Evaluation of Performance Indicators Applied to Several Irrigation Systems in Portugal

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ABSTRACT

A NUMBER OF performance indicators for irrigation projects have been defined and applied to eleven irrigation projects in Portugal. All projects are operated and managed by Irrigation Associations (IA) with irrigated areas between 450 ha and 15,000 ha. All are surface irrigation systems, supplied by large reservoirs built with river dams, and using upstream regulated conveyance canals and low-pressure pipe distribution systems.

Data were collected using a questionnaire filled in during interviews of the persons responsible for the operation and management of the systems. Data collected by the operation, maintenance and management services were also utilized in this analysis.

The indicators cover several management areas: water availability, conveyance and distribution systems, operation and maintenance labor force, operation and maintenance costs, land use, water use and water costs. Selected results are presented. The study reveals that it is necessary to revise the definitions of some of the indicators utilized and, in particular, there is a need for a deeper analysis aiming at the selection of indicators to be used by operation, maintenance and management organizations.

INTRODUCTION

Operation and management of irrigation have often been unsuccessful due to an excessive focus on the physical infrastructure while ignoring the production objectives. This is mainly due to a lack of recognition of the complexity of the factors involved and the absence of a coordinated interdisciplinary approach both in design and in operation. In fact, the concept of operation and management should be expanded to include other activities including the physical, production and institutional components (Pereira 1988):

* The physical infrastructure for water conveyance and distribution must be coherent with the farm structures and the on-farm irrigation systems;

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* Management of the productive system and of the irrigation system requires adequate solutions for optimizing the available resources and appropriate organizational solutions to ensure active cooperation among the entities involved; and

* To guarantee the conditions necessary for the optimal use of those resources by the system agents (farmers and operators) as well as the adoption of appropriate technologies, other components such as education, training, experimentation and information are required.

This corresponds to a high level of complexity making it difficult to apply a structured analysis of the performance of irrigation systems (Rijberman 1987). Alternatively, an *a posteriori* analysis of the irrigation projects may help identify means of intersectorial action. This analysis constitutes the final stage of sequential phases: planning, design, construction and operation. It must be based on an accumulation of experience of the operating schemes (Carruthers and Clark 1981). Nevertheless, this analysis normally focuses on the socioeconomic components.

The importance attributed to functional monitoring and evaluation of the systems with a strong interdisciplinary component is increasingly being recognized. This should create a flow of information on project activities with consequent effects on the operation and management rules resulting in revised actions. However, insufficient attention has been generally given to this activity in irrigation projects (World Bank 1988).

The information necessary to perform the analysis should be reduced to its bare essentials and made available in a condensed form through indicators, which should aim at:

* Defining schemes of logical interference among projects components in order to locate the main functional relationships such as action—immediate result—effect—impact; and

* Evaluating the levels of results obtained and defining the corresponding acceptable target values.

This information can be obtained partially, through a rapid analysis of management conditions, using a comparative study of indicators applied to a number of irrigation projects (Pereira and Lamaddalena 1988). A preliminary definition of these indicators was presented by Pereira and Lamaddalena (1989), which serves as the base indicators utilized in this study.

METHODOLOGY

A study of eleven irrigation projects in Portugal was done with the purpose of identifying relevant indicators and preparing a monitoring and evaluation system.

The selected irrigation projects are: Campilhas (CAMP), Alto Sado (A.SA), Fonte Serne (F.SE), Caia, Divor (DIVR), Idanha (IDAN), Mira, Odivelas (ODIV), Roxo, Vale do Sado (SADO) and Vale do Sorraia (SORR). Three projects — CAMP, A.SA and F.SE — are all presently managed by one irrigation association (CASF). All the projects are managed by farmers' organizations, the Irrigation Associations (IA). All are surface irrigation projects with conveyance canals regulated upstream by means of automatic gates and distribution is mainly through low-pressure pipes.

The methodology applied in the analysis was developed as follows: 1) evaluation criteria were selected, 2) indicators characterizing the various subsystems were defined, 3) questionnaires were designed, 4) data were collected, and 5) the indicators were analyzed to evaluate the systems and to identify critical points.

The evaluation criteria concerned the productivity of the systems in relation to the irrigated areas and yields, the efficiency of water utilization, and the operation and management costs. Secondary objectives relating to environmental impacts and the socioeconomic development were considered but have not yet been analyzed.

