IGRA: AN APPROACH FOR THE APPLICATION OF THE BENCHMARKING INITIATIVE TO IRRIGATION AREAS.

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ABSTRACT

Water is an essential yet scarce resource and its rational use has become a top priority throughout the world. Irrigation is one of the activities involving highest water consumption, hence the importance that it be performed correctly. Irrigation performance indicators are useful tools for improving irrigation management and making optimisation possible. In order to facilitate their use, a computer application called IGRA, Aplicación de Indicadores de Gestión de Riegos (Application of Irrigation Performance Indicators), is developed. This application facilitates the calculation of indicators and defines them using a wide range of zone descriptors and irrigation year variables, allowing comparisons to be established between different zones and irrigation years. IGRA also takes into account certain phases of the benchmarking procedure (comparison with a reference patron). The programme is used in this study to calculate and compare performance indicators for several irrigation zones in Andalusia (Spain).

1. INTRODUCTION AND OBJECTIVES

Irrigation has come to be of great importance to modern agriculture as the world's population is continuously growing and food is basic to our survival. Although efforts towards increased crop production have been focused on the field of irrigation, irrigation has declined throughout the world since the eighties due to a significant decrease of investments in the field (González, 2000). In recent years it has become increasingly difficult to embark on new irrigation projects due to the lack of funds and support from international organisations and governments. The EU Framework Directive on Water Policy (2000/60/EC of October 23rd), for example, has meant that irrigated lands in Andalusia must subsist with a minimum of economic assistance and obliges member States to collect the real price of water from farmers (Rodríguez, *et al.*, 2001).

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All of these factors taken into account together have lead to the conclusion that alternative solutions must be sought. One possible alternative is to increase the efficiency and productivity of irrigation systems so as to optimise water use (less volume of applied water with greater production).

The use of performance indicators is one way of achieving increased efficiency and productivity. This methodology is clearly outlined in the World Bank's Programme of Institutional Reform in Irrigation and Drainage, which includes three main components: performance indicators and benchmarking, public and private partnerships and a regulatory framework.

To establish performance indicator and benchmarking guidelines, the World Bank requested assistance from the IPTRID (International Programme for Technology and Research in Irrigation and Drainage) to initiate a joint study to identify simple, but effective and universally applicable performance indicators for benchmarking and to formulate the methodology needed for in-field data collection.

In August 2000 IPTRID held a workshop in Rome in an effort to review experiences on performance indicators and prospects for benchmarking irrigation and drainage projects and to develop a benchmarking methodology (Malano and Burton, 2001). This has been the starting point for the use of performance indicators and has set the guidelines for future work on the subject.

The IWMI (International Water Management Institute) has developed an on-line programme called the On-line Irrigation Benchmarking System (OIBS), in which users can introduce data and establish a benchmarking procedure using existing data (Malano, 2002).

The main objective of our study is to develop a more specific computer tool which will enable performance indicators to be calculated. With this purpose in mind, we have selected indicators in order to compare different irrigation zones of Andalusia.

As a secondary objective, this methodology can be used by administrative bodies to determine which zones are in need of improvement and how to go about modernising them.

2. METHODOLOGY

A performance indicator is basically a quantitative measure of an aspect of irrigation standards which helps to evaluate and monitor irrigation efficiency (Alegre *et al*., 2000). Performance indicators are therefore relationships between two or more magnitudes of an irrigation zone. In order to calculate these indicators it is necessary to previously define the parameters or variables to be used (Pérez, 2003).

The indicators we have selected correspond to those outlined by the IPTRID (Malano and Burton, 2001). They are divided into four different groups: systems operation (11), financial performance (8), productive efficiency (8) and environmental performance (9). The 36 indicators are detailed below in the results section using the data of the zones under study. To calculate the selected indicators, 37 variables are

chosen and classified into the four above-mentioned categories. It is also useful to characterise the irrigation zones using parameters known as descriptors.

The IGRA computer application has been developed using Visual Basic with a MDI (Multiple Document Interface) format so as to enable several windows to be used at the same time (Microsoft, 1999). It also includes a database to save all the indicators calculated.

2.1. Study zones

Andalusia is a typically Mediterranean irrigated region located in southern Spain (Figure 1).

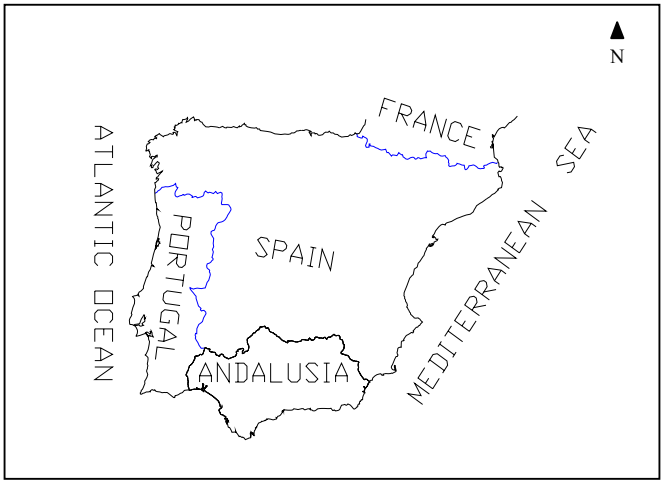


Figure 1. *Location of Andalusia*

A large number of irrigated zones with highly varying characteristics can be found in this region. A small group of four of these zones has been selected to test programme capacity and range of use. Their location is shown in Figure 2.

