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CIMIS (COMPUTERIZED IRRIGATION MANAGEMENT INFORMATION SYSTEM)

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Abstract
CIMIS is a menu-driven system of integrated databases which enables efficient use of data available in the field or project for effective planning, operation, maintenance and management of irrigation system. This will ensure the improved irrigation efficiency and maximum return to the limited supply water. Although the CIMIS involves large number of databases and programmes, the step by step approach of data processing and calculation by menu system enables easy access to those who do not have experience in database operation.

Although the CIMIS programme is composed of 9 menus, the paper centres around the Water Distribution Option which is relevant to this seminar. The Water Distribution Option can carry out tasks indicated in the following menus.

a. Planning, Simulation and Optimization
b. Daily Operation
c. Evaluation and Monitoring

1) Planning, Simulation and Optimization
Planning of water distribution has been carried out in the past crop by crop plot by plot basis. It was quite difficult to simulate on the project basis what will be the change in water demand if some parameters such as possible rainfall, crops, planting period or area are modified. CIMIS made this process very easy so that best possible optimization caan be done in the planning stage with least amount of work. Matching between water supply and water demand can be done graphically.

2) Daily Operation
Based on the crop pattern planned in the previous menu, several options of system operation are provided by different irrigation scheduling methods :

i) Rational Method : Irrigation scheduling is calculated based on the crop water requirements and readily available moisture (RAM) and is adjusted every month.

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ii) Fixed Rotation Method : Irrigation is carried out with predetermined intervals with predetermined amount irrelevant to the soil moisture condition or crops grown in the field.

iii) On-demand Method : Irrigation water is distributed by the request of farmers.

(3) Evaluation and Monitoring
Because CIMIS can monitor the daily fluctuation of soil moisture in every method, data obtained can be used to evaluate the impact of water depletion on crop production. CIMIS can also make comparison between water distributed to the field and water actually used by the plant and calculate the irrigation efficiency.

Introduction

CIMIS is a menu-driven system of integrated databases which allows data available in the field or the project office to be used effectively for planning, operation, maintenance and management of an irrigation system. The initial version of the program was developed and tested for adaptability and applicability by a FAO trust fund project in Brazil (UTF/BRA/027/BRA). The results obtained using the program application were very encouraging, with effective processing of data and improved management of the irrigation system. However, the program at that time was limited in scope and the different applications were not fully integrated. The need was strongly felt to integrate different applications and enable the program to use results from applications.

Based on this experience and the needs identified, work was started in FAO with an aim of establishing more integrated program for managing an irrigation system. After passing through several prototypes, the CIMIS program at present comprises of 10 menus to cover all aspects of irrigation system management: i) land use and tenure; ii) crops, iii) climate; iv) irrigation infrastructure; v) machinery; vi) personnel; vii) water distribution; viii) maintenance; ix) operation and maintenance cost; and x) agricultural production.

The current paper discusses the Water Distribution menu, which is intended to optimize the planning and operation of irrigation water delivery and efficiency. The Water Distribution unit in CIMIS has the following three options: i) Planning, Simulation and Optimization; ii) Daily Operation; and iii) Evaluation and Monitoring. By introducing CIMIS, the burdens of the project manager and his or her staff in handling large amount of information should be reduced and improved, and flexible irrigation system operation will be achieved.

Irrigation Canal Operation

Irrigation canal operation can be divided into three stages, namely the planning of the operation, the actual operation of water delivery, and the monitoring and evaluation of operational results for recording and future planning. Two important elements in canal operation need to be determined and monitored at all three stages: water volume and the timing of water delivery. These have important implications for the system infrastructure and the management set-up.

In the planning stage, the volume of irrigation water is determined by the expected climatic conditions (rainfall, sunshine, humidity, etc.), crop water requirements and expected irrigation efficiency (management and infrastructure). This volume can be supplied continuously or through rotation, and be fixed (constant) or variable. The system capacity, in terms of irrigation infrastructure and management capacity, largely determines whether flexible or rigid irrigation operation can be adopted.

Based on the plan established prior to the irrigation season, the actual canal operation proceeds. If the system is flexible, the actual canal operation and water delivery can be modified from the original plan to cope with varying climatic conditions or changes not anticipated at the planning stage. Without any effective management tool and with limited time and resources, it often happens that irrigation water delivery is carried out as originally planned without reflecting any changes, and the water is wasted or used in-effectively.

In addition, it is important to monitor and evaluate how efficiently water and other resources are utilized for crop production, and to provide feedback to the planning stage. A tool that can manage all this information is thus required also at this stage.

