XVII[th] World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Québec City, Canada June 13-17, 2010

DEVELOPING WEB-BASED IRRIGATION MODELS AND SERVICES

JOSÉ M. GONÇALVES [1,2], ANDRÉ MUGA[1], PEDRO TEODORO[1], GONÇALO RODRIGUES[1], MIGUEL NETO[3], RAUL JORGE[1], PAULA PAREDES[1], LUIS S. PEREIRA[1]

[1]CEER – Biosystems Engineering, Institute of Agronomy, Technical University of Lisbon, Portugal
[2]Escola Superior Agrária de Coimbra, Portugal, jmmg@esac.pt
[3]Instituto Superior de Estatística e Gestão da Informação, Universidade Nova de Lisboa, Portugal

CSBE100887 – Presented at 8th World Congress on Computers in Agriculture (WCCA) Symposium

ABSTRACT This paper describes a research project to develop web-based irrigation models and services based on models integration. Information and communication technologies (ICT) are now a priority in various areas of production and water use. Following this trend, ICT in the irrigation domain should favor efficient water use by farmers and web-based models may contribute for upgrading irrigation management at farm and system level. Adopting decision support systems (DSS) should help farmers to adopt water management practices balancing economic, environmental and water use criteria. To support the development of these approaches when developing web services related to irrigation management it is required to: upgrade the models and combine them using OpenMI technologies, adopt multicriteria analysis (MCA) - consider water use, environment and economic criteria - and provide these models for web multi-users. Tasks include: (1) upgrading design models for surface, sprinkler and micro-irrigation systems from the respective stand-alone versions; (2) integrating design and irrigation scheduling models; (3) creating the engine at the backend of the irrigation scheduling applications to be reached by the users; (4) testing the models with nearby and remote users. Several functionalities will be considered: (a) MCA to support decisions on normal planning of the season irrigation or to develop a deficit irrigation strategy; (b) capabilities to run the models in a GIS environment; (c) adopting spatial remote sensing data to provide for near real-time estimation of crop evapotranspiration. This web-based software will be analyzed to plan related web services.

Keywords: DSS, Design, Irrigation management, Web services.

INTRODUCTION Present trends in information and communication technologies for agricultural water management refer to Decision Support Systems (DSS) and Web-based models (WM) for multi-users and to support farmer's information (Zazueta *et al.*, 2006; Neto *et al.*, 2007). However, contrary to other domains in agriculture and engineering, the applications to irrigation are quite incipient (Thysen and Detlefsen, 2006). The DSS methodology explores the synergy between mathematical simulation models, data and user knowledge to support decision-making when solving problems having adversative solutions. DSS models integrate databases, simulation models and decision tools, such as

those relative to multicriteria analysis (MCA). Therefore, it becomes possible to rank solutions for the problem under consideration using various criteria, e.g. hydraulic, environmental and economic in case of irrigation. A few applications to irrigation are reported in literature (e.g. Bazzani, 2005; Hornbuckle, 2005; Riesgo and Gómez-Limón, 2006; Oad *et al.*, 2006).

This paper describes a research project to develop Web-based irrigation models and services based on models integration. The research team already developed successfully DSS systems for design and management of surface and microirrigation systems (Gonçalves *et al.*, 2007; Gonçalves and Pereira, 2009; Pedras *et al.*, 2009). Results achieved encourage developing new applications to sprinkling and irrigation scheduling (IS), nevertheless, moving from irrigation scheduling simulation modeling into DSS is challenging. This research team has been associated with developments relative to irrigation water requirements (e.g. Allen *et al.*, 1998, Allen *et al.*, 2007b), as well as to crop-water simulation models (Pereira *et al.*, 1995). Several models in use for research in various parts of the world, e.g. ISAREG, are able to consider the fluxes through the root zone bottom and salinity (e.g. Liu *et al.*, 2006; Pereira *et al.*, 2007; Cholpankulov *et al.*, 2008). More recently, to include new developments in computing crop evapotranspiration (*ET*), the new model SimDualKc was developed and tested for various crops and environments (e.g. Godinho *et al.*, 2008). It considers partitioning *ET* into crop transpiration and soil evaporation, which is particularly useful for simulation of incomplete cover crops and water conservation practices.

