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Basic Information System Directed at Monitoring and Evaluation in Irrigation Projects

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Abstract: In this study, we present a new GIS-Based Information System designed to supply information, data query, analysis for irrigation system management and performance assessment. It is called SUGIS which means SUlama, the Turkish term of irrigation and Geographical Information System. The system is composed of three main modules that are Information System Data Input (ISDI), Information System Questioning (ISQ) and Irrigation System Assessment (ISA). In the ISDI module, data is classified and stored in two different groups; as static data that varies according to the project site and dynamic data, which is updated seasonally based on changing environmental conditions and crop patterns. Our preliminary results indicated that this new GIS based information system provides valuable information to both farmers and irrigation engineers as well as system managers.

Key words: Irrigation, information system, monitoring, evaluation

INTRODUCTION

Monitoring and assessment are of special importance in irrigation management. Demands of irrigation management show that there must be an important link between the project management and the farmers. Effectiveness and efficiency of management and/or the monitoring and evaluating unit depends greatly on the extent of the co-operation between farmers and irrigation management.

Despite many significant efforts to increase irrigation system performance around the world, improving system performance is not a trivial task and in many large scale irrigation systems in the world performance indicators such as irrigation rate, production increase and water use efficiency are still far beyond their desired levels.

Efficiency is closely related to water management activities in irrigation systems. Recent field-based research underscore the need for improved water management techniques that would optimize agricultural production given the constraints of water, irrigation technology and farming practices[1].

Among the irrigation efficiency indicators, irrigation delivery performance that is the ratio of supply water toward the demanded is the most critical one. Thus, periodic monitoring of irrigation delivery performance is necessary to improve irrigation management of the scheme. A GIS-based-user-interface program can be adopted to improve the monitoring of irrigation delivery performance. GIS is extensively used in natural resources, agriculture and environmental studies, where monitoring of the spatial distribution of variables is the main component of management task[2]. GIS-based tools are also widely used in irrigation management especially in obtaining and structuring information to improve monitoring and evaluation of irrigation and drainage projects and related policy decisions[3].

Efficient management of land and water resources in irrigated agriculture requires comprehensive knowledge on many variables including climate, soil land use, crops, water availability, water distribution networks, management practices, etc. Most of these data are spatially distributed and their integration and use in irrigation planning and management has promoted the widespread utilization of Geographic Information Systems(GIS) and other modern information technologies[4-6].

Extensive studies have been done on developing an information system for irrigation systems management. Among the notable ones is GIS based Scheme Irrigation Management Information System (SIMIS), developed by Mateos *et al.*[7]. Similarly Rowshon *et al.*[2] developed a program for rice irrigation system. This computer program with a GIS-based user interface was developed to monitor the delivery of irrigation water. The objective of this study was to develop an information system for monitoring periodic irrigation delivery performance to assist in decision-making process on irrigation management during the source of a season.

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Several decision support systems for planning irrigation projects have been reported in literature[8,9] but operational decision support systems are scarcer. Azevedo *et al.*[10] developed Surface Irrigation Real-Time Optimization Model (SIRTOM) to be a real-time decision support system which is capable of improving surface irrigation performance on a real-time basis. It was built up on kinematics-wave simulation and non-linear optimization models to derive soil-water infiltration from real-time measuring data.

In this study, we introduce a GIS based information system model called SUGIS, meaning SUlama, the Turkish term of irrigation and Geographical Information System, developed to monitor and evaluate irrigation projects. The model is planned as a system that would provide the basic information needed in every phase of an irrigation system operation for data query and irrigation system performance assessment. The capabilities of the SUGIS model have been described.

THE SUGIS APPROACH

SUGIS is an interactive irrigation information system designed for irrigation project operation in both small and large scale irrigation systems which can be used by irrigation engineers and managers. The system supplies relevant information to the interested parties, such as irrigation engineers, water managers and farmers for evaluating the system performance and taking the necessary measures during the system operation to increase irrigation efficiency. The interactive data updating capability provides a unique opportunity to monitor and evaluate the effects of any decisions made in the system operation in time. On the monitoring and evaluation of irrigation projects in Turkey is used some basic parameters. SUGIS is designed according to Turkish irrigation project management system. It works on Geographical Information System which is Arc/Info and uses available data on Turkish irrigation projects.

SUGIS consists of three main modules ISDI, ISQ and ISA. The data is handled in two separate groups; static data varies according to the project site and dynamic data, which is updated seasonally based on changing environmental conditions and crop patterns.

With SUGIS, the irrigation manager is able to reach detailed information needed in the irrigation season and make assessments as well as being able to reach and check all the basic information concerning the project. It is necessary to monitor the changes in certain parameters and make measurements when needed in order for the irrigation project to be continuous and maintainable. By utilising these values that were entered in short intervals, SUGIS can produce various information to assist the irrigation manager in decision-making. With this information, as well as geographical demonstration, the size of certain featured areas can numerically be obtained. Thus, changes over the years and months can be monitored and evaluated.

