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An integrated modeling framework for real-time irrigation scheduling: the benefit of spectroscopy and weather forecasts

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Agriculture and agricultural landscapes are increasingly under pressure to meet the demands of a constantly increasing human population and globally changing food patterns. At the same time, there is rising concern that climate change and food security will harm agriculture in many regions of the world (Nelson et al., 2009). Facing those treats, majority of Mediterranean countries had chosen irrigated agriculture. For crop plants water is one of the most important inputs, as it is responsible for crop growth, production and it ensures the efficiency of other inputs (e.g. seeds, fertilizers and pesticide) but its use is in competition with other local sectors (e.g. industry, urban human use). Thus, well-timed availability of water is vital to agriculture for ensured yields. The increasing demand for irrigation has necessitated the need for optimal irrigation scheduling techniques that coordinate the timing and amount of irrigation to optimally manage the water use in agriculture systems.
The irrigation scheduling problem can be challenging as farmers try to deal with different conflicting objectives of maximizing their yield while minimizing irrigation water use. Another challenge in the irrigation scheduling problem is attributed to the uncertain factors involved in the plant growth process during the growing season. Most notable, the climatic factors such as evapotranspiration and rainfall, these uncertain factors add a third objective to the farmer perspective, namely, minimizing the risk associated with these uncertain factors. Nevertheless, advancements in weather forecasting reduced the uncertainty level associated with future climatic data. Thus, climatic forecasts can be reliably employed to guide optimal irrigation schedule scheme when coupled with stochastic optimization models (Housh et al., 2012). Many studies have concluded that optimal irrigation decisions can provide substantial economic value over conventional irrigation decisions (Wang and Cai 2009). These studies have only incorporated short-term (weekly) forecasts, missing the potential benefit of the mid-term (seasonal) climate forecasts
The latest progress in new data acquisition technologies (mainly in the field of Earth observation by remote sensing and imaging spectroscopy systems) as well as the state-of-the-art achievements in the fields of geographical information systems (GIS), computer science and climate and climate impact modelling enable to develop both integrated modelling and realistic spatial simulations.
The present method is the use of field spectroscopy technology to keep constant monitoring of the field. The majority of previously developed decision support systems use satellite remote sensing data that provide very limited capabilities (conventional and basic parameters). The alternative is to use a more progressive technology of hyperspectral airborne or ground-based imagery data that provide an exhaustive description of the field. Nevertheless, this alternative is known to be very costly and complex. As such, we will present a low-cost imaging spectroscopy technology supported by detailed and fine-resolution field spectroscopy as a cost effective option for near field real-time monitoring tool.
In order to solve the soil water balance and to predict the water irrigation volume a pedological survey is realized in the evaluation study areas.The remote sensing and field spectroscopy were applied to integrate continuous feedbacks from the field (e.g. soil moisture, organic/inorganic carbon, nitrogen, salinity, fertilizers, sulphur acid, texture; crop water-stress, plant stage, LAI , chlorophyll, biomass, yield prediction applying PROSPECT+SILT ; Fraction of Absorbed Photosynthetically Active Radiation FAPAR) estimated based on remote sensing information to minimize the errors associated with crop simulation process. A stochastic optimization model will be formulated that take into account both mid-term seasonal probabilistic climate prediction and short-term weekly forecasts.
In order to optimize the water resource use, the irrigation scheduling will be defined by use a simulation model of soil-plant and atmosphere system (e.g. SWAP model, Van Dam et al., 2008). The use of this tool is necessary to: i) take into account the soil spatial variability; ii) to predict the system behaviour under the forecasted climate; iii) define the optimized irrigation water volumes.

Given this knowledge in the three domains of optimization under uncertainty, spectroscopy/remote sensing and climate forecasting, we will be presented as an integrated framework for deriving optimal irrigation decisions.

References

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