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Indicators for Comparing Performance of Irrigated Agricultural Systems

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Abstract

A minimum set of performance indicators are defined which relate outputs from irrigated agriculture to the major inputs of water, land, and finance. These indicators are presented with the objective of providing a means of comparing performance across irrigation systems. Results of application of the indicators at 18 irrigation systems are presented and large differences in performance among systems are shown. In spite of uncertainties in estimation of indicators, the large differences discerned by the indicators justifies the approach taken.

Introduction

With increasing population and demand for food, sustainable production increases from irrigated agriculture must be achieved. With limited freshwater and land resources, and increasing competition for these resources, irrigated agriculture worldwide must improve its utilization of these resources. Few would disagree with these statements, yet we do not have a way of determining the present state of affairs with respect to irrigated agriculture. The question - how is irrigated agriculture performing with limited water and land resources? - has not been satisfactorily answered. This is because we have not been able to compare irrigated land and water use to know how irrigation systems are performing relative to each other and what the appropriate targets for achievement are.

With the many variables that influence performance of irrigated agriculture, including infrastructure design, management, climatic conditions, price and availability of inputs, and socio-economic settings, the task of comparing performance across systems is formidable. However, if we focus on commonalties of irrigated agriculture: water, land, finances, and crop production, it should be possible to see in a gross sense of how irrigated agriculture is performing within various settings.

This paper presents IIMI's "comparative" indicators and experience with their use based on application across several irrigation systems. At this stage, it is hypothesized that through the use of these indicators, we are able to document and compare key performance attributes of irrigation systems. If so, then it should be possible to compare performance across irrigation systems in a number of settings to understand where we presently stand with respect to productive utilization of land and water; to compare relative performance of systems; and to identify where performance can be improved.

Peformance Indicators for Comparison

It is useful to consider an irrigation system in the context of nested systems to describe different types and uses of performance indicators (Small and Svendsen, 1992). An irrigation system is nested within an irrigated agricultural system, which in turn can be considered part of an agricultural economic system. For each of the systems, process, output, and impact measures can be considered. Process measures refer to the processes internal to the system that lead to the ultimate output, whereas output measures describe the quality and quantity of the outputs where they become available to the next higher system (Bos et al, 1993).

Performance assessment is done for a variety of reasons including: improving system operations, assessing progress against strategic goals, as an integral part of performance-oriented management, assessing the general health of a system, assessing impacts of interventions, to diagnose constraints, to better understand determinants of performance, and to compare the performance of a system to others or to the same system over time. The type of performance measures chosen depends on the purpose of the performance assessment activity.

Many authors have proposed indicators to measure irrigation system performance (as summarized by Rao, 1993) and have given examples on their use at particular irrigation systems (as examples: Bos and Nugteren, 1974, Levine 1982, Abernethy, 1986, Seckler and Sampath, 1988, Mao Zhi, 1989, Molden and Gates, 1990, Sakthivadivel et al, 1993, Bos et al, 1994). But, there are very few examples of cross-system comparisons or analysis (Bos and Nugteren, 1974, Murray Rust and Snellen, 1992, Merrey et al, 1994) Recent efforts have attempted to standardize these internal indicators to allow for better comparison across systems (Bos et al, 1994). We are presently at a state in the development of performance assessment of irrigation that we have a limited number of case studies with intensive measurements of performance, and few examples of studies of performance across irrigation systems.

Much of the work to date in irrigation performance assessment has been focused on internal processes of irrigation systems. Many internal process indicators relate performance to management targets such as timing, duration and flow rate of water; area irrigated; and cropping patterns. A major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users. Targets are set relative to objectives of system management, and performance measures tell how well the system is performing relative to these targets. When the performance is not adequate, either the process must be changed to reach the target, or the target itself must be changed. These "internal" indicators aid irrigation system managers to answer the question "Am I doing things right?" (Murray-Rust and Snellen, 1992).

We could conclude, although it would be premature, that these internal, process indicators do not lend themselves well to cross system comparison. This is due to several reasons. First, internal processes of irrigation systems vary widely from system to system, so that performance indicators are tailored to meet system specific needs. Second, indicators related to irrigation processes tend to be data intensive and it is often difficult, time consuming and often expensive to obtain complete data sets. Third, assumptions about relations between internal processes and outputs may not be valid. It is often assumed that meeting a target will improve output in terms of agricultural production or net benefit to farmers.

