



Project: Sustainable Hydro Assessments and Groundwater Recharge Projects

Project acronym: SHARP

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APPENDIX: Long version of good practices to be adapted report

GPA 15	Optimization of water use in agriculture using IT
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Involved Project Partners:

Region of Western Macedonia (RWM)

Regional Agency for Rural Development of Friuli Venezia Giulia (ERSA)

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1. Concise description of the adapted good practice

1.1 The ICTs and their potential

General speaking the specific interest for the Information and Communication Technologies (ICTs) arises from their potential to integrate and manage data and information obtained from different sources which can also be located far away from the site where the “kernel of the system” resides. The kernel of the system consists mainly of the “expert system” (ES) which is specifically designed to process and analyze the input data. The ES is able to process all the available information by means of a specific knowledge domain and then provide solutions and feedback outputs to the concerned system.

Different examples for ICTs can be recalled. Some of them deal with data process and analysis, dissemination of knowledge and information through informatics applications; other more complex ICTs examples can couple both informatics and domain technology. ICTs in water management in agriculture could make use of both these approaches.

In some cases, automation and ICT in water management are considered as one. Automation and ICT can be implemented independently from each other. Actually, the combination of both amplifies the contribution of

each technology to water use efficiency.

The integration of ICT with the automation of irrigation promoted higher levels of sophistication as well as comprehensive services beyond automation, like water supply and irrigation network design, water budgeting, scheduling of irrigation timetables, etc.

Beyond agricultural irrigation, ICT and automation are extensively used in water supply networks, landscape irrigation, municipal household water allocation and consumption monitoring.

Wireless communication

Wireless communication reduces costs and avoids cut-offs of command lines by routine activity in the farm. In due time, wireless communication became highly reliable with the introduction of cell phones, ISM, GSM and Wi-Fi technologies, SMS bi-directional delivery, as well as the use of satellite communications and internet networks for remote control and data transfer.

Technical institutes, extension services and commercial irrigation equipment suppliers, uploaded to the Internet software packages that enable irrigators to calculate online the head losses in irrigation systems and the distribution uniformity of emitters and laterals. Additional online software packages facilitate the scheduling of on-farm irrigation and fertigation.

Wireless communication has all the requested merits of dominance in the future. The miniaturization of wireless appliances, the growing broadcasting range and reliability as well as price decline ranks wireless communication as a technology of choice for a growing number of irrigators. Its potential of incorporation into computer and telephone networks simplifies and amplifies its operation convenience.

ICT technology and web tools

Web technology is showing new opportunities for the community of users; it is also increasing its popularity for a number of reasons:

- usually it is cheap to produce;
- it doesn't require proprietary software to be installed;
- specialist computer skills, at least very basic ones are available;
- SW can be upgraded and disseminated easily.

Besides, a new category of applications called as RIA (Rich Internet Applications) or web 2.0 applications can be installed not only on personal computers but also on other types of electronic devices, such as tablets (iPAD), and Smart Phones.

Future development and expansion of ICT in irrigation and water management is closely linked to the development of the three following preconditions:

1. stricter need for water use rationalization;
2. advancement in communication power;
3. the capacity of financial and advisory bodies to introduce ICT to new user circles of low-tech farmers.

1.2 Informatics and technology. ICT applications for irrigation water management

As for the coupling of informatics and domain technology, an ICT application can be seen as a “neural network” which collect data from the “input layer” (source of data), processes them according to a “knowledge function”, which is part of the ES, and consequently yields solutions from the “output layer” i.e. the feedback of the system itself that could be addressed to improve the management of the resources under control.

Having in mind the general imagine described above, ICTs applications can be described by identifying the system concerned, the inputs, the knowledge function and the ES and finally the feedback outputs to be used to improve the concerned system performances.

Different examples of ICTs coupling informatics and technology for water management in agriculture can be reported. All of them can have a common goal which is to say the optimization of the water resources under control.

Here some examples of possible application of ICTs coupling informatics and technology and dealing with water management in agriculture are considered. They can be distinguished on the basis of the different degree of complexity and objectives concerned.



Fig. 1: General scheme of ICT applications for irrigation and water management.