Information was collected through questionnaires to the managers of the IAs and through analysis of data records on yearly irrigated areas, water consumption and costs (Frazao 1990). The last year in the time series data is 1988.

ANALYSIS OF SOME OF THE RESULTS

All calculated indicators were analyzed and a search made for functional and logical relations. Factors and agents relative to operation and maintenance of the irrigation projects were related to final results. Specific indicators were selected to characterize water management, agricultural production and efficiency of use of financial resources.

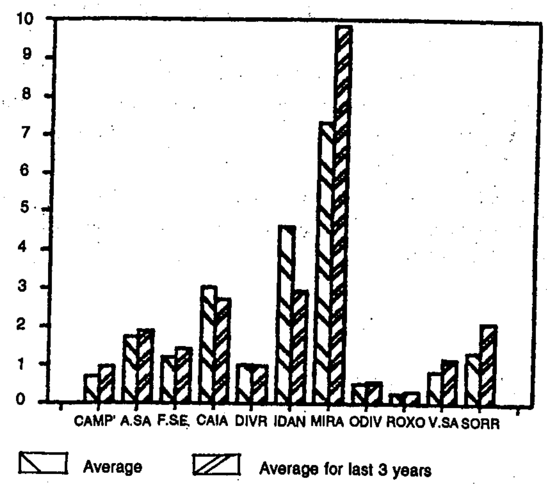
Water Management

Water availability. The evaluation of water availability was based on the frequency analysis of volumes of water stored in the reservoirs at the beginning of the irrigation season. Seasonal indicators were utilized. Among them was the indicator of guaranteed water supply (GWS) defined as the ratio of the first quartile of the series of volumes of water available for irrigation at the beginning of the irrigation season (VAI) to the storage volume required for the irrigated area (SIA). Figure 1 shows the GWS for the average area and for the average areas of the last three 3 years.

A value of unity for GWS corresponds to a condition of equilibrium in which water consumption equals water availability. Values greater than unity indicate that a potential exists to increase the area irrigated, while values below unity indicate that water availability does not permit such an increase.

Scarcity situations in water supply (drought conditions). Scarcity situations occur when the volume available at the beginning of the season is insufficient to satisfy normal irrigation demand. Two main indicators were selected:

Figure 1. Indicators for Guaranteed Water Supply (GWS).

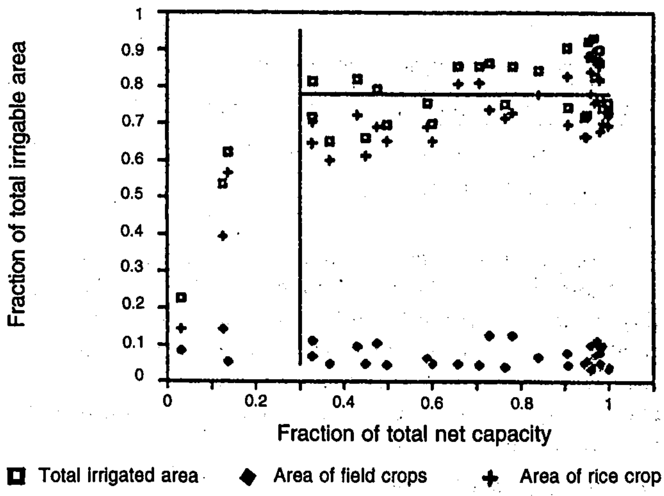


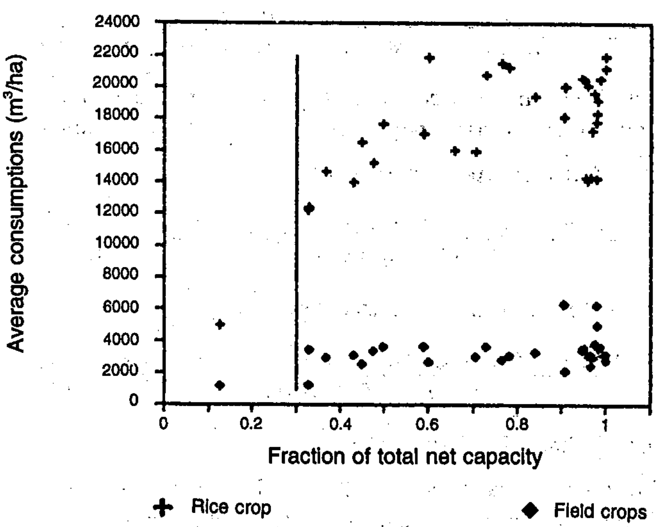
1. Water Deficiency Indicator (WDI), is a fraction of the total storage volume obtained after graphical analysis (see Figure 2. for SADO). Graph (a) shows the relationship between the fraction of the storage volume available at the beginning of the season (VAI) and the total storage volume (TSV), and the fraction of the irrigated areas during the same season (SIA) and the total irrigated area (TIA). These areas are divided into rice crops (high water demands) and extensive field crops. It may be observed that the variation of irrigated areas is independent of the fraction of storage water for values of this parameter above 0.3. Graph (b) confirms the selection of 0.3 as the threshold for the fraction of stored water (FSW). In fact, by relating these parameters to the volume of water consumed per irrigated unit area (m^2/ha) it can be seen that this unit volume tends to decrease for both rice and field crops, in the vicinity of the above threshold. Therefore, for SADO, we have WDI=0.3.

