-by-case basis. Their results tend to indicate that it would be profitable to adopt conservation agriculture or components of it (although not in all cases). This contrasts with disappointing adoption in many of the regions of interest. Potential reasons for this disparity are discussed. A general model of the farm-level economics of conservation agriculture and its components is presented, and used to illustrate influences on the overall economic attractiveness of conservation agriculture. Key factors that would tend to discourage adoption in situations that otherwise look favourable include: the opportunity cost of crop residues for feed rather than mulch, the short-term reduction in yields under zero tillage plus mulching in some cases, combined with short planning horizons and/or high discount rates of farmers, farmer aversion to uncertainty, and constraints on the availability of land, labour and capital at key times of year. Good quality economic analysis should be used more extensively to guide research and extension in this area, particularly in relation to the targeting of effort, and adaptation of the system to suit local conditions.

1. Introduction

In response to concerns about food security, farm profitability, and land degradation in agriculture around the world, a range of practices have been developed and promoted to farmers. In developing countries, much attention has been given to a specific combination of measures packaged under the banner of "Conservation Agriculture" (CA) involving the key components of zero tillage (or at least minimum soil disturbance), retention of crop residues for soil cover (mulching), and rotation (or sometimes intercropping) of cereals with legumes (Kassam et al., 2009), or sometimes with other crops. In 2012 it was estimated that 9% of the world's cropland area was being farmed under CA (Friedrich et al., 2012) with the largest areas being in South America. There has been much more extensive adoption of some of the components but not necessarily within the CA 'package'. For example, zero tillage (or no-tillage) has been a major success story in several agricultural systems of North America (Fulton, 2010; Horowitz et al., 2010) and Australia (Llewellyn et al., 2012) but not always in association with all other CA components.

The success of these land conservation and soil fertility measures in the countries mentioned above has largely evaded South Asia and Africa. There are certain local success stories, but overall, uptake of CA as a package in these regions has been disappointing (Friedrich et al., 2012; Giller et al., 2009). As noted by Erenstein et al. (2012, p. 181), there are "substantial challenges in terms of targeting, adapting and adopting CA—particularly for smallholders in the (sub)tropics". The findings of a meta-analysis of field experiments from around the world (Rusinamhodzi et al., 2011) demonstrate the agronomic challenges for broad adoption. Their analysis shows an increase in maize yield over time with CA practices in low

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rainfall areas, but results are highly dependent on rainfall, soil type and nitrogen fertiliser inputs. For example, one of the key components of CA, mulching, led to reduced yield in most high rainfall situations but was important for success in dry areas. What is clear is that agro-ecological conditions play a major role in determining the benefits of CA and its components. An additional challenge, potentially even more difficult, is the need for socio-economic considerations that favour successful adaptation and adoption (Giller et al., 2011a; Pannell et al., 2006).

Economics may help us to understand and address these challenges. We define economic drivers broadly to include not only returns from production but consideration of the whole-farm management context, constraints on key resources such as labour and capital, risk and uncertainty, interactions between enterprises, and time-related factors, such as interest rates and the urgency of providing for the farm family. Economic drivers at the farm level have been one of the key factors influencing the adoption of CA practices in Australia (D'Emden et al., 2006, 2008) and the Americas (Gray et al., 1996) and are highly likely to be influential in determining potential adoption in Africa and South Asia. The statement that farmers often respond to the farm-level economics of CA does not imply that farmers respond in a strictly predictable or rational way. Rather, the economics provide insights into trends and tendencies that are likely to be observed across populations of farmers, and can help assess the potential of practices for wide adoption.

In Africa and South Asia, when the farm-level economics of CA are sufficiently favourable, adoption of specific practices can be rapid and extensive. One example is the adoption by smallholders of zero tillage for wheat in parts of the Indo-Gangetic Plains in northern India (Erenstein et al., 2012). On the other hand, there has been little sustained adoption of CA in Sub-Saharan Africa, with local exceptions in Ghana, Zambia and Tanzania (Giller et al., 2009). This can be viewed as a result of economic benefits not currently being large or obvious enough to overcome other existing barriers to adoption.

