PERFORMANCE INDICATORS FOR IRRIGATION CANAL SYSTEM MANAGERS OR WATER USERS ASSOCIATIONS

INDICATEURS DE PERFORMANCE À L'INTENTION DES ADMINISTRATEURS DE SYSTÈMES DE CANAUX D'IRRIGATION OU DES ASSOCIATIONS DE CONSOMMATEURS D'EAU

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ABSTRACT

Performance indicators are used for analyzing the performance of various aspects of irrigation systems. In this paper, indicators for existing canal systems are suggested for use by managers or the associated water users associations. These indicators can usually be applied within the limited time and financial resources available to the typical manager or association. The indicators are mostly oriented toward aspects that affect water deliveries, rather than indicators like crop yields that are also affected by other factors.

SOMMAIRE ET CONCLUSIONS

« Notre système d'irrigation est-il suffisamment bien géré ? » , c'est la question que devraient se poser l'administrateur du système, le personnel et les consommateurs. Cet article décrit des indicateurs de performance qui peuvent être appliqués dans le cadre des ressources limitées dont dispose l'administrateur ou l'association typique. Dans la plupart des cas, les indicateurs sont orientés vers les facteurs qui ont une influence directe ou indirecte sur la fourniture d'eau, plutôt que des indicateurs comme les rendements agricoles, qui sont d'ailleurs influencés par d'autres facteurs.

FOURNITURE D'EAU

L'indicateur de performance le plus simple en ce qui concerne la fourniture d'eau consiste à savoir si des volumes d'eau adéquats parviennent aux cultivateurs qui se trouvent à la fin du système de canaux. Le Rapport de fourniture en fin de système est le nombre de jours où des volumes d'eau suffisants sont parvenus jusqu'à la fin du système, divisé par le nombre total de jours. Ce test peut se faire sur la base d'observations régulières, enregistrées par le surveillant de fossés, pour déterminer si les cultivateurs en fin de système ont assez d'eau ou non, ou si l'eau déverse ou non au niveau du dernier déversoir du canal.

Un autre indicateur est le Uniformité de la zone: on divise la zone la moins desservie du système de canaux par la fourniture moyen en fonction de la profondeur d'eau (volume/zone irriguée) fournie. Un rapport de un serait donc parfait. Des valeurs inférieures à un indiquent une inégalité relative. Ce test exige que l'eau soit mesurée précisément au point de fourniture pour chaque zone, et est applicable sur différentes périodes ou pour toute la campagne d'irrigation.

Dans le cas de l’eau fournie sur requête, une analyse de l’opportunité est possible à partir des enregistrements de commandes d’eau. Le Rapport d’opportunité de fourniture est le nombre de commandes dans le cadre desquelles l’eau a été fournie dans les délais prévus et à la date demandée, divisé par le nombre global de demandes.

MAINTENANCE

La capacité des canaux peut signaler des problèmes causés par le dépôt de sédiments, l’érosion ou la présence de végétation. Le Rapport de capacité des canaux est la capacité effective du canal en question, divisée par sa capacité nominale.

Le Rapport de structures détériorées est le nombre de structures en mauvaise condition, divisé par le nombre global de structures. Le terme détérioré peut être défini comme présentant un risque de panne au cours de l’année suivante (ou étant déjà en panne). Un autre indicateur de maintenance structurel consiste à comparer le nombre effectif de structures rénovées ou remplacées au cours de l’année au nombre cible pour cette même année.

ASPECT FINANCIER

La Performance au niveau de la perception de droits est la somme des droits d’irrigation perçus, divisée par le total des droits estimés. On devrait également comparer les droits à ceux perçus par des systèmes semblables.

Le Rapport de budget de maintenance est la somme des dépenses annuelles divisée par les dépenses totales d’exploitation et de maintenance. Ce rapport est généralement trop bas. Un indicateur analogue est le Rapport de budget de personnel, lequel représente les dépenses annuelles pour le personnel divisées par les dépenses globales. Ce rapport est généralement trop élevé. Un indicateur correspondant est le Rapport de chiffres d’effectifs, représentant le nombre d’employés divisé par la superficie irriguée.