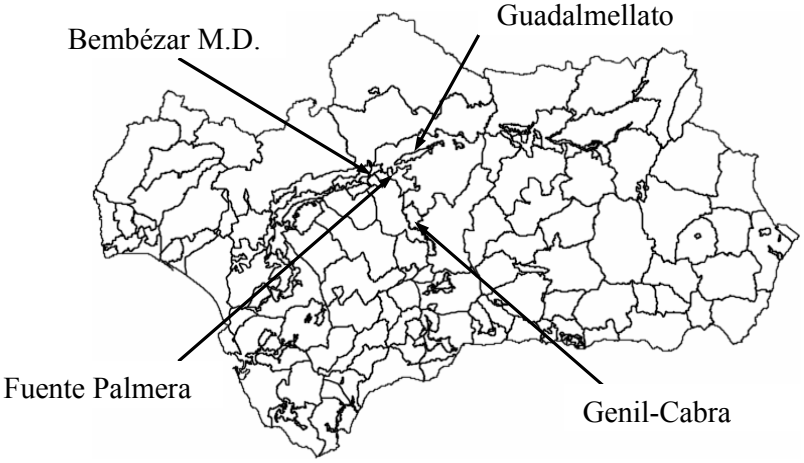


Figure 2. *Selected irrigation zones*

3. RESULTS

The application of irrigation performance indicators (IGRA) is an useful tool for calculating and processing performance indicators. Zone descriptors and irrigation year variable data are entered in several windows which automatically calculate the indicators. Once this operation is complete, the indicators obtained are saved in the database for comparison with other indicators by means of tables and charts. Reports on descriptors, variables and indicators can be viewed and printed easily as an output of the calculation.

A detailed, step-by-step explanation of the complete procedure is given using the Guadalmellato irrigation zone as a sample area.

First, data related to the irrigation zone descriptors is entered in the descriptor window (Figure 3). The different categories that can be selected are presented in a tab format. Although it is not necessary to fill in all the gaps, the irrigation zone is better characterized when more information is given.

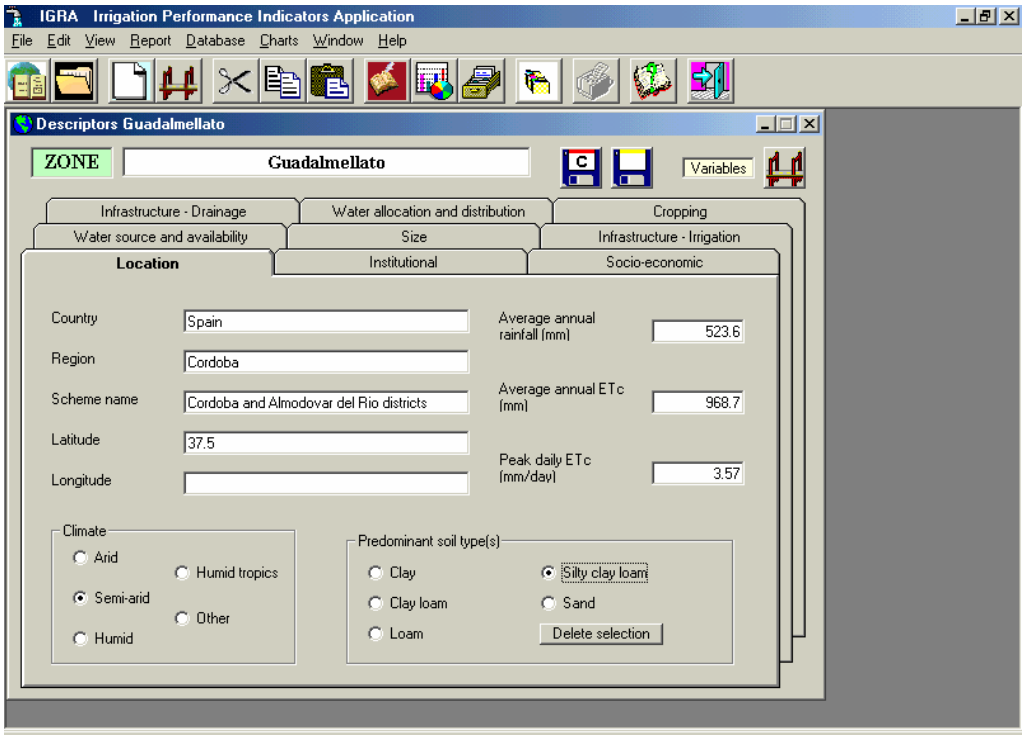


Figure 3. *Descriptor window*

Once the zone is defined, the variables window must be loaded. To obtain every indicator (Figure 4) all the variables must be entered in the different categories. If one of the variables needed for an indicator has no value, that indicator will not be available.

