WATER BALANCE-RELATED PERFORMANCE INDICATORS FOR INTERNATIONAL PROJECTS

Charles M. Burt[1] Stuart W. Styles[2]

ABSTRACT

A unique study to examine the impacts of irrigation project modernization was funded by the Research Committee of the World Bank and managed by the International Program for Technology Research in Irrigation and Drainage (IPTRID). The project examined 16 irrigation projects in 10 developing countries, 15 of which have been partially modernized in some aspects of hardware and/or management. Besides developing specific recommendations for donor agencies interested in irrigation project modernization, this project also accomplished the following:

1. A Rapid Appraisal Process (RAP) was developed to quickly (within a week) evaluate an irrigation project to assess what type of modernization is needed.
2. External performance indicators were quantified and modified. These characterize the inputs and outputs of irrigation projects, including amounts of water, yield, and economics.
3. Internal process indicators were developed and quantified for each irrigation project.

This paper focuses on the RAP as well as various external performance indicators that are related to water balances -- a small fraction of the total report. The complete report has been reproduced by FAO of the United Nations in Rome.

PROJECT SELECTION

Although many irrigation projects have undergone various types of rehabilitation, very few have been modernized to any significant degree. Therefore, it was difficult to locate projects that had undergone modernization programs. The projects (described in the Attachment at the end of this paper) were selected to provide a broad range of climate, crops, control systems, and geographic conditions. Selection was sometimes done by Herve Plusquellec (retired irrigation advisor for the World Bank) or the authors; in other cases (Bhakra, Lam Pao, Beni Amir, Cupatitzio) the local irrigation departments or World Bank staff recommended the projects.

[1] Director and Professor, Irrigation Training and Research Center (ITRC), BioResource and Agricultural Engineering Dept., California Polytechnic State Univ. (Cal Poly), San Luis Obispo, CA 93407 (cburt@calpoly.edu).

[2] Project Manager, Cal Poly ITRC (sstyles@calpoly.edu).

RAPID APPRAISAL PROCESS (RAP)

The project used a Rapid Appraisal Process (RAP) - a technique that has rarely been used in the diagnosis of international irrigation projects. The basic ingredients of a RAP are:

1. A detailed questionnaire is developed to obtain information needed for external performance indicators and internal process indicators (not covered in this paper).
2. A list of baseline project data (acreage, budgets, crops, climate, water availability) is requested from project authorities prior to the visit. Typical baseline data is either available or it isn't. If the data does not already exist, spending an additional 3 months on the site will not create the data. Baseline project data is needed to quantify external performance indicators.
3. A 3-5 day visit by one expert is made to the project. Ideally, only 1 day is spent in the office to examine system maps and to review the baseline project data that has been prepared in advance. The majority of time is spent in the field with field engineers/operators, making observations and collecting the data needed for internal process indicators. The field visit includes:
   a. Substantial lengths of the main canal, some secondary canals, tertiary canals, etc. are visited. Observations are made regarding the types of structures, general conditions, operator instructions, quality of flow and water level control, and other operational points.
   b. Impromptu conversations are held with farmers and operators.
   c. Short visits are made to any water user associations that may exist.

ITRC has successfully used a similar RAP in the western U.S.A. for several years to diagnose irrigation district modernization needs; another RAP is used to evaluate on-farm (field) irrigation performance. ITRC experience has shown that successful RAP programs require (i) evaluators with prior training in irrigation, (ii) specific training in the RAP techniques, and (iii) follow-up support and critique when the evaluators begin their field work.

The RAP does not eliminate the need for detailed monitoring of the water control and distribution in a *few* irrigation projects. Such detailed monitoring programs are very valuable for documenting the need for improved control, and in convincing the skeptical and unbelieving that there are indeed water control problems. The International Water Management Institute (IWMI, a.k.a. IIMI) has provided excellent documentation of Pakistani and Indonesian irrigation system performance that has helped to raise the level of awareness of project deficiencies. However, a good experienced irrigation engineer should not need such documentation to know that there are problems with certain designs. With an RAP such as was developed with this project, a good irrigation engineer should be able to quickly assess the suitability of the existing hardware and operational rules in a project, and to develop a plan for modernization needs. The RAP has a special focus on *how to solve the problems* through modernization that can be

used worldwide. There is such a lack of awareness of good design and operation principles that the detailed monitoring by IWMI is necessary to make the case for improvement.

EXTERNAL PERFORMANCE INDICATORS

Murray-Rust and Snellen (1993) described the framework of using performance indicators, and noted two approaches for the use of performance indicators in the field of irrigation:

1. Attempts to develop indicators that allow the performance of one system to be compared to similar systems elsewhere.
2. The use of indicators to compare actual results with what was planned.

External indicators examine values such as economic output, efficiency, and relative water supply (i.e., ratios of outputs and/or inputs). Because of the tremendous differences in water availability, climate, soil fertility, topography, and crop prices, the authors believe that external performance indicators are primarily applicable for item (2) -- to compare project inputs/outputs before vs. after modernization/intervention.