L’autosuffisance financière représente les revenus provenant des droits relatifs à l’eau (et d’autres revenus générés localement), divisés par les dépenses globales.

VIABILITÉ INDICATEURS

Viabilité de la zone irriguée: la zone actuellement irriguée, divisée par la zone irriguée initiale lorsque le système avait été complètement mis en exploitation pour la première fois. Une tendance vers une zone réduite indique généralement que le système n’est pas viable. Si la zone s’est considérablement agrandie par rapport à la zone en question, cela peut indiquer que l’eau est actuellement distribuée sur une trop grande superficie, ou que la capacité de fourniture d’eau est épuisée.

Profondeur relative de l’eau souterraine: la profondeur réelle de l’eau souterraine divisée par la profondeur minimale requise pour une bonne production végétale. Dans le cas où l’eau souterraine est une source appréciable de fourniture d’eau, son utilisation excessive indiquera également que le système n’est pas viable.

L'une des variables-clé qui influencent la viabilité économique d'un système est le Rapport Superficie/Infrastructure, que l'on peut définir comme la superficie irriguée divisée par la longueur totale des canaux et déchargeoirs. Les revenus provenant des terres irriguées doivent pouvoir supporter le coût de l'infrastructure.

COMMENTAIRES ADDITIONNELS

La qualité des données est cruciale. Il faut procéder à des vérifications ponctuelles des données. Les appareils de mesure de l'eau doivent être correctement calibrés et entretenus. En effet, les données peuvent être présentées avec parti pris par les personnes qui les fournissent, produisant ainsi des résultats trompeurs. Les erreurs peuvent être dissimulées. Il faut faire en sorte que le personnel accepte et supporte les analyses. Cela ne se produira pas si les employés se sentent menacés.

On peut se servir d'indicateurs pour comparer le système à d'autres systèmes. À l'intérieur d'un même système, ils peuvent être comparés d'année en année afin de signaler les performances relatives ou les tendances.

Deux autres techniques pour assurer l'évaluation de performance sont : (1) l'emploi occasionnel d'un évaluateur externe et (2) des sondages d'opinion auprès des irrigateurs.

INTRODUCTION

How well is our irrigation water delivery system being managed? This question should be asked by the system's manager, staff, and water users. This paper describes performance indicators which can be applied within the limited time, money, and information resources available to the typical manager or water users association. Indicators are oriented toward items that directly or indirectly affect water deliveries, rather than indicators like crop yields that are also affected by other factors. Indicators are also oriented toward the existing system, aspects which do not require major modification of the infrastructure.

WATER DELIVERIES

The simplest indicator of water delivery performance is whether adequate water is reaching the farmers at the end of the canal system. The Tail-end Supply Ratio is the number of days that sufficient water reached the end of the canal system, divided by the total number of days. Ideally, this ratio would be close to one. This test can be based on regular, recorded observations made by the ditch rider if farmers at the end are short of water or not, or if water is spilling or not at the final waste way on the canal. Ideally this waste way will have a water level recorder, so that continuous data is available. TSR is simple and inexpensive, but is only a qualitative indicator. It is based on the common situation that irrigators at the end of the canal are usually the ones shorted.

A more quantitative indicator is Area Uniformity: divide the worst supplied area on the canal system by the average supply, in terms of water depth (volume/irrigated area) supplied. Thus an AU of one is perfect. Values below one indicate the relative shortage suffered by the worst area. This test requires good water measurement at the supply point for each area, and the test can be applied over various time periods (such as a month) or for the whole irrigation season. It is not necessary that a certain number of areas be used, or that the areas are of similar size, but each area must have accurate water measurement.

Proper interpretation of AU requires consideration of known or possible contributions from other water sources within or to the area, such as inflows, return flows, or groundwater. Interpretation can be difficult if water deliveries are made by volume rather than area, or if different volumes are provided for different crops. AU indicates the fairness of distribution of the existing water supply, but does not indicate whether the existing supply is adequate.

