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Decision support system for sustainable irrigation in Latin America

MAX BILLIB[1], EDUARDO HOLZAPFEL[2] & KARIN BARDOWICKS[1]

1 *Leibniz University of Hannover, Institute of Water Resources Management, Hydrology and Agricultural Hydraulic Engineering, Appelstr. 9A, D-30167 Hannover, Germany*
billib@iww.uni-hannover.de

2 *University of Concepción, Department of Water Resources / Agricultural Engineering, Avda. Vicente Mendez 597, Chillán, Chile*

Abstract In a bilateral research cooperation between the University of Concepción (Chile) and the Leibniz University of Hannover (Germany) a Decision Support System (DSS) was developed to improve the sustainability of intensive irrigated agriculture. Environmental, socio-economic and technical aspects are included into the DSS. The structure is divided into three parts: Geographic Information System for the visualization through GIS maps, Model Base System, which includes simulation and optimization models (e.g. irrigation design and management), evaluation criteria and scenario techniques, and Database System to manage the data within the DSS. The integration of the local stakeholders, especially farmers, plays an important role to assure the sustainability of this research. Therefore socio-economic modules and an interactive training of the farmers are included. The DSS can be used through a user-friendly interface. It is intended to transfer the application of the DSS to less developed arid and semiarid regions in Latin America.

Key words Decision Support System; irrigation; sustainability

INTRODUCTION

In many developing countries the socio-economic pressure to increase agricultural production is in conflict with the preservation of the environment, and with other users of the natural resources. The intensification of agricultural production in arid and semiarid regions includes activities such as irrigation and fertilization, often associated with inadequate management and lack of knowledge, which produce serious contamination problems. However, among others Hadas *et al* (1999) have shown that contamination problems derived from agricultural processes can be minimized, when root uptake is improved, and when chemicals, nutrients and water are positioned in the correct place, in adequate quantity and at the precise time.

Recent approaches for irrigated agriculture in arid and semiarid regions include the development of decision support systems, e.g. to improve planning and management in large irrigation schemes (Mira da Silva *et al.*, 2001), the involvement of multiple decision tools to find conflict resolutions (Cai *et al.*, 2004), or the integration of multi-discipline aspects into a web-enabled spatial DSS (Dymond *et al.*, 2004).

The main focus of this research project is to develop a DSS to improve the sustainability of intensive irrigated agriculture. The DSS provides innovative multidisciplinary environmental, socio-economic and technical interactions, delivered at a web platform.

DECISION SUPPORT SYSTEM

Structure

The structure is divided into three parts (Fig. 1):

(1) Geographic Information System for the visualisation through GIS maps;
(2) Model Base System, which includes simulation and optimization models (e.g. for irrigation design and management), evaluation criteria and scenario techniques;
(3) Database System to manage the data within the DSS.

