SILASOL: A MODEL-BASED ASSESSMENT OF PEA (*PISUM SATIVUM* L.) CULTIVARS ACCOUNTING FOR CROP MANAGEMENT PRACTICES AND FARMERS' RESOURCES

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INTRODUCTION

Integrating pea into cropping systems has agronomical and environmental advantages which are linked to the capacity of the pea plant to fix atmospheric nitrogen, in turn available to the following crop (Munier-Jolain and Carrouée 2003). It also allows a diversification of the crops in systems containing frequently cereals and oilseed rape, thus a decrease of diseases and weed pressure. Moreover, *Pisum sativum* L. species offers a wide range of winter and spring cultivars that should enhance integration of pea in various types of farming systems. However, spring cultivars, which represent the major part of cultivars in French fields, suffer from high temperatures, water shortage at the end of their life cycle and compacted soil structures when they are sown too early. Winter cultivars escape to thermal and water stress at the end of the crop cycle, but remain sensitive to frost during winter. Seed breeders thus endeavour to create cultivars that have phenotypic characteristics allowing to cope with climatic stresses and to escape to compacted soil structure. Further more, the assessment process for registration of new cultivars in France relies on optimum field experiments, which differ significantly from those encountered in real production situations. Due to shortage of working resources (labour and machinery) for instance, farmers often have to perform cultivation operations at unsuitable climatic periods, leading to the compaction of the soil structure which affects yields (Vocanson 2006). The performances of the cultivars depend on the climatic conditions during the crop cycle, but also on the crop management applied to the cultivar (sowing date for example), itself depending on the global organisation of the farm. In order to help breeders identifying the characteristics allowing the best performances, an ex ante evaluation, based on modelling, can be useful. The paper outlines the simulation model SILASOL developed to support the design of pea cultivars. The originality of the model lies in its capability to take into consideration the interactions between biophysical processes (crop growth, soil compaction) and practical crop management concerns.

MATERIALS AND METHODS

The biophysical part of the SILASOL model is based on two existing dynamic models. The first one, AFISOL (Vocanson 2006), is a climate-responsive pea growth model simulating the plant development, biomass production and storage within the vegetative parts of the plant and the seeds (yield) and the frost resistance mechanism. The second one, SISOL (Roger-Estrade et al. 2000), estimates the dynamic evolution of the soil structure (compaction or fragmentation) as a consequence of mechanical operations, thanks to equations linking equipments features, hydraulic dynamics and properties of soil layers. In addition, simple models simulating the water balance and mineralization are designed for barley, wheat and oilseed rape, which are the other crops potentially interacting with pea production for resource demand in this case study. The re-engineering and integration of these models have been done using an object-oriented simulation package called DIESE that includes a discrete event simulation engine and an ontology-based modelling framework (Martin-Clouaire and Rellier 2009). This tool has specifically been designed to support the modelling of the interactions between a biophysical system (crop and/or livestock systems) and its management by a farmer in relation with climatic conditions. DIESE provides basic constructs to represent management activities, their temporal organization in plans and their requirements for resources such as labour and equipments. The farm management and crop practices included in the model come from interviews carried out with a farmer from the North of France and an analysis of his technical notebooks over the last fifteen years.

RESULTS AND DISCUSSION

Presently, the main result of the project concerns the SILASOL model, essentially the biophysical models and management plans for the different crop sequences on the farmer's fields. The first step in building crop management plans is to make a particularization of the generic concept of operation involved in the crop production process: *ploughing*, *secondary ploughing*, *sowing*, *weed killer spraying* and *harvesting*. Each of these operations has properties such as speed, feasibility conditions, required machinery resources and effect on the biophysical system. For instance *secondary ploughing* requires specific resources - a tractor and a plough - that determine its speed. Its feasibility conditions refer to the soil humidity properties and thresholds above which mud prevents proper use of the equipments. Its effect is to suppress compactness of the soil caused by previous operations. In the second step we specify primitive activities that are composite objects consisting each of an operation (e.g. *ploughing*) applied to a biophysical entity (e.g. a field) by one or several workers. Among its essential properties, a primitive activity possesses two conditions defined by calendar dates or state-based conditions. These conditions allow the execution of the activity when it is relevant according to the farmer's objectives and practices. For instance, the activity *pea-harvest* involving the *harvesting* operation on a pea crop is declared relevant as soon as pea seeds reach their maturity and irrelevant after a given date. Then, the way the farmer grows each crop on each field of his farm during a year is described by a sequence of primitive activities. Finally, human resources (workers) are specified by the constraints pertaining to their time availability and the possibility for them to be engaged simultaneously in several operations or on several fields. Since several crops are grown at the same time on different fields of the farm, the demand for resources may be larger than the supply.

SILASOL simulates (i) the dynamic examination of the activities that are ready for execution, (ii) the allocation of the farm's resources, and finally (iii) the execution of these activities. We simulate the crop sequence over the duration of the rotation in order to assess the pea performance (e.g. yield variability) as well as the management practices with respect to a range of climate scenarios. Like in any experimental approach, this type of virtual exploration requires the construction of a kind of design experiments. The results obtained with the SILASOL model as a framework of virtual experimentation are too preliminary to be reported in this communication. SILASOL will be used by farming systems researchers in partnership with seed breeders to design pea cultivars that have suitable features (e.g. flowering precocity, speed of growth, seed weight) regarding real production situations.

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