Area Uniformity is defined above so that it is analogous to Distribution Uniformity, which is typically used for individual farm fields or for a particular irrigation method such as a sprinkler.

Although it is not necessary that the individual areas be of similar size, use of quartiles (dividing the total system into fourths) has standardization value, for comparing one irrigation delivery system to another. Distribution Uniformity is usually based on quartiles. Use of areas smaller than quartiles will decrease the AU value calculated, because the worst area will have a lower depth than the corresponding quartile's depth. Use of quartiles may not be possible on a particular system, however, because divisions must be based on the locations of good water measurement devices.

It would of course be better to compare delivered water depth for each individual delivery point on the system. However, this requires accurate water measurement at each delivery point, which is a rare condition and expensive to achieve. It also requires analysis of a large amount of data, though a representative sample could be taken.

If water is delivered on request, an analysis of timeliness may be possible from the individual water order records. The Delivery Timeliness Ratio is the number of orders where water was delivered within the target time of the requested date, divided by the total number of orders. Ideally, this ratio would equal one. Is there a difference in DTR between the upper part of the canal system and the lower end? If DTR is low, or lower than normal, why did this occur? Did demand exceed the canal capacities? Did demand exceed the available water supply? Or was the water supply itself mis-managed? Possible reasons for the latter could be poor reservoir management, or failure by the watermaster to anticipate demand. It could also be caused by poor maintenance or management of the diversion dam, pump stations, or canals.

MAINTENANCE

Canal capacity can indicate problems related to sediment deposits, erosion, vegetation, or possibly inadequate capacity of some structures. The Carrying Capacity Ratio is the actual capacity for the selected canal (or pipeline), divided by its designed capacity (Ijir and Burton, 1998). The ideal ratio would be one. In applying this indicator, flow should be measured at the designed water level or head. It is possible to operate a canal at a higher flow than its actual capacity, by operating the canal too full and reducing canal freeboard to an unsafe margin.

The Poor Structure Ratio is the number of structures in poor condition, divided by the total number of structures. Poor can be defined as Anot functioning adequately, or at risk of failing during the coming year@. Ideally, this ratio should be zero. Ijir and Burton used the Structure Condition Index, which is the number of structures working normally divided by the total number of structures. Bos (1997) used the same indicator but called it "Effectivity of Infrastructure". PSR and SCI are similar, but one emphasizes structures that aren't functioning adequately; the other emphasizes structures that are. For example, if 5% of the structures are in poor condition, SCI would be 95%, which sounds good but isn't.

Another structural maintenance test is to compare the actual number of structures rehabilitated or replaced during the year to the target number for that year. For this test, an appropriate target number must be determined for the system, based on age and condition of the system and probable life expectancies of the structures. This can be a useful tool for determining whether maintenance goals are being achieved, but it is not appropriate for comparisons between systems.

FINANCIAL

Fee Collection Performance is the annual irrigation fees collected, divided by the total annual fees assessed (Bos, 1997). This indicates the effectiveness of the collection program, but it can also be affected by the economic condition of the irrigators and the degree to which the irrigators feel the system is worth supporting. Ijir and Burton called this the Fees Recovery Ratio, but that is a less clear description. Values greater than 1 are possible if some delinquent assessments from previous years are collected.

Fees should also be compared to those charged by similar systems in the region, particularly with well-run systems. Fees can be too high (more than is justified by the benefits produced) or too low (less than needed for optimum long-term performance of the delivery system).

