Irrigation Efficiency and Users' Performance in Water Management

J. Chambouleyron,[49] *S. Salatino*[50] *and L. Fornero*[51]

ABSTRACT

THIS PAPER IS the result of research conducted in Mendoza Province, Argentina. An attempt has been made to determine performance parameters for irrigation management users' associations in order to rate water use efficiency. To this end, 130 farms and 14 users' associations were surveyed in an 85,000 hectare oasis. Data were interpreted by means of multiple regression, and the effectiveness of the parameters to evaluate Application Efficiency (EAP) in an irrigated area was verified. To this end, the values were calculated for a set of 10 farms and high performance values were found to coincide with high EAP values. Likewise, low performance values coincided with low EAP values. Although the result is encouraging, further case studies will have to be examined to evaluate the performance indexes obtained.

INTRODUCTION

Mendoza Province in Argentina is an arid region where the irrigated area has expanded most rapidly in recent years. Some authors point out that the causes of this expansion were the timely selection of an agricultural development model that has easily responded to the country's food requirements, and an evolution in the demand for agricultural products.

The increase in land use brought about a greater demand for water. Thus, in the 1950s, the province's total surface water rights were transferred to the farmers and 360,000 ha were cultivated with an annual regional flow of 5,600 hm3. It was in this period of intensive land and water use that a water management agency was set up, which — unlike similar agencies in arid provinces — is basically decentralized and participatory.

The participation of users in the water management agency brought about an improvement in water use, and a regional efficiency of 39 percent was attained in Mendoza's five oases.

---

49 Agricultural Engineer, Head of the Department of Irrigation and Drainage Engineering, INCYTH — Andean Regional Center, P.O. Box 6, 5500 Mendoza, Argentina.

50 Agricultural Engineer. Researcher. Department of Irrigation and Drainage Engineering. INCYTH-Andean Regional Center.

51 Certified Public Accountant. Head of the Statistics and Data Processing Department.

Water was administered through users' associations in charge of managing all the irrigation systems in the province. Now, there are over 370 canal associations that manage irrigation water at secondary canal level.

Modern lifestyles and ever-increasing industrial activities brought about a higher regional demand for water. It has been estimated that by the year 2000 urban and industrial water demand will be over 500 hm^3. Therefore, if agriculture is to continue expanding, greater water use efficiency will have to be attained.

This paper focuses on the activities of farmers and users' associations in relation to application efficiency (EAP) and defines water use numerical indexes. Performance parameters were derived from these indexes to evaluate water use efficiency and individual and collective participation.

BACKGROUND

Several authors have dealt with this topic, and lately a good number of papers have been written to explain what the parameters are, why they are measured, and how to proceed with their evaluation.

In this regard, it is important to mention Wolter and Bos's contribution (1990). They stress the importance of measuring efficiency as a performance parameter in irrigation water use, and they point to the variations between these values and rainfall. Clemmens and Bos (1990) also stress the importance of evaluating water distribution in an irrigated area as a performance parameter of efficient water use.

Smedema (1990) considers that waterlogging and salinity should be measured as performance parameters of water use in an irrigated area.

Plusquellec et al. (1990) make an interesting review of irrigation system performance with respect to initial objectives.

Finally, mention should be made of the contributions of Small and Svendsen (1990) concerning the conditions under which performance parameters should be measured in an irrigated area.

Some of these important concepts and methodologies are included in this paper.

METHODOLOGY

As stated above, this paper aims at determining which are the main performance parameters affecting water EAP in irrigated agriculture in the province. To this end, water use was examined in one of the oases in Mendoza Province, with 85,000 cultivated hectares irrigated by the Lower Tunuyán River.

Work was divided into three stages. Through 130 field surveys, the first stage determined the on-farm EAP, which yielded water use values from the farm intake to the irrigated plot.

In addition to measuring efficiency, a personal survey was conducted which aimed at measuring the farmers' training and participation level in irrigation water management.

Two aspects were taken into account in the surveys: quantitative and qualitative aspects. The quantitative aspect was used to calculate efficiency values applying the technique of Merriam and Keller (1978).

The qualitative aspect of the survey was divided into three parts: 1) mechanization, i.e., whether or not machinery is used in land farming; 2) irrigation infrastructure, to evaluate water delivery to the farm (earthen, mixed material or concrete pipes); and 3) users' training (literacy, agricultural know-how, participation in water management at canal level, and managerial skills).