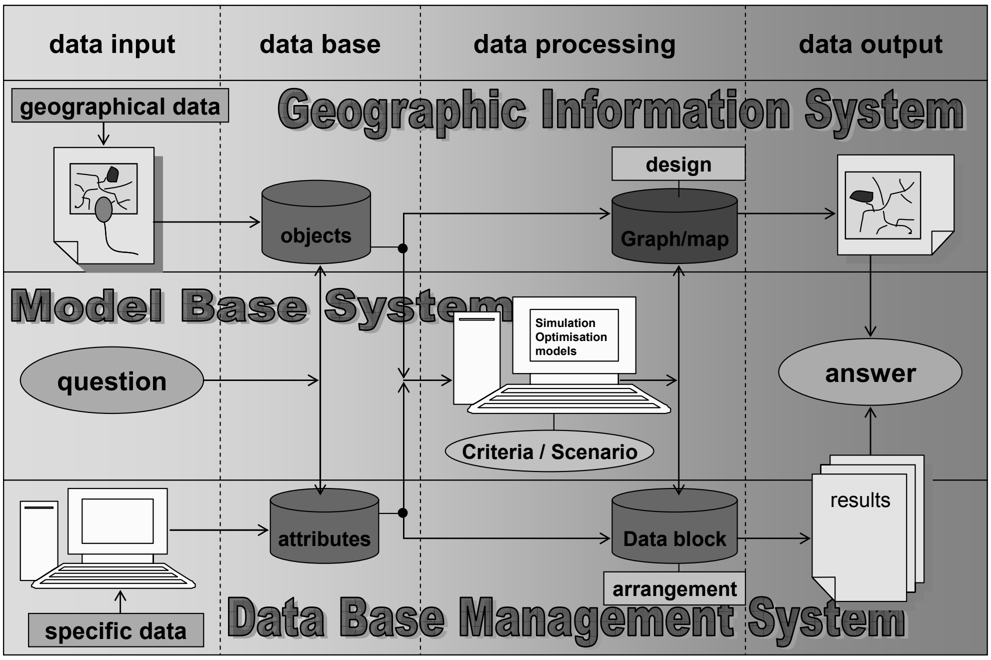

Fig. 1 Structure of the DSS.

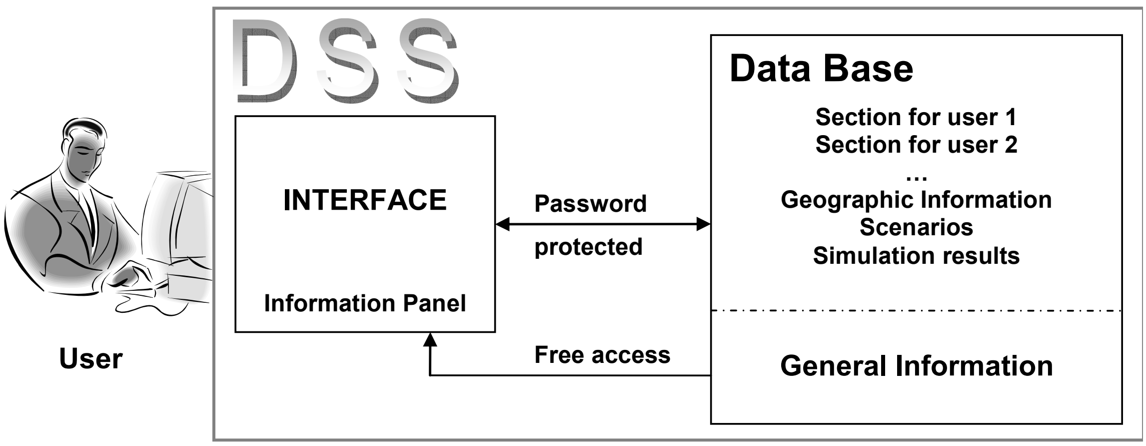

Fig. 2 Interface between the user and the support of the DSS.

Interface

A user-friendly interface was built up to ensure that the farmers can be supported. At the Internet page the user can decide between an information panel and a link to the support of the DSS (Fig. 2).

The information panel provides several types of general information, e.g. the concept, objectives and benefits of DSS, regional and provincial agricultural information, and publications. The support by the DSS is protected by a paid password for each user, who only has access to his data, which can be changed, and general data within the database. A new user can create a new section in the database, after paying and getting a username and password. The support action starts by a choice of the user between the optimization of an existing irrigation system and the planning of a new irrigation system. If the user choses to optimise the existing irrigation system, the DSS asks questions, like “Do you want to know how much water you have to apply?” or “Do you want to know when you have to apply fertilizer?”. The DSS then searches for existing data for the selected activity and shows it. The required data, which have to be entered to receive other support, will then be displayed. The second main function of the DSS can be used to plan a complete irrigation system, including the economic aspects. The models and scenarios are used to show possible decisions of the farmers for improving the management or design of the irrigation system at their field.