An approach to cross-system comparison is to compare outputs and impacts of irrigated agricultue. "External" indicators are used to relate outputs from a system derived from the inputs into that system. They provide little or no detail on internal processes that lead to the output. For example, the critical output of an irrigation system is the supply of water to crops. This output in turn is an input to a broader irrigated agricultural system where water combined with other inputs, leads to agricultural production. As each and every irrigation system deals with water and agricultural production it should be possible to develop a set of external indicators for comparison across systems.

The purpose of this study is to present and apply a minimum set of external and other comparative performance indicators that will allow for comparative analysis of irrigation performance across irrigation systems. The indicators reveal general notions about the relative health of the irrigation system, yet they are not too data intensive to discourage widespread and regular application. Data requirements to calculate the minimum set of indicators are given in annex 1. Such a set of indicators potentially has several purposes. The indicators will allow for comparison between countries and regions, between different infrastructure and management types, and between different environments. They will allow an initial screening of systems that perform well in different environments, and those that do not. They will allow for assessing impact of interventions and allow for managers to assess performance against strategic, long-term objectives.

Features of the Selected Indicators

IIMI's minimum set of external indicators were originally presented by Perry (1996). They have been widely field tested and slightly amended, resulting in this present list. The intent of presenting this set of indicators is to allow for cross-system performance. Some of the features of the indicators are:

- the indicators are based on a relative comparison of absolute values, rather than being referenced to standards or targets
- the indicators relate to phenomena that are common to irrigation and irrigated agricultural systems
- the set of indicators is small yet reveals sufficient information about the output of the system
- data collection procedures are not too complicated or expensive
- the indicators relate to outputs and are bulk measures of irrigation and irrigated agricultural systems, and thus provide limited information about internal processes.

This set of indicators are designed to show gross relationships and trends and should be useful in indicating where more detailed study should take place - for example where a project has done extremely well, or where dramatic changes have taken place. This approach differs from that of using ratios of actual to target in that the interpretation of these ratios relative to performance is not always clear (i.e. is 0.9 better than 1.1?). A relative comparison of values at least allows us to examine how well one system is performing in relation to others. And, if we have enough samples, this approach may ultimately allow us to develop standards and targets. The main audience for internal indicators are irrigation system managers interested in day-to-day operations where ratios of actual to target may be quite meaningful. The main audience for these external indicators are policy-makers and managers making long-term, strategic decisions, and researchers who are searching for relative differences between irrigation systems.

As water becomes a limiting resource, an important question becomes:

> *What is the value of irrigated agricultural production per unit of water consumed from the hydrological cycle?*

To answer this question requires an indicator that measures the contribution of the irrigation activity to the economy in relation to consumption of the increasingly scarce resource, water. Even answering this question requires better understanding than we often have of cropping activities—the output component of the basic indicator, and water balances which indicate the input. The basic indicators here are the output of irrigated agriculture per unit land and per unit water.

The Indicators

Nine indicators are developed related to the irrigation and irrigated agricultural system. The main output considered is crop production, while the major inputs are water, land, and finances.

Indicators of Irrigated Agricultural Output

The four basic comparative performance indicators relate output to unit land and water. These "external" indicators provide the basis for comparison of irrigated agricultural performance. Where water is a constraining resource, output per unit water may be more important, whereas if land is a constraint relative to water, output per unit land may be more important.

1. Output per cropped area $(\frac{\$}{\text{ha}}) = \frac{\text{Production}}{\text{Irrigated Cropped Area } (A_{\text{cropped}})}$

2. Output per unit command $(\frac{\$}{\text{ha}}) = \frac{\text{Production}}{\text{Command area } (A_{\text{net}})}$

3. Output per unit Irrigation Supply $(\frac{\$}{\text{m}^3}) = \frac{\text{Production}}{\text{Diverted Irrigation Supply } (V_{\text{div}})}$

4. Output per unit Water Consumed $(\frac{\$}{\text{m}^3}) = \frac{\text{Production}}{\text{Volume of Water Consumed by ET } (V_{\text{consumed}})}$

where,

Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices (see below),

Irrigated Cropped Area is the sum of the areas under crops during the time period of analysis,
Command Area is the nominal or design area to be irrigated[1],
Diverted Irrigation Supply is the volume of surface irrigation water diverted to the command area, plus net removals from groundwater, and
Volume of Water Consumed by Crops is the evapotranspiration of crops.