ICID (1995) defined several irrigation system performance indicators for international projects. Burt et al. (1997) described the detailed process needed to effectively evaluate Irrigation Efficiency and Irrigation Sagacity. Molden et al. (1998) provided a summary of recent IWMI indicator work, including values for 9 IWMI indicators for 27 different irrigation projects. The authors recommend that several IWMI indicators be modified, and that several new ITRC external indicators and one ASCE indicator be adopted.

This paper will first provide definitions and discussions of the IWMI indicators that are related to water supply, followed by a more detailed discussion of the new indicators. The new indicators were developed to reduce the difficulties of application of some IWMI indicators, and to clarify ambiguity with some indicator definitions. There was also a need for indicators of additional topics.

IWMI INDICATORS OF WATER SUPPLY

Molden et al. (1998) define several supply indicators for comparative purposes. Three below characterize the individual irrigation system with respect to water supply.

IWMI5. Relative water supply (RWS) = $\frac{\text{Total water supply}}{\text{Crop demand}}$ (1)

IWMI6. Relative irrigation supply (RIS) $= \frac{\text{Irrigation supply}}{\text{Irrigation demand}}$ (2)

Total water supply = Surface diversions plus net groundwater draft plus rainfall (but does not include any recirculating internal project drainage water).

Crop demand = Potential crop ET, or the ET under well-watered conditions. When rice is considered, deep percolation and seepage losses are added to crop demand.

Irrigation supply = Only the surface diversions and *net* groundwater draft for irrigation (i.e., this does not include rainfall and does not include any recirculating internal project drainage water).

Irrigation demand = The crop ET less effective rainfall.

The following can be noted regarding IWMI5 and IWMI6:
First, in most arid-region projects, there is an additional net water requirement for the removal of salts on a project-level basis. RIS and RWS do not include these. Second, the definition of "total water supply" is almost guaranteed to give double counting of rainfall in most tropical climates, because the groundwater is actually resupplied by rainfall. Third, although Molden et al. (1998) state that RIS is the inverse of Irrigation Efficiency, such is not the case if Irrigation Efficiency is computed by the rigorous standards set forth by the ASCE task committee in Burt et al., (1997), and defined later in this paper.

Fourth, the present IWMI definition of "crop demand" includes deep percolation and seepage loss water for rice, in addition to crop ET. There are two difficulties when including those values:

a. There is a question of the validity of including deep percolation and seepage losses as a "crop demand". The ASCE task committee document (Burt et al., 1997) is consistent with U.S. performance measurements in not including these water destinations as beneficial uses on the field nor on the project level. The ASCE document recognizes that such water destinations may be unavoidable, but "unavoidable" is not the same as "beneficial".
b. Inclusion of those values can cause serious problems with double counting of water. On one hand, RWS is proposed as an indicator for project-level performance. On the other hand, "deep percolation and seepage losses" are typically field-level values. One cannot mathematically mix field-level and project-level values in such a manner.

This point is illustrated in the following example.

Example Calculations for RWS

* Assume 12 units of water are applied to an area having 3 parcels.
* 6 units of water are initially applied to each of 2 parcels (total = 12 units).
* Of the 6 units of water on each parcel,
  - 3 units are used at crop ET, and
  - 3 are destined as deep percolation or seepage losses.
* The third parcel receives drainage water that originated in the first 2 parcels - a total of 6 units.

The RWS for this example is:

Crop demand = ET + deep percolation + seepage
= 3 parcels x (3 units ET + 3 units DP/seepage)
= 18 units

Total water supply = 12 units

$$RWS = \frac{12 \text{ units}}{18 \text{ units}} = .67, \text{ indicating insufficient water}$$

If the "Crop demand" does not include (deep perc. + seepage) on the farm-level, but does include the amount of (deep perc. + seepage) which leaves the 3-dimensional project boundaries, then RWS can be computed as:

Crop demand = ET + deep percolation + seepage
= (3 parcels x 3 units of ET) + (3 units of DP/seepage)
= 12 units

Total water supply = 12 units

$$RWS_{modified} = \frac{12 \text{ units}}{12 \text{ units}} = 1.0$$

This would be a more correct accounting of the conditions, because in this example there was sufficient water for all three fields. The 3 units of deep percolation and seepage that left the final field was NOT counted because it left a field, but because it left the boundaries of the area of study - the area of 3 fields.

Some accounting procedures double count the deep percolation from the first two *fields* as part of the *project* supply, and come up with:

Crop demand = ET + deep percolation + seepage
= (3 parcels x 3 units ET) + (3 units DP/seepage from proj.)
= 12 units

Total water supply = 12 units into area + 6 units recovery = 18 units

$$RWS_{modified} = \frac{18 \text{ units}}{12 \text{ units}} = 1.5$$

The points of this illustration are that:
(i) all performance indicators must be consistent in using values from an identical 3-dimensional boundary, whether it is field-level or project level. One cannot mix field-level values with project-level values.
(ii) field-level irrigation indicator values cannot be used to represent project-level performance
(iii) the computation procedures for any indicator must be clearly defined.

