4 - INFORMATION SYSTEM FOR IRRIGATION MANAGEMENT TO COMBAT DESERTIFICATION. APPLICATION TO FERGANA VALLEY

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Abstract: The article provides key information with regard to Fergana Valley – where the pilot site of the CIRMAN-ARAL project is located – and gives a brief description of the newly developed information system containing data necessary for implementing the project and modelling the processes that occur in the course of water application to various crops. The structure of the system is discussed as well as three stages of its development: 1) elaboration of topology within the surveyed area; 2) monitoring designed to accumulate and up-date information on a regular basis; 3) development of GIS and database to be used in modelling and for improvement of decision support system.

Keywords: Integrated Water Resources Management, Anthropogenic desertification, Database, Mathematical models, Interface.

Introduction

The information system designed for irrigation management is based on several hierarchical levels of water and land resources management and relevant water use facilities as well as various levels of water resources formation and use taking as example the Fergana Valley (Fig. 1). The system is unified – i.e. provides uniformity (or compatibility) of technical means, technologies and procedures of collecting, processing and analyzing information, as well as ensures identity of software products and table algorithms, formats of obtaining and transmitting various types of information by hierarchy levels. It also represents time aspects and consumable-qualitative parameters describing available and used land and water resources. The system allows conducting control over relevant indicators at four basic levels of the current water management hierarchy:

Level 1 – Farms, including separate fields;

Level 2 – Water User Association (WUA) and cooperative farms;

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Level 3 – Irrigation system;

Level 4 – The Basin (Fergana Valley – the Syrdarya river basin).

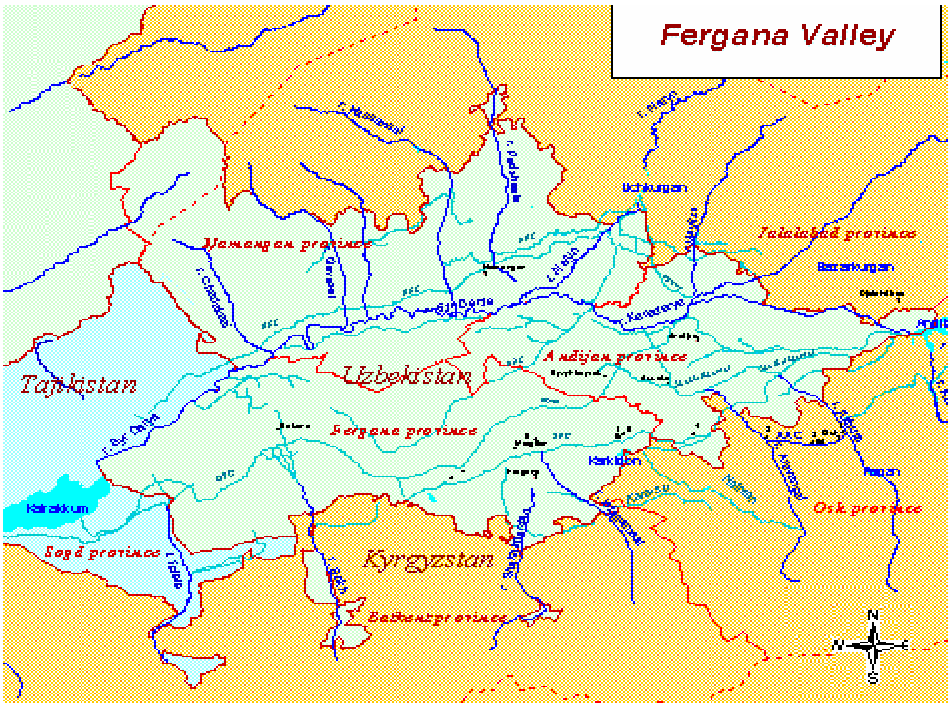

Fig. 1. The Fergana Valley.

It should be noted that the third level is a connecting-link between various current databases – the regional database "WARMIS" and the "IWRM-Fergana" project's database. Interfacing with the database of BWO "Syrdarya" also takes place here.

Each level contains a relevant database designed for centralized storage and management of interrelated data packages, which adequately represent the state of targeted objects at the given level and relations between them.