Output per unit of irrigation water supplied and per unit of water consumed are derived from a general water accounting framework (Molden, 1997). The water consumed in equation 4 is the volume of process consumption, in this case evapotranspiration. It is important to distinguish this from another important water accounting indicator -- output per unit total consumption, where total consumption includes water depletion from the hydrologic cycle through process consumption (ET), other evaporative losses (from fallow land, free water surfaces, weeds, trees), flows to sinks (saline groundwater and seas), and through pollution (Keller and Keller, 1995, Seckler, 1996).

We are interested in a measurement of production from irrigated agriculture that can be used to compare across systems. If only one crop is considered, production could be compared in terms of mass. The difficulty arises when comparing different crops, say wheat and tomatoes, as 1 kg of tomatoes is not readily comparable to 1 kg of wheat. When only one irrigation system is considered, or irrigation systems in a region where prices are similar, production can be measured as net value of production of gross value of production using local values.

The Standardized Gross Value of Production (SGVP) was developed to compare across irrigation systems as obviously there are differences in local prices at different locations throughout the world. To obtain SGVP, equivalent yield is calculated based on local prices of the crops grown, compared to the local price of the predominant, locally grown, internationally traded base crop. The second step is to value this equivalent production at world prices. To do this we are presently using average World Bank prices for the period 1985 to 1995 (see annex 2 for the list). This should not be adjusted for FOB/CIF and internal transport since we are interested in the productivity of irrigation, rather than the efficiency of markets, transport system, and project location.

Thus if the local price of tomatoes is three times the local price of wheat, we consider the production yield of 10 ton/ha of tomatoes to be equivalent to 30 ton/ha of wheat. Total production of all crops is then aggregated on the basis of 'wheat equivalent' and the gross value of output is calculated as this quantity of wheat multiplied by the world market price of wheat. The point of this is to capture local preferences--for example specialized varieties that may have a low international price, but are locally highly valued--and also to capture the value of non-traded crops.

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[1] For example, consider an irrigated area that nominally is to serve 1,000 ha. During the rainy season, 800 ha are irrigated, and during the dry season, 400 ha are irrigated. In this case, the irrigated cropped area is 1,200 ha. The command area is 1,000 ha.

$$SGVP = \left(\sum_{crops} AiYi \frac{Pi}{Pb} \right) Pworld ,$$

where,

SGVP is the standardized gross value of production,
Yi is the yield of crop i,
Pi is the local price of crop i, and
Pworld is the value of the base crop traded at world prices.
Ai is the area cropped with crop i
Pb is the local price of the base crop

Other Comparative Indicators

An additional 5 indicators were identified in this minimum set for comparative purposes. These are meant to characterize the individual system with respect to water supply and finances.

Relative water supply as presented by Levine (1982) and relative irrigation supply as developed for this indicator set (Perry, 1996) are used as the basic water supply indicators:

5. Relative Water Supply $= \dfrac{\text{Total Irrigation Supply}}{\text{Crop Demand}}$

6. Relative Irrigation Supply $= \dfrac{\text{Irrigation Supply}}{\text{Irrigation Demand}}$

Relative irrigation supply is the inverse of the irrigation efficiency presented in Bos (1974). The term relative irrigation supply was presented to be consistent with the term relative water supply, and to avoid any confusing value judgements inherent in the word efficiency.

7. Water Delivery Capacity (%) $= \dfrac{\text{Canal capacity to deliver water at system head}}{\text{Peak consumptive demand}}$

where

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.
Total Water Supply = Surface diversions plus net groundwater water draft plus rainfall
Irrigation Supply = only the surface diversions and net groundwater draft for irrigation
Irrigation Demand = the crop ET less effective rainfall.
Capacity to deliver water at the system head = the present discharge capacity of the canal at the system head, and
Peak Consumptive Demand is the peak crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system.

