MODELING DYNAMICALLY THE MANAGEMENT OF INTERCROPPED VINEYARDS TO CONTROL THE GRAPEVINE WATER STATUS

Ripoche A.[1], Rellier J.-P.[2], Martin-Clouaire R.[2], Biarnès A.[3], Paré N.[3], Gary C.[1]

1. INRA, UMR System, Montpellier, France, aude.ripoche@supagro.inra.fr.
2. INRA, UR 875 Biométrie et Intelligence Artificielle, Castanet-Tolosan, France.
3. INRA, UMR LISAH, Montpellier, France.

INTRODUCTION

In vineyards, introducing a grass cover as intercrop is a common practice around the world. Indeed, it can provide some ecological services such as mitigation of runoff and erosion, and control of grapevine vegetative development (Battany and Grismer, 2000; Smart et al., 1991). Moreover, it can constitute an interesting alternative to the systematic use of herbicides. However, introducing a new crop makes the system more complex, and farmers have to adapt their way to manage them. In Mediterranean vineyards, a major difficulty is to manage correctly the two crops, to satisfy production and environmental objectives with respect to the competition for soil resources and climate variability.

As experiments are time consuming and difficult to carry out in these perennial systems, the use of a modeling approach is more appropriate to test and evaluate different types of intercrop management plans. A recent study showed the difficulty in finding robust management plans over a 30-years period. It can be explained by the fact that they did not manage responsively to observed states of the biophysical system and they did not take into account the high inter- and intra-annual climate variability (Ripoche et al., 2009).

This study analyzes the merit of introducing some flexibility in the management of intercrops in vineyards. The investigation relies on a simulation model that reproduces the interactive dynamics of decision-making and biophysical processes. Simulation is used to support the design of more robust management plans enabling control of the grapevine water status in these cropping systems.

DESCRIPTION OF MODEL

A generic modeling platform, DIESE (Martin-Clouaire and Rellier, 2009), created to simulate a manager interacting with and operating on a biophysical system has been used to write and simulate dynamic models of management that reproduce the chain of decisions and actions that affect the biophysical processes of both grapevine and intercrop. The simulated decisions are informed by climatic and biophysical indicators. This software platform offers a conceptual object-oriented modeling framework under the form of a production system ontology. DIESE relies on three main concepts: entity, process and event, which correspond to the structural, functional and dynamic aspects involved in the dynamic systems to be modelled. In addition, DIESE provides a discrete event simulation engine and a modeling environment tailored to the underlying ontology.

Biophysical system

The biophysical system is represented by different entities related by processes coming from a water balance model adapted to intercropped vineyards (Celette, 2007). For instance, *Field* is an entity composed of 3 other entities: a *Soil Reservoir*, an *Inter-Row* and a *Row*. The last two entities include a *Soil Surface* entity and a specification of the *Vegetation* entity, namely *Grapevine* or *Grass*. As assumed in the water balance model, a *Soil Reservoir* component is also attributed to the Inter-Row to represent the volume of soil explored by the grass. The grapevine can explore the two soil reservoirs.

Management system

As we focuss on the intercrop management, the management system is defined to account for the activities directly related to the grass management (e.g., tillage for preparing seed-bed, sowing, mowing) and also activities related to soil management in case of grass destruction (e.g., tillage or chemical weeding). These activities concern the inter-row and impact the biophysical processes linked to this component as well as processes at field level such as the evolution of the grapevine water status. They are combined to form annual plans themselves aggregated into different pluri-annual strategies for the cropping systems.

Flexibility takes place at different levels. Operational flexibility relates to the feasibility conditions of the activities (e.g., rainfall on the candidate day of sowing or the day before precludes the immediate execution of the activity). Tactical flexibility corresponds to the determination and timing of activities in function of the state of the biophysical system (e.g. performing a mowing at the right moment depending on grass state). Strategic flexibility refers to the context-dependent replacement of parts of the strategy with other activities more suited to the overall objective assigned to the system.

RESULTS AND DISCUSSION

Different strategies were built including different levels of flexibility. The first strategy considered as ‘standard’ consists in maintaining a bare soil in the inter-row. In the second one, a permanent grass cover is installed and sustained over years. In the third one, the intercrop is sown then destroyed every year as a function of the grapevine water status. The so-called ‘mixed strategy’ offers the choice between keeping the intercrop or destroying it, i.e. switching to bare soil management for the rest of the year. The next year, intercrop may be sown again.

These strategies were simulated over 5 years of contrasted climatic data of Montpellier (South of France) and their agronomic performances were compared. Because a flexible strategy responds to climate variability and to changes in the state of the biophysical system, its application results in different calendars of executed actions. For example, the ‘mixed’ strategy resulted in a permanent intercrop in 2004 and 2005 (with different series of dates of mowing). Its destruction was decided in 2006, 2007 and 2008 in relation to a dry spring. This strategy resulted in better agronomic performances than the one with permanent intercropping.

The use of the ontological framework DIESE to build this model is efficient in representing the complexity of a perennial multi-crop system and for helping to design innovative and robust management strategies. The dynamic interactions among the weather, the biophysical and management systems are consistent and realistic. To confirm these results and extend the scope of our study, strategies have to be evaluated under various climates and for longer periods. Moreover, constraints related to time and material resource consumption by all the activities should be taken into account in order to deal with the possible competition between activities at field or farm scales.

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