2. Frequency of drought conditions (FDC), which is calculated from the frequency analysis of the yearly ratios between VAI (volume stored at the beginning of the irrigation season) and TSV (total storage volume) by determining the experimental frequency corresponding to the above indicator WDI.

A low value for WDI indicates that irrigated areas and irrigation water consumption are only affected when initial storage volumes are exceptionally low. A higher WDI indicates that there is a strong dependency of irrigation areas on initial storage volumes, and that the reservoirs have low capability to regulate multiyear variations in water availability. This information is complemented with the FDC; for two projects with the same WDI, management must pay particular attention to measures to cope with droughts and water shortages when the FDC is high. Obviously, farmers can irrigate more readily under conditions of low WDC and FDC.

Figure 2. Graphic Analysis for selection of the Water Deficiency Indicator (WDI).





A comparison of values obtained from the IAs studied is shown in Table 1. It may be seen that SADO and SORR are able to make good use of their irrigated areas while severe problems occur in ROXO.

Table 1. Indicators for the analysis of drought and water scarcity.

	CAMP	A.SA	F.SE	CAIA	DIVR	IDAN	MIRA	ODIV	ROXO	SADO	SORR
WDI	0.45	0.30	0.60	0.30	0.35	0.50	–	0.13	0.25	0.30	0.40
FDC	0.32	0.29	0.40	0.15	0.35	0.03	–	0.33	0.65	0.08	0.07

Water distribution. The operation and maintenance of a collective irrigation system determine the global quality of water distribution to the irrigated area, which should be evaluated by means of efficiency and equity parameters (Bottrall 1981). The nature of existing regulation and water supply devices prevents major inequity problems in the systems under analysis. Though it was not possible to evaluate these parameters other aspects were analyzed.

To understand the physical conditions under which water is distributed to farmers, the following indicators were selected:

1. Irrigation Network Density (IND)

$$IND = \frac{Total\ Irrigated\ Area}{Total\ Length\ of\ Conveyance\ \text{and}\ Distributors} = \frac{TIA}{TCD}$$

2. Distribution Network Density (DND).

$$DND = \frac{Total\ Length\ of\ Distributors}{Total\ Length\ of\ Conveyance\ \text{and}\ Distributors} = \frac{TLD}{TCD}$$

The same network densities may be operated by a larger or smaller number of workers, which also influences supply conditions to farmers. Therefore, the following indicators can be used:

1. Density of Network Operators (DNO).

$$DNO = \frac{Total\ Length\ of\ Conveyance\ Distributors}{Number\ of\ Workers} = \frac{TCD}{NWM}$$

2. Density of Operators in the Irrigated Area (DIO).

$$DIO = \frac{Average\ Irrigated\ Area\ \text{for}\ the\ Last\ 3\ Years}{Number\ of\ Workers} = \frac{AIA3}{NWM}$$

3. Average Discharge by Operator (ADO)

Values for this indicator may be seen in Table 2. It is interesting to note (compare Table 3) that lower network densities do not correspond to higher intensity of irrigation. Also it may be noted that variations in the density of operators do not explain variations in the intensity of irrigation.

Table 2. Indicators relative to distribution conditions.