Geographic Information System

GIS maps (ArcInfo) are used to visualize the conditions in the valley under investigations in Chile, e.g. land use, irrigation and drainage canal systems, location of pumping and observation wells, and soil types.

Through a map (Fig. 3) the user can access the data of existing sets. For some fields lots of special information was collected from former research projects. This was added to the database of the DSS.

Model base system

Several simulation and optimization models are included or connected with the DSS. Special attention is given to technical, socio-economic and environmental aspects of irrigation systems. Three models for the management and design of surface and pressurized irrigation systems were developed. Additionally, scenarios for different irrigation systems and variable management are simulated to show the impact on the environment. Especially the impact on the water resources can be analysed with the models HYDRUS 2D (unsaturated soil) and Visual MODFLOW (groundwater). The results of the scenarios are evaluated by criteria of the European Union (EU) to support the export of the agricultural products, e.g. table grapes, to the EU.

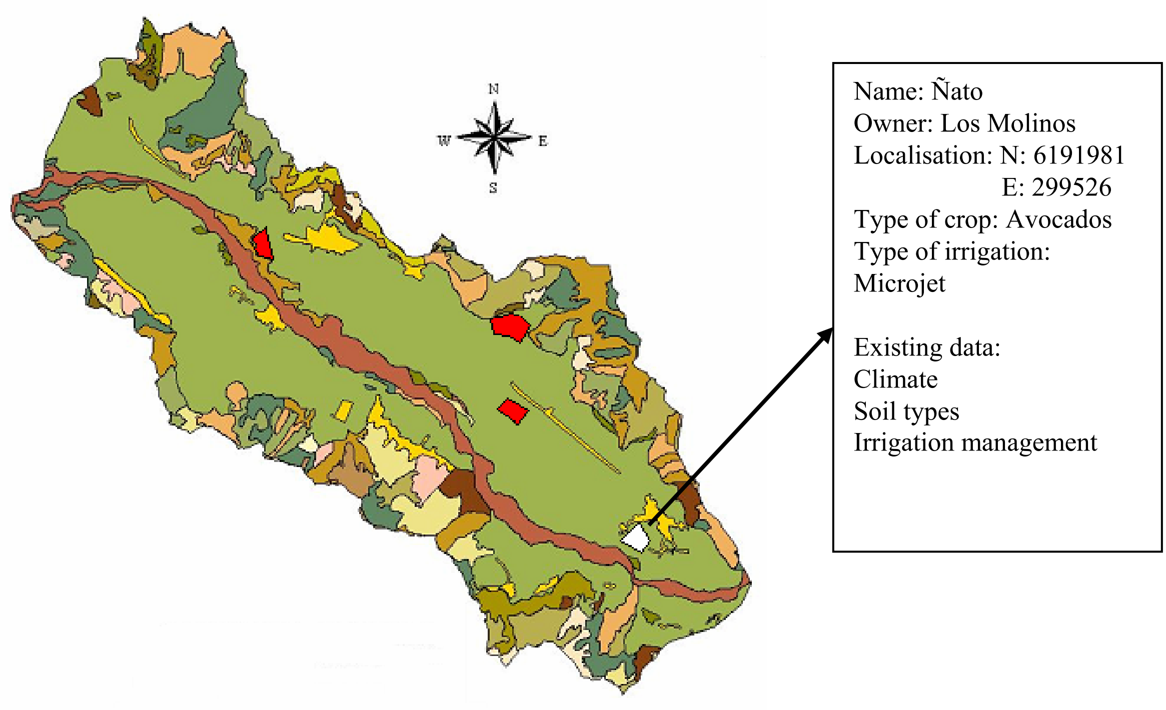

Fig. 3 Study area with selected field under special investigations.

Database system

The database is located on an Internet page. The access is separated into two parts, an open access is provided for general information and a password protected part contains special data for each farmer, e.g. about the irrigation system and management at his field. The database is the connection between the user interface and the model base system.