Canal operation activities as mentioned above have, in the past, been carried out separately on a crop-by-crop basis, with hand calculator or computer. However, difficulties were encountered when one of the assumptions of the simulation had been modified. All the calculations had to be repeated and the simulated result has to be processed again, which involved a lot of work. These difficulties and the associated increased work-load prevented the operator from adopting the flexible operation practises, even when the system capacity was not a limiting factor.

The 'Water Distribution' unit of the CIMIS was developed to solve the above-mentioned difficulties at the planning, operation and monitoring stages, with only minimal additional work requirements. The program provides many options in terms of possible operations, so it can be easily be adapted to varying local conditions and help to establish the most flexible system under particular constraints of local infrastructure and management capacity.

Computerized Irrigation Management Information System

System Requirements

Although the CIMIS involves a large number of databases and programs, the step-by-step approach to data processing and calculation by using a menu system enables easy access for users who do not have experience in database operation. The hardware requirement of CIMIS are a 'standard personal' computer (40 Mb hard disk, 1 Mb of RAM and VGA or CGA card) with a fast co-processor (80386 or greater). The software used is dBASE IV (version 4.1) for programming and data management, and dGE (version 4.1) for graphics presentation.

Planning and Optimization of Water Delivery

Planning of water distribution has been carried out in the past on a crop-by-crop or plot-by-plot basis. It has been quite difficult to simulate on a project basis what would be the change in the water demand if some parameters, such as possible rainfall, crops, planting period or area, are modified. CIMIS makes this process very easy, so that a reasonable optimization can be done at the planning stage with the minimum amount of work. Matching the water supply and the water demand can also be done graphically, as an integrate part of the system.

In the program, crops grown in the project area and their normal planting month are input and stored in the database. The program then calculates the crop water requirements (mm/day) according to the climatic data (effective rainfall and evapotranspiration, which is obtained from the Climate Menu) and the crop data (crop factor and growth stage). All crop data and climatic data are processed and stored in different databases in the Crops and the Climate options of the program. The calculation is carried out on a decadal basis for the entire growing period of the crops. The crop water requirements of 9 different planting decades (3 decades before and 3 after the planting month) are calculated to enable the staggering of planting in the optimization process.

The operator/designer then assigns the early planting and late planting decade numbers and the planting area of each crop to be grown in the project, as proposed by farmers. The program can then calculate the scheme water needs, with a prevailing irrigation efficiency, which can be compared with the stored scheme water supply, which is stored in different database. If the supply and the demand do not match, the designer/operator can adjust the water demand by modifying either the planting period (including staggering) or the area planted to each crop. Different types of rainfall can be used to analyze the impact of rainfall on crop water requirements. The matching can also be done graphically. The selected cropping pattern will then be used in the daily operation.

The calculation of monthly irrigation interval and irrigation water depth on a crop-by-crop basis is carried out at this stage to check various combinations of irrigation interval and water depth for each month.

Daily Operation and Management

Difference between the planning/design and the daily operation of the irrigation system is that the latter relies on the real rainfall instead of the expected one. Slight variations in the area planted and the date of planting can also be expected at the operational stage. If one knew exactly when and how much rainfall/sunshine is expected, or one can monitor the water needs of a crop (tensiometer or moisture block, etc.), one could decide exactly when and how much irrigation water must be applied to maximize crop production. However, because rainfall is difficult to predict and monitoring of soil moisture conditions is not easy, one has to make a forecast of when and how much to get the most effective irrigation application under the specific water supply condition. Because the total amount of water needed by a crop is fixed by crop water requirements, it is the scheduling (interval of application and the depth of application) of irrigation which makes the difference in the efficiency of water supply. The system becomes easier to operate the longer the interval and the larger the volume of the water application. However, the possibility of crop damage and inefficient water use increases by adopting longer intervals and larger volumes of water application.

CIMIS uses the actual date of planting for each plot with different crops, and calculates when each plot (specific date and hour of irrigation) will be irrigated, with different irrigation scheduling methods. Four methods of irrigation scheduling are considered, namely:

i. *Rational Method*. Irrigation intervals and water application depths are calculated based on the crop water requirements and readily available moisture (RAM), and are adjusted every month.

ii. *Semi-fixed Method*. Irrigation intervals and water application depths are calculated as for the rational method, but they are varied at larger intervals - a few times a year - depending on the crop mix of the scheme.

iii. *Fixed Rotation Method*. Irrigation is carried out with predetermined intervals and depths irrespective of the crop water requirement or RAM, and the intervals and depths are fixed throughout the year or the irrigation season.

iv. *On-demand Method*. Irrigation water is distributed as requested by farmers. The amount and timing of irrigation is decided by the farmers concerned on the basis of their experience.