Both descriptor and variable data can be saved as independent files with *.zdr and *.vrc extensions, respectively. One variable file will be available for each irrigation year.

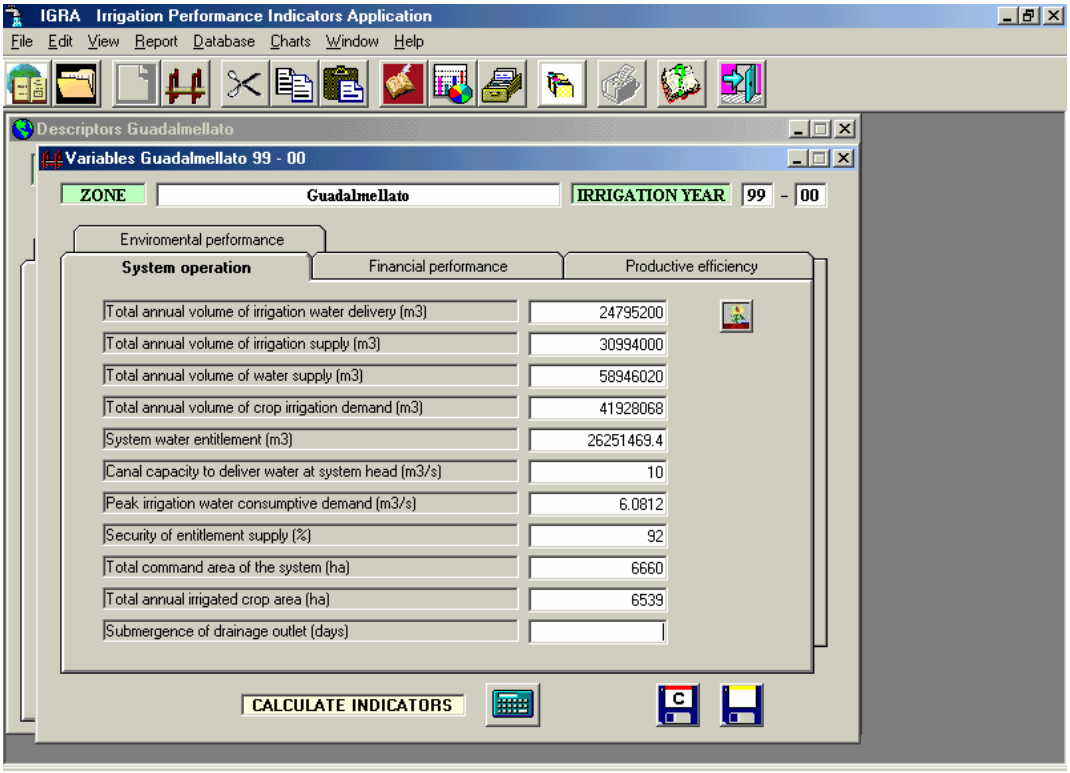


Figure 4. *Variables window*

Once all the variables are entered, the application is ready to calculate the indicators. To view the indicators window with the value for each indicator (Figure 5), click on 'Calculate indicators'.