Both RWS and RIS relate supply to demand, and give some indication as the condition of water abundance or scarcity, and how tightly supply and demand are matched. Care must be taken in the interpretation of results: an irrigated area upstream in a river basin may divert much water to give adequate supply and ease management, with the excess water providing a source for downstream users. In such circumstances, a higher RWS in the upstream project may indicate appropriate use of available water, and a lower RWS would actually be less desirable. Likewise, a value of 0.8 may not represent a problem, rather it may provide an indication that farmers are practicing deficit irrigation with a short water supply in order to maximize returns on water.

The water delivery capacity is meant to give an indication of the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands. Again, a lower or higher value may not be better, but needs to be interpreted in the context of the irrigation system, and in conjunction with the other indicators.

Financial Indicators

Two financial indicators are used:

$$8.\ \text{Gross Return on Investment (\%)} = \frac{SGVP}{\text{Cost of Irrigation Infrastructure}}$$

$$9.\ \text{Financial Self Sufficiency} = \frac{\text{Revenue from Irrigation}}{\text{Total O\&M Expenditures}}$$

where:

Cost of Irrigation Infrastructure considers the cost of the irrigation water delivery system referenced to the same year as the SGVP,

Revenue from Irrigation, is the revenue generated, either from fees, or other locally generated income,

Total O&M Expenditures is the amount expended locally through O&M plus outside subsidies from the government.

Policy-makers are keenly interested in the returns to investments made. Similarly, researchers would like to be able to recommend systems that yield acceptable returns within a given environment. Large irrigation investments are made in irrigation infrastructure, thus returns compared to investment in infrastructure is presented here. We focus on water delivery infrastructure to be able to analyze differences between various types of delivery systems such as structured, automated, lined, and unlined canals sections. Infrastructure related to river diversions, storage, and drainage is not included here, because of the desire to be able to compare different methods of water delivery. Also, diversion and storage works often serve other non-irrigation purposes so their costs cannot be entirely allocated to irrigation. The cost of the distribution system can either be estimated from original costs, or estimated by using present costs of similar types of infrastructure development.

Financial self sufficiency tells us what percent of expenditures on O&M are generated locally. If government subsidizes O&M heavily, financial self sufficiency would be low, whereas if local farmers through their fees pay for most of O&M expenditures, financial self-sufficiency would be high. Financial self sufficiency does not tell us the O&M requirement, only the expenditures, so it does not tell us whether the expenditures on O&M are meeting the requirements. A high value of financial self-sufficiency not automatically indicates a sustainable system as the O&M expenditures might be too low to meet the actual maintenance needs.

Application

The minimum set of external indicators proposed by IIMI was tested in eighteen systems, or parts of irrigation systems located in eleven countries: Burkina Faso, Colombia, Egypt, Malaysia, Mexico, Morocco, Niger, India, Pakistan, Sri Lanka and Turkey. The sites are those at which IIMI is involved either through their field offices, or in collaborative efforts with research partners. The major features of the systems used for computing the indicators are indicated in Table 1. These features suggest that the data used for computation come from a wide range of agro-climatic regions and systems having different characteristics, crops and cropping patterns, water distribution patterns, water resource availability and management style.

Three types of data were collected: water supply, agricultural, revenue and irrigation costs. Most of the data used for analysis are survey data; derived from official statistics and measurements; or collected and compiled by IIMI and collaborating scientists working in different countries. Although much of the data used come from the secondary sources such as Irrigation Departments, Agricultural Departments, Revenue Departments and State Statistical Departments, IIMI has put in much effort by way of initiating survey and field observations to acquire reliable data and to check the secondary data for their consistency. The actual data collection procedure adopted in different countries are documented in IIMI's country reports. Table 2 gives the results of the performance indicators computations for all schemes.

1. SGVP per Unit Command

The gross value of output per unit command varies between $679 and $2888 per ha with a variation ratio of 1 to 4.25 (Fig. 1). The systems at the low end of the spectrum (less than $1500/ha) are those which mostly grow paddy with low cropping intensity. Middle range values of SGVP per ha ($1,500 to 2,000) are produced by those which grow paddy with high cropping intensity of the order of 200%. Those at the high end ($2000/ha and above) include orchards, industrial crops and some cereals. These initial results indicate that the two important factors contributing to higher gross value of output per unit command are the cropping intensity of rice and the type of crop grown, especially those of orchards and industrial crops.