The Maintenance Budget Ratio is the annual maintenance expenditures, divided by the total operation and maintenance (O&M) expenditures (Ijir and Burton, 1998). This ratio typically is too low. Water delivery usually gets done because the irrigators scream when it doesn’t, but maintenance often gets delayed in the effort to “stay within this year’s budget”. Based on the author’s experience in the Great Plains region of the United States, at least as much should be spent on maintenance as on operations. But that generalization is certainly not true for new systems, which need relatively little maintenance, and may also not be true for other types of irrigation systems in other regions of the world. Allen and Brockway (1977) found that systems in Idaho in the United States spent 60-70% on maintenance. Care must be taken in applying this indicator, because some divide O&M costs into operation or maintenance, while others (such as Allen and Brockway) divide costs into administration, operation, or maintenance. Some administration costs can be specifically attributed to operation or maintenance, and the remainder should be equally divided between the two functions to avoid bias.

A similar indicator is the Personnel Cost Ratio, which is the annual expenditures on personnel divided by the total expenditures. This ratio often is too high. Staffing tends to grow beyond the optimum level, in comparison to amounts spent on other items. The author’s experience indicates that optimum values of PCR are in the range of 50-60%. A high number does not necessarily mean that the system is over-staffed; it sometimes means that not enough money is being spent on maintenance.

So the evaluation should also check the Manpower Numbers Ratio, which is the number of staff (full-time equivalent) divided by the total irrigated area (Ijir and Burton, 1998). Ijir and Burton used a target value of 6 per 1000 hectares, based on Nigerian conditions. In the United States, this author has found a range of 0.4 to 1.0 per 1000 hectares in the northern Great Plains (with a winter shut-down period), and 1.36 on a year-round system in Arizona with 24 hour a day ditch rider service. The optimum value for this indicator may vary widely among different regions of the world, because of differences in labor productivity and irrigation intensity.

Financial Self Sufficiency is the annual revenue from water user fees and other local income (not including subsidies), divided by total annual expenditures. For self-sufficiency, this indicator should be near one. Molden et al (1998) and Ijir and Burton (1998) used this indicator, but divided only by O&M expenditures, not total expenditures. Using only O&M expenditures ignores other costs related to self sufficiency, especially investment repayment costs. Water user fees frequently exceed O&M expenditures, which leads to FSS values greater than one and the unfortunate implication that the irrigators are being overcharged. Use of total costs rather than just O&M costs becomes increasingly important as use of pipelines and automation increases, because these components have high investment costs but relatively low O&M costs.

FSS is actually a measure of the present state of financial self sufficiency. A value less than one does not mean that the system cannot become self sufficient; the system may just be taking advantage of subsidy opportunities. FSS also does not indicate whether total expenditures are at the appropriate level.

SUSTAINABILITY INDICATORS

Sustainability of Irrigated Area is the current irrigated area, divided by the initial irrigated area when the system was first fully developed (Bos, 1997). A trend toward reduced area generally indicates that the system is not sustainable (for water supply, environmental, or economic reasons). If area has increased significantly from the designed area, it may indicate that the water supply is now distributed over too much land, or delivery capacities are being exceeded. The "current irrigated area" must be updated periodically to reflect the actual situation on the land. Bos used "irrigable" area instead of "irrigated" area, but irrigated area can be more precisely determined and can be easily updated from aerial photos. If irrigable land is not being irrigated, that can also indicate a problem, such as an undependable water supply.

Relative Groundwater Depth is the actual groundwater depth, divided by the Critical minimum depth needed for good crop production (Bos, 1997). This ratio should be greater than one, preferably at all locations and for the whole season. If the ratio is getting closer to one over time, it may indicate a need for improved drainage. Minimum depth should be based on the most sensitive crop grown in the area; one meter is a value frequently used. Where wells are used as a source of water, increasing depth to groundwater over time usually indicates groundwater over drafting.

A key variable affecting the economic sustainability of a system is the Area/Infrastructure Ratio, which can be roughly defined as the irrigated area divided by the total length of canals and laterals. The critical value for this variable is determined by the economics of the region. In the northern Great Plains of the USA, it is about 35 hectares per kilometer. The higher the number, the easier it is for the irrigated lands to support the cost of the infrastructure.

ADDITIONAL COMMENTS

Data quality is critical. Spot checks of data are needed. Water measurement devices must be properly calibrated and maintained. Data can be slanted by the people supplying it, to give misleading results. Mistakes may be covered up. There is a need to develop acceptance and support for the analysis within the staff. This will not happen if the staff feels threatened.