SUGIS is an information system that can also be used for not only the information concerning maintenance work in the irrigation project area but also to calculate the cost of maintenance work estimated and used by taking the unit cost (such as in canals, water inlets and art constructions, etc.) into account as well.

As irrigation projects have geographical distribution and every kind of irrigation process is carried out in a geographical area, GIS is the most proper system for this aim. Thus, not only the visual geographical questioning and display can be carried out but also various properties of the geographical areas and other information can be reached.

Monitoring and evaluation standards and practices of the State Hydraulic Works of Turkey (SHW) which is the actuator of large scale irrigation projects and had been the manager of these projects until 1993 and of state irrigation unions which took over the irrigation projects after this year were taken into consideration while designing SUGIS. SHW and Irrigation unions carry out scheme irrigation delivery in irrigation project areas. These enterprises gather the production information from the producers before the irrigation season and carry out water delivery according to this information. Scheme Water Delivery practice here was taken in to account and accepted principals were adapted in SUGIS.

INTRODUCTION TO SUGIS

Software: SUGIS is a program concordant with the management of irrigation systems and the user. Information input and display of this input are carried out by using the prepared forms. Input of graphical information can be entered on the graph data entry screen formed by using the opportunities of GIS used and it can be displayed as needed. Schematic data are transferred to INFO tables with GIS. Attribute information belonging to graph can be entered attribute tables of coverage. SUGIS allows data transfer from some common data transfer formats. (for example: dxf, dbase and ascii etc.). Different map coverage can be coincided exactly and questioning can be made via the new coverage that is formed out of this coinciding when necessary.

SUGIS was developed in ArcMacro language which is the language for programming Geographical Information System software ArcInfo. Screen Forms were prepared with FormEdit software of ArcInfo, vector processes in

ArcEdit module, Raster processes in Grid Module and ArcPlot Module was used for mapping and drawing processes[11-16].

System components: The SUGIS information system was organized in three main groups. These are ISDI, ISQ and ISA. While determining the system components, great care was taken for the system to include components that will be reached at all times in irrigation project management or have permanent access. In order to do this, as well as examining the studies that other researchers have made, applications of the General Directorate of SHW and local irrigation unions' members were also applied. SHW has 2 251 625 ha irrigation area which will be opened to operation. After determining the system components, data were classified and designed in a certain order within the system.

Information system data input: SUGIS has the property of being able to study more than one irrigation project. Therefore, when the program is run, the project to be studied can be selected among the projects input formerly or the new project from the user with the screen form.

Data input of irrigation projects were designed as below; while ISDI was being designed, seasonal and annual stable information was organised as constant annual data and the data which change according to irrigation year was organised as changeable information.

In Constant Information entry section, mostly map-based information is entered. This is the information defining the irrigation project area. Information such as; database components; project border map, location map of the village within the project border, parcel map, topographical base map, road system, irrigation and drainage system map, soil survey map, groundwater observing well location map, location map of meteorology stations in the irrigation project area, etc. The Info data other than the attribute tables that attribute values will be entered are; features of the plants produced in the irrigation area, plant water consumption, parcel ownership information. Maps can be entered into the system as vector based and in coverage format. Each coverage can include polygon, line and point characterised data types. Data type in each coverage is applied in accordance with the map automatically. If change happens in the information input in the system, this new information can be transferred into the system.

Annual Information is a piece of information which changes in each irrigation season and therefore must be entered in each irrigation season. This information is mostly info data. There are six sub-choices in the screen form. Land Use Information of the Irrigation Season is requested from the farmers at the beginning of each irrigation season. In this declaration, every farmer reveals the crop he will grow in his parcels, area, irrigation method to be applied and sowing date. This information is used in scheme water delivery. In Irrigation Project Annual Data we can enter the information on daily amount of water taken from water resource, inlet flow amount given to irrigation canals of every level on a daily basis, outlet flow amount from drain canals of every level which is measured daily and maintenance, made or planned daily, name of the building where maintenance is to be done; type, amount, unit and unit cost of maintenance information can be input. In Groundwater Data Input choice, groundwater depth and groundwater salinity statistics which are measured monthly from the wells constructed in order to measure groundwater depth changes in the irrigation project area. With the choice Water Charge data input, water charges to be applied in irrigation season are entered. In Turkey, water charges are estimated mostly according to the produced crop and field area[17]. In some projects, irrigation is charged according to irrigation period. Average crop yield and price information is entered in order to determine the income after harvesting. Every year, during the harvest time average crop yield value and average crop price of the modelled farmers are entered. In Other Data Input information such as monthly number of operating structure, number of total structures, number of working equipment, number of total equipment are entered.

Information system questioning: In the ISQ module, constant, seasonal and annual data entered into the system are questioned.

In Questioning Constant Information, all the entered data can be questioned and displayed on graph screen. Questioning parcel information can be done both in the name of the farmer and the village. In village based questioning situation the whole area can be assessed by using individual parcels in the selected village. Parcel questioning is done by name, surname, father's name of the farmers. Parcels that belong to a certain farmer are graphically displayed in the whole irrigation area and information on these parcels can be listed.