In the Fixed Rotation Method, because the intervals and depths are fixed for the entire irrigation season, there is not much room to satisfy the demands of different combinations of crops and soils. Therefore, there could be a large chance of over supply or water shortage, depending on the value of the interval and the depth of water application. For example, to accommodate the peak demand period, the depth of water application should be large enough, but the size of RAM, which changes according to the crop growth stages and the soil type, might not be large enough to store all the applied water. However, many of the gravity schemes in the developing countries are operated by this method because the method is very practical and easy to operate, involving no difficult operational infrastructure or sophisticated management capacity. In methods (i) and (ii), more flexibility of operation can be achieved because there is more room to change the scheduling on a monthly or seasonal basis.

The On-demand system can be most efficient when the irrigator/operator knows exactly when and how much to irrigate, and when the irrigation system can accommodate all the requests. The interval is usually fixed at one week or one decade for practical reasons and several days before each interval the farmers put in their requests for water delivery for that interval. The requests are summed and if it is within the system capacity, it will be delivered according to the requests. If the demand is larger than the system capacity, the irrigation will be deferred to the following interval, but then giving priority to the plots which could not be irrigated in spite of the requests.

From the point of canal water delivery, the discharge in the tertiary canal is fixed in most irrigation schemes. Varying water demand can be adjusted by changing the duration of water delivery. When irrigation is under way, the tertiary canal is fully opened, and it is fully closed when there is no irrigation. Thus at the peak water demand period, the canal will be open all the time.

Another factor to consider is the capacity of farmers to handle the size of canal flow for irrigation (irrigation module). Experienced farmers can handle a large flow while inexperienced farmers can handle only a limited amount of flow, and horticultural crops require smaller flows than field crops. The ranging capacity of farmers or various combinations of crops in different project areas should be reflected in canal operation to achieve effective delivery of water from the tertiary canal to the farmers' field. CIMIS has the option of varying this parameter. When the canal discharge is larger than the irrigation module, it can be subdivided into several units and several farmers can be irrigated at the same time.

Based on the irrigation module, the size of canal discharge and the volume of water application, the time needed to irrigate each plot is calculated, and ordered according to the predetermined priority. Therefore, farmers can know exactly when they start and stop their irrigation, and when they have to plan the next irrigation.

Evaluation and Monitoring

It is important to know the efficiency of irrigation and the possible impact on the crop production so that best possible method of water application can be adopted, thus attaining optimal crop production. The program can calculate the total volume of water required for each scheduling method, and thus the efficiency of operation can be calculated by comparing the calculated volume with the net crop water requirement. In addition, the program monitors the fluctuation of soil moisture on an irrigation interval basis by calculating the soil moisture balance. If the available soil moisture falls below RAM, the possible damage to crop production is calculated by using the yield response factor for different growth stages. The overall damage to crop production by any water shortage can then be calculated by accumulating the damage for the entire growing season.

Actual Application of the Program

To test the applicability of the program, an irrigation scheme of about 170 ha with 78 plots was considered. Crops grown in the region are onion, cotton and potato, and they are normally planted in April, July and October respectively.

In the planning and optimization stage, CIMIS calculates the crop water requirements of each proposed crop, with different planting periods (a total of 9 planting decades is used to enable staggering of planting). After this, the actual planting decade, with staggering, and the planted area to be planted to each crop are assigned, and the net scheme irrigation need is calculated. By assigning the irrigation efficiency and operational criterion (hour of irrigation/day), the gross scheme irrigation need and the water supply are compared. The area to be planted and the timing of planting are adjusted to have the best possible fit to the water supply. For an example of a final cropping pattern see TABLE 1. Based on this cropping pattern and crop water requirements, RAM and irrigation intervals for different months are calculated for each crop and for different planting decades. The minimum values of RAM and interval for each month are selected as values for irrigation scheduling. The result is shown in TABLE 2.

Table 1. An axample of Cropping Pattern

crops	Early Pl.	Late pl.	Tot. Grow	area
	Decade	Decade	days	ha
cotton	July 1st	Aug. 2nd	180	80
onion	Apr. 1st	May 1st	150	100
potato	Oct. 1st	Nov. 1st	130	50
Total				230

Table 2. Typical Irrigation Interval and RAM

crop			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
cotton	Interval	day								21	7	5	6	18
	RAM	mm								32	32	32	32	92
onion	Interval	day				5	4	4	11	16	14	14		
	RAM	mm				22	22	22	38	38	54	54		
potato	Interval	day	9	11	19							12	9	6
	RAM	mm	49	49	65							32	32	32

Based on this initial optimization, in the daily operation stage, a specific planting date and irrigation area was assigned to each plot which in practice would correspond to the actual planting date and irrigation area, and the scheme irrigation need for each section (tertiary canal) is calculated.(See TABLE 3.)