We note that our concept of the farm-level economics of CA is broader than commonly considered in many mentions of economics in the CA literature, or indeed in many of the published economic analyses we review below. Farm-level economics is not just about immediate financial gain, but should also include, at least: farming systems complexities (e.g. enterprise interactions); long-term comparisons (consistent with the length of the planning horizon of relevant farmers); and personal preferences (e.g. for or against risk). In the case of resource-poor agriculture, the potential trade-off between ensuring the basic immediate-term needs of smallholder farm households and the promise of future improved productivity needs particular recognition (Affholder et al., 2010). Conclusions on the economics of CA should not be reached without consideration of constraints (e.g. on labour or capital) and the potential for acquiring information and skills.

Economic outcomes of CA are likely to be specific to particular people, places and situations (FAO, 2001; Uri, 1999; Gowing and Palmer, 2008). This is due to heterogeneity between regions (e.g. Erenstein et al., 2012, p. 186) and between farms in a region (Tittonell et al., 2005), and heterogeneity in institutional factors (Stonehouse, 1996), farm sizes, risk attitudes, interest rates, access to markets (for inputs and outputs), farming systems, resource endowments, and farm management skills, driving differences in benefits and costs of CA.

Heterogeneity may also operate within a farm where soil types may result in farmers choosing to adopt CA on some parts of their farm but not others (e.g. Baudron et al., 2012) and different cropping systems suiting some crops and not others (e.g. Erkossa et al., 2006). There may also be heterogeneity in how adoption proceeds. In some cases it may involve step-wise adoption, starting with the component of a 'package' that provides the best returns to the farmer's limiting resources (Byerlee and Hesse De Polanco, 1986) rather than adoption of the full CA package. As a result, the component that is adopted first can vary depending on the situation (Mazvimavi and Twomlow (2009). Chiputwa et al. (2011) found that in a study of CA use by Zimbabwean farmers only 20% had adopted all components of CA and that adoption of each component was affected by a distinct set of factors. CA systems can also diverge through local adaptation to suit farmers' own personal circumstances or preferences (Giller et al., 2011b; Erenstein, 2002).

Reviewing a large number of studies of CA adoption, Knowler and Bradshaw (2007) concluded that the adoption process for CA is highly heterogeneous, and that "there are few if any universal variables that regularly explain the adoption of conservation agriculture across past analyses". In reference to the plethora of individual specific variables that have been related to adoption (e.g. proportion of land devoted to row crops, expenditure on fertilizer, length of growing season), this is not surprising. However, the great majority of factors that have been found to be statistically significant explanators of extensive CA adoption relate one way or another to the farm-level economics of CA; they generally relate to the benefits, costs or risks of CA, the farm's human, financial or land resources, or the farmers' risk and time preferences. The study also highlights social capital as being widely relevant in CA adoption. All this means that it is necessary to consider site-specific conditions in determining the financial attractiveness of CA (FAO, 2001) and efforts to promote CA should be targeted to those regions and situations where there is confidence that it generates sufficient benefits to outweigh the costs and the risks. Thus, not just CA itself, but CA extension efforts need to be tailored to reflect the particular conditions of individual locales (Knowler and Bradshaw, 2007).

The aim of this paper is to help understand the farm-level economics of CA in smallholder agriculture, typified by those of Africa and South Asia. There are important differences between agriculture in these two regions, with South Asia having more examples of larger and better-resourced farming systems. As will become clear below, some of the advantages and disadvantages of CA are related to farm scale and intensity, so the economic performance of CA should not be presumed to be the same in both regions. Nevertheless, compared with most commercial farmers in developed countries, farmers in these two regions have smaller properties and may face tighter constraints on key resources of labour and capital, have higher levels of aversion to risk and uncertainty, have poorer access to markets for farm inputs and outputs, and may face different time-related pressures through a pressing need to provide for the farm family and/or through high costs of borrowed finance. These factors influence the economics of CA. Relevant questions include, under what circumstances are the farm-level economics of CA likely to be favourable, which factors influence the economic attractiveness of CA (and its components) to farmers, and is adoption of the whole CA package more beneficial than adoption of a subset of the CA components?

In the next section we present a conceptual framework for thinking about the role of the farm-economics of CA. In subsequent sections we use the framework in two ways. First we use it as a prism to review existing literature on the farm-level economics of CA in Africa and South Asia. Secondly, we use it as the basis for development of a quantitative model of the economics of CA adoption, and use that model to explore how the economic performance of CA and its components vary in different circumstances.