Level 1 – The database includes all principle parameters of water use and agricultural production. Among basic indices there are: - characteristics reflecting the state of separate fields, water management and irrigated lands reclamation in various economic entities; - volumes of water withdrawal from irrigated systems, water and land resources use at the farm level; - crop patterns; - indicators of agricultural production on irrigated lands; - technical condition of on-farm irrigation network. The database also contains information obtained through ground-based observations enabling to evaluate land productivity with application of GIS and remote sensing methods. The main function of the database is to facilitate efficient water and land resources use at the farm level through working out pertinent assessments coupled with correlation between actual data and potential water/land productivity.

Level 2 – The database includes all principle parameters reflecting performance of current WUAs. It runs such basic indices as: - indicators of financial support necessary for operation of irrigation and collector-drainage network; - indicators of uniformity in water delivery within a group of farms (in vegetation and non-vegetation periods); - characteristics of irrigated and drained areas; - dynamics of irrigated land reclamation; the state of technical means in a representative farm, etc. The main function of the database is to facilitate evaluation of current WUAs (a group of farms) performance and feasibility studies with regard to effectiveness of would-be WUAs.

Level 3 – The database includes all principle parameters reflecting performance of water management organizations (systems). It runs such basic indices as: - volumes of water withdrawals from irrigation sources by administrative districts and main canals; - characteristics of irrigation water delivery (required volumes of water delivery, allotted quotas, actual volumes) by administrative districts and sources of water; - technical efficiency of irrigation systems and amount of organizational water losses; - financial-economic characteristics of water management systems by their main structural sub-divisions. The main function of the database is to facilitate evaluation of performance with regard to water management organizations (systems).

Level 4 – The database includes all principle parameters describing the region as a whole (Fergana Valley and the Syrdarya river basin).

Fergana Valley – the territory of pilot studies

Fergana Valley is one of the world ancient oases with the history of irrigation and civilization evolution that has been dated by millenniums – similar to those in India, Egypt, China and Middle East. Fergana Valley is located in the southwest of the vast Tien-Shan mountain ridge with glaciers and perennial snow being water sources for the Naryn and Karadarya rivers. Both rivers flow down to the Valley in the east and through joining form the Syrdarya River that flows down to the southwest dividing the Valley into two asymmetric parts. The Valley extends about 250 km (measuring the distance from Uchkurgan HPS on the Naryn river to the town of Hodjent) and about 300 km to the west (measuring the distance from Kampyrravat Dam on the Karadarya river). The expansion of the plain in the alignment of Kassan-Namangan – Fergana – Vuadil reaches 130 km and gradually narrows to 5 - 10 km in the west. The Valley is surrounded by the Fergana (in the east), Alay and Turkestan (in the south), Chatkal and Kuramin (in the north) mountain ridges.

A significant part of tributaries into the Syrdarya river within the Valley (more than thirty) at present do not reach the Syrdarya since their flows are entirely used for irrigation. There are the following major lateral streams: - the

Padshaata, Gavasay, Kasansay, Karaungur, Kugart, Ak-Bura, Aravansay, Isfayramsay, Shahimardan, Soh, Icfara, Hodjabakirgan (Fig. 2.), etc., which mainly flow down from the Fergana and Turkestan ridges. The Syrdarya river generates about 70% of the total surface water flow in the Fergana Valley, the rest of rivers form about 30% (Table 1).

Fig. 2. Hodjabakirgan head works.

Table 1. Surface water flow from the flow formation zone in the Syrdarya river Basin and its share in Fergana Valley (Km^3/year).

River flow according to readings at hydrometric posts	Inflow from the a flow formation zone		
	Maximal (P=5%)	Average long-term	Minimal (P=90%)
The Syrdarya Basin, total	58.91	37.20	23.97
The Syrdarya down to Chardara reservoir	54.46	35.42	23.44
Naryn - Uchkurgan	20.68	14.54	10.68
Karadarya – inflow to Andijan reservoir	6.49	3.92	1.83
Interfluvial, between Naryn and Karadarya rivers	3.69	2.07	1.10
The right bank of Fergana Valley	2.16	1.18	0.73
The left bank of Fergana Valley	5.79	4.54	3.49
Fergana Valley, total	38.81	26.25	17.83
Share of Fergana Valley in the Syrdarya flow,	65.9	70.6	74.4
The flow down to Chardara	71.3	74.1	76.0

Favourable living conditions in the oasis have been for a long time fostering development of irrigated agriculture. Characteristics of land resources in Fergana Valley with regard to irrigation are given in Table 2.