The present challenge is combining these models and consequently to add various functionalities for their operation in a GIS environment, to accommodate spatial information resulting from remote sensing (RS) and to adopt MCA to support irrigation planning, i.e. creating a DSS for irrigation scheduling with multiple application functions.

Information and communication technologies (ICT) are now a priority in various areas of production and water users. Are ICT in the irrigation domain usable by farmers? Could Web-based models contribute for an upgraded adoption of irrigation management technologies by farmers? Could decision support systems help farmers to improve water management practices balancing economic, environmental and water use criteria? To answer these questions, and in line with achievements of this research team and innovation coming recently into the open literature, this research aims developing Web services on irrigation management and therefore upgrade related selected models, combine models using OpenMI technologies, adopt MCA for decision-making and provide these models for multi-users through the Web.

Irrigation water use is under pressure by the society to reduce consumption, increase water productivity and to control contamination hazards. Adversely, farmers need to maximize yields and incomes, optimize investments and combine water related decisions with those relative to all other cropping activities. Therefore, developing tools to help farmer's decisions, turning them easily accessible to farmers and their advisers is important and constitutes a research challenge. Moreover, this constitutes an opportunity to upgrade existing simulation models, to add MCA for ranking solutions and decision making, to adopt innovative approaches, such as relative to databases and GIS, as well as to use data derived from remote sensing. In addition, placing the models accessible

through the Web creates innovative Web-services and an in-depth analysis of the conditions required for effective use of Web-services.

METHODOLOGY Models may be combined with the adoption of common data inputs or keeping the peculiar model data requirements. To avoid difficulties inherent to the former option, the recently developed OpenMI approach for model integration is selected, that is proved for DSS applications (Blind and Gregersen, 2005; Dirksen *et al.*, 2005). It will result in an irrigation management engine that shall provide for operation with the Web, the WebIM. This software engine will constitute the backend of the intended DSS irrigation scheduling application, the WebIS (Fig. 1). Then, purposeful functionalities will be added for operating with GIS and for acceding *ET* base information from remote sensing.