Water resources management with farm flow meters

One of the possible application of the ICTs could be represented by the remote control of the individual flow meters installed for each of the farms served by irrigation. This case is typical of the new irrigations plants where each farm or land plot is supervised by a flow meter. In that case the opening and the shutdown of the flow meters can be regulated by the ES through a wire-less remote control. One of the possible benefits is to optimize the water allocation in a given system, for instance avoiding the excess of water consumption by individual farmers. This implies that the ES has been instructed on the maximum amount of water that should be delivered for each individual farm. Another possible option is the regulation of the timing of the irrigation interventions for the farms of a given district. In that case only a scheduled number of farms in turn are enabled to withdraw water from the network; then the system can be kept far from its maximum water load and an excessive water abstraction from the water pools can be thus avoided. Such a system could also be integrated with the meteorological data in order to prevent excessive water uptake by the users when precipitations assuring the necessary amount of water are forecasted in the short term. The device installed can also easily provide a large set of information on the water consumption and costs billing, e.g. for the binomial fee application.

Water management in green-houses

When a closed system or an homogenous system is considered, the application of the ICTs can be focused on even more precise challenges and tasks. Irrigation in the greenhouses can be managed directly by the ES thus reducing the employment of manpower. Fertilization management and water balance control are peculiar activities of the cultivation techniques applied in the green-houses. Many different sensors can be installed in the substrates for hydroponic cultivations in order to measure the concentration of the nutrients in the solutions used for fertilization as well as to compute the water balance of the plant-substrate-environment in the greenhouse closed system. The amount of water delivered and nutrient concentration in the solution used for fertilization is directly computed by the “knowledge function” of the ES. When a large group of green-houses is concerned, the entire irrigation plant of the district can be managed directly by the system which receives data and signals from the peripheral probes and sensors and consequently generates operations to be effected automatically by the irrigation plant.

In advanced irrigated agriculture, fertilizers are applied with irrigation water by fertigation technology. Precise dosing of the fertilizers in a pre-defined ratio to the irrigation water is carried out by various types of fertilizer injectors that are synchronized with the applied water amount by controllers. Water flow rate is measured by flow/water meter and the fertilizer solution flow rate is measured by counting the pulses of the fertilizer pump or by dedicated small flow meters. The information is sent to the controller that regulates the ratio between the irrigation water and the fertilizer solution. In intensive agriculture in greenhouses, nurseries and detached beds, the ratio of water – nutrients and the ratio between the different nutrients are adjusted according to feedback from sensors that measure the EC and pH levels in the drainage water.

In highly sophisticated greenhouses, the fertigation control is embedded in a comprehensive control system of the environmental parameters like temperature, light, aeration, relative humidity, etc. inside the greenhouse.

Future development seems to branch in two paths:

1. Higher sophistication and comprehensiveness in the greenhouses sector.
2. Wide scale dissemination and expansion in open field agriculture, relying on soil and crop nutrient level measurements.

Central management of water resources

In this case the system to be supervised is represented by the whole irrigation network which can be managed by the organization in charge of the regulation of water supply to a given district. The goal is to optimize the water flow to an irrigation district, therefore the system should be able to supply a scheduled amount of water to the irrigation network by checking the inflow rate and the outflow rate at the fields.

Two sort of input data can be considered, i.e. inflow of the system and targeted outflow of the system.

The system should be able to measure the water inflow rate, then it is equipped with probes installed upstream aimed at measuring the actual outflow from the water pools and reservoirs as well as the amount of water stored in the latter.

The targeted outflow of the system is represented by the amount of water which should be supplied to the irrigation network and to the fields according to the scheduled consumptions. Two different input signals

should be considered, the flow rate of the main network, where flow meters record the water flow in the main channels of the irrigation system, and the information gathered by probes installed in some strategic points of the secondary network. Some flow meters can also be applied in specific sample points of the irrigation network i.e., at the head of the fields, so as to measure the actual amount of water supplied to the cultivations. These set of sensors installed in the secondary network and in the pipelines delivering the water to the fields could be meant to signal the water losses occurring in the network to the ES.

The knowledge function process of the ES is aimed to optimize the water abstraction from the different pools so as to assure the scheduled amount of water to be delivered to the irrigation network. The ES should be fed with basic data and information: a) the area cultivated for every sort of crops (e.g. arable crops, meadows, orchards, horticulture, greenhouses cultivations), b) the crops water requirement according to the plants physiological phase, c) the water distribution pattern (“scheduled” vs. “on demand”) applied in the different subareas, d) the schedule of the input data monitoring (i.e. how many times the remote information are recorded by the sensors and sent to the system).

One of the target functions of the system is the optimization of the water uptake from the different reservoirs, having regard of the amount of water stored and available in each of them. This task can be achieved by acting on the number of water pumps engaged (i.e. lower energy demand objective) or controlling the outflow rate from every single reservoir according to the water stored and available. Compensation of abstraction of water from the different reservoirs could also be achieved by enabling the functioning of secondary tubes or channel connections among the reservoirs regulated through a set of valves controlled by the ES.

