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Role of Crop Weather Modelling in Quality Grape Production

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Crop modeling is a formal way to present mathematical algorithms that represent quantitative knowledge about how a crop grows in interaction with its environment. Crop models often simulate different aspects of a crop using daily weather information such as solar radiation, maximum and minimum temperatures, and rainfall. Models play an important role in informing farmer practices, breeding strategies, and government policies that aim at addressing challenges such as food security and climate mitigation and adaptation. To address production and natural resource management issues, crop models that consider the various aspects of climate change as drivers (including rainfall, atmospheric CO2, temperature, and ozone) and capture the main crop physiological functions and other biophysical aspects of crop–soil–atmosphere systems.

Keywords: Climate change, Crop model, Grape, Viticulture.

Introduction

Crop models combine the knowledge of crop physiology accumulated over many years of laboratory and field experiments and thus provide an effective means of assessing the response of crops to climate change and alternative management scenarios. Perennial crops represent a long-term investment by all landowners. Compared with annual crops, there are fewer opportunities to change locations, genotypes, and plant configurations to adapt to climatic change. As a result, reliable models for the evaluation of options at the establishment and for ongoing management would be a useful tool for decision-making. However, compared to annual crops, in which a large amount of modelling work has been carried out to assess yields and adaptation options to climate change, less work has been carried out on perennial crops. Research on perennial crop models lags behind annual crop models mainly due to the physiological complexity that regulates yield formation and the difficulty and high cost of data collection.

Grape is one of the major important commercial fruit crops of India. The grapevine has emerged as a model perennial fruit crop species due to its global economic importance and diversity in the growing climate. Over the year, a large number of scientific studies have been carried out on grapevines, ranging from genomics studies to production practices. Numerous functional-structural plant (FSP) models have been developed that provide precise descriptions of the architecture of the grapevine canopy. These studies often concentrate on the impacts of whole-plant carbohydrate and water status on berry water and sugar intake, vegetative growth, light interception, canopy photosynthesis and transpiration, and plant water status. These models allow us to better understand the functioning of a grapevine plant, and the important processes highlighted by FSP models can often be summarized by functional relationships for inclusion in other models. A number of models of grapevine farming or cropping systems have been developed namely Vine Logic, STICS grapevine model, Cropsyst, VIMO, NVINE, SWAP, Vitisim, WALIS, APMIS next generation and MoDeM_IVM DSS (Monitoring and Decision Making in Integrated Vineyard Management

Decision Supporting Systems) (Cola *et al.,* 2014). Crop models have been used to predict outcomes such as phenology, canopy management, vegetative growth, photosynthesis rate, end-of-season yield (Nogueira *et al.,* 2018) and berry compositional attributes such as sugar concentration as well as how these outcomes are impacted by exogenous factors.

Model used in viticulture

VineLOGIC: Grapevine Growth and Development Model: VineLOGIC is a model for the growth and development of grapevine. It combines the effects of climate, soil water and salt balance on growth and yield. It operates on a point-by-point basis and uses a daily time step that requires historical weather data from the closest station. Inputs include the amount and salinity of irrigation water, how the irrigation is applied, e.g. full or partial ground cover, and key components of a typical vineyard, e.g. wine grape variety and rootstock type, pruning and trellis system type, soil type, vine carbohydrate reserve and depth to water table at the start of the season, groundwater salinity, root zone salinity at simulation start time and mid-row floor management, such as presence or absence of a cover crop. Outputs include key phenology dates, for example, budburst, flowering, veraison and harvest time, growth parameters such as leaf area index and weight of dormant pruning wood per vine, bunch number and yield per vine, berry number per bunch, berry attributes at harvest plus all key parameters of soil water and salt balance, e.g. total evapotranspiration, vine water uptake, surface soil water evaporation, irrigation added, drainage and water stress indices if water deficits occurred at specific growth stages (Walker *et al.,* 2020).

CropSyst, a cropping systems simulation model: A multi-year, multi-crop, daily time step cropping systems simulation model called CropSyst was developed as an analytical tool for analysing how soils, climate, and crop management affect the environment and productivity of cropping systems. CropSyst models stimulates agricultural phenology, canopy and root growth, soil water budget, biomass production, soil-plant nitrogen budget, crop yield, residue production and decomposition, soil erosion by water, and salinity (Moriondo *et al.,* 2015). These processes depend on weather conditions, soil characteristics, crop characteristics and crop management options, such as crop rotation, selection of cultivars, irrigation, nitrogen fertilization, soil and irrigation water salinity, tillage operation and residue management.

Vitisim: Vitisim is a model for describing seasonal dry matter production of a grapevine that was originally developed for apple trees and modified over time and adapted to grape cultivation. In order to simplify the requirements for weather data and the complexities of diurnal radiation/canopy geometry, the model runs at a daily time-step. For simplicity, the model used "big-leaf" approach combined individual organs, such as shoots or fruit, into a few super organs. One leaf (canopy), one fruit (crop), one woody structure, and one root are assumed to consist of a population of individuals that may vary in number or activity. The model requires two types of inputs: vine descriptions and weather data. Latitude, day of budbreak, number of shoots, number of clusters per shoot, number of berries per cluster, and row vine spacing are required to describe the vine parameter. All these inputs come from field experiments data.

STICS model: STICS is a model developed at INRA (France) since 1996. Model simulates the behavior of the soil–crop system over one crop cycle or a sequence of several crop cycles, using daily temp steps. It calculates agricultural variables (yields and inputs) as well as environmental variables (water and nitrogen losses). One of the key elements of STICS model is its adaptability to various crops. The data needed to run the model relate to the climate, the soil (the initial characteristics of water and nitrogen, as well as permanent soil characteristics) and crop management. Its output is related to the yield in terms of quantity and quality and to the environment in terms of drainage and nitrate leaching. The simulated object is a crop situation for which a physical medium and a crop management schedule can be determined. The main simulated processes are crop growth and development as well as water and nitrogen balances. Among the mentioned models, the STICS grapevine model has the most functionalities. It can simulate light interception by grapevine rows based on the geometry description, water balance of the whole vineyard, and grapevine yield.

APSIM next generation model: The Agricultural Production System sIMulator Next Generation (APSIM Next Generation) platform has advantages over other modelling platforms, allowing scientists to construct and configure a crop model visually, by dragging and dropping components in the user interface. It combines a number of user interface (UI) tools to assist model developers in building, running, testing, evaluating and auto-documenting the model. The long-term dynamics of phenology, canopy development, yield, and carbohydrate reserves under different pruning systems at different locations can be explored using the APSIM grapevine model. In addition, it assesses the environmental footprint of viticulture practices, such as water and nutrient footprints, as well as the suitability of an integrated grapevine–livestock farming system.

Conclusion

The model is a simple and effective tool to simulate the physiological parameters of an intercropped cropping system. With few parameters and inputs, it could provide sound advice on how to manage such a system. In a nutshell, crop models offer vast potential resources to solve several issues related to precision agriculture and agro-hydrological systems in a more robust manner and pave the path toward CSA with the advancement of accurate data acquisition, computing facilities and Remote Sensing techniques.

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