2. SGVP per Unit Cropped Land

The gross value of output per unit cropped land, in Figure 2, presents two broad classes of irrigation systems. Rice producing irrigation systems have their gross value of output per unit cropped land roughly equal to $1000 and below while systems producing other non-rice crops including industrial and orchard crops have their gross value of production/unit crop land between $2000 to $3500. This parameter between these two types of systems varies between a ratio of 1:2 to 3.5. In other words, other non-rice producing irrigation systems can be more productive than the rice producing irrigation system by 100% to 200%.

3. SGVP per Unit Irrigation Supply

The gross value of output per unit irrigation supply in Figure 3 varies between 1 to 15 and can be grouped into three classes. Purely rice based systems give a gross value of output per unit volume of irrigation water varying between $0.04 to $0.10. Irrigation systems which grow rice during rainy seasons and other field crops during a dry season give a gross value of output per unit irrigation water varying between $0.10 to $0.29. Systems which grown orchards, industrial crops and vegetables yield an SGVP per cubic meter of irrigation water higher than $0.20. The SGVP per cubic meter of irrigation tend to be higher in humid regions where irrigation need are generally lower. Obviously, this also depend on the ability of farmers and system managers to use rainfall effectively.

4. SGVP per Unit Water Consumed

Consumed water is the actual evapotranspiration by irrigated crops (ET). The gross value of output per unit water consumed in Figure 4 shows variation of 1 to 6. It is seen that purely rice based systems with abundant water supply and rice based system, with cropping intensity less than 100 percent give a gross value of output per unit water consumed of about $0.10 whereas water-short systems with orchard and industrial crops and those systems with private-well pumping give a gross value of output per unit water consumed between $0.20 to $0.60. This parameter among these two types of systems varies over a range of 1:2 to 6.

5. Relative Water Supply (RWS)

Values for RWS vary between 0.80 and 4.0 (Figure 5). Half of the systems have RWS values greater than two showing an adequate supply relative to demand.

6. Relative Irrigation Supply (RIS)

Relative Irrigation Supply (RIS) focuses on supply of irrigation water alone, in contrast to RWS which also includes rainfall. When irrigation tightly fills the gap of water requirements after they are met by rain, RIS is near unity. The RIS values plotted in Figure 6 indicate that there is a wide variation in the RIS values among the systems studied (0.41 to 4.81). In situations where water not consumed is lost, say to a sea, and there is a scarce water supply in the river basin, it is better to have a relative irrigation supply near one than a higher value.

It is instructive to note that the Muda system in Malaysia which uses a real-time monitoring of water-depth in paddy fields is able to use rainfall effectively and has the lowest RIS value. This is particularly impressive as the storage is about 200 km upstream from the diversion point. Water not consumed by ET in the Muda system is lost to the sea, so it is important for this area to closely match supply with demand. At Muda, RIS and RWS values are minimized by using a real-time monitoring rainfall and adjusting the irrigation release from storage/diversion structures to effectively use the rainfall component of water supply.

7. Water Delivery Capacity Ratio

Water delivery capacity ratio indicates whether the system design is in anyway a constraint to meet the maximum crop water requirement. Values much greater than one indicate that there capacity is not a constraint to meeting crop water demands. Values close to one indicate that there may be difficulties meeting short term peak demands. Often times, additional capacity is designed (at additional cost) to allow for more flexible water deliveries, or to ease management.

8. Financial Self-sufficiency

Table 2 presents percent of self-sufficiency attained by different systems studied. The figures indicate that in systems where management has been turned over from government to locally management entities, a higher percentage of O&M expenditures is generated locally than in government managed systems. While the locally managed systems achieve a self-sufficiency of nearly 100 percent, agency managed systems have a financial self sufficiency of 30 to 50 percent. This result has to be interpreted cautiously as we have taken into account only two systems which have been turned over from government to local management.