The outputs of the system are represented by the signals sent to the peripheral stations regarding the number and the individual pumps to be switched on or off in order to regulate the water pressure which assures the desired flow rate; in that way the water abstraction optimization goal can be achieved. Given that different pools could show different energy demand for their utilization, mainly related to the amount of water stored, the ES should also promote a different water uptake rate from each individual pool according to their replenishment degree and thus reduce as much as possible the overall energy demand.

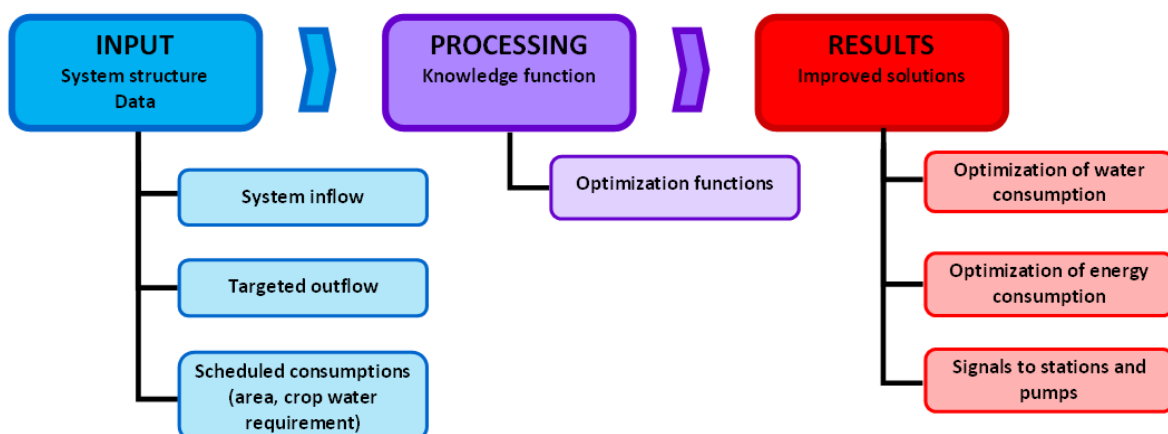


Fig. 2: Central management of water resources.

How the input and output feedback signals are delivered and where the kernel of the system resides? Remote control of the sensors installed at the input and output points of the network through wireless and radio

connections can be seen as a convenient and flexible way to manage the input data. This technology can also be applied to control the functioning of the water pumps as well as to coordinate the set of valves of the system.

The ES and the “knowledge function” of the system can be ideally seen as SWs which can be reached through the web. The software should access different databases and should be provided with dynamic routines able to simulate different scenarios for the system under control such as: i) low energy consumption, ii) lower water abstraction from the pools having less water available, iii) full connectivity of the system through the opening of the valves which regulate the inflow of the water among the reservoirs, iv) optimum water distribution schedule.

An integrated management of water resources in agriculture

When a larger district is considered, being featured by a variety of soil types, different cultivation crops and different reservoirs and water basins facilities, water management could be more efficiently regulated through a higher degree of integration of data and information.

The general architecture of the system is the same as shown in the paragraph 1.2.3 above, but the ES should be able to integrate a wider set of data. Most of them are organized in different GIS layers describing: i) soil characteristics, ii) land use, iii) cultivations grown, iv) dams and water basins feeding the irrigation system, v) type of water abstractions (i.e. groundwater, surface water), vi) water reservoirs, vii) irrigation networks.

Beside these wider set of data to be considered, the ES could also receive information from additional specific probes, such as sensors installed in the soil, and a series of on-field small-scale meteorological stations organized in adequate networks, which altogether are aimed at estimating the water balance of significant plant-soil-environment sub-systems. The on-field sensors should transmit data on the variations in temperature, wind, precipitation and on soil humidity to the central system. The ES should then be able to estimate the water balance of the specific area-cultivation sub-system. These data could be also integrated with the local weather forecast service.

The ES could then be able to process the input data and, on the basis of its “knowledge functions” and target functions, it should yield a wide set of information that could be translated into operational commands to the water pumps and valves of the peripheral units so as to improve the water distribution efficiency. The system could control the water to be supplied to the individual farms on the basis of the standard information on the cultivations grown integrated with the on-filed data collected by the sensors. The system could automatically set the amount of water to be flowed and, if that is the case, it could also decrease the amount of water supplied to the individual farms, thus reducing the overall volume of water engaged. The farmer could be informed on the optimal amount of water to be used for irrigation, these information can be extensively documented on the web page of the system or can be shortly summarized in brief alerts to be delivered through SMS messages. The ES could also be able to simulate dynamics of nutrients in the soil with respect to the local conditions and amount of water supplied, then it could highlight possible runoff or leaching events in the soil with respect to different precipitation events, thus preventing, indirectly, water pollution from agricultural sources.