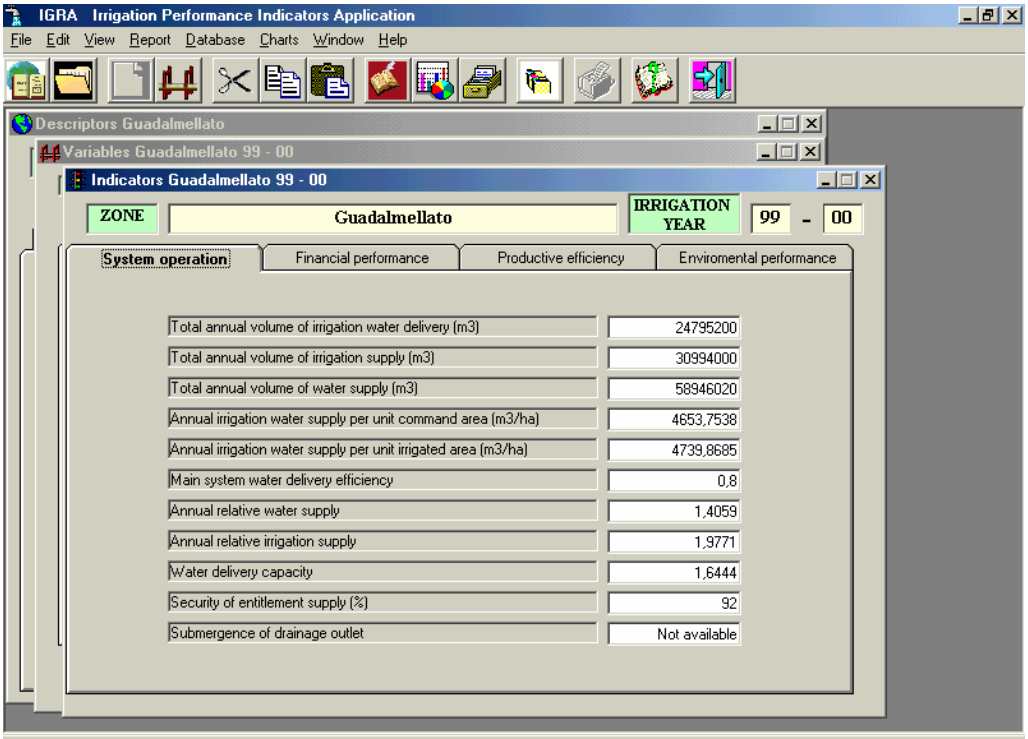


Figure 5. *Indicators window*

At this point, the indicators must be entered into the database for their comparison using records (Figure 6), tables (Figure 7) or charts (Figure 8).

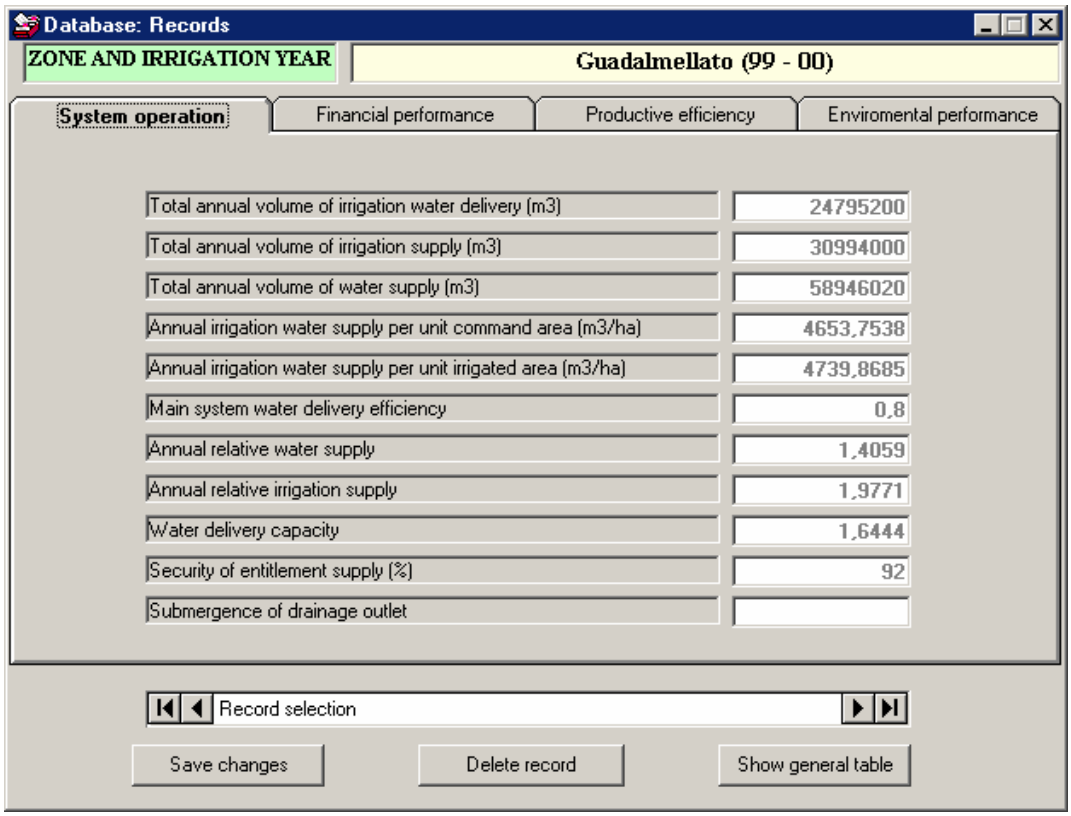
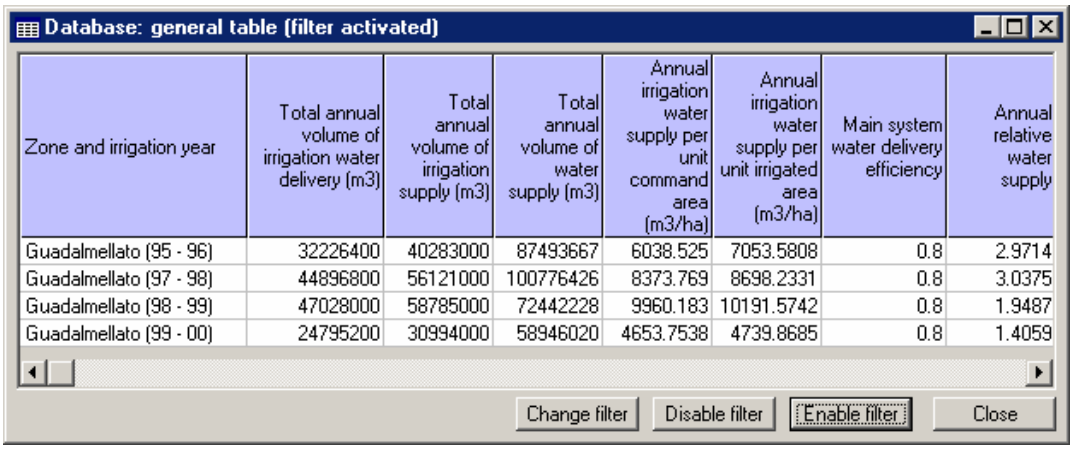