RESULTS AND DISCUSSION

This section shows three examples of using the DSS:

– **Example 1:** A farmer would like to know which emitter type is the best for his existing drip irrigation system. Therefore he has to enter some data into the database, e.g. the soil type, the infiltration rate of the soil, the irrigation frequency, the area of his field, the possible irrigation time per day, and the number of emitters per plant (Fig. 4). The arrangement of the irrigation pipes can be entered as shown in Fig. 5. Figure 6 shows the results of the simulation. The farmer can directly compare the results for different drip emitters, which can support his decision for installing a new emitter type at his field. If the user needs further information, he can get support from a specialized engineer. Nevertheless, for farmers the most important aspect is the economic impact of potential changes, thus the DSS also delivers economic calculations, like in the following example for the planning of a new pipe system.

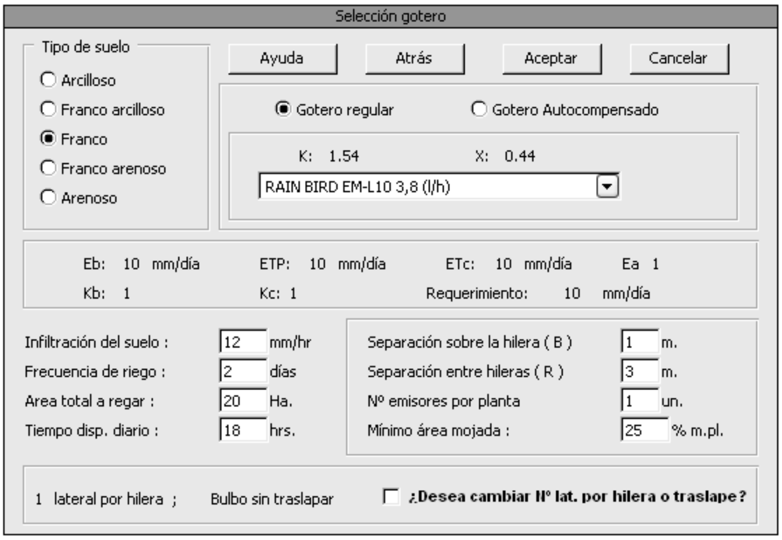

Fig. 4 Input for a drip irrigated field.

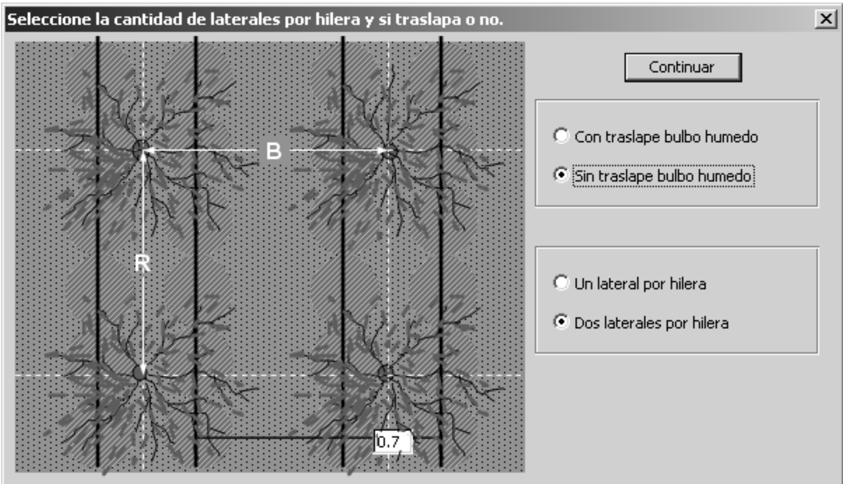

Fig. 5 Arrangement of irrigation pipes.