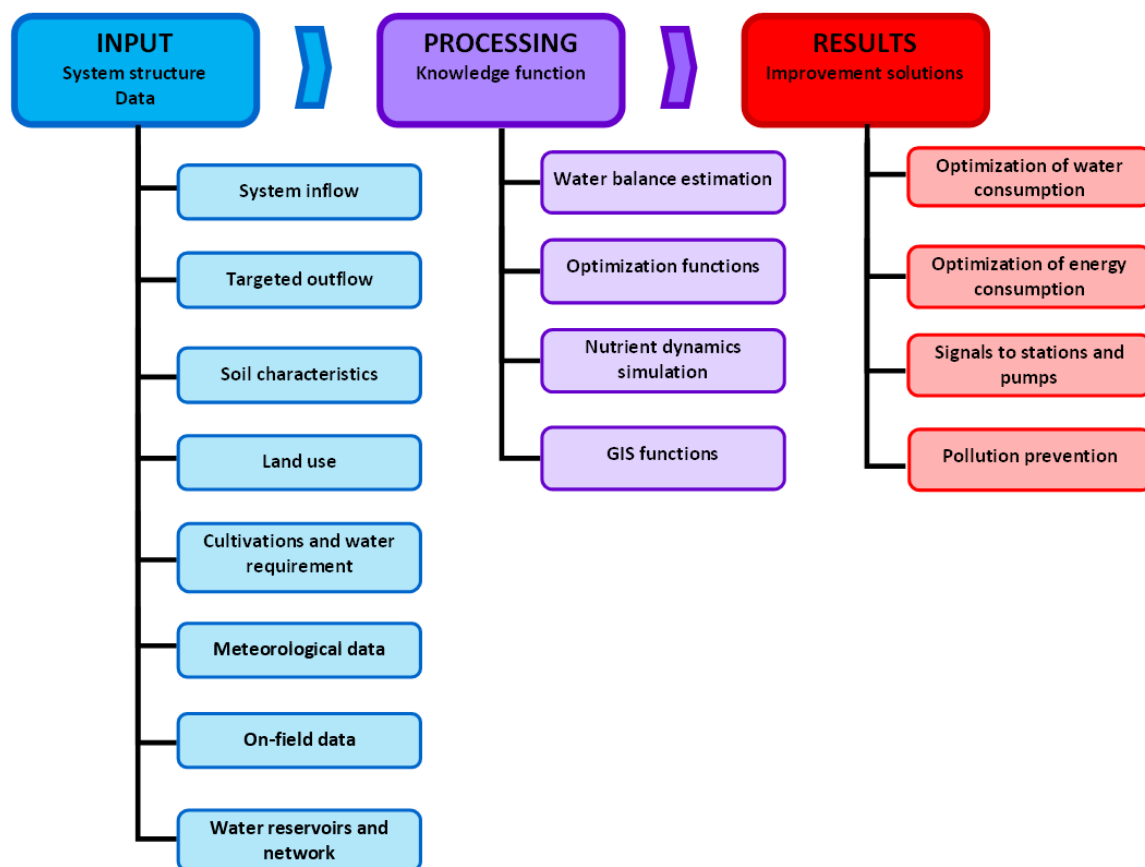


Fig. 3: Integrated management of water resources in agriculture.

Higher hierarchy level of water resources management

If the whole water balance of the territory is concerned, especially when the water resources are limited, then the partition of water available among the different uses (i.e. agriculture, households, civil and industrial) could be optimized by the supervision of an ES similar to those described above.

In this case the input data of the system could arise from a set of different probes and sensors aimed at collecting information and parameters in very specific critical points of the network.

The following domains of input data can be figured out:

- level of water table of the different groundwater bodies involved;
- inflow assured by the surface waters;
- water stored in basins or reservoirs;
- water uptake for civil uses (households and public buildings);
- water uptake for industrial use (hydroelectricity, cooling of industrial engines);
- water uptake for agricultural use (irrigation).

The “knowledge function” of the system should be provided with some basic data source consisting of long time series of data on the water consumption for different purposes, the groundwater dynamics, the threshold standards of water outflow for each of the different uses as well as the environmental standards.