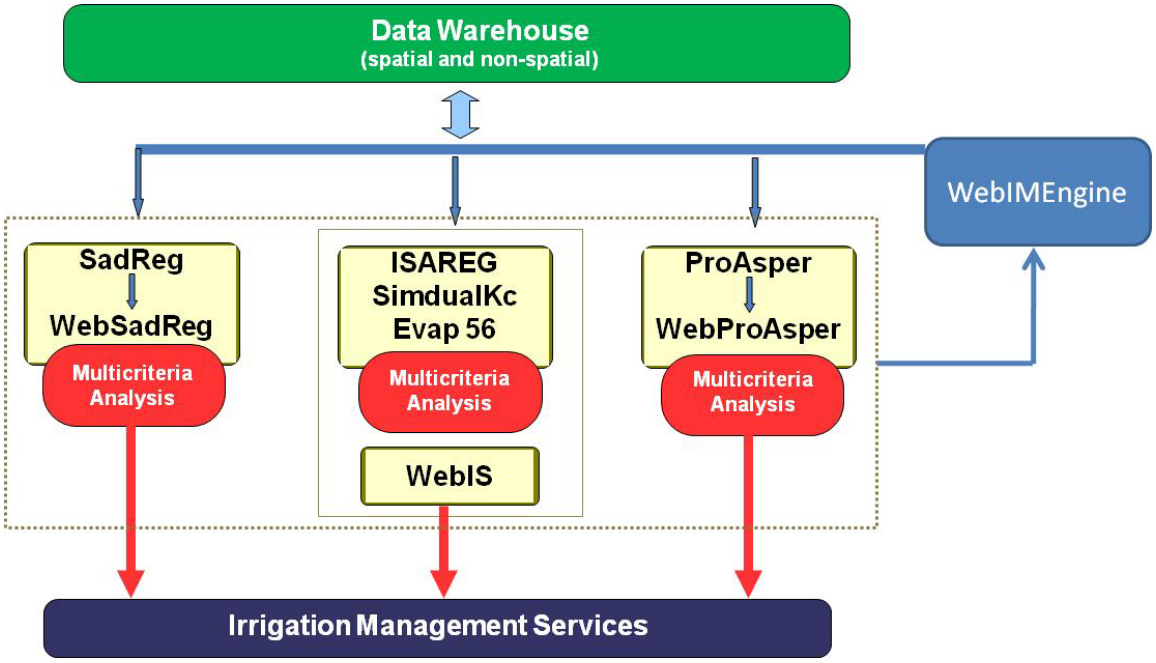

Figure 1. Data, model integration, new functionalities and web services.

Various GIS developments have been used by the research team (e.g. Mateus *et al.*, 2007). Developments are presently running for RS applications (Café *et al.*, 2008) and alternative methodologies are under consideration (Allen *et al.*, 2007a; Calera *et al.*, 2005). Tests in farmers fields will be performed for assessing the quality of results, included those based on RS and those relative to MCA ranking and support to decision making. The research team has already some experience in operating Web models (Branco *et al.*, 2007; Muga *et al.*, 2008) that allow to recognize difficulties and to envisage appropriate research orientations in this respect. First advances in research refer to the change of the DSS SadReg (Gonçalves and Pereira, 2009) from stand-alone to multi-users through the Web (Muga *et al.*, 2008). Respective developments will be carefully tested and learned lessons shall be used with the above referred DSS WebIS. Adopting DSS for sprinkling design is quite complex. The hydraulics of set systems is well known (Martin *et al.*, 2007a), but the variety of equipment tools, their functionality as impacted by wind, and related selection criteria are complex (Martin *et al.*, 2007b),

which make it possible to aim a first application to set systems. This may base upon an existing model, ProAsper (Rodrigues *et al*., 2010), that may be improved following the approach in other models (e.g. Carrión *et al.*, 2001). In addition, economic aspects may follow recent approaches e.g. by Montero *et al.* (2004).

The approach envisaged is to introduce MCA in set sprinkler design, to provide for model accessibility through the Web, thus creating the WebProAsper from the simple model prototype ProAsper. The prototype model will also be combined through OpenMI in the WebIM engine, which will constitute its backend. Basing upon the experience gained with the above referred DSS MIRRIG, appropriate design and MCA submodels will be added. The experience gained in adopting this approach shall later be used to improve other models and make them available through the Web. Farmer's fields will be tested to assess the quality of results and the users interface abilities. The rational of the approach intended with this research project is shown in Fig. 1. Particular care is given to data quality for specific model requirements, whatever spatialized or not.

At present, the GIS functionalities refer only to the DSS WebIS. Then, OpenMI models are combined resulting in the creation of WebIM, which will serve as backend of the models. MCA specific for the problems dealt with the models will be added; consequently, changing models from simulation tools into decision tools. These tools if functioning through a central server with distant users through the Internet create a Web service for irrigation design and management, thus building opportunities for remote users and support to farmers. An analysis of the Web service requirements and limitations shall complete this study aiming the transfer of existing irrigation management knowledge into the farmers practice. The methodologies to be adopted are summarized in Fig. 2, which express the inter-relations among the several tasks that are explained in next topics.

UPGRADING IRRIGATION DESIGN MODELS FROM STAND-ALONE VERSIONS A novel DSS system to support design of surface irrigation (Gonçalves and Pereira, 2009) has been successfully proved in various applications in Portugal, Syria and Uzbekistan. Both the design features relative to data handling, hydraulics and infiltration computations, and generation of alternative design solutions, and the MCA application to select and rank the alternatives were positively used. Thus, conditions were created to change it from the stand-alone version to a Web-based version enabling to support distant users in Syria and Egypt. These developments revealed positive and constitute an opportunity to improve the model functionalities, revise MCA criteria, attributes and utility functions, as well as the user interface, including the selection of user's language. Hence, the WebSadReg will be created.