Table 2. Land resources in Fergana Valley with regard to irrigation (10^3 ha).

Region, Country	Territory	Fit for irrigation	Irrigated			Land available for development
			1930	1970	2000	
Fergana Valley	9053	1539	675	1066	1376	163
Kyrgyzstan	6408	341	162	214	331	10
Tajikistan	699	197	39	97	134	63
Uzbekistan	1946	1001	474	755	911	90

As a result of agricultural development Fergana Valley has turned out to be one of the most densely populated regions of Central Asia – this exerting high demographic pressure on sustainability of development owing to low migration capacity of local population (Table 3).

As evident from Table 3, a share of rural population constitutes 62.5% in Namangan province (Uzbekistan) and up to 77% in Osh province (Kyrgyzstan). It should be borne in mind that on average only 0.16-0.22 ha fall to the share of one person living in rural area and the reserves of land available for development (Table 2) have been almost exhausted. Hence, in order to solve problems of social welfare in the Valley it is necessary to focus on addressing the ways to increase irrigated agriculture productivity, enhance secondary processing of agricultural produce and develop small and medium businesses – both in agrarian sector and other industries.

Table 3. Demographic indicators in Fergana Valley (2000).

Indicators	Andijan (Uzbekistan)	Fergana (Uzbekistan)	Namangan (Uzbekistan)	Sogd (Tajikistan)	Osh (Kyrgyzstan)	Djalalabad (Kyrgyzstan)	Batkent (Kyrgyzstan)
Population (10^3 people)	2216.5	2697.5	1953.2	1904	1211.7	893.9	384
Including rural (10^3 people)	1550.9	1916.7	1221.4	1245	926.3	685.6	310.3
Population growth rate (%/year)	2.4	2.4	2.7	1.4	1.83	1.61	1.5
Density of population (person/km^2)	527.7	402.6	263.9	75.2	41.5	26.5	23.3
Irrigated land (ha/capita)	0.171	0.186	0.222	0.145	0.159	0.192	0.184

At the same time, indicators for the recent years reveal signs of increasing social tension, especially with regard to Uzbekistan. The population growth rate has been increasing here by 2.4-2.7% a year (Table 4), only less than half of labour resources in rural areas have been used directly in agricultural sector, GDP is within the range of 2.9%-7 % under average level of GDP per capita of 377–572 \$/capita/year – significantly less than the average value in the country.

Table 4. Socio-economic indicators in Fergana Valley provinces of Uzbekistan (2000).

Indicators	Andijan	Namangan	Fergana
GDP, billion Uzbek sums	260.55	167.92	326.783
GDP, million USD	1267	746	1562
GDP per capita	566	377	572
GDP growth rate (%)	7	5.8	2.9
Population growth rate (%)	2.4	2.7	2.4
Labour resources (10^3 people)	1104	939	134
Including those in rural areas	761	586	951
Employment in agriculture	339	245	420
% of rural population	69.0	62.5	71
Average monthly wage, Uzbek sums	8573	8053	9039

At present, number of jobless in the Valley has exceeded several thousands of people. It is clear that the problem of providing agriculture with water and other necessary prerequisites has become to be a task of great importance and priority in conditions of productivity slowdown in irrigated agriculture and recession of profitability caused by land degradation processes.

The current irrigation system operating in Fergana Valley provides services to more than 40 thousand independent self-supporting water users – including 38.5 thousand farmers, 1.5 thousand cooperatives, 119 Farmers' Associations and 306 non-irrigation water users. Water delivery is carried out through the network of inter-farm canals (12.4 thousand km) and inter-farm collectors (more than 9.5 km). Irrigation systems and facilities that are now in use were constructed as far back as Soviet times and they have been operated for decades. Canals and water facilities, which used to represent state-of-the-art schemes, require now radical rehabilitation or reconstruction. This virtually applies to a significant part of main systems and all inter-farm irrigation networks and - not to a lesser extent – on-farm irrigation net, which as far back as Soviet times failed to match inter-farm systems.