The ES should then be able to output signals to the control points of the network so as to optimize the partition of the water among the users and prevent possible conflicts. One possible example of system outputs could be the timing of water flow in the different networks, i.e. a different timetable for daylight and night according to the different users (for instance civil users network are advantaged for the daylight timetable, industrial users network can be advantaged for the night timetable). The system could also regulate timing in water distribution for irrigation so as to avoid over-abstraction of water in specific periods.

The different control system outputs could act on the remote control of pumps and valves the water network is provided with.

The ES could also comprise a decision support system (DSS) which is aimed at providing solutions and scenarios on the overall water management of the district concerned, both in the short term and in the long term.

The inflow into the different water use networks (agriculture, civil, industrial) could be set directly by the system within a certain degree of freedom (“low” and “medium” sensitivity control level), however, given the complexity and the sensitivity of the decisions to be taken, choices having a deep impact on the water allocation for different uses (i.e. “high” sensitivity control level) should be exclusively taken by the decision makers taking advantage of the scenarios depicted by the DSS of the ICT application.

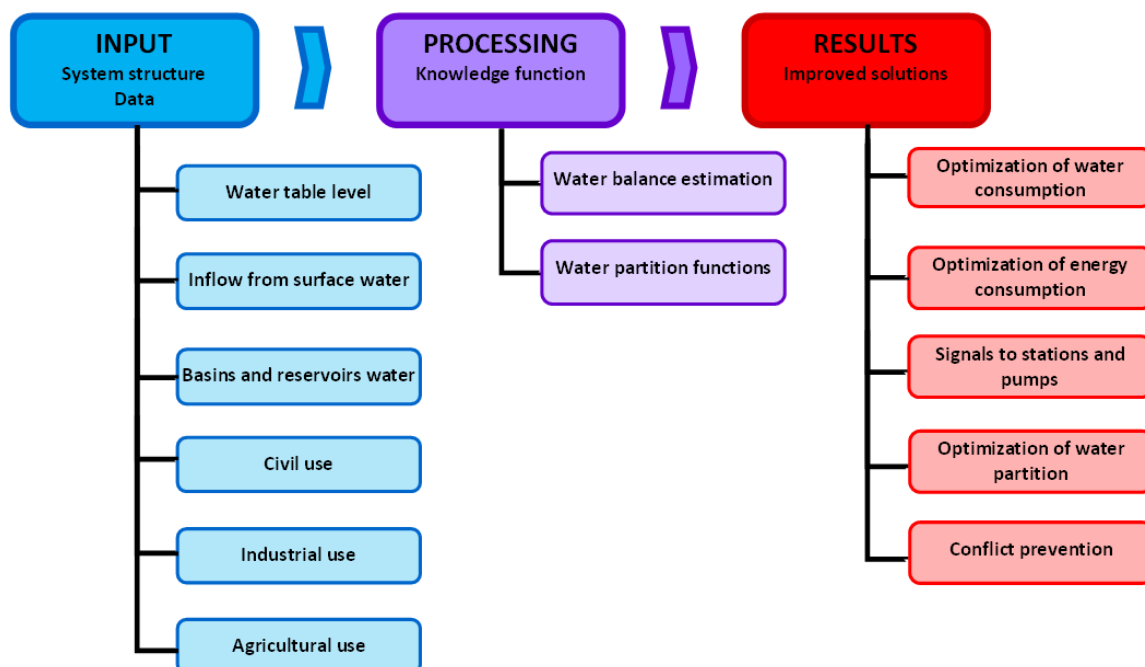


Fig. 4: Higher hierarchy level of water resources management.

1.3 Modelling and DSS systems for irrigation water management

ICTs benefit of the progress and advances made in modelling and in data process and analysis. Most of these computer applications are part of the ES in the examples of solutions coupling informatics and technology domains described in paragraph 2 above.

These ES can be seen as a “prediction” or “what if” tool to be used by different users: researchers, experts, extension service technicians, farmers, decision makers involved in spatial planning. The interested people can access the ICT platform through Internet or being informed directly with different modalities (e.g. Internet, e-mail or SMS alerts).

In this paragraph some general features on modelling and DSS applications aimed at information and knowledge dissemination are described.

Basic functionalities of ICT SWs dedicated to water management in agriculture

Optimization of water use of agriculture, dealing with a huge number of data to be processed and collected at different levels of organization, can benefit of the ICT applications. The following sort of input data can be considered and managed by the ICT tools:

- data related with irrigation network;
- surface water data availability (quantity and quality);
- groundwater data availability (quantity and quality);
- meteorological data;
- soil features data;
- irrigation system;
- crop physiological phase in the growth cycle, water consumption, yield;
- farm costs, farm revenues, farm income.