Figure 6. *Records window*



Zone and irrigation year	Total annual volume of irrigation water delivery (m3)	Total annual volume of irrigation supply (m3)	Total annual volume of water supply (m3)	Annual irrigation water supply per unit command area (m3/ha)	Annual irrigation water supply per unit irrigated area (m3/ha)	Main system water delivery efficiency	Annual relative water supply
Guadalmellato (95 - 96)	32226400	40283000	87493667	6038.525	7053.5808	0.8	2.9714
Guadalmellato (97 - 98)	44896800	56121000	100776426	8373.769	8698.2331	0.8	3.0375
Guadalmellato (98 - 99)	47028000	58785000	72442228	9960.183	10191.5742	0.8	1.9487
Guadalmellato (99 - 00)	24795200	30994000	58946020	4653.7538	4739.8685	0.8	1.4059

Figure 7. *Database table window*

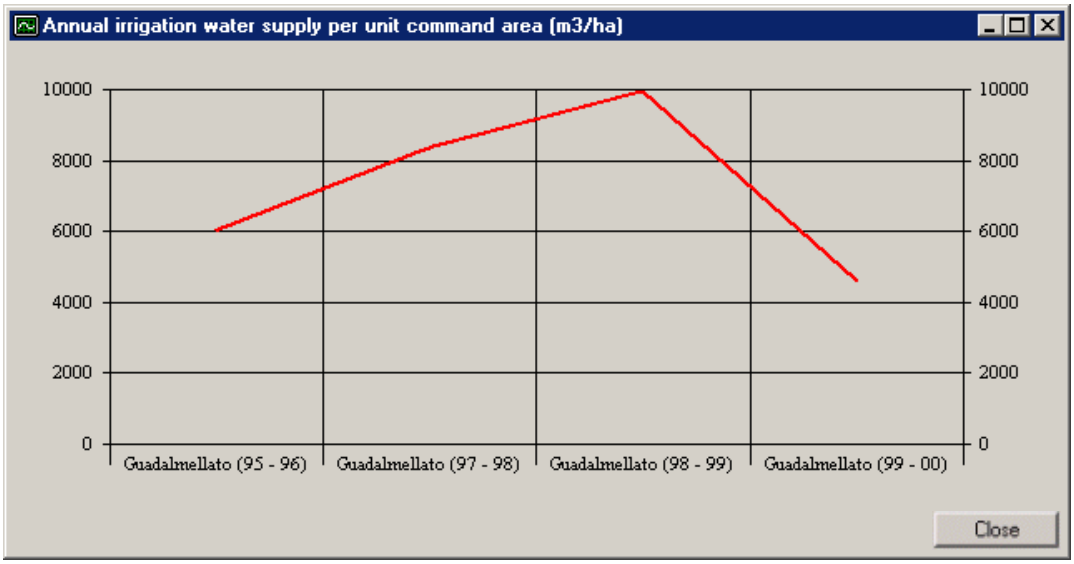


Figure 8. *Chart window*

All the indicators are included in the database table whereas only one indicator is shown in the charts. It is possible to activate a filter for both windows so as to enable more comparison options.

Table 1 shows all of the indicators calculated with IGRA for the zones studied for several irrigation years. The indicators could not be calculated for some zones as data was not available for them.

The results permit a comparative study of different irrigation zones. It is first necessary to account for the varying characteristics of the zones in order to justify differences between values of the same indicators. Descriptors are used for this purpose. Using different combinations of zones with a certain characteristic or particular irrigation years, the study can be focused to determine if irrigation management is being properly performed and to eliminate problems or errors in organisation.