EMISOR	POSTURAS POR DIA un.	POSTURAS POR RIEGO un.	LATERAL X HILERA un.	NET un.	AREA POR POSTURA Ha	TIEMPO APLICACION hr	CAUDAL EMISOR l/hr	PRESION EMISOR m	PORCENTAJE MOJADO %	DIAMETRO MOJADO m	TASA APLICACION mm/hr	CAUDAL POR POSTURA m3/hr
RAIN BIRD EM-L10 3,8 (l/h)	1	2	2 S/T	1	10.0	18.0	**3.3**	**5.7**	14.89	1.07	0.56	56
	2	4	2 S/T	1	5.0	9.0	**6.7**	**27.1**	26.89	1.43	1.11	56
RAIN BIRD EM-L20 7,6 (l/h)	1	2	2 S/T	1	10.0	18.0	**3.3**	**1.5**	14.89	1.07	0.56	56
	2	4	2 S/T	1	5.0	9.0	**6.7**	**6.5**	26.89	1.43	1.11	56
	3	6	2 S/T	1	3.3	6.0	**10.0**	**15.3**	42.41	1.80	1.67	56
LEGO IRRIGATION LB4 4 (l/h)	1	2	2 S/T	1	10.0	18.0	**3.3**	**6.1**	14.89	1.07	0.56	56
LEGO IRRIGATION LB8 8 (l/h)	1	2	2 S/T	1	10.0	18.0	**3.3**	**1.6**	14.89	1.07	0.56	56
	2	4	2 S/T	1	5.0	9.0	**6.7**	**6.8**	26.89	1.43	1.11	56
	3	6	2 S/T	1	3.3	6.0	**10.0**	**15.9**	42.41	1.80	1.67	56
NETAFIM 4,1 (l/h)	1	2	2 S/T	1	10.0	18.0	**3.3**	**6.7**	14.89	1.07	0.56	56
	2	4	2 S/T	1	5.0	9.0	**6.7**	**26.6**	26.89	1.43	1.11	56
Azud S-50 P/ 4 (l/h)	1	2	2 S/T	1	10.0	18.0	**3.3**	**8.2**	14.89	1.07	0.56	56
	2	4	2 S/T	1	5.0	9.0	**6.7**	**23.5**	26.89	1.43	1.11	56

Menu Recalcular

Fig. 6 Comparison of possible drip emitter types.

– **Example 2:** In this case the farmer wants to implement a drip irrigation system, thus as one part he has to calculate the pipe distribution network system. The DSS is searching the cheapest diameter for the pipes of his field (Fig. 7). The farmer has to enter data about fixed costs, e.g. the installation of the pipes, and variable costs, e.g. the type of energy used and the efficiency of his pump. The result in Fig. 8 shows that in this case the diameter of 2″ is the optimal value with the lowest total costs of the installation and operation at the simulated field.

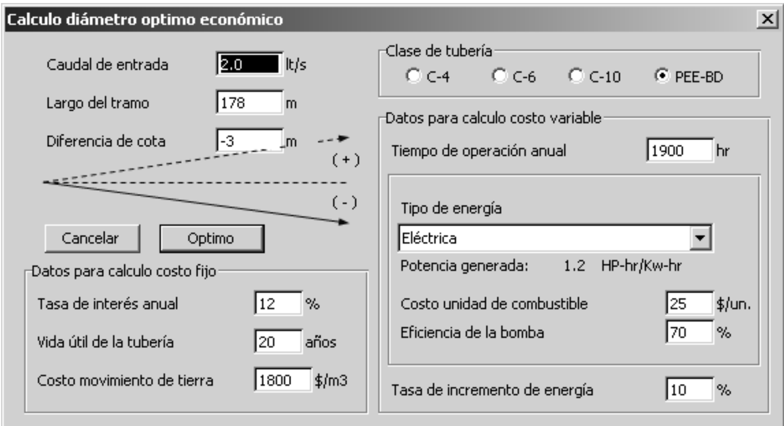

Fig. 7 Input for the calculation of the pipe diameters.