Data and numerical inputs should be treated with the same format and stored in databases accessible to the ICT system along with spatial information stored in Geographical Information Systems (GIS) components. Long term data series (usually 30 – 40 years) are needed to allow the system make a reliable prediction of meteorological scenarios. This set of data can be used by the system to yield some possible “what if” scenarios. Recent series of meteorological data such as rainfall, temperature, relative humidity, solar radiation, wind speed and temperature and precipitation variations are used by the SW to predict real-time water balance of the soil-plant-environment system.

Crop management (seeding time, variety of seeds, irrigation technique applied) can significantly modify the plant water consumption during the growing season. The more accurate the plant growth description and the crop management model, the more the knowledge on the actual crop requirements and then the accuracy in predicting the water balance, thus the ability of the ES to formulate outputs to reduce water use inefficiencies or limit occurrence of crop stress because of water deficit.

Integration with meteorological data and soil features is of crucial importance. The ICT software concerned should be able to take into account both long-term and short-term meteorological information in order to enhance predictability of water balance components. Soil characteristics are useful to describe water dynamics,

water capacity and to show crop ability in root deepening to increase water uptake. Usual outputs of these ICT tools are the water balance components, water losses, runoff, deep percolation, evaporation or network losses. ICT tools can provide and disseminate information and outputs through a website in the form of numerical data, graphs or user friendly indications with symbols and alerts.

The water balance daily prediction can suggest on how much irrigate and when irrigate. Volume of water to be used for irrigation and irrigation timing can be very useful for water optimization purposes and to achieve an efficient use of water in agriculture. Crop water requirements can be estimated on the basis of the standard data already stored in the ES or that it has directly computed on the basis of real data referred to soil evaporation and crop evapotranspiration. When coupled with economic assessment objectives the system can also provide information on the profitability of the irrigation interventions.

These ICT SW can be reached on Internet, this makes the information and the knowledge available to a wide community of users: farmers, technicians, researchers. Farmers can also receive alerts and messages delivered by the system through SMS messages or e-mail, then very simple and direct advise are disseminated to the farmers on when and how to irrigate.