9. Gross Return on Investment

In computing the gross return on investment, computations of investment cost of distribution systems posed a problem. In many cases, we used a current estimated cost of construction per hectare prevailing in those countries where we could not get reliable construction cost of project under consideration. The values of gross return on investment presented in Table 2 show a wide variation between 6 and 75 percent. Rice-based irrigation systems with less abundant water give a low return on investment (6 to 30%) while private pump irrigation systems provides the highest rate of return on investment (75%).

Temporal and Spatial Variation of Indicators Within a Project

If the minimum set of external indicators are desegregated in time and space, they serve as tools for internal management of irrigation systems and for evaluating impacts of interventions. These concepts are demonstrated by applying indicators to two systems: Samaca in Colombia for impact assessment, and Alto Rio Lerma in Mexico for operational management.

In Colombia, for the Samaca Irrigation Project, the indicators were computed for a period of 11 years (1986 to 1996). Two of the indicators, Output per unit command and the financial self-sufficiency, are displayed in figure 7.

Despite yearly fluctuations, SGVP per unit command show a clear rising trend. This increase in SGVP is mainly attributed to a general increase in yield of the 2 main crops (potato and onion) grown in the area. Over the last decade Colombia's economy has been liberalized with subsidies in agriculture cut or reduced substantially. Attitudes in farming changed from mainly subsistence to commercial farming. Agro-inputs and improved irrigation facilities are now widely used and this resulted in increasing yields.

Until 1991, the financial self-sufficiency averaged 35% indicating that 65% was subsidized by the government. In 1992 this situation altered dramatically when the government decided to turnover the system operation and management to the users' association. From then onwards farmers had to bear the full costs to run the system. Water fees were raised by 170%, the financial self-sufficiency increased to around 100%.

For Mexico, the entire district of Alto Rio Lerma and its two transferred sub-systems Cortazar module and Salvatierra module were selected for comparison of indicators on spatial basis. Figure 8 displays the computed indicators for these sub-systems irrigated with surface and public well systems. The results indicate that Cortazar module outperforms in all indicators compared to Salvatierra Module as well as the entire district of Alto Rio Lerma, while Salvatierra modules' performance is less impressive. This gives some indication of differences in results of the turnover program.

Limitations of the Indicators

The major difficulty of using the indicators is the uncertainty involved in many of the estimates. Two major types of uncertainties exist: uncertainties in the source of data, and secondly uncertainties in the estimates. Much of the data comes from secondary sources, not directly measured by the researchers. There is a wide variety in the quality of data obtained from these sources. Secondly, means of estimating lead to errors. For example, there are large uncertainties in estimates of actual crop evapotranspiration and effective precipitation related to the methodology of estimating these terms.

The largest degree of uncertainty exists in the estimation of effective precipitation. Several methods exist to estimate effective precipitation (Dastane, 1974), and the results vary depending on the method chosen. We also know that differences in physical and management characteristics of irrigated areas play a large role in determining how much rainfall is effective. For example, a flat area with low rainfall using bunds where farmers practice deficit irrigation will capture rainfall much more effectively, than a sloping irrigation system in a hilly area, with a plentiful surface supply. At present there are inadequate methods to estimate effective rainfall under the variety of situations that exist. For this study, we relied on the best judgment of the researcher to estimate effective precipitation.

Similar to effective precipitation, but to a lesser extent, estimates of actual crop evapotranspiration are subject to uncertainties in their quantification. On a regional scale with varying soils, water deliveries, and farmer practices, it is quite difficult to obtain a regional estimate. It is even more difficult to get a good estimate when deficit irrigation is practiced or crops are stressed.

Uncertainty is introduced using SGVP. Variations in local prices is one source of error. Fluctuations in local prices relative to world prices causes distortions. Switching of base crops can change results. In order to minimize errors, IIMI uses standardized world prices based on inflation adjusted averages between 1985 and 1995. It is recommended that a 10 year inflation adjusted local price be used so that performance will not vary greatly with adjustments of local prices. We are more concerned with the productivity of irrigation rather catching effects of local market prices. As an example, figure 9 gives the differences between the SGVP calculated with real prices and computed with average prices. The graphs clearly shows that although the general picture remains the same, seasonal and yearly fluctuations of SGVP tend to be less pronounced if average (or constant) prices are used.
In spite of these difficulties, SGVP is one means that appears sufficiently robust to use to compare between countries.

