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Review

Advances in crop insect modelling methods—Towards a whole system approach

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ABSTRACT

A wide range of insects affect crop production and cause considerable yield losses. Difficulties reside on the development and adaptation of adequate strategies to predict insect pests for their timely management to ensure enhanced agricultural production. Several conceptual modelling frameworks have been proposed, and the choice of an approach depends largely on the objective of the model and the availability of data. This paper presents a summary of decades of advances in insect population dynamics, phenology models, distribution and risk mapping. Existing challenges on the modelling of insects are listed; followed by innovations in the field. New approaches include artificial neural networks, cellular automata (CA) coupled with fuzzy logic (FL), fractal, multi-fractal, percolation, synchronization and individual/agent-based approaches. A concept for assessing climate change impacts and providing adaptation options for agricultural pest management independently of the United Nations Intergovernmental Panel on Climate Change (IPCC) emission scenarios is suggested. A framework for estimating losses and optimizing yields within crop production system is proposed and a summary on modelling the economic impact of pests control is presented. The assessment shows that the majority of known insect modelling approaches are not holistic; they only concentrate on a single component of the system, i.e. the pest, rather than the whole crop production system. We suggest system thinking as a possible approach for linking crop, pest, and environmental conditions to provide a more comprehensive assessment of agricultural crop production.

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Contents

1. Introduction

Crop production schemes can be considered as complex systems with multiple interacting processes consisting of several subsystems (particularly crop growth and insects crop interactions in this context) and components, each having their own unique characteristics and behaviour while contributing to the overall arrangement and function of the complete system (Wallach et al., 2013; Fath, 2014; Walters et al., 2016). In crop production systems, many components interact simultaneously in a highly nonlinear nature (Wallach et al., 2013; Walters et al., 2016). These interactions and nonlinearities need to be taken into account when attempts are made to understand or predict the system behaviour. Understanding, managing and forecasting the impacts of pests in crop production, therefore, are challenging (Garrett et al., 2013). Although modelling efforts focusing on insect pests and their interactions with plants, weather, nitrogen, water control, supply, demand and others factors (Gutierrez et al., 1988; Gutierrez et al., 1991; Bawden, 1991; Van Ittersum et al., 2003) exists; still studies that include the full range of interactions among system components are limited (Wallach et al., 2013; Walters et al., 2016). Additionally, pest simulation models commonly simulate the dynamics of single insect as the host and physical environment affect it. A holistic view is supported in which systems management is predicated on the admission that overall system behaviour will be influenced by changes in any system component (Wallach et al., 2013; Walters et al., 2016). While models are useful tools for synthesizing information and hypotheses, their application must be in the context of the system to be managed. Implicit in the latter is determination of the ecological and socio-economic characteristics within which the model, its outputs or a simplified version of the model, must operate to assist in decision-making for pest management. The recent publication by Walters et al. (2016) applied system dynamics modelling to explore ways of using sustainable practices in agriculture production. It is suggested that complete models that include biological, ecological, economical and social processes and their interactions can provide considerable insight into the behaviour of crop production and guide on the ways of managing the system with the aim of sustainably increasing productivity (Walters et al., 2016).

This paper highlights some important research questions that stimulated the development of methods and tools for agricultural pest modelling. A summary of the most common concepts, tools, methods techniques are given. A list of some challenges is specified with possible new directions that consider system-thinking approach as a prospect for including pest impacts in crop models is also provided.

The approaches, methods and tools for pest modelling developed and used during the last decade focused on answering a number of relevant questions that arose while conducting research activities. Indeed, models are useful in answering relevant questions such as:

a How can pest population dynamics be predicted in the presence of multiple factors?