INTEGRATE DESIGN, SCHEDULING IRRIGATION AND MULTICRITERIA MODELS Two different water balance models are now successfully developed, one using the traditional K_c approach, the other adopting the dual K_c for partitioning *ET* into soil evaporation and transpiration. Because the water balance approaches are similar, combining both models is appropriate if the user (or the type of data available) may select which *ET* computational version to use. Therefore, considering the facilities for model integration provided by the OpenMI approach, models are integrated within WebIM that will later become the backend for the irrigation scheduling applications, including a MCA sub-model tool for creating decision support capacities. Similarly, the design model for

set sprinklers will also be integrated, thus gaining capabilities for sprinkler irrigation scheduling. Therefore, the base engine WebIM will be developed.

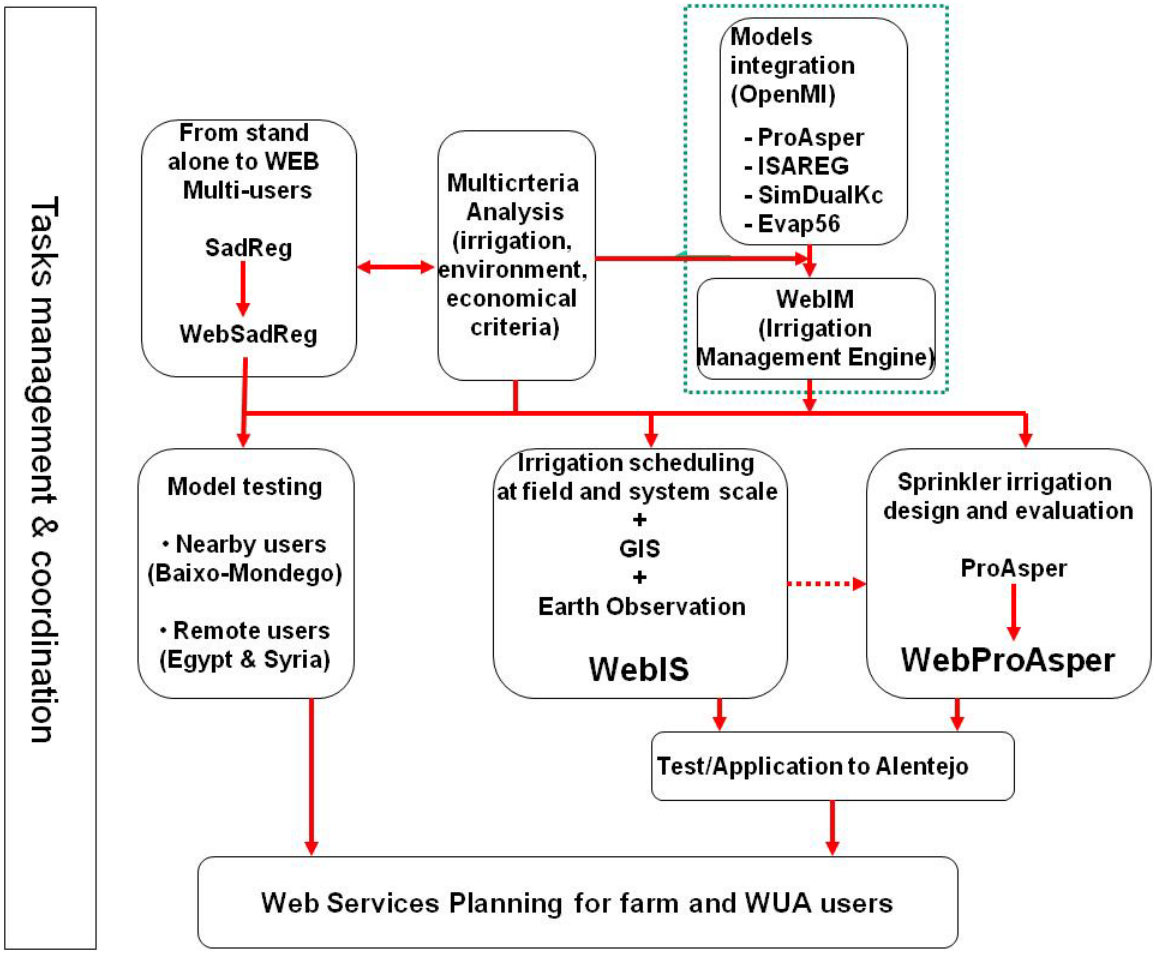

Figure 2. Project tasks and links.

MCA constitutes a main input for model upgrading aimed at providing for decision support. MCA developments based upon those successfully adopted in SadReg and MIRRIG, i.e. for design purposes (Gonçalves and Pereira, 2009; Pedras *et al.*, 2009) called for adopting MCA in other models. Therefore, for the WebSadReg and the WebProAsper, both aimed at farm systems design and management, respectively for surface and sprinkler irrigation, MCA will be upgraded and adapted for the peculiarities of surface and sprinkler irrigation, mainly relative to differences in performance indicators to be used in both models. However, for irrigation scheduling a different approach has to be used to support decisions on deficit irrigation, i.e., on relating aimed yields and incomes with water amounts available, production costs, water - yield impacts, water costs, as well as on the system performance related costs and benefits. This approach is particularly challenging but feasible using appropriate economic modeling.

The application WebIS will apply the WebIM as a backend engine with various functionalities for easy use through the Web. First, MCA will be integrated with appropriate interface relative to the nature of decision to be supported: normal planning of the season irrigation or development of a deficit irrigation strategy when water availability is limited. Second, the integration in a GIS environment will be developed