For interpretation purposes, the farms were divided into two groups: those using surface water and those using groundwater, the latter being subdivided according to the irrigated crop — vegetables or deep root crops. Each of the above elements was duly assessed in order to identify which is the one that affects farm irrigation efficiency the most. The second stage of the research dealt with users' associations to define performance parameters beyond the farm boundaries.

The irrigated area under study is broken down into 14 large canal "inspections" (associations) that manage water for the whole area. Not all the associations manage water with the same level of efficiency. In general, each of the large associations has administrative limits that coincide with the physical area irrigated by a secondary canal. The General Irrigation Department (DGI) usually delivers monthly varying flows of water at the secondary canal intake. To obtain the delivered depth, the instant flow delivered to the system is multiplied by the number of seconds/month, and divided by the area with water rights. As the areas with water rights are larger than the actually irrigated ones, and since they are not the same for all canals, different depths are derived along the irrigation system. The depth derived at the secondary canal intakes on the Lower Tunuyán River varies from 9,000 to 12,000 m^3/ha/year. This is a most important parameter in EAP evaluations, especially if different water requirements (deep root crops and vegetables) are taken into consideration.

In this second stage, canal inspectors were interviewed. The surveys included questions that would help reveal the farmers' level of participation; for example, interest in the solution of problems,

participation (or not) in the operation and maintenance of the irrigation system, and relationship with the General Irrigation Department.

The third stage consisted of a general evaluation of the total irrigated area. On the basis of the above aspects, which were correlated to indicate greater or lesser efficiency, each of them was rated and weighted in order to interpret project efficiency for the whole irrigated oasis with due consideration of the elements that exert a greater influence.

The multiple regression method was applied to interpret the data collected in the three stages of the surveys as it permits an accurate interpretation of the importance of each parameter in EAP.

RESULTS

As already stated, 130 field surveys were evaluated with reference to both quantitative and qualitative parameters. For the quantitative analysis, the results were divided into deep-root crops (fruit trees, vineyards, alfalfa, forest trees) and vegetables. Each crop type, in turn, was divided into sandy (low storage capacity) or sandy-loam (greater water storage capacity) according to soil type. Finally, a separation was made between efficiency values in farms that use surface water for irrigation and efficiency values in farms that use groundwater.

The calculated efficiencies were compared with the depths applied on the irrigation plots, in order to establish performance parameters that rate water management at farm level. The results obtained are summarized in Table 1. EAP values above and below 70 percent are also included.

The applied surface water depths are usually in excess of 100 mm and variations in soil texture are not taken into account. Thus, for deep-root crops in compact soils, the EAP is higher than in sandy soils. Water is distributed according to the registered area of the canal and not according to soil type or crop requirements. When the depth is reduced, the soil's storage capacity remaining constant, efficiency increases as shown in the second part of Table 1.

The characteristics of surface water use have been transferred to groundwater use and the same problems have arisen: no variations in depth according to soil and crop types. It may be concluded that the farmers' knowledge and control of the applied water depth, using both, surface water and groundwater, is an excellent performance parameter of water use efficiency.

Table 1. Physical performance parameters: Applied depths and efficiency according to soil type.

Soil type	Sandy				Loam			
Source	S.W.*	G.W.**	S.W.*	G.W.**	S.W.*	G.W.**	S.W.*	G.W.**
EAP 70% Applied depth (mm)	60	96	160	166	121	86	147	133
EAP %	51	38	35	48	25	27	41	37
EAP 70% Applied depth (mm)	86	84	88	86	–	65	107	107
EAP %	80	80	80	80	–	73	88	88

* Surface Water
** Groundwater

The qualitative analysis of the first stage of this paper yielded the results given in Table 2.

The results in Table 2 were interpreted applying multiple regression techniques. Crop types (vegetables or deep root crops), mechanization, irrigation infrastructure (earthen or concrete ditches, or reinforced concrete pipes), users' training in agricultural and irrigation activities were correlated. The results show that, at the individual level, crop type is the most significant parameter as it increases efficiency by 19 percent, while the use of machinery yields a 9 percent increase in efficiency, and reinforced concrete pipes lead to a 7 percent increase.

Although training is an important parameter, it does not raise efficiency as much as the other qualitative elements. It raises efficiency by only 5 percent, which is not statistically significant.

From the analysis of Tables 1 and 2 it may be concluded that water depth is the most significant physical performance parameter for EAP at user level whereas for the qualitative aspects, crop characteristics, mechanization and irrigation infrastructure are the most important.

Table 2. Qualitative performance and efficiency parameters.