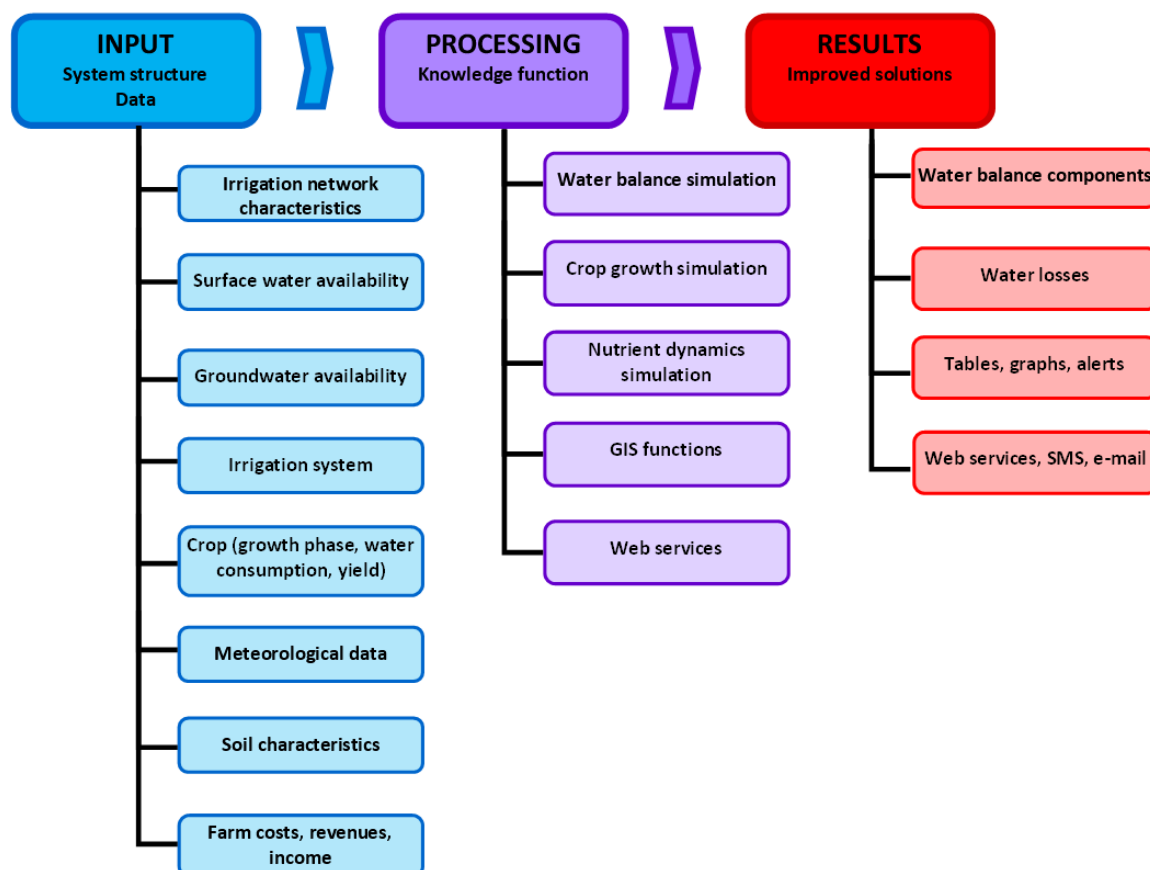


Fig. 5: Water management in agriculture and modelling tools.

This sort of ICT applications are not only meant to provide day-by-day information on the irrigation interventions but also show their great potential for knowledge dissemination. In fact, in the long terms, these tools could be intended to become the standard for techniques dissemination in a given region and therefore

the reference source of technical information for the final users (technicians and farmers). Thus the whole system will be positively affected and, from the general point of view, the global water balance of the involved area results to be improved.

Several software programs have been developed to assist on irrigation scheduling (e.g.. FAO has developed a simulation model 'AquaCrop' to assist farmers to manage their fields more efficiently) Some are free to be used by anyone providing a friendly and easy to use interface. Farmers and agronomists should be aware of these programs and get informed or trained to use such tools. The local authorities may have an informative or training role on this task. Also irrigation may be managed according to available soil moisture. Useful tools in order to monitor soil water content are the soil moisture sensors, tensiometers. Automated irrigation has started to be applied according to sensor readings. Possibly, the use of soil moisture sensors in combination with the weather station or weather data from local agencies would lead to optimized water balance.

ICT SWs as Decision Support System in water management in agriculture

Data on water use in agriculture can be integrated with a wide set of information such as environmental data, common agricultural policy (CAP), economy of the agricultural sector, water dynamics in the soil, water tables of groundwater bodies, availability of surface water, water plans and general spatial plans of a given region. The SW can be shaped as a modelling tool which provide long-term simulations on the global water balance in agriculture with respect to different plans and decisions taken, then it can be used as a Decision Support System (DSS). This represents a very powerful instrument to investigate water management in agriculture, with the aim of providing necessary information for the best decisions to be taken at a specific management level.

Having in mind the importance of the spatial components of the information provided, the data should be related to all the concerned objects (point, line and area) and then should be mapped geographically. Thus, it is necessary to integrate the DSS with a software that runs under a GIS environment.

The DSS can be used as a "what if tool" showing mid-term an long-term effects of decisions and behaviours of the actors playing their role in the water use domain. Effects of decisions taken at different levels can be simulated, for instance:

- decision of the farmers concerning the internal irrigation techniques adopted, given that different techniques have different efficiencies;
- use of water supply patterns ("scheduled" pattern and "on demand" pattern have different implications);
- decision of the farmers concerning the cultivation to be grown (i.e. different crops have different water consumption);
- decision taken by the organizations supervising the water allocation in agriculture for the water pricing system to be adopted;
- decision taken by the planners and the decision makers for the investments and the works to be effected;
- effects on the environment, water quality, water pollution;
- effects of agri-environment measures and the CAP on water consumption;
- effects of climate change;
- possible scenarios with respect to droughts occurrence.

This DSS can produce numerical outputs to be taken into consideration by policy makers (agricultural policy, environmental policy, water plans, spatial plans), graphs, indexes (water efficiency indexes, water pollution

indexes, environmental and biodiversity indexes), scenarios on the water tables of the ground water, scenarios on the surface waters, spatial visualization of the scenario and effects.