	CAMP	A.SA	F.SE	CAIA	DIVR	IDAN	MIRA	ODIV	ROXO	SADO	SORR
IND (ha/km)	27.01	20.80	18.61	30.60	28.14	27.84	19.95	24.03	25.58	31.67	39.81
DND		0.60		0.69	0.66	0.52	0.70	0.61	0.74	0.11	0.44
DNO (km/op)	6.82	11.47	21.92	9.30	8.68	12.80	14.24	17.81	10.37	2.38	5.96
DIO (km/op)	141.90	108.90	140.30	153.20	147.80	106.60	109.80	133.50	87.40	69.80	204.50
ADO (l/s/op)	212.90	174.30	210.50	176.20	151.40	117.30	103.20	193.60	87.40	90.80	275.30

Irrigation Intensity

The percentage of actual irrigated areas (PIA) is commonly used to measure the global performance of a project. The average PIA and the average for the last 3 years (PIA3) have therefore been used as the index for irrigation intensity. Results may be seen in Table 3.

Table 3. Indicators of agricultural intensity and water consumption by unit area.

	CAMP	A.SA	F.SE	CAIA	DIVR	IDAN	MIRA	ODIV	ROXO	SADO	SORR
PIA	0.77	0.46	0.34	0.54	0.61	0.30	0.39	0.31	0.34	0.93	0.86
PIA^3	0.62	0.38	0.25	0.52	0.50	0.38	0.33	0.22	0.28	0.75	0.73

As may be seen, the variations in the indicators shown in Tables 1 and 2 do not explain the variations in the irrigation indicators. Water consumption by unit area also has an independent variation.

Available information on the average consumption per unit of area for the rice crop (CRC) and field crops (CFC), is shown in Table 4.

Table 4. Average consumption of irrigation water.

	CAMP	A.SA	F.SE	CAIA	DIVR	IDAN	MIRA	ODIV	ROXO	SADO	SORR
CRC (m^3/ha)	10 042	17 268	13 277	16 247	10 535		11 676	17 311	16 227	14 341	15 389
CFC (m^3/ha)	3 048	4 861	4 356	5 415	3 065		3 097	4 957	5 955	3 145	5 368

Operation Costs

Operation costs of the systems are met by the users. This is essential for the economic stability of the projects, for their management and maintenance and in consequence for the quality of the services.

Table 5 includes several indicators:

(1) Operation and maintenance costs per unit of actual irrigated area (OMA)

(2) Operation and maintenance costs per unit length of conveyance and distributors (OMC)

(3) Percent of operation and maintenance costs covered by farmers' contributions: average (COM)

(4) As above, average for last 3 years (COM3)

(5) Water cost for rice crops (WCR)

(6) Water cost for field crops (WCF)

(7) Water costs as a percentage of the average gross income from rice (PCR)

(8) As above for corn (PCC)

(9) As above for tomatoes (PCT)

It may be seen that a positive relation exists between coverage of costs and intensity of irrigation (Table 3). Higher costs per unit length of distributors also correspond to higher intensity of irrigation. It may be concluded that good farming implies good operation and maintenance and that farmers are willing to pay for good service. Reduction of water costs does not have positive impacts.

Table 5. Indicators for the operating costs of the project and of irrigation.

	CAMP	A.SA	F.SE	CASF	CAIA	DIVR	IDAN	MIRA	ODIV	ROXO	SADO	SORR
OMA (US$/ha)				133	98	129	96	68	75	191	117	81
OMA (US$/km)				1 588	1 597	2 165	799	52	561	1 602	3 443	2 803
COM (%)				94	82	84	83			78	103	116
COM^3				105	105	110	48			104	126	116
WCR (US$/ha)	157	262	204		140	106		147	126	301	162	110
WCF (US$/ha)	65	71	73		53	41	29	43	41	118	87	57
PCR (%)	6.3	10.4	8.1		7.6	6.4		11.9	6.8	14.2	7.0	5.7
PCR (%)	3.5	3.8	4.0		2.6	1.7	1.4	5.2	2.8	5.6		2.5
PCR (%)	2.5	2.8	2.9		3.8	1.9	1.2	2.5	2.4	3.5	3.2	1.9

CONCLUSIONS

The study reported above covered a large number of indicators (Frazao 1990). The small size of the sample (11) did not permit a deep analysis of the relations among the indicators. Nevertheless, the study shows the usefulness of indicators in aiding an understanding of operation, management and maintenance.

The results obtained are now being applied in the preparation of a monitoring and evaluation study. Other management data, as well as measured data, should help to develop better indicators. This is necessary to help monitor the achievement of management goals of irrigation systems.

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