Land use information, irrigation water demand, ISQ and water charge questionings are carried out in seasonal and annual questioning. Questioning of the cropping pattern can also be done. After this process, other irrigation canal is selected where the plant data is to be questioned. Here we can question the plant pattern in the parcels getting water from only a certain canal or questioning on the whole project area. In addition to displaying the result of questioning on the graphical screen, information such as plant growing, area, number

Table 1: Irrigation scheme performance indicators of SUGIS

Net water supply ratio	$\frac{\text{Water delivered at the head (m}^3\text{/ha/year)}}{\text{Net irrigation water demand (m}^3\text{/ha/year)}}$
Total water supply ratio	$\frac{\text{Water delivered at the head (m}^3\text{/ha/year)}}{\text{Total area water demand (m}^3\text{/ha/year)}}$
Irrigation efficiency	$\frac{\text{Irrigation water demand (m}^3\text{/ha)}}{\text{Water delivered at the head (m}^3\text{/ha)}} \times 100$
Irrigation ratio	$\frac{\text{Irrigation cropped area (ha)}}{\text{Command area (ha)}} \times 100$
Functionality of the system	$\frac{\text{Number of structures functioning}}{\text{Total number of structures}}$
Effectiveness of the maintenance program	$\frac{\text{Number of structures repaired}}{\text{Number of strcutures in need of reparation}}$
Fee collection performance	$\frac{\text{Irrigation fees collected}}{\text{Irrigation fees due}}$

of parcels can be listed on a table. With Irrigation Water Demand Questioning, the total irrigation water needs of the plants being grown in the project area can be questioned on the level of project or canal.

In irrigation system questioning section, daily flow amounts of the canals of every level in the irrigation and drainage system can be listed for desired periods in question. Furthermore, maintenance work carried out on drainage, irrigation and road systems as well as in art constructions can be listed for periods in question. In the questionings on water charges, water charges of all farmers can be questioned.

Irrigation system assessment: ISA module covers some project assessment indicators. These indicators are net water supply ratio, total water supply ratio, irrigation efficiency, irrigation ratio, functionality of the system, effectiveness of the maintenance program, fee collection performance and evaluation of groundwater measurement results (Table 1).

In assessment of groundwater measurement results section, a map of water depth and salinity values that are measured monthly is formed. These maps are, depth-to-groundwater-table map, groundwater-table contour map, electrical conductivity map and problematic area maps showing the areas where groundwater depth from ground surface is equal and less 0.5 m and salinity value is over 2500 micromhos/cm.

In profit derived from irrigation assessment, profit gained in the irrigation that were run by irrigation management is as Turkish Lira (TL) ha^{-1}; production values in the areas irrigated without a project (before the irrigation project was constructed) and in today's state and Gross National Agricultural Income can be evaluated here.

In proportion of cost/benefit section, after calculating profit and expense, proportion of profit and expense can be calculated[18].

CONCLUSIONS AND SUGGESTIONS

In recent years, most of the irrigation systems in the world have been turned over to user unions. Thus, it is intended to make irrigation projects run more efficiently and productively and improve the projects. To do this, the system should be constantly monitored and evaluated. An easily comprehensible and useful system is needed for monitoring and evaluating.

With this study, a main information system called SUGIS was developed to monitor and evaluate irrigation projects. Opportunities and capabilities of geographical information system was used in this system. SUGIS can be used in large- and small-scale irrigation projects equally.

Information can be transferred to the main information system via forms and the information in dxf format can be transferred directly. Information is classified as constant and yearly and some of it is held constant in the system and used and some of it is kept ready in order to be used yearly.

In the monitoring and evaluating system, great care was taken in order to ensure that the main structure is created first and then other structures in low level are added. Thus, the burden on the user eases while obtaining information, it gets easier to make decisions and evaluations about the projects and it's possible to take necessary precautions in due course.

In SUGIS basic information system, information about irrigation projects of any size and also information of more than one irrigation schemes can be processed. The system will meet the information and evaluation needs of project managers as well as the upper establishments that will be founded in all the country and it is designed so the user can reach the information easily. Although the system was created according to data obtaining conditions used in irrigation projects in Turkey, it is open to be developed. Changes that might take place in the project information can be updated when wished. The feasibility level of aims can be determined and new aims can be updated when wished.

The feasibility level of project aims can be determined and new aims can be taken with the information system. It is possible to make additions to the program and alter and develop it in order to evaluate the obtained information or project as time passes.

The system was tested with the information of a present project. It is better to test it on other projects to reveal probable errors. In irrigation system evaluating module, only the evaluating criteria that the SHW managing and maintenance department uses are used. It

is possible to enrich the model by using other criteria that has a common usage in the literature and evaluates the performance of the system.

With the basic information system developed, by using capabilities and properties of GIS, operating and managing of irrigation projects can be ordered, related and evaluated. Thus, graphical and tabular information are evaluated separately or together and become more understandable and results of questioning and analysis can be displayed in graphical form. The model is easy to use and purified of the complex command system of GIS.

SUGIS works in ArcInfo environment. It does not contain Irrigation Management Module as it is in the character of basic information system. By adding this module, a more decision-support environment will be created for the user.

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