Adapting precision farming principles to organic crop production

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***Abstract* - Precision farming is a discipline that aims to increase efficiency in the management of agriculture throughout new technologies. Organic crop production systems in the future need to combine satisfactory productivity with long term sustainability. The aim of this paper is to present potentials and limits using precision farming priciples in organic crop production**[1]

INTRODUCTION

Public awareness of the environmental impacts of agricultural production on soil, water, air and habitat resources has highlighted the need to develop more sustainable practices. Organic crop production systems in the future need to combine satisfactory productivity with long term sustainability and be socially sound (Ohlander et al, 1999). In organic grain production, the combination of climatic (i.e water deficit or excess, heat temperature), harmful organisms (i.e pest, pathogens and weeds) and agronomical factors (i.e nitrogen deficiency, soil compaction) often induce irregular and low productivity (5 to 50 % less than conventionally managed crops*,* Nieberg and Schulze Pals, 1996) and low quality (i.e low protein content for baking wheat, Gooding et al, 1993). Despite environmental benefits of organic production on biodiversity and habitat resources, inadequate farmers' practices (i.e crop rotation, soil tillage and N management) could create nutrient leaching and volatilization.

The aim of this paper is to outline the potential interest of precision farming on organic crop production. Precision farming is an agricultural method that aims to increase efficiency in the management of agriculture. It is based on the development of new technologies and integration of monitoring and computing at farm and/or field level to achieve a particular goal (Blackmore, 1994).

Model-based decision support

Mechanistic models are increasingly used to improve crop management and farming systems (Boote et al, 1996). This trend results from the development of mechanistic models and inadequacies of field experiments for responding to the development of sustainable agriculture (Meynard et al, 2002).

Therefore, several models have been developed to meet limited and well-defined objectives like N management by simulating the dynamics of crop requirements and N supply in the soil (i.e CERES, EPIC, APSIM, ARCWHEAT, STICS models).

Although these models are highly used in research, their complexity and input requirements have limited their practical use for farm decision makers. Furtermore, Doyle (1990) outlines that farmers are rightly suspicious of computer-generated predictions when researchers are more preoccupied by model-building rather than applications.

Potential use of decision support system on organic crop production

Recently, there has been substantial advance in modeling capable of (1) simulating a diverse range of crops and forages in rotations or mixtures, (2) exploring yield performance but also quality indicators, (3) considering strongly resource constrained situations (Keating and McCown, 2001). For instance, Brisson et al (2004) adapted the STICS simulation model to intercropping system to predict intercropped yield performance, evaluate N fixation and leaching and define intercropping strategies (sowing dates, plant density, earliness). This technique is extremely relevant in organic agriculture to prevent N leaching, improve quality of products and manage pests, diseases and weeds via natural competitive principles. Within INTERCROP EU project, this model was tested to predict organic pea-barley intercropping system with a special emphasis on N fixation and uptake. Nonetheless, this study showed that STICS model is not suited to organic agriculture when limiting factors as weed infestation and pea weewil damage during nodule establishment affected strongly yield performance.

Thus, it is necessary, first, to adapt model to organic agriculture by direct or indirect insertion of the incidence of limiting factor, and then, combine models with field observations or diagnosis tools that allow adjustment of the models in the course of the growing season.

Furtermore, decision-making tool could be useful in organic crop production for tactical decisions. The analysis and evaluation of spatial pattern of harmful organisms (pest, pathogens and diseases) in crop yield losses is essential in organic agriculture. Although the general effects of spatial pattern of harmful organisms on crop yields have been characterised in crop models, the importance of these effects in particular cases will only be established by increased emphasis on field studies and diagnosis (Hughes, 1996) For instance, David et al (2005a) demonstrated that optimal strategies of N fertilization on organic wheat can be selected from the Azodyn-Org model (calibrated in conventional agriculture and adapted in organic agriculture, David et al, 2004), as soon as the occurrence and effect of limiting factors on the field can be predicted. Then, it is necessary to develop early indicators to forecast the occurrence of limiting factors (climatic stress, harmful organisms and agronomical factors) and their effects on yield and grain protein content by using field observations, existing decision

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support systems and/or diagnosis method (David et al, 2005b; Casagrande et al, 2006).

There is also a need to calibrate model prediction during the crop cycle. For instance, rapid, non-destructive estimation of total chlorophyll and nitrogen content, as chlorophyll meter (Minolta Soil–Plant Analysis Development (SPAD)), is an efficient tool to adjust model prediction before nitrogen fertilizer application (Aregui et al, 2006. Nonetheless, most decision support systems are calibrated under optimal conditions (where others limiting factors are controlled) when it is not suited to constrainted situations, such as organic farming.

At a later stage and "in order to make it more accessible to others in an intellectual and practical sense", simplifications may be necessary to solve practical problems. In its simplest form, a decision support tool could be a threshold pest or weed infestation level calculated from empirical relations based on field data and/or detailed experimental work (Zadoks, 1985). However, their value is generally limited to the specific conditions at which the experiments were done.

Precision farming and applications

The need to link model assessment of production practices and technology options with farmer-led experimentation poses new challenges of how to communicate model outputs in simple ways that have meaning with farmers. For instance, David (2004) demonstrated that recommendations managing N fertilization in organic wheat crops are hardly transferred to farmers in terms of tables and graphs that researchers are familiar. While this initiative is in its infancy, David et al (2005) show the interest to use spatial elements (maps combining soil, weather and farming systems at the regional scale) and simulation procedure to enrich discussions between farmers, advisers and researchers at the regional scale. Moreover, Rossing et al. (1997) indicated that models could be a useful tool by bringing together researchers, farmers and processors to come to an agreement on the requirements, for instance, on price and quality, between farmers and millers.

Conclusion

The diverse engineering approaches used in organic agriculture had clearly illustrated the difficulty to achieve balance in modelling between simplicity and complexity, transportability and performance (Montheith, 1996). For instance, the prediction of pest, diseases and weeds dynamics and/or incidence on crop production is quite difficult because of the complexity and nature of the process (Kropff et al, 1995). Nonetheless, there is a crucial need to develop new knowledge on the incidence of combined limiting factors on yield losses in organic agriculture. Therefore, risk analysis method should be incorportate in the decisions rules to take into consideration weather, soil, harmful factors variability.

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