	Application efficiency		EAP increment	
	Low	Medium	High	(%)
1. Crop type				
vegetables	33	–		
deep root			53	19%
2. Mechanization				
no tractor	36	–		
tractor			51	9%
3. Infrastructure				
earthen	36			
mixed		47		
lined			50	7%
4. Training				
low	34			
medium		41		
high			47	5%

Four variables were analyzed at canal inspection level. Since they cover the full range of water use, they must be added to what has already been obtained at farm level (Table 3).

These variables were identified as participation, operation, management and relationship with the General Irrigation Department.

The participation variable was obtained from the answers to seven questions related to canal cleaning, attendance to meetings, money or labor contributions to canal repairs, interest in the election of authorities, etc.

The operation variable was obtained from the answers to five questions on: number of owners and farm size per canal, legal problems, pressures to change irrigation turns, trends in water demand, etc.

The management variable shows from the user's own point of view, what he knows of the factors affecting irrigation efficiency. It was obtained from the answers to eight questions on: size of water depths and flows, knowledge of soils and crops, adequacy of water depths to soils and crops, use of groundwater, etc.

Finally, the relationship with the General Irrigation Department variable summarizes in eight questions the relationship between all levels of the water management agency and the users, including an appraisal of the agency's performance.

The inspectors of the 14 users' associations in the area were interviewed. They answered 36 questions with three possible answers each — from affirmative to negative. The results are given in Table 3, together with the indexes for each variable (Ip: participation index; Io: operation index; Im: management index; and Ir: relationship with the General Irrigation Department). In each case, the indexes are defined as a number of positive answers divided by the number of negative answers. The average value per inspection as well as the maximum and minimum values for each parameter are given so as to facilitate performance evaluation.

Table 3. Indexes of participation, operation, management and relationship between users' associations and the General Irrigation Department.

Association	Indexes					
	(Ip)	(Io)	(Im)	(Ir)	Registered ha	Irrigated ha (%)
1	1.00	0.50	0.50	–	13,900	60
2	0.67	1.00	0.33	–	10,500	70
3	3.00	0.67	0.50	5.00	9,800	71
4	0.40	0.67	0.67	1.00	22,000	50
5	–	1.50	0.25	3.00	10,800	70
6	0.17	1.50	4.00	6.00	3,000	76
7	0.50	3.00	0.33	–	4,500	82
8	0.25	4.00	2.00	5.00	600	75
9	2.00	4.00	2.00	7.00	4,000	100
10	0.50	1.50	1.50	3.00	4,950	100
11	0.25	0.50	3.00	–	3,400	100
12	0.20	0.33	0.67	6.00	11,000	90
13	0.40	1.50	0.20	–	2,100	76
14	0.50	2.00	1.00	2,50	5,520	90
Average	0,46	1.26	0.83	6,23	–	–
Maximum	6.00	4.00	7.00	7.00		
Minimum	0.17	0.25	0.14	0.14	106,070	83,795

* Ratios between positive and negative replies.

Table 3 also shows the registered and actually irrigated areas to indicate the real use of water distributed in each canal association. The sum total of hectares is an indication of the representativeness of the sample under study; effective water use is 79 percent. It may be observed that the "participation" variable has an average index of 0.46 (24 affirmative answers/52 negative answers), which is quite low as compared to the maximum value (6.0). Only 2 out of the 14 associations (No. 3 and No.9) have a medium-level index. The absence of values in the case of association No. 5 indicates a very high level of participation (0/6).

The operation variable shows a higher average index (1.26) which, in turn, reveals that there are 20 percent more users interested in participating in the operation of the distribution system. In this case, the number of associations with medium- to high-level indexes is greater, 8 out of 14.

The management variable indicates, through its average index (0.83), that most farmers do not know what "efficient" irrigation means; only 33 percent of the farmers seem to have some idea.

Only four associations have medium-level management indexes, and they coincide with relatively small areas (an average of 2,750 ha).

With the "relationship with the DGI" variable the situation is completely different. The average index is a relatively high value (6.23) and only two associations have very low values. The absence of IR values in all cases indicates a very high value (7/0).

After each of the elements in the different research stages was analyzed, they were assembled and duly weighted according to their greater or smaller influence on overall water use efficiency.

In order to evaluate users' or a users' association performance in water use efficiency, an evaluation mechanism has been devised which does not require any prior physical measurement.