enabling the DSS model utilization by a single farmer or a water user association manager. Third, spatial RS data available for near real-time scheduling using maps of NDVI, the Spider tool (now under test, using the approach by Calera *et al.*, 2005) or *ET* derived from the METRIC model (Allen *et al.*, 2007a). Evolving from ProAsper, the DSS WebProAsper will be developed. The existing hydraulics and performance computational algorithms will be upgraded, the database improved, particularly relative to economic data, and a MCA integrated for supporting the selection of alternative design and management decisions.

MODEL TESTING WITH NEARBY AND REMOTE USERS Following developments in previous tasks and related improvements resulting in input data produced by WebIM relative to irrigation scheduling and from MCA upgrading, WebSadReg will be tested by nearby users in Baixo Mondego Valley, in collaboration with the respective Water Users Association (WUA), and by remote users in Syria through collaboration in a development project now initiating there. The multi-functional DSS for irrigation scheduling and WebProAsper will be tested in Alentejo, on Alqueva Irrigation Project.

DEVELOPING WEB SERVICES Creating Web-based software is not enough for making it usable by farmers and other end-users. Therefore, specialized studies and analysis are planned to transform that software in Web-services. Particular attention is to be devoted to create conditions favoring their access by farmers, farmer's advisers and other end users.

CONCLUSION The intended research constitutes an evolution of the state of the art relative to the adoption of ICT in irrigated agriculture: on one hand, models adopt updated knowledge to create information; on the other hand, adopting DSS and Web-based modeling is an innovative approach following detectable present trends. The project shall have results appreciable in various ways: (1) the Web-based DSS applications for design and management of various irrigation methods; (2) further methodologies for analysis of irrigation strategies and policies by exploring the envisaged software tools; (3) disseminated Web-based models presented as Web services to farmers and other end-users; (4) after used, the described decision making tools may allow better farming practices with favorable impacts on incomes and environment.

Acknowledgements The support of CEER - Biosystems Engineering (POCTI/U0245/2003) is acknowledged. Studies referred herein will be developed in the framework of the research project PTDC/AGR-AAM/105432/2008.

REFERENCES

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. Crop Evapotranspiration. Guidelines for Computing Crop Water Requirements. FAO Irrig. and Drain. Paper 56, FAO, Rome.