Table 3. Scheme Irrigation Needs by Section (l/s)

								MONTH							
Sector-	Num.	Area	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Section	Plots	ha													
1-1	19	57.5	12	8	2	15	18	23	12	6	15	7	8	12	138
1-2	17	45.0	7	4	2	8	12	16	9	8	15	13	9	8	111
1-3	16	38.5	9	4	2	5	5	6	4	4	14	16	14	11	94
2-1	4	13.0	3	2	2	4	4	5	3	1	4	2	2	2	34
2-2	12	45.0	10	2	0	7	9	11	6	5	20	16	15	12	113
2-3	10	31.0	9	1	0	2	2	3	2	4	13	16	14	10	76
TOTAL	78	230.0	50	21	8	41	50	64	36	28	81	70	62	55	566

The operator then selects the appropriate interval and the depth of water application according to the crop involved and interval-water depth requirement calculated earlier which will be discussed with farmers and hopefully agreed upon. For the purpose of comparison, four different options of scheduling were analyzed by CIMIS. TABLE 4 shows different combinations of irrigation interval and volume which could be adopted in different situations. Option I is Rational Method which adopted different intervals and volumes for each month. The minimum value among three crops planted are selected for this purpose. Option II is Semi-fixed Method in which different values of interval and volume are assigned for different combination of crops. Thus from April to July when only onion is growing the irrigation is planned with 4 days interval and 22 mm of irrigation volume. Options III and IV are Fixed Methods in which interval and volume of irrigation are selected arbitrary. Option III uses shorter intervals (5 days) and smaller volume (32mm) of application, while Option IV adopts longer intervals with larger volume.

Table 4. Selected Irrigation Interval and Volume of Application

Options			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
								MONTH						
OPTION I	Interval	day	9	11	19	5	4	4	11	16	7	5	6	6
	Volume	mm	49	49	65	22	22	22	38	32	32	32	32	32
OPTION II	Interval	day	9	9	9	4	4	4	4	7	7	5	6	6
	Volume	mm	49	49	49	22	22	22	22	32	32	32	32	32
OPTION III	Interval	day	5	5	5	5	5	5	5	5	5	5	5	5
	Volume	mm	32	32	32	32	32	32	32	32	32	32	32	32
OPTION IV	Interval	day	10	10	10	10	10	10	10	10	10	10	10	10
	Volume	mm	60	60	60	60	60	60	60	60	60	60	60	60

After establishing the operational criteria such as the start and the end of irrigation, the time required for switching the plot, the field application efficiency and the irrigation module, CIMIS calculates the date and time of irrigation for each plot for each month. In this example, it is assumed that irrigation is carried out from 8 to 20 (12 hours per day) with one hour for switching the plot, field application efficiency of 50 % and irrigation module of 35 l/sec. The calculated ordering of irrigation in different sections (tertiary unit) of canal is shown in TABLE 5. CIMIS subdivides the canal flow into several flows if the canal flow is bigger than the irrigation module. In the example, the canal flow of 105 l/sec in section 1 is subdivided into 3 units of 35 l/sec, and three farmers start irrigation at the same time.

Table 5. Calculation Example of Irrigation Ordering

Sector 1
Section 1

SECTOR 1 IRRIGATION
SECTION 1 VOLUME : 22 mm
INTERVALS : 5 days

WD	INT	Month M1	M2	Irrg.	Plot	AREA	Irrigation Start	End	Actual	Time Required	Left Ov
mm	day			day	No.	ha			hour	hour	hour
22	5	4	4	1	1	3.0	8	12	4	4	0
22	5	4	4	1	2	4.5	8	14	6	6	0
22	5	4	4	1	3	5.0	8	14	6	6	0
22	5	4	4	1	4	3.0	13	17	4	4	0
22	5	4	4	1	5	3.0	15	19	4	4	0
22	5	4	4	1	6	2.0	15	18	3	3	0
22	5	4	4	1	7	4.0	18	20	2	5	3
22	5	4	4	2	7	4.0	8	11	3	5	0
22	5	4	4	1	8	2.0	19	20	1	3	2

22	5	4	4	2	8	2.0	8	10	2	3	0
22	5	4	4	2	9	1.5	11	13	2	2	0
22	5	4	4	2	10	4.0	12	17	5	5	0
22	5	4	4	2	11	3.5	14	19	5	5	0