Indicators can be used to compare the system to other systems. Within the system, they can be compared from year to year to indicate relative performance or trends. Careful interpretation is necessary to determine causes of any problems detected. Performance statistics should be included in the annual report to the irrigators.

Burt and Styles (1999) has a list of qualitative ratings in its Attachment C, which may be of value to managers for analysis of some specific items. Qualitative ratings for frequency, flow rate, and duration for water deliveries are described in Burt, 1998.

Two other techniques to evaluate performance are (1) occasional use of an outside evaluator and (2) opinion surveys of the irrigators. Even the best systems can benefit from an outside evaluation, perhaps once every 5 to 10 years. Biswas (1990) has a good discussion on use of outside evaluators. Loof et al (2000) and Abernethy et al (2001) discuss use of opinion surveys. These two tools can be combined with performance indicators to achieve improvement in virtually any irrigation system.

CONCLUSIONS

Dozens of irrigation performance indicators have been proposed over the years. But they still receive relatively little use, and that use is mostly by researchers and agencies rather than managers. The irrigation community needs to select a core group of key indicators that are applied often enough to establish an appropriate range of values for interpretation. Molden et al (1998) developed a list of nine key comparative indicators, but this list intentionally excluded many of the internal process indicators that are of interest to system managers. For key delivery system indicators, the author suggests the following:

1. Area Uniformity (indicates the fairness of distribution of the existing water supply)
2. Carrying Capacity Ratio (indicates overall adequacy of the maintenance program)
3. Sustainability of Irrigated Area (integrates the impact of all factors affecting sustainability)

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TABLE: Performance Indicators for Irrigation Water Delivery Systems (Indicateurs De Performance pour Systèmes De Canaux D'irrigation)

Water Deliveries:

1. Tail-end Supply Ratio $TSR = N_S / N_T$

N_S is the number of days that sufficient water reached the end of the canal system
N_T is the total number of days the canal system was delivering water.

The ratio ideally should be close to one. Preferably it is based on daily ditch rider records of sufficiency, but a flow recorder can be used at the final waste way. With flow recorders, not spilling does not necessarily imply a shortage, but spilling indicates that sufficient water was reaching the end of the canal. In the USA, a typical value for water spilling at the terminal waste way might be around 70% of the time.

2. Area Uniformity $AU = D_W/D_{AVE}$

D_W is the water depth (volume/irrigated area) for the worst supplied area in the system.
D_{AVE} is the average water depth supplied to the whole system during the same time period.

A ratio of one is perfect. Values below one indicate the relative inequity. The ratio is calculated from the total water delivered to major sections of the system and the irrigated area of those sections. It is a rough indicator of fairness of water deliveries on systems which do not measure water at each turnout. Soils differences return flows, and use of groundwater can affect values calculated for different areas.

Values found by author in USA: 0.70, 0.72, 0.76
India: values from roughly 0.50 to 0.90 (From data in Santhi and Pundarikanthan, 1999)

3. Delivery Timeliness Ratio $DTR = N_t/N_T$

N_t is the number of orders where water was delivered within the target time.
N_T is the total number of orders (from the individual water order records).

The ratio should be close to one.

Number found by author in USA: 78% (within 2 days), in a water-short year.

In a district in southwest USA, 72% of deliveries occurred within 1 day and 90% were within 2 days. (Palmer et al, 1991)

A survey of 58 irrigation districts in California USA, indicated that deliveries were nearly always made on the date requested, with an average failure rate of only 0.59 a year per turnout (Burt et al, 2000)

Maintenance:

4. Carrying Capacity Ratio $CCR = C_A/C_D$

C_A is actual canal capacity for the selected canal (measured at designed head)

C_D is the designed canal capacity for the selected canal.