Zone and irrigation year	Bembézar MD (95 - 96)	Bembézar MD (96 - 97)	Bembézar MD (97 - 98)	Bembézar MD (98 - 99)	Bembézar MD (99 - 00)	Bembézar MD (00 - 01)	Bembézar MD (01 - 02)
Total annual volume of irrigation water delivery (m^3)	No data	No data	No data	No data	No data	No data	No data
Total annual volume of irrigation supply (m^3)	69865531	90906189	101406444	100712000	45767971	93261506	80584962
Total annual volume of water supply (m^3)	150448182	172017664	182834825	125809952	93974620.9	175357011	137582494
Annual irrigation water supply per unit command area (m^3/ha)	5865.28	7753.39	8513.18	8454.88	3842.27	7829.4	6765.19
Annual irrigation water supply per unit irrigated area (m^3/ha)	6255.03	7898.22	8733.35	8698.04	4025.86	7829.4	6765.19
Main system water delivery efficiency	No data	No data	No data	No data	No data	No data	No data
Annual relative water supply	1.942	1.982	2.1581	1.4197	1.2232	1.8787	1.4688
Annual relative irrigation supply	9.6054	7.2688	20,5297	1.4954	1.2109	6.925	2.1973
Water delivery capacity	No data	No data	No data	No data	No data	No data	No data
Security of entitlement supply (%)	No data	No data	No data	No data	No data	No data	No data
Submergence of drainage outlet	No data	No data	No data	No data	No data	No data	No data
Cost recovery ratio	No data	No data	No data	No data	No data	No data	No data
Maintenance cost to revenue ratio	No data	No data	No data	No data	No data	No data	No data
Total MOM cost per unit area (€/ha)	No data	No data	No data	No data	No data	No data	No data
Total cost per person employed on water delivery (€/person)	No data	No data	No data	No data	No data	No data	No data
Revenue collection performance	No data	No data	No data	No data	No data	No data	No data
Staffing numbers per unit area (persons/ha)	No data	No data	No data	No data	No data	No data	No data
Average revenue per m^3 of irrigation water supplied (€/m^3)	No data	No data	No data	No data	No data	No data	No data
Total MOM cost per unit volume supplied (€/m^3)	No data	No data	No data	No data	No data	No data	No data
Total gross annual agricultural production (Tm)	141894	138876	149673	146043	107372	189252	200164
Total annual value of agricultural production (€)	39953455.9	39919844.4	42675687	42540547.2	36712262	44278744.7	49460108.3
Output per unit command area (€/ha)	3354.13	3404.76	3582.67	3571.32	3082.03	3717.24	4152.22
Output per unit irrigated area (€/ha)	3577.01	3468.36	3675.32	3674.03	3229.3	3717.24	4152.22
Output per unit irrigation delivery (€/m^3)	No data	No data	No data	No data	No data	No data	No data
Output per unit irrigation supply (€/m^3)	0.5719	0.4391	0.4208	0.4224	0.8021	0.4748	0.6138
Output per unit water supply (€/m^3)	0.2656	0.2321	0.2334	0.3381	0.3907	0.2525	0.3595
Output per unit crop water demand (€/m^3)	0.5157	0.46	0.5037	0.4801	0.4779	0.4744	0.528

Table 1. *Indicator results*

Zone and irrigation year	Fuente Palmera (96 - 97)	Fuente Palmera (97 - 98)	Fuente Palmera (98 - 99)	Fuente Palmera (99 - 00)	Genil-Cabra (95 - 96)	Genil-Cabra (96 - 97)	Genil-Cabra (97 - 98)
Total annual volume of irrigation water delivery (m^3)	No data	No data	No data	17081926	14081728	32213872	32714555
Total annual volume of irrigation supply (m^3)	11698000	10507000	20080100	17873000	23927010	41314000	34878000
Total annual volume of water supply (m^3)	48086680	46464360	31162920	39160220	119382537	119561916	128103469
Annual irrigation water supply per unit command area (m^3/ha)	2223.95	1997.53	3817.51	3397.91	1587.94	2741.84	2314.71
Annual irrigation water supply per unit irrigated area (m^3/ha)	2444.5	2162.23	4127.82	3583.02	1660.68	2800.2	2409.8
Main system water delivery efficiency	No data	No data	No data	0.9557	0.5885	0.7797	0.938
Annual relative water supply	1.4426	1.4396	0.9088	1.071	1.461	1.2772	1.4298
Annual relative irrigation supply	4.7791	-9.4421	0.792	0.9194	-5.06	1.8074	69.25
Water delivery capacity	1.4751	1.3277	1.2716	1.24	4.4067	4.9322	3.6849
Security of entitlement supply (%)	60	60	60	60	66.7	66.7	66.7
Submergence of drainage outlet	No data	No data	No data	No data	No data	No data	No data
Cost recovery ratio	0.9601	0.9121	0.9669	1.0043	0.9818	0.9981	0.9888
Maintenance cost to revenue ratio	0.0527	0.0637	0.0668	0.0508	0.0196	0.0159	0.018
Total MOM cost per unit area (€/ha)	260.417	309.2533	278.448	346.0244	132.0998	196.0285	189.296
Total cost per person employed on water delivery (€/person)	26696.62	31556.14	31893.48	33516.7	15081.89	24420.56	26662.61
Revenue collection performance	0.9588	0.9706	0.9811	0.9906	1	1	1
Staffing numbers per unit area (persons/ha)	0.0015	0.0014	0.0014	0.0014	0.0009	0.0011	0.0011
Average revenue per m3 of irrigation water supplied (€/m^3)	No data	No data	No data	0.1015	0.1327	0.0896	0.0828
Total MOM cost per unit volume supplied (€/m^3)	No data	No data	No data	0.101	0.1352	0.0898	0.0837
Total gross annual agricultural production (Tm)	16766	18960	21721	22361	43502	54770	59972
Total annual value of agricultural production (€)	9900748.06	9582778.76	12188221.5	15702431.6	30657941.8	42522273.2	42384624.8
Output per unit command area (€/ha)	1882.27	1821.82	2317.15	2985.25	2034.64	2822.03	2812.9
Output per unit irrigated area (€/ha)	2068.94	1972.04	2505.51	3147.88	2127.85	2882.09	2928.45
Output per unit irrigation delivery (€/m^3)	No data	No data	No data	0.9192	2.1771	1.32	1.2956
Output per unit irrigation supply (€/m^3)	0.8464	0.912	0.607	0.8786	1.2813	1.0292	1.2152
Output per unit water supply (€/m^3)	0.2059	0.2062	0.3911	0.401	0.2568	0.3557	0.3309
Output per unit crop water demand (€/m^3)	0.297	0.2969	0.3555	0.4294	0.3752	0.4542	0.4731