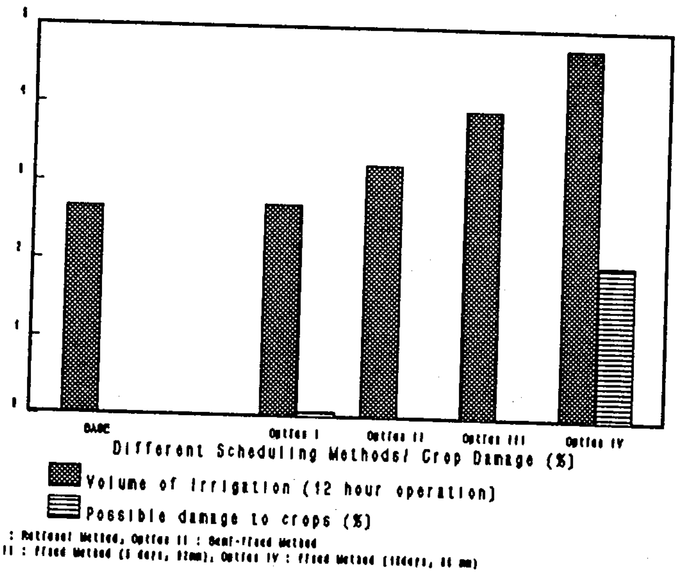
The total volumes of water for irrigating under different scheduling options as discussed in the previous section are calculated and compared. The result is shown in TABLE 6 and Figure 1.

Table 6. Comparison of Different Scheduling Methods. Irrigation Volume and Crop Damage.

Operation :
- 12 hours oper. Net Crop Water Requirement is 1,336 thousand m3
- 50 % App. Effic.

	Volume	Oper. Eff	Crop
	1,000 m3	%	Damage
BASE	2,672		%
Option I	2,730	97.9%	0.7
Option II	3,245	82.3%	0
Option III	3,965	67.4%	0
Option IV	4,755	56.2%	20

FIG 1. Comparison of Different Scheduling Methods



From the example calculation, the total net volume of water required by the scheme is 1 336 000 m^3, which was calculated by crop water requirements. Since this is a net volume required, the total volume will increase to 2 672 000 m^3 when the same operational criteria (50 % of application efficiency and 12 hours of irrigation) is applied. Option I (Rational Method) requires 2 730 000 m^3, Option II (Semi-fixed Method) 3 245 000 m^3, Options III and IV (Fixed Method) 3 965 000 and 4 755

000 m^3 respectively. When the operation efficiency is defined as the efficiency measured by the loss due to canal operation, Option I results in the operation efficiency of 97.9 %. This means 2.1 % of water is lost during canal operation. The total volume of water required increases - and the operation efficiency decreases - as the scheduling becomes more and more fixed. Option IV, with fixed intervals of 10 days and depth of application of 60 mm resulted in the operation efficiency of 56.2 %. As much as 2.1 million m^3 of water will be lost by applying Option IV, compared to the system without a loss in operation and about 0.5 million m^3 of waste of water by adopting Option II (Semi-fixed Method). Rational Method which adopts very flexible irrigation operation will have almost no operational loss.

Damage to crop production and the change in soil moisture balance are monitored by CIMIS, taking into account the average rainfall which was used to calculate the evapotranspiration. The soil moisture balance just before the irrigation is calculated and when the balance becomes below RAM the total water deficit is calculated as described in the previous section. The result can be given on a plot-by-plot basis for different crops. In the example, the calculated average damage is 0.7 % using Option I, 0 % using Options II and III, and 20 % with Option IV as is shown in TABLE 6 and FIGURE 1. Crop-by-crop analysis of damage in Option IV suggests that the crop with long root length, which means large RAM, will not be very much damaged by shortage of water because large RAM can work as a buffer. In the example, onion is most seriously affected, followed by potato and cotton, with average production reduction of 35.3 %, 17.2 % and 2.5 % respectively. Through the simulation of possible damage by CIMIS, the operator or manager of the scheme can make reasonably good decision on canal operation especially when water supply is limited.

Summary

As discussed, CIMIS can provide an effective management tool by allowing simulation of different scheduling and operation options. For example, to avoid damage from water shortage, the hour of irrigation during the peak period can be extended (and interval be shortened), or the depth of water application can be increased, which result in increased volume of water use. These simulations can be done easily, and several alternative of canal operating options can be compared. Furthermore, when supply conditions become tight and only a reduced supply of water is available, CIMIS can simulate alternatives and provide an answer for coping with varying local conditions in an effective manner to minimize farmers' losses.