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A participatory approach to design spatial scenarios of cropping systems and assess their effects on phoma stem canker management at a regional scale

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ABSTRACT

Phoma stem canker is a worldwide disease of oilseed rape, responsible for major economic losses. The main control methods are the use of resistant cultivars, cropping practices and spatial territory organization, involving large-scale spatial processes. A participatory approach can be useful for dealing with this problem, which requires stakeholders' coordination as regards to the timing and spatial layout of cropping practices. The scenario concept is used to plan possible future cropping systems and to reveal their main drivers. In this paper, we test a method to build quantitative land use scenarios and to test them with an existing spatially-explicit model to assess the effects of various scenarios on phoma stem canker management. It was built from previous participatory methods. The method we tested is composed of six steps: stakeholder identification, building with them a common vision of the disease behaviour, collective scenario design, and discussion with stakeholders of model-based scenario evaluations. We tested this method on a regional case study application in France. This application revealed benefits of the method with respect to the diversity of the designed scenarios (predictive and exploratory scenarios; driven by local or global context change) and the diversity of results on phoma stem canker management. Based on this application, recommendations for participation improvement and model acceptance are made: (1) build a partnership with a key local stakeholder; (2) describe and discuss precisely model functioning with stakeholders (avoid the "black box"); and (3) facilitate interpretation of scenario assessment by adapting model outputs. This method, combining a participatory approach (qualitative and quantitative construction of scenarios and their evaluation with an existing model) highlights the potential benefits of involving stakeholders in attempting to solve a local problem, in this case, phoma stem canker management.

1. Introduction

Phoma stem canker (caused by *Leptosphaeria maculans*) is a worldwide disease of oilseed rape, responsible for major yield and economic losses (Fitt et al., 2006). In a context of an increasing oilseed rape area and production in Europe (Eurostat, 2011), controlling this disease is of prime importance, through (i) a reduction in the pathogen population size and (ii) a limitation of the selection pressure on pathogen populations (Avirulence Management concept, Aubertot et al., 2006). The main field control method is the use of resistant cultivars: partial (quantitative) resistance, reducing the effect of the disease (Delourme et al., 2006) or specific resistance halting the disease if the pathogen and plant harbour a common resistance gene (Flor, 1971). Yet specific resistance can be quickly overcome if the pathogen population adapt when cultivars with this resistance are grown on large areas (Rouxel et al., 2003), leading to risks of large epidemics and subsequent economic losses because of the breakdown of the resistance. Other control methods include cropping practices, e.g. sowing date, fertilization (Aubertot et al., 2004) and tillage practices after Winter OilSeed rape harvest (Schneider et al., 2006). However, studying phoma stem canker

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requires scaling up in both time and space. Firstly, considering the landscape scale is necessary to control this disease, as the responsible pathogens are wind-dispersed up to several kilometres (5–8 km; Bokor et al., 1975). Secondly, management strategies have to be planned for the medium term because of the epidemic cycle of the disease, i.e. the disease in a given year affects its severity in the next year, as primary inoculum develops on oilseed rape-infected residues (Hall, 1992). According to Sprague et al. (2006), these "integrated strategies" have to consider cropping practices, cultivar resistance and deployment. While scaling up, control methods may thus involve distributions of cropping practices over time and space (Lô-Pelzer et al., 2010a), including genotype deployment (Delourme et al., 2006), but also the proportion of oilseed rape within the landscape (Fitt et al., 2006). Thus cropping systems enabling sustainable disease control through an increase in the duration of cultivar resistance efficacy have to be managed on a regional scale to minimize disease incidence, helping to stabilize yields and keep oilseed rape economically competitive. With this aim, a spatially explicit numerical model (SIPPOM-WOSR; Lô-Pelzer et al., 2010a, 2010b) has been developed to support the design and assessment of scenarios of regional cropping system management to allow efficient control of the disease and resistance sustainability.

To study potential impacts of spatially distributed cropping systems, land use scenarios can be very useful. van Notten (2005) describes scenarios as "descriptions of possible futures that reflect different perspectives on past, present and future developments", consisting of an initial situation and a description of driving forces inducing a specific future (Alcamo and Henrichs, 2008). Scenarios require identification and consideration of the main drivers of future changes (Dockerty et al., 2006). The causes of change can be physical/ecological (e.g. climate change), social and/or economic (e.g. political, urban). Designing, analysing and assessing future scenarios for phoma stem canker management require consideration of the regional context, together with the spatial extent of the disease and the stakeholders' activities affecting and/or affected by the disease.