Fifth, a similar double counting error can occur with groundwater. Both RWS and RIS include "net groundwater draft". The problem with double counting rainfall was pointed out earlier. It is also common for evaluators to add irrigation surface supplies and groundwater pumping to estimate the total project supply - a serious mathematical error in most cases. Such an error leads to gross over-estimations of how much land can be farmed, as may be the case in Beni Amir, Morocco. Often the groundwater is recharged by the surface water inefficiencies. Again, one must establish 3-dimensional boundaries to a project. A surface supply may be re-used two or even three times within a project via groundwater pumping or recirculation of surface drainage waters. Regardless of the amount of recirculation, in the final count, only a certain amount of irrigation water came into the project boundaries. That incoming water is what must be counted in project-level indicators as the supply to the project.

One reason to move toward indicators such as RWS and RIS is the confusion that frequently arises in understanding "Irrigation Efficiency" estimates. Some people have an aversion to using any indicator with the term "efficiency" because of the value judgments that are attached to an "efficiency" term. The discussion above shows that the same misunderstandings and miscalculations can arise with any indicator, such as RWS and RIS. There is no shortcut to standardization of the proper definitions and techniques of computations. Education is necessary to properly implement and explain all standardized techniques.

The third IWMI indicator to be discussed is found below:
IWMI7.

$$\text{Water delivery capacity (\%)} = \frac{\text{Canal capacity to deliver water at system head}}{\text{Peak consumptive demand}} \times 100 \qquad (3)$$

Capacity to deliver water at the system head = The present discharge capacity of the canal at the system head.

Peak consumptive demand = The peak crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system. In this paper, this does *not* include seepage and deep percolation losses for rice.

There may be some confusion in the terminology of IWMI7 as the definition reads. "Peak consumptive demand" includes the ET of rainfall by crops - and therefore does not give an indication of *irrigation* requirements. The wording of the definition of "peak consumptive demand" by IWMI clarifies this point, but any confusion can be avoided by making a slight modification to the terminology. A suggested terminology change is "Peak *irrigation water* consumptive demand".

ITRC3.

$$\text{Water delivery capacity (\%)} = \frac{\text{Canal capacity to deliver water at system head}}{\text{Peak irrigation water consumptive demand}} \times 100 \qquad (4)$$

NEW OR REVISED EXTERNAL INDICATORS

The following are additional modifications of the IWMI (Molden et al., 1998) indicators. The major improvements are (i) the elimination of double counting of water and (ii) the addition of seasonal indicators. The component descriptions are found after the proposed indicators are presented.

ITRC 4: Dry season relative water supply (Dry Season RWS_{ITRC}) = $\frac{\text{Total water supply}}{\text{Crop demand}}$ (5)

ITRC 5: Wet season rel. water supply (Wet Season RWS_{ITRC}) = $\frac{\text{Total water supply}}{\text{Crop demand}}$ (6)

ITRC 6: Annual relative water supply (Annual RWS_{ITRC}) = $\frac{\text{Total water supply}}{\text{Crop demand}}$ (7)

ITRC 7: Dry season rel. irrig. supply (Dry Season RIS_{ITRC}) = $\frac{\text{Irrigation supply}}{\text{Irrigation demand}}$ (8)

ITRC 8: Wet season rel. irrig. supply (Wet Season RIS_{ITRC}) = $\frac{\text{Irrigation supply}}{\text{Irrigation demand}}$ (9)

ITRC 9: Annual relative irrigation supply (Annual RIS_{ITRC}) = $\frac{\text{Irrigation supply}}{\text{Irrigation demand}}$ (10)

Total water supply = Surface diversions (including uncontrolled flows entering the project boundaries) plus rainfall plus net groundwater pumping (groundwater which did not originate from surface irrigation supplies or from rainfall which fell within the project boundaries). The water supply pertains to the period of time stated, such as "dry season", "wet season", or "annual".

Crop demand = Potential crop ET, or the ET under well-watered conditions. Deep percolation and seepage losses are *not* included in crop demand. The crop demand is only for the designated time ("dry season", "wet season", or "annual").

Irrigation supply = The surface diversions and other surface inflows, plus *net* groundwater draft (which does not include groundwater recharged by surface diversions and inflows which are already counted, but does include any groundwater which was recharged by rainfall or external sources). This does not double count internal drainage recycling. The value is only for the designated time ("dry season", "wet season", or "annual").

Irrigation demand = The crop ET less effective rainfall. The value is only for the designated time ("dry season", "wet season", or "annual").

The use of "dry season" and "wet season" indicators arises because the two may have completely different values, and the differences may be masked when only examining a single annual value. For example, a wet season indicator may look very low (poor), but may in reality have no negative impact if there is good drainage and very high, uniform rainfall. In such a case, it may be most important to examine the dry season indicators.

The RWS and RIS indicators are useful but still fall short of providing some of the insights offered by the use of Irrigation Efficiency. Therefore, ITRC proposes that the ASCE definition of IE be widely promoted in project evaluation.