Allen, R., M. Tasumi, and R. Trezza. 2007a. METRICtm. Mapping evapotranspiration at high resolution. Applications Manual for Landsat satellite imagery. University of Idaho, Kimberly, Idaho.

Allen, R.G., J.L.Wright, W.O. Pruitt, L.S. Pereira, and M.E. Jensen. 2007b. Water Requirements. In: G.J. Hoffman, R.G. Evans, M.E. Jensen, D.L. Martin, R.L. Elliot (eds.) Design and Operation of Farm Irrigation Systems (2nd Edition), ASABE, St.

Joseph, MI, pp. 208-288.
Bazzani, G.M. 2005. An integrated decision support system for irrigation and water policy design: DSIRR. Environmental Modelling & Software, 20 (2): 153-163.
Blind, M., and J.B. Gregersen. 2005. Towards an Open Modelling Interface (OpenMI) the HarmonIT project. Adv. Geosci., 4, 69-74.
Branco, R., P. Teodoro, P. Mateus, and L.S. Pereira. 2007. WEBISAREG – Web based decision support tool for irrigation management. In: Ensuring Water and Environment for Prosperity and Posterity (Proc. 10th Inter-Regional Conference on Water and Environment, New Delhi, Oct 2007), Indian Society of Water Management, New Delhi, India, pp. 289-295.
Café, B., R. Tavares, R. Branco, and L.S. Pereira. 2008. Estima de coeficientes culturais duais a partir de imagens Landsat. Aplicação ao regadio do Caia. In: Workshop Tecnologias de informação e comunicação para a modernização dos sistemas de irrigação e valorização dos sistemas de irrigação ancestrais, Florianópolis, Brasil (CD-ROM) (In Portuguese)
Calera, A., A.M. Jochum, A. Cuesta, A. Montoro, and P. López. 2005. Irrigation management from space: Towards user-friendly products. Irrig. and Drainage Syst. 19: 337–353.
Carrión, P., J. Tarjuelo, and J. Montero. 2001. SIRIAS: a simulation model for sprinkler irrigation. I. Description of model. Irrig Sci 20, 73-84.
Cholpankulov, E. D., O. P. Inchenkova, P. Paredes, and L.S. Pereira. 2008. Cotton irrigation scheduling in Central Asia: Model calibration and validation with consideration of groundwater contribution. Irrig. and Drain. 57: 516–532.
Dirksen, P.W., M.W. Blind, T. Bomhof, and S. Nagandla. 2005. Proof of Concept of OpenMI for Visual DSS Development. Proceedings of the MODSIM 2005 conference, Melbourne, Australia.
Godinho, P., B. Sequeira, P. Paredes, and L.S. Pereira. 2008. Simulação das necessidades de àgua das culturas pela metodologia dos coeficientes culturais duais. Modelo SIMDualKc. In: E. Ruz and L.S. Pereira (eds) Modernización de Riegos y Uso de Tecnologías de Información. CYTED and PROCISUR/IICA, Montevideo, pp. 26-28, CD-ROM paper 1.5. (In Portuguese)
Gonçalves, J.M., and L.S. Pereira. 2009. A decision support system for surface irrigation design. J Irrig. Drain. Engng. 135 (3), pp. 343-356.
Gonçalves, J.M., L.S. Pereira, S.X. Fang, and B. Dong. 2007. Modelling and multicriteria analysis of water saving scenarios for an irrigation district in the upper Yellow River Basin. Agricultural Water Management 94 (1-3): 93-108.
Hornbuckle, J.W., E.W. Christen, and R.D. Faulkner. 2005. Use of SIRMOD as a quasi real time surface irrigation decision support system. In: A. Zerger, and R. M. Argent, eds., MODSIM 2005 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, 217-223.
Liu, Y., L.S. Pereira, and R.M. Fernando. 2006. Fluxes through the bottom boundary of the root zone in silty soils: Parametric approaches to estimate groundwater contribution and percolation Agric. Water Manage. 84: 27-40.
Martin, D.L., D.F. Heermann, and M. Madison. 2007a, Hydraulics of sprinkler and microirrigation systems. In: G.J. Hoffman, R.G. Evans, M.E. Jensen, D.L. Martin, R.L. Elliot (eds.) Design and Operation of Farm Irrigation Systems (2nd Edition), ASABE, St. Joseph, MI, pp.532-556.
Martin, D.L., D.C. Kincaid, and W.M. Lyle. 2007b. Design and operation of sprinkler