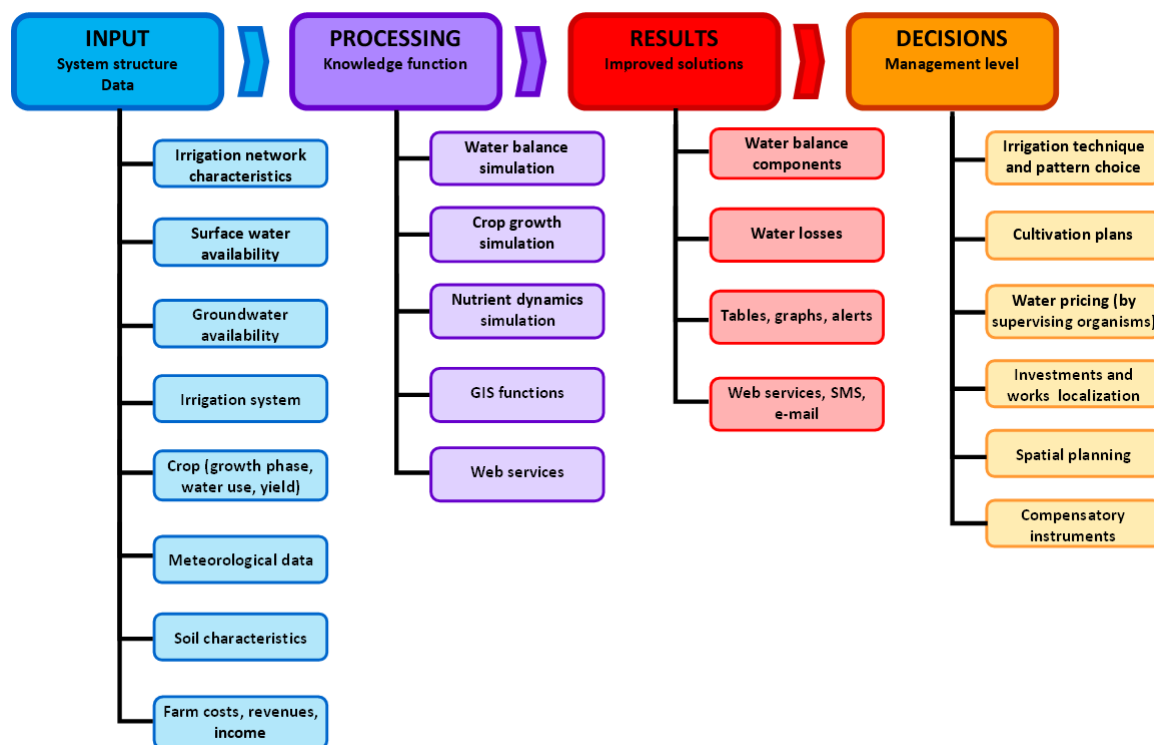


Fig. 6: DSS for water management in agriculture.

1.4 Who can advantage from the ICTs technology

As described above ICT tools are available on the web and a wide categories of users can reach and use them. As far as a user friendly environment is concerned and a training plan has been carried out, farmers can use directly the ICT tools, choose simulation options, scenarios, and manage in the right way the ES outputs. Probably this could be seen suitable only for simple tools, while for more complex ICT tools, only few farmers can have a complete competence to access directly to them. In this case the information and suggestions provided by the ICT application can be addressed to the farmers by using different technologies such SMS alerts and e-mail alerts carrying direct indications on the irrigation intervention to be effected.

Technicians from the farmers associations or from advisory services are usually much more skilled and familiar with these applications and thus could assist farmers in advantaging of these ICTs tools: showing the effects and benefits gained with the adoption of a more efficient irrigation strategy with the graphs, scenarios, comparison and economic predictions provided as outputs by these ICT ESs.

For public Institutions, policy makers and decision makers the use of DSS can be of great importance for exploring different options and scenarios and for the elaboration of various water management plans. The DSS could be an important planning tool enabling the regional authorities to design optimal spatial development policies and to protect the groundwater from the agricultural land use. It also supports production planning

and water and fertilization management. From the results we can summarise that the DSS achieves to decrease both fertilizers use and water consumption.

2. Description of adaption process

ICT tools and transferability in other regions

This question arises when it comes to transfer ICT tools to areas which differ from those where the applications were originally intended or developed.

A quite common problem is the system and its different basic conditions. It should be kept in mind that the ICT system under evaluation has its own peculiarities and these are specifically related to the local situations where the ES was originally developed. It should be reminded that a model or a DSS applied to water management describe a specific situation concerning water use, water availability, water management, crop cultivation and crop management. It is obvious that the specific options underpinning a model cannot be directly transferred to another situation. It is necessary to conceptualize the new system considered and most of the times new data should be collected in order to parameterize the equations of the model supervising the ES.

The most interesting point is not the model or the ICT tool itself, rather the idea and the rationale behind it that can be adapted and adjusted to other situations taking advantage of the experience already carried out. Most of the times is not a question of technology rather to be able to identify the strength points and needs of a general solution and apply it at a specific level or in a specific area.