Proposed ITRC10 (ASCE definition):
Annual Project Irrigation Efficiency, IE

$$= \frac{\text{volume of irrigation water beneficially used}}{\text{vol. irrig. water applied} - \Delta \text{ storage of irrig. water}} \times 100\% \quad (11)$$

The two components of irrigation water beneficial use in the computations for this paper are crop ET and necessary salt leaching. In most of the projects, the salt leaching requirement was 0.0, since rainfall accomplished the leaching for the whole year. The change in storage value was assumed to be 0.0 in all cases. Irrigation Efficiency gives a much more in-depth description of water destinations than RIS or RWS, which only look at total volumes of water which are available or needed. RIS and RWS do not consider the timing of the water availability, nor the corresponding crop/soil needs. Irrigation efficiency, if properly computed according to ASCE guidelines (Burt et al., 1997), considers the amounts, timing, and usage of the water, not just the amounts of water. RIS and RWS have value in that they provide a snapshot view of the magnitude of water available, but they miss the details of irrigation management which IE includes. For example, irrigation water may be applied when the crop does not need it, in excessive amounts (resulting in excess deep percolation for field irrigation), or with a high percentage of unrecoverable surface losses - factors which are accounted for in the computation of IE.

GRAPHS OF INDICATORS

Figures 1 and 2 both show Relative Water Supply values. Figure 1 uses the IWMI computation technique, whereas Fig. 2 uses the ITRC recommended computation that does not include deep percolation for rice as a "crop demand". The differences in the two RWS values are substantial in the rice projects (Saldaña, Coello, Muda, Kemubu, Lam Pao). Confidence intervals are supplied - an extremely important procedure to indicate the level of uncertainty which exists for almost all water balance values.

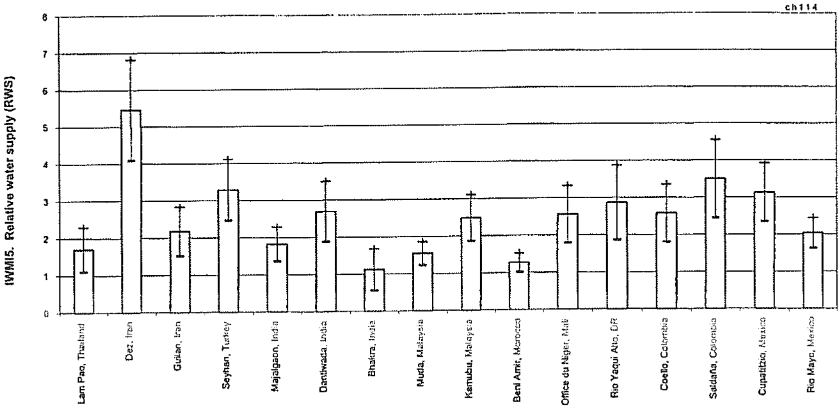

Fig. 1. IWMI5 External Indicator. Relative Water Supply (RWS)

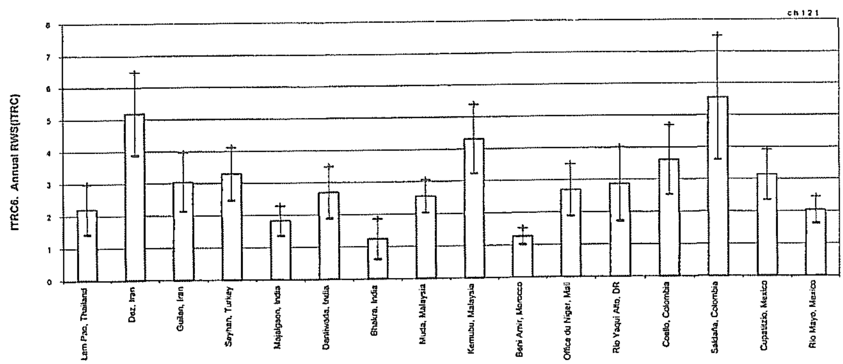

Fig. 2. ITRC6 External Indicator. Annual RWS_{ITRC}.

Figures 3 and 4 promote the usage of seasonal RWS values, in addition to annual RWS values. The seasonal values provide additional insight to the temporal usage of total water supplies. A "zero" value indicates that (i) no crops are grown in a season, or (ii) the crops are all permanent crops, so the values are consolidated into one season.

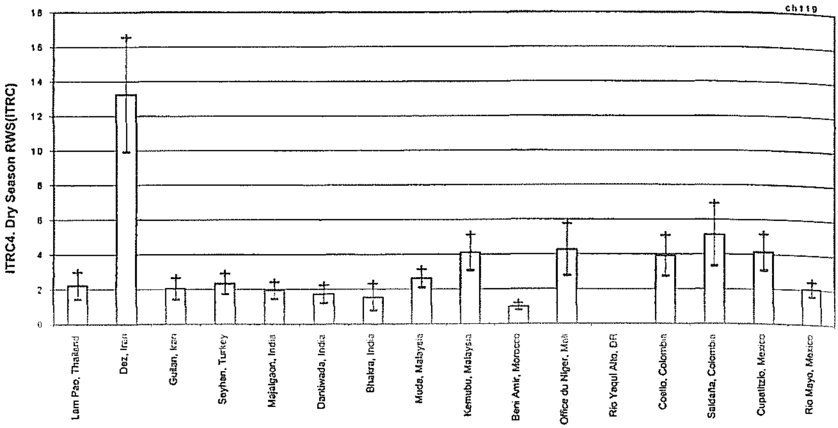

Fig. 3. ITRC4 External Indicator. Dry Season RWS_{ITRC}.