Table 5 show the actual water availability and distribution of volumes withdrawn from sources in Fergana Valley in general and by each State.

Table 5. Total volumes of water withdrawal, delivery and conveyance in Fergana Valley (2000).

State	Total volume of water withdrawn from sources		Total volume of water delivery at borders of farms		Total volume of water conveyance	
	Million m^3	%	Million m^3	%	Million m^3	% of water withdrawal
Uzbekistan	10161.1	69.7	7931.1	69.1	3790	37.3
Kyrgyzstan	2675.8	18.4	2155.1	18.8	764.2	28.56
Tajikistan	1728.9	11.8	1391.0	12.1	672.5	38.9
Всего	14565.9	100.0	11477.2	100.0	5226.7	35.88

The database and software package consist of the following blocks:

- Supplemental information and Field Passports: This block incorporates database directories ("Reference Books") describing permanent or slightly varying information on countries, provinces, districts, farms, inflow, fields, canals, water outlets, outflow, transit, hydro-posts (HP), control stations (Section lines), wells, type of drainage flow, method of water application, type of spill-weir and crops. In addition, the structure of the farm (including plan-scheme of irrigation net, characteristics of HP, characteristics of plots and the characteristics of canals)and the Field Passports;
- Registration of actual data: includes the register at HP and the reports;
- Introduction of irrigation norms and their updating;
- Activities related to groundwater and salt-affected soils: includes Groundwater tables (GWT) by section lines, GWT by fields, GWT according to GIS, soil salinity and types of soil residuals;
- Drainage flow – data input and updating;
- Climate data: includes data of average long-term, decade and daily;
- Mathematical model calculating Plans of water delivery to fields;
- Methods and recommendations: includes methods to increase land productivity, recommendations on mineralized water use, methods of determining land productivity, methods to determine parameters and evaluate drainage efficiency, methods of determining water-salt balance, methods of determining water use and RZWQM model.

Each block stipulates generation of reports, data can be presented in table or graph forms.

The software has been developed on the basis of DBES ACCESS represents a set of files:

- “CopernicusEng and CopernicusRus” that incorporates all software, time-worksheets, database queries, forms of inputting and updating information, and reports;
- “Copern_Data” – storing residence of all data for one season or a year.

There may be several files of the “Copern_Data” type, depending on a necessity to keep data for the previous periods saved. The “Change over to another year” Menu contains the “Option” entry enables to select a needed item and the “New” entry creates a new file of the “Copern_Data” type with a copy of “Reference Book” from the current file and empty tables (formats) of the documents.

The program being loaded and the system Principle Form appears on the display (Fig. 3.), as well as the Menu enabling to run remaining blocks. The user selects a farm (irrigation system) in the Principle Form and calculates water distribution parameters. The Menu’s options are describes in the Table 6.

The operation is run in two regimes: 1) input and 2) look-up and data updating.

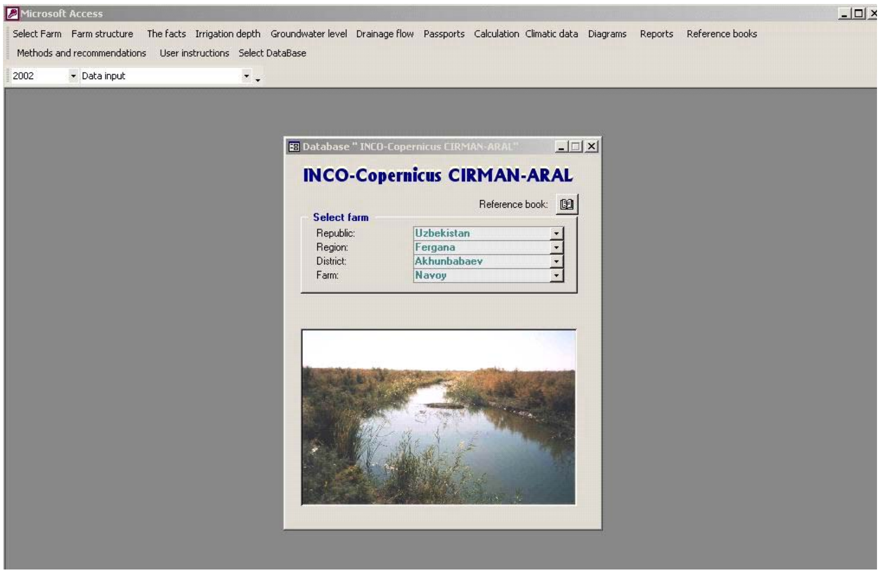

Fig. 3. Principle Form of “CIRMAN-ARAL” information system.