Table 4 groups the different physical, qualitative and management parameters for the study area. Each parameter has been rated as low, medium or high. In the case of quantitative parameters, numerical values and units are given, whereas for qualitative parameters, only estimates are provided.

The rating has been devised in such a way as to assign the "high" category a value that coincides with the weighting percentage of each parameter in relation to the total weight (100 percent). Then, the "medium" and "low" categories were assigned the corresponding values so that the maximum potential rating for each category is 23, 49 and 100 for a low, medium and high performance evaluation, respectively.

Table 4 also contains estimates of two well-known associations, the "Constitución" Main Canal (No. 12) and the "Montecaseros" Canal (No. 3).

To test the strength of the proposed rating mechanism, five farms on each association's canal were randomly selected. The EAP was field-measured (73 percent for No. 12 and 64 percent for No. 3) and each of the parameters was evaluated. The score obtained through this rating makes it possible to estimate performance values which coincide with the measured efficiency values (71 points and 73 percent EAP and 54 points and 64 percent EAP).

In view of the above, it can be said that the EAP of an irrigated area can be rated by measuring or evaluating physical and qualitative aspects that weight or take into account the degree of users' participation in irrigation water management. With these values, performance may be rated "excellent" (above 80 points), "good" (between 60 and 79 points), or "fair" (below 60 points).

It is worth noting that this rating mechanism serves two important purposes: to ascertain whether performance, in general, is efficient or not; and, once parameters (physical, qualitative, participation) have been analyzed in groups and checked against the possible maximum values, to detect which aspect or aspects have more serious drawbacks and correct them.

Table 4. Performance parameter evaluation in users' associations of the Lower Tunuyán River.

Parameters	Weighting (%)	Evaluation (points)			Examples (associations)	
		Low	Medium	High	(n^o12)	(n^o3)
1. Physical						
Depth at intake (mm/ha.year) (-1000, 1000, +1000)	15	3	7	15	3	3
Surface water/groundwater (%) (-40, 40, +40)	13	2	6	13	13	10
Crop type (vegetables, both deep root)	12	2	6	12	13	6
Irrigated area v. registered area (smaller, same, greater)	10	2	5	10	10	5
2. Qualitative						
Mechanization (no tractor; horses/rents tractor; with tractor)	15	3	7	15	14	13
Farm conveyance infrastructure (earthen, minor works, concrete pipes)	9	2	4	9	3	4
Farmer training (no, scarce, yes)	6	2	3	6	5	3
3. Management						
Of participation (low, medium, high)	6	2	3	6	2	3
Of operation (good, fair, bad)	5	2	3	5	2	3
Of irrigation (good, fair, bad)	4	1	2	4	1	1
Relationship with the DGI (good, fair, bad).	5	2	3	5	5	3
Total:	100	23	49	100	71	54

CONCLUSIONS

This paper seeks to define parameters that will make it possible to rate on-farm EAP through the performance of users' associations in the Mendoza Province, with the aid of qualitative values observed in situ and evaluated by means of a field survey. The results obtained after assessing 130 farms and 14 associations ("inspections") show that there is a relationship between physical aspects, such as distributed water depth, and aspects related to area operation and users' participation in determining water application efficiency. As this paper is the result of field surveys carried out to establish performance parameters, further evaluations will have to be carried out in other areas so as to confirm the correlation between these performance parameters and irrigation efficiency.

References

Clemmens, A.J. and M. Bos. 1990. Statistical methods for irrigation system water delivery performance evaluation. Irrigation and Drainage System. 4:345–365. Kluwer Academic Publisher. The Netherlands.

Chambouleyron, J. 1984. El riego en la provincia de Mendoza. Departamento General de Irrigación. Mendoza.

Merriam, J. and J. Keller. 1978. Farm irrigation system evaluation: A guide for management. Utah State University. Logan, Utah.

Morábito, J. and J. Chambouleyron. 1989. Análisis de la distribución del agua de riego en los ríos Diamante y Tunuyán. INCYTH-CRA. Mendoza.

Plusquellec, H., K. McPhail and C. Polti. 1990. Review of irrigation system performance with respect to initial objectives. Irrigation and Drainage System. 4:313–327. Kluwer Academic Publisher. The Netherlands.

Small, L. and M. Svendsen. 1990. A framework for assessing irrigation performance. Irrigation and Drainage System. 4:283–312. Kluwer Academic Publisher. The Netherlands.

Smedema, L.K. 1990. Irrigation performance and waterlogging and salinity. Irrigation and Drainage System. 4:367–374. Kluwer Academic Publisher. The Netherlands.