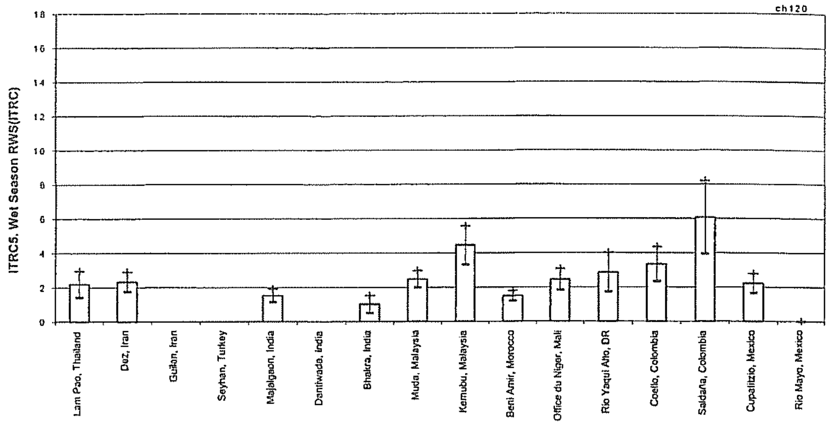

Fig. 4. ITRC5 External Indicator. Wet Season RWS_{ITRC}.

Figures 5-8 provide RIS values which only account for the irrigation water supply, as opposed to the total water supply of RWS. As with RWS, the ITRC values of Fig. 6 and 8 do not include rice deep percolation as a "crop demand" for the reasons explained earlier in this paper.

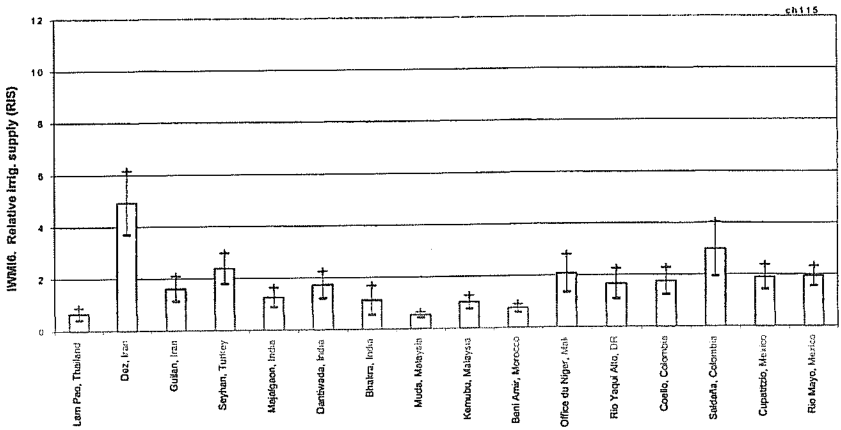

Fig. 5. IWMI6 External Indicator. Relative Irrigation Supply (RIS).

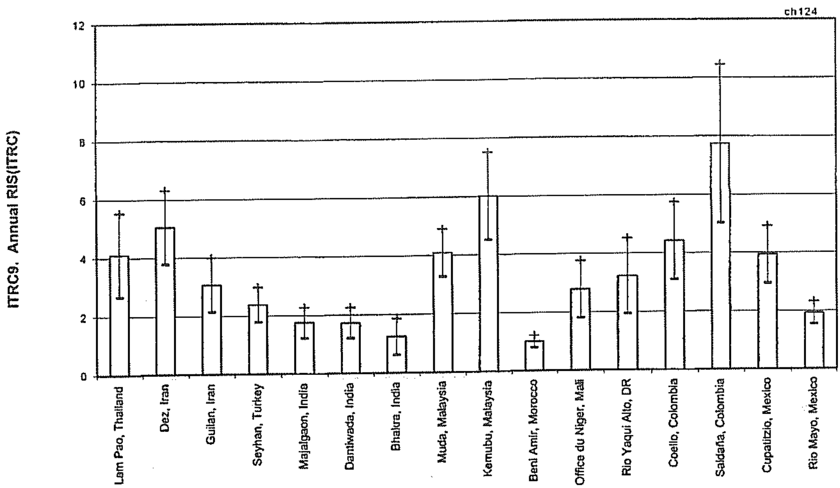

Fig. 6. ITRC9 External Indicator. Annual RIS_{ITRC}.