The following steps are necessary for computation of the Water Distribution Model:

1) Select the irrigation system structure;
2) Designate irrigation norms;
3) Start computation.

There are relevant diagrams in the submenu “Graphs” to be applied for comparison of irrigation “Plan”, “Fact” and “Norm” values. The “Reference Book” button is placed in the right top corner. With the button pressed a certain “Reference Book” appears depending on the option positioned by the cursor. For instance, if the user selects “Farm”, then “Reference Book” button is pressed the relevant “Farm – Reference Book” appears. The “Report” button is placed in the left lower corner – with this button pressed the report format appears. Users may look-up and print out needed information.

There are “Reference Books” in the program relevant to water users, water diversions, attachment of diversions to water users, water measuring devices, calibration curves, responsible executives, executives, hydro-module districts, and ordinates of hydro-modules, districts and irrigation networks.

Table 6. The Menu’s options.

Submenu	**Options**
Selection of a farm	
Actual data	
Irrigation norms	
Groundwater table	
Drainage flow	
Passports	
Computation of the model	
Climate data	
Graphs	Discharge schedules at HP Irrigation schedules for fields Comparative “Norm/Plan” graphs Comparative “Fact/Norm/Plan” graphs Inflow to the irrigation contour Discharges along canals
Reports	The register of water discharge at HP Reports Drainage flow by drains
Reference Books	
Methods and recommendations	
Users’ Manuals as they apply to the systems	CROPWAT ISAREG GISAREG
Data base selection (by year)	

The “User-Reference Book” is represented in the form of an ordinary list, to which data record can be made, changed or deleted. Though, in case of deletion there is a risk of loss of all information relevant to a would-be deleted water user. The "Water outlet-Reference Book" is also represented in the form of an ordinary list, but it is subdivided according to types of diversions – a main canal, secondary canal, diversion canal, discharge and recharge (Fig. 4). The user should select a type of a waterway from the evolving list located at the top of the form, and then all types of diversions would be represented. In the "Attachment of diversions to water users - Reference Book" each diversion is assigned to a water user. At that, several diversions may be assigned to one water user. The "Water measuring devices-Reference Book" displays a type and designation of measuring devices. There is an outlet from this "Reference Book" to the "Calibration curves-Reference Book", in which marks and amounts of pertinent discharges are to be entered for every measuring device.

Fig. 4. A diversion from the South Fergana canal by Andijan.

"Ordinates of hydro-modules – Reference Book" is designed for selecting a hydro-module district, specifying corresponding crops and inputting relevant ordinates. Reference Books containing information on "Responsible executives", "Executives", "Districts" and "Irrigation networks", are represented by set of entries, which can be supplemented, changed or deleted by users. The Table 7 shows the types of report in the program.

Reports can be derived for both – a single user and all users depending on propositions. The user specifies a period (for annual reports) or a decade (for decade reports). Available documents are to be indicated in the table. If relevant documents are not available, corresponding data are missing in the report. There are two buttons in the lower part on the form: for look-up and print-out of reports.

Table 7. Types of reports.

Report	Type
Plan	for a year for a decade
Quotas	for a year for a decade estimated
Water demand	for a year for a decade

The experimental site (Fig. 5) has been selected in the "Azizbek-1" farm of Akhunbabaev district, Fergana province. Water is delivered to this site by the canal with several smaller diversions. Parameters are determined for every diversion canal, which are inputted into the database. There are 16 water outlets to the fields. An outlet delivers water to a corresponding field (plot). A set of parameters is determined for each plot. The information on each experimental plot is passed over to the mathematical model for computation of the Plan. The data output of the model in the form of the Plan is passed over to the database and submitted to the user.