CAUDAL l/s	LARGO 0.09	D.COTA m	DIAMETRO COMERCIAL	VELOCIDAD m/s	(J x L) EN 178 METROS metros	COSTO TUBERIA $Mil	COSTO FIJO $Mil	COSTO VARIABLE $Mil	COSTO TOTAL $Mil	F.R.C.	F.C.E.	C.A.E.E.	
2.00	178	-3.00	**1"**	3.9	100.70	25	17.04	226.15	243.19	2.03	0.13	114535.19	
2.00	178	-3.00	**1 1/4"**	2.2	25.28	30	17.71	56.78	74.49	2.03	0.13	114535.19	
2.00	178	-3.00	**1 1/2"**	1.4	9.04	61	21.95	20.29	42.24	2.03	0.13	114535.19	
2.00	178	-3.00	**2"**	0.9	2.56	83	24.86	5.76	30.61	2.03	0.13	114535.19	OPTIMO
2.00	178	-3.00	**3"**	0.4	0.42	179	37.65	0.95	38.61	2.03	0.13	114535.19	
2.00	178	-3.00	**4"**	0.3	0.17	354	61.10	0.38	61.48	2.03	0.13	114535.19	

Fig. 8 Results of the calculation of different irrigation pipe diameters.

– **Example 3:** Additionally the DSS provides information about the impact of irrigation systems on the environment. Therefore several scenarios have been developed to evaluate the impact of different irrigation systems and managements on the water resources.

Figure 9 shows the results of a scenario of nitrate leaching produced by an excessive application of irrigation water. The nitrate of the fertilizer is percolating very fast, until it reaches the shallow groundwater. The results of scenarios like this are used for the interactive training of farmers, where it is explained that such an impact on the water resources is also a high money loss by losing the fertilizer and water. The training is used to improve the knowledge of the farmers and especially to explain the use of the DSS functions. These activities are essential to ensure the sustainable use of the DSS.

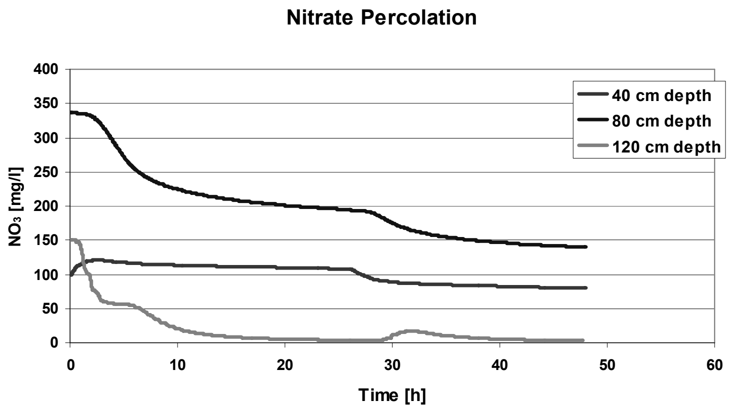

Fig. 9 Percolation of nitrate simulated by HYDRUS 2D.

These are only three of several possibilities for supporting the decisions of farmers for changing and optimizing their irrigation system and management. Especially the implementation of the costs can improve the socio-economic situation of the farmers.

CONCLUSIONS

The DSS is an effective web-enabled approach for supporting the decisions of farmers. Lots of information and support with simulation and optimization models are used to improve existing irrigation systems, or to build up new ones. The training of the farmers is built up as a learning system, which should raise their awareness of the socio-economic and environmental impact of their irrigation system. The data, information and also the models, will be updated due to the requirements of the user to ensure the sustainability of the DSS. The innovative approaches are the multidisciplinary environmental, socio-economic and technical interactions within the DSS, and additionally the impact analysis of the irrigation at the basin scale. In future research it is planned to transfer the DSS to other study areas in South America.

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