Table 1. *Indicator results (continued)*

Zone and irrigation year	Genil-Cabra (98 - 99)	Genil-Cabra (99 - 00)	Guadalmellato (95 - 96)	Guadalmellato (97 - 98)	Guadalmellato (98 - 99)	Guadalmellato (99 - 00)
Total annual volume of irrigation water delivery (m^3)	62478209	37390907	32226400	44896800	47028000	24795200
Total annual volume of irrigation supply (m^3)	66093500	39775600	40283000	56121000	58785000	30994000
Total annual volume of water supply (m^3)	95234935	97244799.4	87493667	100776426	72442228	58946020
Annual irrigation water supply per unit command area (m^3/ha)	4386.36	2639.75	6038.52	8373.77	9960.18	4653.75
Annual irrigation water supply per unit irrigated area (m^3/ha)	4443.33	2721	7053.58	8698.23	10191.57	4739.87
Main system water delivery efficiency	0.9453	0.94	0.8	0.8	0.8	0.8
Annual relative water supply	0.8608	1.0513	2.9714	3.0375	1.9487	1.4059
Annual relative irrigation supply	0.7933	0.7006	-5.175	-5.7838	2.3507	1.9771
Water delivery capacity	5.0738	3.8005	2.8242	2.5408	1.8845	1.6444
Security of entitlement supply (%)	66.7	66.7	98	98	93	92
Submergence of drainage outlet	No data	No data	No data	No data	No data	No data
Cost recovery ratio	0.9947	0.9922	0.98	0.98	0.98	0.98
Maintenance cost to revenue ratio	0.0207	0.0239	0.1312	0.1317	0.1266	0.1335
Total MOM cost per unit area (€/ha)	204.26	176.75	176.87	185.18	217.5	183.42
Total cost per person employed on water delivery (€/person)	26476.32	29166.91	15242.73	17977.33	18366.22	16510.15
Revenue collection performance	1	1	0.98	0.98	0.98	0.98
Staffing numbers per unit area (persons/ha)	0.001	0.001	0.003	0.0026	0.0029	0.0026
Average revenue per m3 of irrigation water supplied (€/m^3)	0.0484	0.0686	0.0307	0.0261	0.0261	0.0474
Total MOM cost per unit volume supplied (€/m^3)	0.0486	0.0691	0.0313	0.0266	0.0267	0.0484
Total gross annual agricultural production (Tm)	67301	65729	55694	82066	71535	53476
Total annual value of agricultural production (€)	45408249.9	43491370.4	12778806.5	17049722.8	16235698.8	17745003.2
Output per unit command area (€/ha)	3013.56	2886.35	1915.57	2543.97	2750.88	2664.41
Output per unit irrigated area (€/ha)	3052.7	2975.2	2237.58	2642.55	2814.79	2713.72
Output per unit irrigation delivery (€/m^3)	0.7268	1.1632	0.3965	0.3798	0.3452	0.7157
Output per unit irrigation supply (€/m^3)	0.687	1.0934	0.3172	0.3038	0.2762	0.5725
Output per unit water supply (€/m^3)	0.4768	0.4472	0.1461	0.1692	0.2241	0.301
Output per unit crop water demand (€/m^3)	0.4104	0.4702	0.434	0.5139	0.4367	0.4232

Table 1. *Indicator results (continued)*

These results can be very useful for determining if irrigation management and performance are being conducted properly. The values for the 'Cost recovery ratio' in Fuente Palmera are a good example within one irrigation zone (Figure 9). The optimal value for this indicator is 1, indicating in this case that financial performance has improved in recent years.