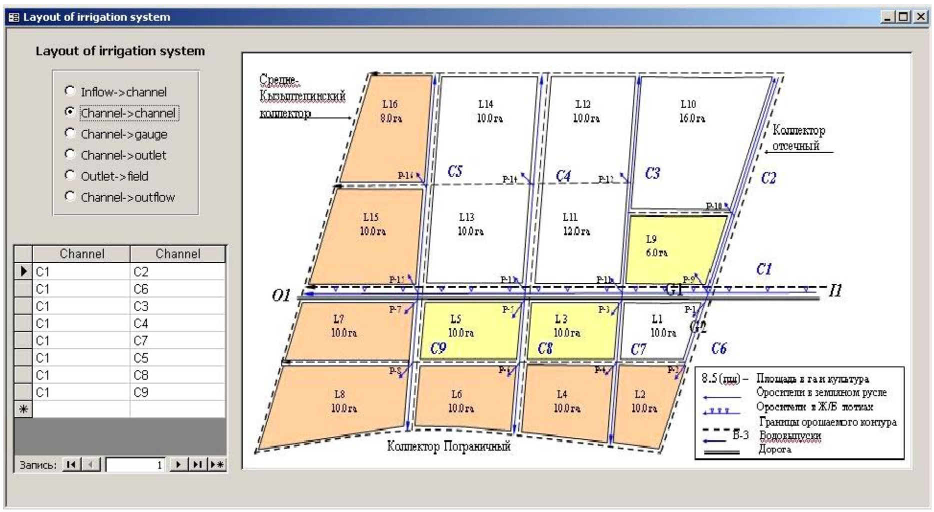

Fig. 5. Window showing the irrigation system of the experimental site.

GIS materials are of significance for performance of the information system in processing data (Fig. 6). GIS enables to present visual information about the fields. GIS maps and various layers may provide users with a powerful tool of analysis. GIS allows carrying out easy calculations of grid objects as well as solving some problems – for instance, of path determination and others. GIS employs effectively space images and their application permits making the information on farms' structures more accurate.

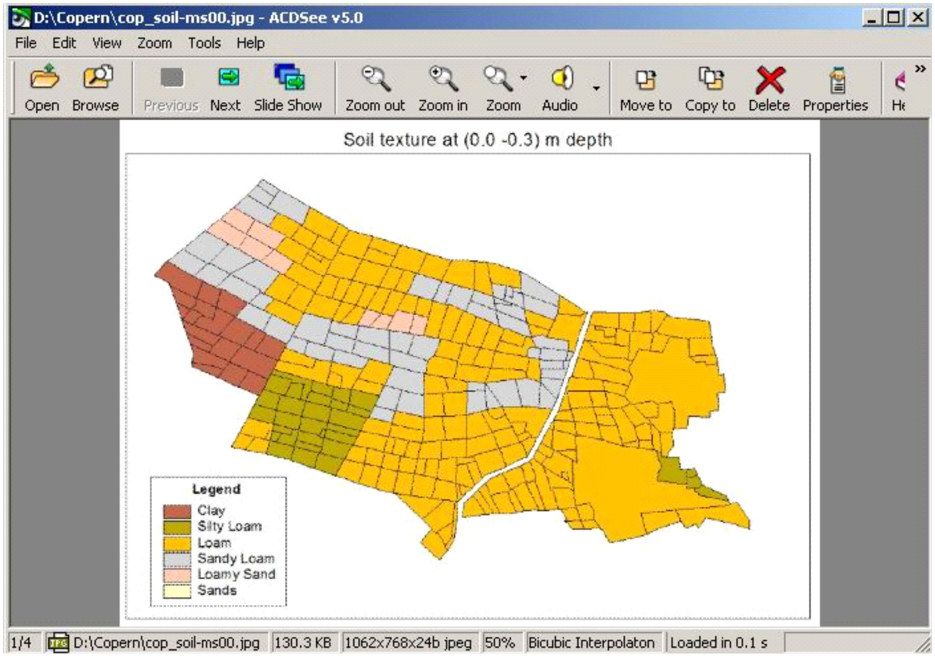

Fig. 6. Example of a GIS representation of soil textural classes at a pilot site.

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