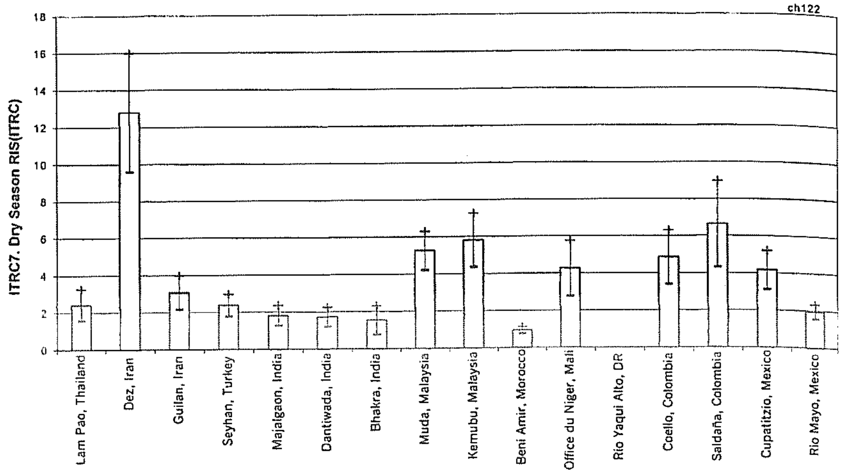

Fig. 7. ITRC7 External Indicator. Dry Season RIS_{ITRC}.

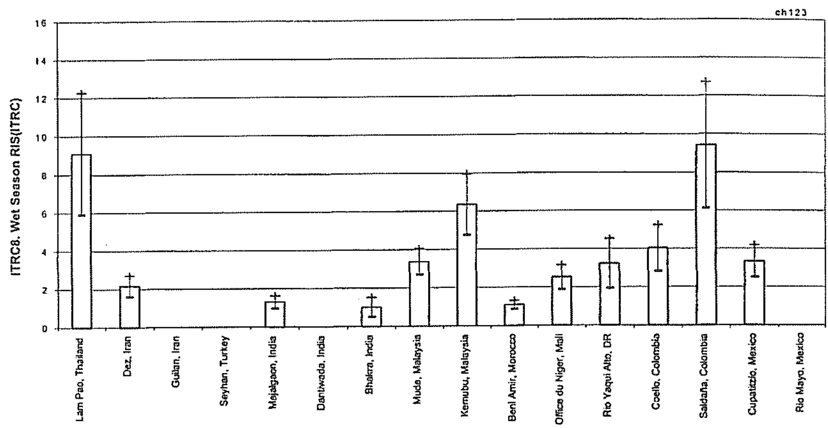

Fig. 8. ITRC8 external indicator. Wet Season RIS_{ITRC}

The importance of clear definitions of terms is brought out when one compares Figures 9 and 10. Both provide information about the adequacy of the peak inflow rates to irrigation projects. For most projects, ITRC3 and IWMI7 provide similar values. However, there are major differences between the two indicators for Beni Amir, Rio Yaqui Alto, and Cupatitzio. IWMI7 (as computed here) compares the peak inflow rates to the crop water requirement, whereas ITRC3 compares the inflow rates to the irrigation water requirement (ET of irrigation

water) - a major difference in rainy conditions. If there is substantial rainfall, the ET of irrigation water is much lower than the total ET.

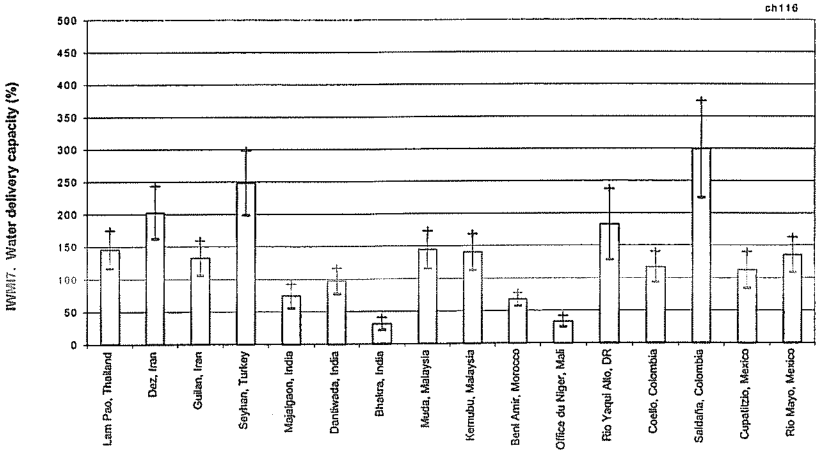

Fig. 9. IWMI7 External Indicator. Water Delivery Capacity (%).

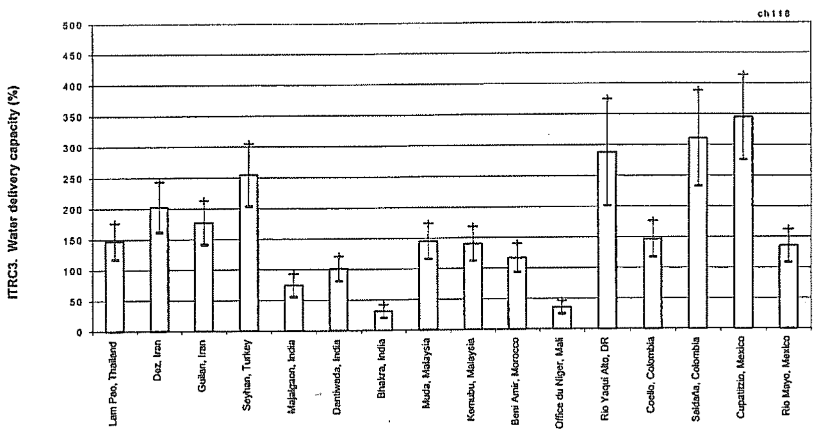

Fig. 10. ITRC3 external indicator. Water Delivery Capacity (%).