For issues involving large-scale spatial processes, designing land use scenarios can benefit from a participatory approach: different studies have shown the value of involving stakeholders concerned with the coordination of actions to promote scenarios that are effective with regard to the issue (e.g. on erosive runoff risks, Souchere et al., 2010). Indeed, local stakeholders take or influence decisions for agricultural production and landscape changes (Primdahl, 1999), so it is appropriate for them to propose ways of solving the problems involved (Voinov and Gaddis, 2008); with solutions probably better adapted to local socio-cultural and environmental contexts (Reed, 2008). Cropping system scenarios aimed at controlling a disease without jeopardizing yields or profits are therefore likely to be better when designed together with stakeholders, whose actions (e.g. input choice, collected crops, advice) and coordination influence cropping systems.

In participatory studies, scenarios have often been designed by research teams themselves, for the purpose of analysis, evaluation and/or discussion with various stakeholders (e.g. Bacic et al., 2006; Dockerty et al., 2006; Tress and Tress, 2003), sometimes to include stakeholders' preferences (e.g. Tompkins et al., 2008), recommendations (e.g. Lippe et al., 2011) or objectives (e.g. Nidumolu et al., 2007). When scenario design *per se* has been participatory, it has often resulted in qualitative scenarios (e.g. Walz et al., 2007; Kok et al., 2006), i.e. narratives/storylines. Translating these into quantitative scenarios that are required for model simulations can be difficult (Alcamo, 2008). In most studies, this type of conversion has been realized with interactions between stakeholders and modellers occurring prior to modelling, either by co-designing or adapting the modelling framework (e.g. Cornwell, 2004; Therond et al., 2009 respectively). However, few procedures have been described in the literature for a (semi-) quantitative description of key variables by stakeholders. "Fuzzy Cognitive Map" (FCM) is the main semi-quantitative method for participatory scenario development (e.g. Kok, 2009; van Vliet et al., 2010). Although this method can improve the consistency between qualitative scenarios and quantitative models, quantifications by stakeholders are relative and mostly concern the relationships between the key variables instead of the variables themselves. The FCM method thus does not provide direct model parameterization by stakeholders. Two methods for direct estimation of scenario key variables have been proposed recently: Fuzzy Sets (Alcamo, 2008; Dubrovsky et al., 2011) and Bayesian statistical reasoning (Kemp-Benedict, 2010). The Fuzzy Sets approach combines a collective description of qualitative changes by stakeholders with "linguistic variables" (e.g. low/moderate/high change); and individual quantifications of these qualitative changes by stakeholders. These individual opinions, resulting in a distribution of values, are then combined by the research team to be translated into a single variable value (Dubrovsky et al., 2011). This last step can hinder the reliability of this value, as extreme opinions can potentially strongly influence it. This problem is partially solved by the Bayesian statistical reasoning, which provides a probability distribution of variable values (Kemp-Benedict, 2010), based on the qualitative description of how a variable differs from its reference value. Thus detailed and accurate reference distributions are crucial. Kemp-Benedict (2010) proposed to use historical data to do so, but the availability of such data clearly depends on the considered issue and its working scale. For local issues (e.g. phoma management), the required level of detail on numerous variables could make this method hardly feasible.

In this paper, we aimed at designing, directly with stakeholders, diverse scenarios of cropping systems, numerically-described and linked to possible future contexts and their uncertainty. The objectives of this work were twofold. The first objective was to test on a case study a method for the participatory design of quantitative scenarios of local cropping systems and their assessment with an available model. The second objective was to evaluate this method in order to provide recommendations and guidelines for its improvement. The case study concerned the regional management of phoma stem canker and of the sustainability of a new resistant gene. The Rlm7-gene was used as an example; this gene was introduced in some cultivars in 2004 and is still efficient.

2. Materials and methods

2.1. Study area

The study area was the "Centre region" of France (46°N, 2°E, Fig. 1), which is France's main producer of Winter OilSeed Rape (WOSR), providing 20% of the total French production in 2010 on about 15% of the region's arable land (Agreste, 2011). A threefold increase in the area cropped with WOSR has occurred in the "Centre region" since the early 90s, from 92,300 ha in 1990 to 305,300 ha in 2010 (Agreste, 2011).

This region has experienced numerous phoma stem canker epidemics, which were particularly severe in the late 90s. These large epidemics were due to the rapid loss of a specific resistance efficacy (Rlm1), which has been intensively used in the "Centre region": registered in 1992 and widely introduced in 1995, cultivars with this gene represented more than half of the total acreage of WOSR grown in 1998–1999 (Rouxel et al., 2003).

The precise area used for simulations (step 5 of the method, Fig. 2) is located in the "Centre region", around Civray (Fig. 1). An area of 121 fields was chosen (Lô-Pelzer et al., 2010a), whose landscape characteristics and cropping practices are representative of the region according to local experts (Regional Cetiom: the French technical centre for research and development of oilseed production, hereafter referred as the Specialist Technical Organization). Present-day cropping systems, based on local farmers' interviews and described in previous studies (Lô-Pelzer et al., 2010a,b) are composed of about 31% of oilseed rape per year throughout the