

# Spatial and Seasonal Simulations of Irrigated Processing Tomato

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**Abstract:** Crop simulation models are used to compare crop management techniques, allowing for multi-year and multi-location runs over minimum time intervals. In Southern Italy, where water-limited conditions are common, it is important to identify irrigation scenarios which allow for a more efficient transformation of water (and irrigation water) into commercial yield. In this research project, a spatial analysis of a long-term simulation was carried out with AEGIS/WIN, a GIS interface of the DSSAT crop simulation package. The case-study refers to a 1000 km<sup>2</sup> area, characterized by 481 soil samples collected over a regular grid. The processing tomato was simulated punctual-based using long-term weather data. The evaluated crop management scenarios were a) rainfed and b) 13 automatic irrigation levels based on soil CAW thresholds. Commercial yield, water and irrigation water use efficiencies (WUE and IRRWUE respectively), and NR were evaluated for each soil sample in order to select the optimum irrigation scenario. This choice was based on different criteria which were defined taking into account the objectives of different stakeholders involved in the tomato crop chain. All the above variables were visualised and mapped with GIS. According to the criteria, the results of the rainfed scenario were not useful, showing low values for fruit yield and negative net returns for WUE. An increase in the threshold of soil water content in order to start irrigation improved the fruit yield, its temporal stability and the WUE. The overall mean of the IRRWUE decreased for thresholds of CAW higher than 50%. Results showed that the optimum CAW threshold was on average 45% for the different criteria parameters. The selection of the optimum scenarios based on yield and profitability were affected by the hydrological properties of the soils. The option criterion based on WUE maximisation proved to be suitable from different points of view and matched the interests of several stakeholders. In this work, a methodological approach is proposed for the spatial and temporal evaluation of irrigation scenarios, developing a support decision system for different stakeholders in planning irrigation water distribution. Some relationships among the stakeholders are also discussed, based on simulated results.

**Keywords:** DSSAT, simulation model, criteria choice, WUE, yield, net return

## 1 Introduction

The ever-decreasing availability of water for irrigation and the problem of water resource allocation at district and basin scales are important issues faced by several research projects using crop models and remote sensing information (<http://www.demeter-ec.net/index.html>; <http://www.inea.it/aquater/>; <http://wasamed.iamb.it/programmi/home.php>; <http://www.attempto-projects.de/aquaterra/1.0.html>). In order to develop a decision support system, biophysical processes and human intervention need to be modelled, such as changes in agricultural to external conditions like water scarcity. CM, if

calibrated and accurately validated, are able to simulate potential crop yield, climate change influence on crop yield, the effect of changes in cropping patterns (crops, cultivars and sowing times), cultivation intensity (rotations) and management practices (irrigation, fertilisation) on yield, profitability and soil fertility (Matthews, 2002). CM should appreciate “soil-climate-crop” interaction, offering stakeholders suggestions for better water allocation and advising farmers on the best irrigation scheduling from an economic point of view.

The applicability of these models can be extended to much broader spatial scales by combining them with GIS, with layers providing information on soil, climate and crop management data. Several researchers have demonstrated or discussed the strength of this concept for agricultural management decision and planning at various spatial scales (Dent and Thornton, 1988; Hartkamp et al., 1999a; Hoogenboom and Thornton, 1990; Thornton et al., 1995).

Climatic variability, in particular rainfall amount and distribution, is very wide in Mediterranean environments; rainfed crop yield is largely dependent on yearly rainfall and in-field experiments and their interaction with other treatments often show significant statistical analysis results. The capability of CM to simulate multi-year crop sequences with daily recorded or generated weather data allows us to examine the yearly variability and to display the output on a frequency distribution base.

Experiences of DSSAT application at spatial scale are reported by Hoogenboom and Thornton (1990) who applied GIS to bean, maize and sorghum CM in Guatemala. Calixte et al. (1992) developed an Agricultural and Environmental Geographic Information System (AEGIS), which combined DSSAT crop models with GIS to assess the impact of different agricultural practices in Puerto Rico. Georgiev et al. (1998), Heinemann et al. (2002), Batchelor et al. (2002) and Nijbroek et al. (2003) reported further applications of DSSAT at spatial scale, especially for water requirement estimates. This permits an upscale of CM use at irrigation district or regional level.

In previous studies, the CM embedded in DSSAT software were calibrated and validated for Southern Italy conditions for wheat (Rinaldi, 2001; Rinaldi, 2004), sunflower (Rinaldi et al., 2003) and tomato (Rinaldi et al., 2007): it proved to be a useful tool in the simulation of field crops in several soil and climatic conditions; the reasons for the selection of DSSAT software include its large number of users, a user-friendly interface and an improved version with further applications.

The seasonal analysis tool (Thornton and Hoogenboom, 1994) allows for multi-year simulations with real or generated daily weather data; it also has an economic module that is useful in comparing management scenarios and geographical areas from an economic point of view. Spatial analysis and interface with GIS is a tool embedded in the latest versions of DSSAT (v.3.5 and the subsequent upgrades) for the simulation of a large number of combinations “soils x climate x management” and to display the output.

The objective of this paper is to apply a GIS-based CM to compare irrigation strategies for processing tomato, an important field crop in Southern Italy. Crop yield, crop water and irrigation water use efficiency and net return were predicted and calculated over a long-term time scale. For each “soil x climate” interaction, optimum irrigation strategies were then estimated and discussed according to the needs of different stakeholders.

## **2 Materials and Methods**

The “Capitanata” is a plain of about 4000 km<sup>2</sup> in South-Eastern Italy, mainly cropped with durum wheat, tomato, sugar beet, olives and grape orchards. Irrigation is managed by the local authority “Consorzio per la Bonifica della Capitanata” of Foggia, that provides irrigation water on demand at low pressure (2-3 bar) for a large part of the plain (1800 km<sup>2</sup>). Part of this plain (about 1000 km<sup>2</sup>, in the 0–180 m a.s.l. altitude range) was studied from pedological and climatic points of view. A