Irrigation Efficiency provides valuable insight into several aspects of irrigation project performance. For example, Fig. 11 shows that almost all of the irrigation water supply is presently being beneficially used in Beni Amir (Morocco). This is extremely important insight, because evidently there are some plans to increase the irrigated acreage with the same water supply. That is obviously an error if the irrigation efficiency value is correct. If irrigation efficiency is properly

understood and defined, it helps to avoid double counting of water and unwarranted expansion of acreage.

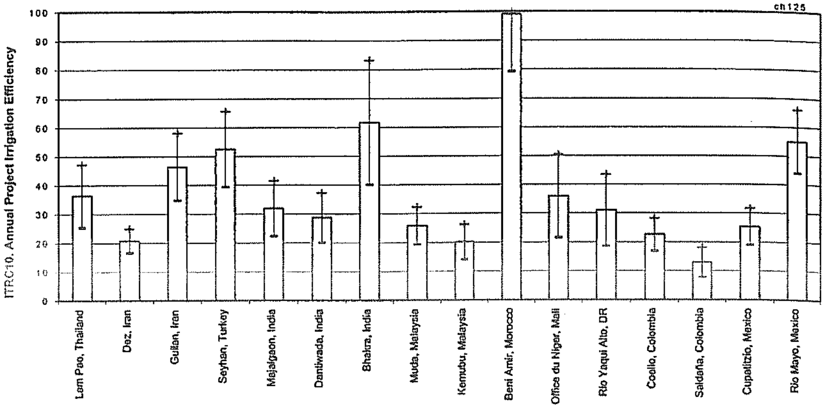

Fig. 11. ITRC10 (ASCE definition). Annual Project Irrigation Efficiency (%).

Figure 11 shows that Dez, Dantiwada, Muda, Kemubu, Rio Yaqui, Coello, and Cupatitzio may all have the same annual project irrigation efficiency of 20%. The confidence intervals for all of these projects overlap the 20% value.

A third point from Fig. 11 is that there are tremendous differences in performance between various projects, and that there is great room for improvement in some cases. Figure 11 does not show where inefficiencies occur, such as spills, unrecovered seepage, on-farm surface spills not recovered within the project, or on-farm deep percolation not recovered within the project. However, in all cases, better control and flexibility of the water delivery system is essential for reducing such inefficiencies.

REFERENCES

Burt, C. M. 1995. The Surface Irrigation Manual. Waterman Industries, Exeter, CA.

Burt, C. M., A. J. Clemmens, T. S. Strelkoff, K. H. Solomon, R. D. Bliesner, L. A. Hardy, T. A. Howell, and D. E. Eisenhauer. 1997. Irrigation Performance Measures - Efficiency and Uniformity. Journal of Irrigation and Drainage Engineering. ASCE 123(6):423-442.

ICID. 1995. Currently Used Performance Indicators. Research Program on Irrigation Performance. Contact: M. G. Bos, Wageningen, The Netherlands.

Molden, D., R. Sakthivadivel, C. J. Perry, C. de Fraiture, and W. H. Kloezen. 1998. Indicators for Comparing Performance of Irrigated Agricultural Systems. IWMI Research Report 20.

Murray-Rust, D. H. and W. B. Snellen. 1993. Irrigation System Performance Assessment and Diagnosis. IWMI.