Given that there are large uncertainties, can the indicators be used to show differences in irrigation performance? Where the magnitude of difference is large, say greater than 50% difference, we are confident we are discerning differences. And there are many cases where the magnitude is quite large. If the difference noted is small, say less than 20%, then we cannot confidently say there is a difference in performance between systems. As further research, sensitivity to uncertainties in parameter estimation to results is required.

Interpretation of Results

With nine indicators per system, how do we interpret results? How do we say that system A is better than system B? The output indicators (indicators 1 through 4) represent the basic performance indicators. Where land is limiting relative to water, output per unit land may be more important. Where water is a limiting factor to production, output per unit water may be more important.

The water supply indicators (RWS, RIS, and WDC) are better suited to place the irrigation system in its physical and management context. Higher values of RWS, RIS, and WDC indicate a more generous supply of water. In this case productivity to land may be more important. Where the water supply indicators show a lower value indicates a situation of a more constrained water supply and values of productivity per unit of water is more important.

If performance in terms of output per unit land or water was high, what was the cost? The Gross Return on Investment indicator can give an idea of the costs involved to give such a return. With more data on external indicators we can ask such questions as in similar environments, can we achieve the same performance at cheaper costs? Or, what additional infrastructure costs are required to achieve better performance.

The external indicators can be used in irrigation management to assist in setting strategic objectives and measuring progress against those objectives. In this case, SGVP is not an appropriate term for output. Rather, gross or net returns from production should be used. The main purpose of SGVP is to allow comparison between systems.

Discussion

The indicators are able to discern large differences in performance relative to land, water, and production. The magnitude of these differences, in our view, justify the approach taken and the aggregate nature of the analysis made. We are confident that ratios of indicators of 2:1 and greater represents clear differences in levels of performance.

With a larger sample, it may be possible to relate performance to key features of irrigation systems: infrastructure (fixed, flexible), management (agency, joint, farmers), allocation and distribution procedures (demand versus supply), climate (wet, dry), and socio-economic setting. The performance study will allow comparison of how well one system is performing relative to others in similar settings. This is an important tool for policy makers who want to know how and how much to invest in irrigation. The comparative assessment will give gross indications of where improvements can be made - in types of management, infrastructure, or water allocation.

The external indicators should allow us to set up a screening process for selecting systems that perform relatively well, and those that do not. Based on the initial experience from the external indicators, we can probe further into determinants of system performance using more refined techniques.

These external indicators are not meant to replace day-to-day monitoring techniques that allow for performance based management. They are useful in answering the question “am I doing the right thing?”. They can be used to identify long-term trends in performance and to set and verify long-term strategic objectives.

The next steps is to proceed with gathering these indictors for a greater variety of irrigation systems. A typology will be developed for irrigation systems. The typology will allow comparison of irrigation systems with similar settings. Additionally, it will allow us to identify different aspects that lead to better performance. The comparative study will allow a screening of irrigation systems to highlight key issues relative to performance, and allow targeting of research to better understand key determinants of performance.

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Annex 1:
Data requirements to calculate performance indicators

Climate

- monthly precipitation (in mm)
- mean daily maximum and minimum temperatures, per month (in °C)
- mean monthly windspeed (in m/s)
- mean monthly relative humidity (in %)
- mean daily hours of sunshine, per month (in hours per day)

Crops

- total command area (ha)
- cropping pattern irrigated crops (planting dates, grow lenghth in days)
- area per crop, per season or per year (ha)
- yields, per season or per year (ton/ha)
- local prices, per season or per year (local currency per ton)
- world market prices for main crop (US dollar per ton)

Irrigation

- total amount of irrigation water derived, scheme level, per season or per year (m^3)
- total amount of irrigation applied at field level, per season or per year (m^3)
- actual capacity of main canal and secondary canals (m^3/s)

Financial

- expenditures for Operation, Maintenance and Administration i.e. all cost to run the system (in local currency, per year)
- total income from water fees, farmers' contributions, outstanding debt payments etc. excluding all governement subsidies (local currency, per year)
- investment cost of irrigation infrastructure (local currency per hectare)