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Graphics:
Patricia Scullion

Book composition:
Claudia Maestrini

Viale Golgi, 2 - 27100 Pavia
Tel. 0382529570 - 0382525709 - Fax 0382423140
www. lagoliardicapavese.it
e-mail: info@lagoliardicapavese.it

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MULCH AND COVER CROPS BASED CROPPING SYSTEMS: DO THEY FIT INTO SMALL SCALE FARMS OF THE TROPICS?

M. Corbeels[1], F. Affholder[1], E. Scopel[1], D; Jourdain[2], F. A. Macena Da Silva[3]

[1] UMR System, Dep. PERSYST, CIRAD, Montpellier, France, marc.corbeels@cirad.fr
[2] UR Geau, Dep. ES, CIRAD, Montpellier, France, damien.jourdain@cirad.fr
[3] Embrapa Cerrados, Planaltina, DF, Brazil, macena@cpac.embrapa.br

Introduction

Smallholder farming systems in the tropics are characterized by poor productivity and unsustainable soil management. Over the past three decades many attempts have been made to reverse this situation by introducing new, more sustainable cropping systems. However, only few of them were successful. Direct seeding mulch-based cropping systems (DMC) based on no-tillage and with a permanent cover of a mulch of plant residues are increasingly cited as a promising and innovative alternative to conventional cropping systems with tillage. The potential of DMC systems to improve soil fertility and sustain crop productivity is widely cited. It is also often supposed that DMC systems bring an economical advantage to farmers because of savings in energy, labor and operational costs. Yet, while DMC is rapidly disseminating among large, mechanized farms in north and south America and in Australia, their adoption by smallholder farmers in the tropics remains rare.

In this paper we present results of ex-ante evaluations of DMC systems using simulation modeling and linear programming with the aim to gain insight in factors that influence adoption by smallholder farmers in the tropics.

Methodology

Although adoption decisions are complex and depend on a range of personal, economic, social and cultural factors, the degree to which innovative cropping systems provide relative benefits compared to the existing systems is often a determining factor. A systematic ex-ante assessment of the relative agronomic and environmental advantages or benefits of DMC opposed to tillage-based cropping systems can be done through quantitative simulation models that represent the current process-based knowledge.

For the evaluation of DMC systems at field scale we modified the crop growth model STICS (Scopel et al., 2004) to simulate effects of surface crop residues on soil water, carbon and nitrogen dynamics and tested the modified model against experimental data from studies on DMC in west Mexico (semi-arid climate) and central Brazil (subhumid to humid climate). As indicators for productivity we considered grain yield and its variation with rainfall. Soil organic matter and nitrogen balances were used as indicators for sustainable soil management. To quantify the effect of DMC on long-term dynamics of soil organic matter we used the linked plant-soil model G'DAY (Corbeels et al. 2006). The performance of the model was tested against data from a DMC chronosequence in central Brazil.

For the assessment of the feasibility and impact of DMC at farm level, we developed a linear programming model, and used this model in a case study in the northern mountain region of Vietnam. In this study different farm types were considered, ranging from subsistence farms to farms that were market oriented. The potential adoption of growing maize under DMC on these farms was analyzed. The objective functions of the model maximized household food security and cash income.

Results

Evaluation of DMC at field scale

Retention of crop residues on the soil surface is the major factor that contributes to a better soil water balance under DMC. Our modeling results showed that under the semi-arid conditions in Mexico, where rainfall variability is high, even small amounts of surface residues are effective at reducing water loss (surface runoff and soil evaporation) giving rise to higher crop yields with smaller risks of crop failure. Under the humid conditions of the Cerrado region in Brazil, potential gains in water trough a decrease in runoff and evaporation are largely offset by increased drainage losses, with possible leaching of nutrients. As a consequence, under these climatic conditions the impact of DMC on water-limited crop yield is small and the use of cover crops as nutrient recyclers becomes crucial. A reduction of the bare fallow period under DMC by implementation of a cover crop induces positive effects on the nitrogen balance and maize productivity.

Continuous DMC cropping is effective in increasing soil organic matter in the long-term in the context of the large, mechanized farms in the Cerrado region of Brazil. The extra biomass produced through the cover crop allows rates of soil carbon storage of between 0.7 to 1.2 Mg of C ha^{-1} $year^{-1}$. In contrast, our modeling scenarios show that the lower crop productivity as a result of the lower inputs of nitrogen and phosphorus in the smallholder farms of the Cerrados limits the potential of DMC for soil organic matter storage under these conditions.

Evaluation of DMC at farm scale: a case study in Vietnam

The linear programming model allowed us to test whether farmer's objectives are best met by adopting DMC or conventional cropping given the available land and equipment resources and taking into account seasonal cash and labor constraints. The feasibility of DMC for the various types of farms in the study area was highly variable as a result of the (i) strong variation of the agronomic performances of DMC across environments as compared to the conventional systems, and the (ii) strong heterogeneity of the farming systems, especially with regard to their access to markets and assets. In many cases incentives would be required to counterbalance the reduction of farm income associated with adopting DMC during the first years after implementation due to the higher input and labor requirements, especially at planting time, compared with conventional systems. Even though the profitability of DMC may increase with the number of years, the first-year income reduction is likely to determine the attractiveness of DMC for smallholder farmers. Moreover, DMC systems require a greater intensity of management than the conventional systems and may be perceived as increasing the overall complexity of the farming system. More complexity may contribute to an increased risk of non-adoption.

Conclusions

Mechanistic, process-based crop growth models are an excellent tool for an ex-ante quantitative evaluation of agronomic and environmental performances of DMC systems at field scale. Our results underlined the great potential of DMC for improving crop productivity through a better water and nitrogen use efficiency. In terms of environmental indicators (soil organic matter and nitrogen balances) the modeling scenarios confirmed the clear advantages of DMC over the conventional cropping systems. Evaluation of DMC at farm scale highlighted, however, the constraints for adoption of DMC as a result of higher labor and cash inputs.

Our ongoing research aims at a more integrated evaluation of DMC, taking into account social indicators and perceptions by farmers and other stakeholders (Lopez-Ridaura at al.,2005). This will allow a more refined understanding of DMC adoption constraints and can help in identifying economic measures that may support adoption of DMC by farmers. Further evaluation of the environmental services provided by DMC systems is also required in order to test whether these services are worth the cost of incentives.

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