Attachment - Irrigation Project Descriptions

	Lam Pao, Thailand	Dez, Iran	Guilan, Iran	Seyhan, Turkey	Majalgaon, India	Dantiwada, India	Bhakra, India	Muda, Malaysia	Kemubu, Malaysia	Beni Amir, Tadla, Morocco	Office du Niger (ODN), Mali	Rio Yaqui Alto, Dominican Republic	Coello, Colombia	Saldaña, Colombia	Cupatitzio, Mexico	Rio Mayo, Mexico
Average service area (ha)	49,338	98,500	235,000	103,135	11,283	36,600	683,000	97,000	20,430	28,000	56,000	3,574	25,711	14,000	9,878	97,047
"Typical year" crop intensity	1.4	1.0	1.0	0.9	0.3	1.1	1.9	2.0	1.5	1.3	1.2	1.2	1.4	1.6	0.7	1.1
Average net farm size (ha)	2.2	5.6	1.2	5.6	0.6	1.4	3.2	2.0	0.7	3.0	3	2.5	100.0	100.0	8.2	100.0
Typical field size, ha	0.4	5.0	0.3	3.4	0.3	0.5	0.5	1.0	0.5	0.5	3	2.5	12.0	5.0	9.5	12.0
Land consolidation on what % of area	0	30	0	0	0	0	0	100	0	100	75	0	0	0	0	0
Percent rented land	0	0	0	0	0	0	0	0	0	10	0	10	85	80	1	50
Silt level in canals (10=high; 1=low)	3	2	9	2	1	10	3	5	4	6	1	3	7	10	2	2
Cost of land, $US/ha	17,500	13,300	17,000	2,500	4,200	9,700	8,300	12,500	10,000	12,000	n/a	8,200	8,000	6,000	4,500	1,900
Gross income per farm unit, $US/yr	1,490	3,115	2,163	7,500	700	764	2,900	2,500	2,000	2,416	1,400	1,100	60,000	179,500	2,200	40,000
Farm labor cost, $US/day	6	3	15	10	2	1	2	15	15	3	2	7	8	10	6	4
Major crop	Rice	Wheat	Rice	Maize	Sorghum	Wheat	Rice	Rice	Rice	Wheat	Rice	Pasture	Rice	Rice	Sorghum	Wheat
Second major crop	Rice	Sugar Cane	n/a	Cotton	Cotton	Mustard	Cotton	Rice	Rice	S. beets	Veg.	Tobacco	Sorghum	Pasture	Lemon	Corn
Water source	Reservoir	Reservoir	Reservoir	Reservoir	Reservoir and wells	Reservoir and wells	Reservoir and wells	Reservoir	River	Reservoir and wells	River	Reservoir	River	River	Reservoir	Reservoir and wells
LPS/ha irrigated	2.5	3.3	1.0	1.9	0.9	0.9	0.2	1.3	1.9	0.6	2.3	1.3	1.1	2.6	2.1	0.8
Annual avg. ETo, mm	1,695	1,670	771	1,285	2,055	1,893	1,550	1,420	1,400	1,326	2,628	1,945	1,676	1,532	2,280	2,350
Annual rainfall, mm	1,336	250	1,290	721	774	604	545	2,300	2,700	376	238	984	1,306	1,442	671	323
c.v. of annual rainfall (yr-yr)	0.16	0.39	0.15	0.33	0.22	0.45	0.45	0.14	n/a	0.30	0.25	0.15	0.18	0.18	0.26	0.26
MAIN CANALS																
Is there a fixed advance official schedule of main canal deliveries for the year?	N	Y	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N
How often are main supply discharges re-calculated, days?	7	365	7	30	365	120	30	1	1	1	30	120	75	365	3	5
Total length of Main Canals, km	159	190	132	483	39	77	165	146	105.6	42	288	33	14	69	55	245

% lining of Main Canal	95	90	60	100	100	100	100	0	0	100	0	100	0	3	100	24
Principal type of cross regulator in Main Canal	Manual Sluice	Manual Radial	Hyd. AMIL, LCW	Manual Sluice	Automatic Radial	Manual Sluice	Manual Sluice	Manual Overshot	Hyd. D/S (AVIS)	Hyd, LCW	Manual Sluice	Manual Sluice	Radial plus LCW	Radial with LCW	Radial plus LCW	Manual Sluice
Condition of cross-regulators in Main Canal (10=horr.;1=XInt)	3	2	3	2	1	2	3	2	3	2	2	7	3	5	4	3
Operators live at each X-regulator site	Y	N	N	N	Y	Y	Y	Y	N	N	N	Y	N	N	N	N
Flow Measurement (not control) - Entrance to Secondary	CHO	Rated Gate	Baffle Distributor	Parshall Flume	Rated Gate	Flume	Flume	Rated Overshot gate	Baffle Dist and CHO	Baffle Dist.	Baffle Dist.	none	current meter	Rated Sec., Parshall	Baffle Dist.	Flume
SUBMAIN CANALS																
Total length of SUBMAIN Canals in project, km	452	560	640	2550	273	675	2000	1530	408	240	75	91	226	93	39	1194
% lining of SUBMAIN Canals	95	90	50	95	90	100	50	40	0	99	0	95	6	0	100	8
Type of cross regulator	Manual Sluice	90% Radial, 10% mixed	Long Crested Weir (LCW)	Manual Sluice	LCW	Proport. Divider, a few Weirs	none	Combin. Weir, gate	Manual Radial and Sluice	LCW	various	Begemann	Sluice gate	Sluice gate	LCW with Underflow gates	Sluice gate
FARMER																
Final distribution to farmer	unlined; field-field (65/35)	unlined; lined (50/50)	unlined, field-field (50/50)	pipeline, lined (10/90)	lined	unlined	unlined, lined (98/2)	field-field, lined (60/40)	field-field	unlined	unlined	unlined	unlined	unlined	unlined	unlined, lined (99/1)
Water distribution schedule to farmer	Contin., rotation (60/40)	Continuous/Unknown Rotation (50/50	Contin., known rotation (60/40)	Arranged	Known Rotation	Known Rotation	Known Rotation	Contin., known rotation (25/75)	Contin.	Variable rotation	Arranged	Arranged	Known Rotation, Arranged (20/80)	Known Rotation, Arranged (50/50)	Arranged	Arranged
Who makes final distribution of water?	Farmer	Farmer	Farmer	WUA or Farmer	Farmer	Farmer	Farmer	Farmer	Farmer	Farmer	Farmer	Farmer	WUA or Farmer	WUA	Farmer	WUA
Average number of farmers involved at lowest level	20.0	10.0	20.0	2.8	15.0	5.0	50.0	20.0	20.0	10.0	7.0	2.8	1.1	2.5	3.7	3.0