systems. In: G.J. Hoffman, R.G. Evans, M.E. Jensen, D.L. Martin, R.L. Elliot (eds.) Design and Operation of Farm Irrigation Systems (2nd Ed.), ASABE, St. Joseph, MI, pp.557-631.

Mateus, P., L. Correia, and L.S. Pereira. 2007. HIDROGEST, a GIS framework for integration of decision support tools for improved water use and participatory management in pressurized on-demand irrigation systems. In: N. Lamaddalena, C. Boglioti, M. Todorovic, A. Scardigno (Eds.) Water Saving in Mediterranean Agriculture & Future Research Needs, Options Mediterr., Série B, 56, vol. I: 303-317.

Montero J., R.S. Martínez, and J.M. Tarjuelo. 2004. Analysis of water application cost with permanent set sprinkler irrigation systems. Irrig Sci 23, 103-110.

Muga A.P., J.M. Gonçalves, and L.S. Pereira. 2008. Web Decision Support System for Surface Irrigation Design. CIGR International Conference of Agricultural Engineering, 11th Inter-Regional Conference on EnviroWater, Foz de Iguaçu, Brasil.

Neto, M.C., J.C. Coelho, and A.C. Pinheiro. 2007. Tecnologias de Informação e Comunicação na Gestão da Empresa Agrícola. Gestão da Empresa Agrícola no Século XXI - Manual III. Lisboa, Associação dos Jovens Agricultores de Portugal. (In Portuguese)

Oad, R., L. Garcia, K. D. Kinzli, and D. Patterson. 2006. Decision support systems for efficient irrigated agriculture. In: G. Lorenzini, and C. A. Brebbia, eds., WIT Transactions on Ecology and the Environment, Vol 96, WIT Press, Wessex, 247-256.

Pedras, C.M.G., and L.S. Pereira. 2009. Multicriteria analysis for design of microirrigation systems. Application and sensitivity analysis. Agric. Water Manage 96: 702-710.

Pedras, C.M.G., Pereira L.S., and J.M. Gonçalves. 2009. MIRRIG: A decision support system for design and evaluation of microirrigation systems. Agric. Water Manage. 96: 691-701.

Pereira, L.S., J.M. Gonçalves, B. Dong, Z. Mao, S.X. Fang. 2007. Assessing basin irrigation and scheduling strategies for saving irrigation water and controlling salinity in the upper Yellow River Basin, China. Agric. Water Manage.93 (3), 109–122.

Pereira, L.S., B. van den Broek, P. Kabat, and R.G. Allen (eds). 1995. Crop-Water Simulation Models in Practice. Wageningen Pers, Wageningen.

Riesgo, L., and J.A. Gómez-Limón. 2006. Multi-criteria policy scenario analysis for public regulation of irrigated agriculture. Agric. Systems 91, 1–28.

Rodrigues, G.C., P. Paredes, M.I. Valín, C. Henriques, R. Rosa, J.M. Gonçalves, and L.S. Pereira. 2010. Improving the performance of landscape sprinkler irrigation through field evaluations and modeling. (submitted to this Conference)

Thysen, I., and N.K. Detlefsen. 2006. Online decision support for irrigation for farmers. Agricultural Water Management 94 (1-3): 93-108.

Zazueta, F.S., J. Xin, L.S. Pereira, and A. Musy. 2006. Information Technologies in Water Management. In: Munack, A (Ed.) CIGR Handbook of Agricultural Engineering, Vol. VI: Information Technologies, ASABE, St. Joseph, MI, 314-324.