The ratio should be close to one. Ijir and Burton (1998) found 70% on a main canal in Nigeria. The author has found flow ratios from about 0.60 to 1.36 (using typical peak flows during the last few years, and not necessarily at the designed head). Canal flows higher than the designed capacity are also undesirable because of the risk of canal failure.

5. Poor Structure Ratio $PSR = N_P/N_T$

N_P is the number of structures in poor condition (not functioning adequately or at risk of failure)

N_T is the total number of structures on the system.

Ideally this ratio should equal zero. The author has found a range of <1% to 20% in the USA. Information in Ijir and Burton (1998) indicated 89% for a scheme in Nigeria, but the definition was not exactly comparable.

Financial:

6. Fee Collection Performance $FCP = F_C/F_A$

F_C is the annual amount of water charges collected.

F_A is the annual amount of water charges assessed.

The ratio should be close to one. The author has found values from 62% to near 100%. Ijir and Burton (1998) found 80% for a scheme in Nigeria. A low value can indicate financial problems of the irrigators, lack of support from the irrigators, or a poor collection program.

7. Maintenance Budget Ratio $MBR = E_M/E_{O\&M}$

E_M is the average annual expenditures for maintenance.

$E_{O\&M}$ is average annual expenditures for both operations and maintenance.

This ratio is used to detect whether maintenance is being neglected. The optimum value may vary from region to region, but in the USA it appears to be about 50% for mature systems (older than about 30 years) with very few pipelines. Ijir and Burton (1998) found 16% for a scheme in Nigeria.

8. Personnel Cost Ratio $PCR = E_P/E_T$

E_P is annual expenditures on personnel (wages, fringe benefits, training, etc.).

E_T is total annual expenditures.

This ratio is used to monitor expenditures on personnel, which tend to become too high relative to other costs. The optimum may be between 50% and 60%.

9. Manpower Numbers Ratio $MNR = N_S/A_T$

N_S is number of staff (full-time equivalent)

A_T is total irrigated area

This ratio will likely vary widely between regions, due to such things as labor productivity and intensity of irrigation. In the USA, the author has found a range from 0.4 to 1.0 per thousand hectares on systems which shut down for the winter, and 1.36 on a year-round system with 24 hour a day ditchrider service. Ijir and Burton (1998) found 20 per thousand for a scheme in Nigeria.

10. Financial Self Sufficiency $FSS = I_F/E_T$

I_F is income from water user fees and other local income (not including subsidies).

E_T is total annual expenditures.

For financial self sufficiency, this should be near one. In the USA, most systems are in the 90% to 100% range, but construction cost repayment is often significantly subsidized and thus not truly reflected in the total annual expenditures. Molden et al (1998) reported values for 16 systems ranging from 28% to 139%, but these numbers were based on O&M expenditures, not total expenditures, which often leads to values higher than 100%. Kloezen and Garces-Restrepo (1998) reported values ranging from 78% to 108% on a system in Mexico, but again it was based only on O&M expenditures, not total expenditures.

Sustainability:

11. Sustainability of Irrigated Area $SIA = A_C/A_I$

A_C is current total irrigated area.

A_I is total irrigated area when system development was completed.

This should be near one. The ratio integrates the effect of many variables which affect sustainability. The author has found values from about 50% to over 100%. If it is significantly less than at completion, why has it decreased? If it is significantly higher, are design capacities being exceeded?

12. Relative Groundwater Depth $RGD = D_A/D_m$

D_A is actual depth to the water table.

D_m is the minimum intended depth to the water table, based on most sensitive crop.

This indicator should be greater than one. If not, it is likely that drainage improvements are needed, or over-irrigation (applying too much water) needs to be reduced. Real-world values from 0 to >100 can occur.

13. Area/Infrastructure Ratio $AIR = A_T/L_C$

A_T is the total irrigated area.

L_C is the total length of canals and laterals on the system.

This indicates how much irrigated land is available to support the cost of the infrastructure. The ratio will likely vary widely from region to region, because of varying profitability of crops grown and intensity of irrigation practiced. In the northern USA, roughly 35 hectares or more per kilometer is required to support the cost of the system.