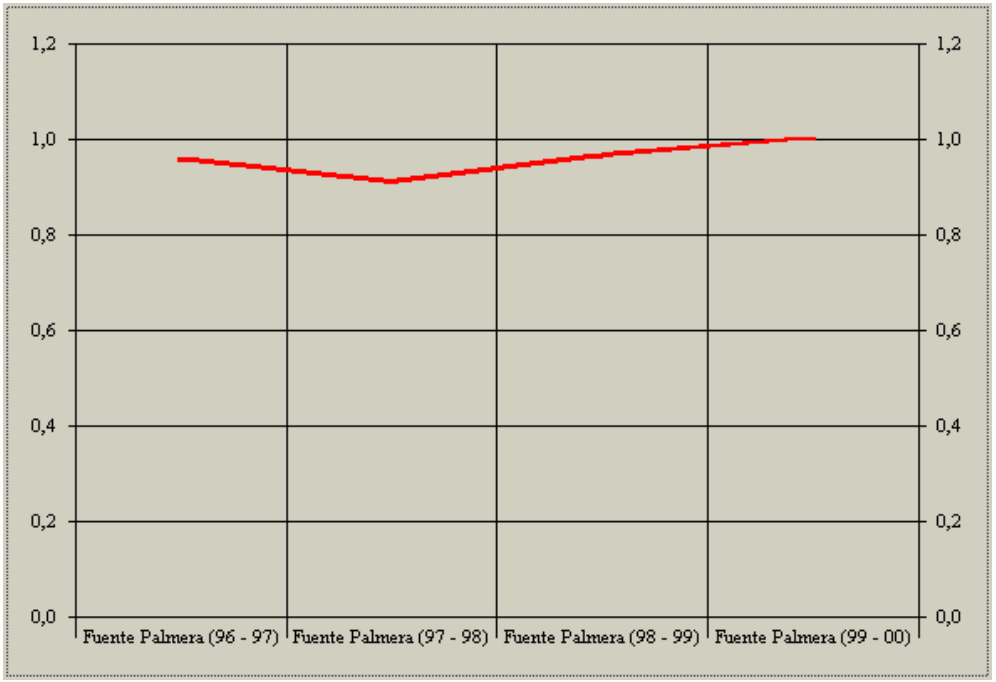


Figure 9. *Cost recovery ratio*

To illustrate the comparison between different zones, Figure 10 shows the values for the 'Annual relative water supply' indicator for the 97–98 irrigation year. In this case, Fuente Palmera and Genil-Cabra obtain the best values, while more water than needed was used in Guadalmellato.

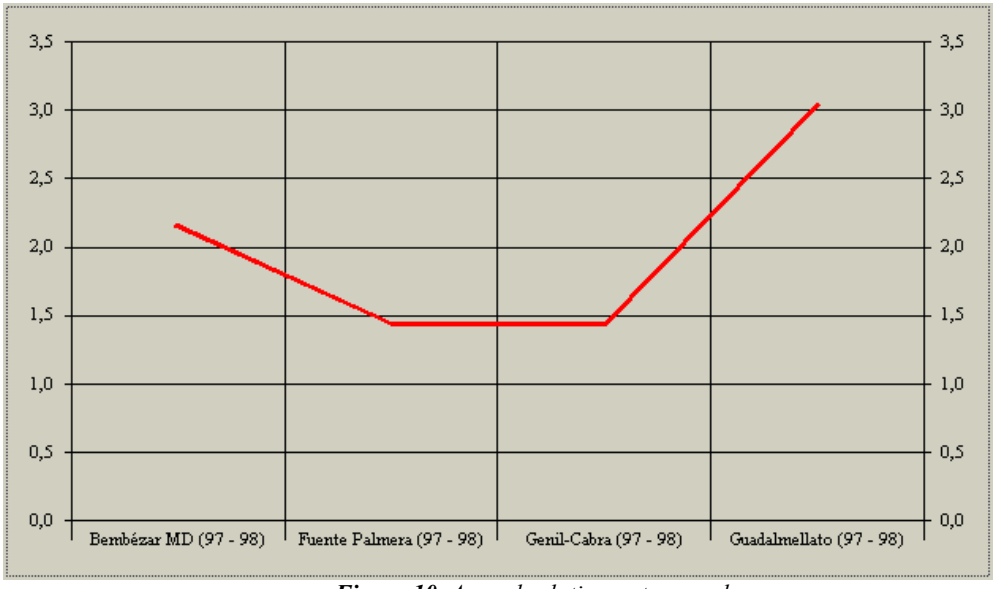


Figure 10. *Annual relative water supply*

4. CONCLUSIONS

The benefits of using performance indicators in irrigation projects are clearly evident. However, this methodology is still difficult to apply outside of research fields. This may be explained by the fact that farmers are unaware of the need to improve their water management systems and are lacking in the resources to do so. As the indicators selected here are universal, they can be used to compare totally different irrigation zones throughout the world. It is at this point when IGRA becomes an useful tool for any irrigation zone or association in order to collect data regarding performance indicators that will enable comparisons between their own and other management systems. This approach also makes it possible to track water management over time using the data obtained for each irrigation year, thus allowing farmers to make more effective improvements. As irrigation techniques advance, further methods will be available to facilitate the calculation of more accurate indicators and to perform more precise and in-depth studies of water management systems. The procedure described here is only the starting point for future studies that will be able to use the data obtained by IGRA for a wide range of applications.

5. ACKNOWLEDGEMENTS

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