

ASSESSMENT OF IRRIGATION PERFORMANCE AT REGIONAL AND PROPERTY SCALE

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Abstract

A method is described by which irrigation performance on a whole farm scale can be assessed from readily available data, using an annual water balance approach. The method is demonstrated using data from horticultural properties in the South Australian Riverland and the New South Wales and Victorian Sunraysia regions. The data used in this method is readily available, and includes crop survey data, annual pan evaporation and rainfall data, and water meter readings collected by water authorities.

A method was selected which allowed the comparison of total water volumes (irrigation plus rainfall) applied to properties with the annual crop water requirements of plantings on those properties. Annual Water Balance Efficiency (AWBE) is a direct measure of the estimated annual water requirement of the crops present on a property as a proportion of the total annual volume of water applied to that property as rainfall and irrigation. This figure can be used as a measure of an irrigator or region's performance. Annual Water Balance (AWB) accounts for all water moving to and from the property, and estimates the extent to which the water applied was in excess or deficit to requirements.

Excess application is an estimate of drainage past the rootzone, and can be summed to give an estimate of average drainage depth and total drainage volume produced within a region. Deficit indicates crops being placed under some level of stress.

Storage of data in a GIS platform facilitates the visual comparison of performance between irrigators on the basis of irrigation system type, predominant crop type, water source, water supplier, region, state or any other parameter. Perhaps more importantly, however, is the ability to monitor changes in performance over time, by comparing AWBE and AWB in the same groupings in different years. This will highlight changes that may occur as a result of continuous improvement in irrigation performance through benchmarking and training activities within regions, for example.

Data is presented to illustrate possible applications of the methodology. Comparison is made between private diverters and irrigators whose water is delivered by a water supply authority. In addition, a comparison is made between irrigators in the Riverland of South Australia, and the Sunraysia region within Victoria and New South Wales.

Introduction

Efficient irrigation is a very pertinent topic at present, and there is much effort going into improving the performance of irrigation across Australia, as well as elsewhere in the world. Within the Murray Darling Basin there are many areas being impacted by rising water tables, many of which are saline. In addition, water diversion for irrigation within the Basin has been capped, and the efficient use of these resources is vital to the very survival of the irrigation industry within the Basin.

It is desirable to focus education and training for improved irrigation performance into those areas where there are the greatest problems, and thus the greatest gains can be anticipated. In addition, many of the bodies funding such education and training programs require demonstration of the effectiveness of the program, in the form of some assessment of performance before and after education programs.

The figure of 85% efficiency has been proposed as a target for on-block irrigation efficiency (The River Murray Water Resources Committee, 1995). The underlying assumption behind this figure is that drainage beyond the rootzone of up to 15% of applied water is acceptable. Methods are available to assess on-farm irrigation performance at the scale of irrigation units (Skewes, 1998), but quite detailed information is required, which must be collected manually, limiting the number of assessments that can practically be carried out.

The aims of this project were to:

- Establish a geographically referenced database of individual growers, districts and regions that describes crop mix, crop water use, and water consumption by irrigators.
- Develop a consistent GIS based approach to irrigation data collection and analysis in the Mallee Irrigation Zone.
- Use the geographic database information to support community and agency based groups to identify inefficient water use and encourage improved water use efficiency.
- Monitor change in irrigation performance.

Data

Certain information is collected as a matter of course by many irrigation water supply utilities, in particular water meter readings, for the purpose of monitoring supply and diversions. In the Riverland almost all individual properties have a water meter, and in Sunraysia many supply utilities now use water meters. Water meter readings are collected at least annually, and thus information on the annual volume of irrigation water diverted for each irrigation licence across whole irrigation districts is routinely collected. Much of this data is currently stored electronically, making retrieval and manipulation of the data potentially quite simple, although this is not always the case.

Irrigation allocations, and associated water meters, are usually associated with specific parcels of land. Some irrigation districts already collect annual crop survey data from their customers. In other cases, data on crops has been collected as part of wider projects to establish GIS databases for other purposes. It is relatively simple in most cases to match property boundaries with crop data, and to delineate crop types and, in most cases, crop ages present on individual parcels of land.

Crop factors for each month of the year for each crop type present in the study area were sourced from Primary Industries and Resources SA. Using representative sites for which good rainfall and evaporation data was available, these crop factors were used to estimate the annual water requirements of the crops present on each property. Young plantings were assessed as a proportion of mature crop water use, according to age. The estimated water requirement and water application data for each property was then compared by two methods, to assess the irrigation performance of that property.

A database was set up to compare the effects of factors such as geographical location, irrigation system type, predominant crop type, and irrigation water supply method on property and regional scale irrigation performance. SunRISE21 and the Information and Data Analysis Branch, Planning SA gave valuable assistance in linking this database with existing GIS platforms, and providing some of the data.

One shortcoming of the data collected by the above methods was the different standards of data available. For example, data on crops and areas planted was only available from growers surveys for some areas, and some of this data was of extremely questionable accuracy. For other areas, however, very accurate crop data had been collected for other purposes, and was made available to this project. Differences in accuracy of data certainly complicates the comparison of performance between areas.

Irrigation Performance Assessment

Irrigation efficiency is the term that is used most often when talking about irrigation performance. This term, however, has a specific definition (Anonymous, 1998), and the accurate calculation of irrigation efficiency requires very detailed information, information well beyond the scope of the information used here. Therefore, other terms were developed to express irrigation performance at a whole farm scale.

Two terms were developed, with associated definitions. One is a measure of the efficiency with which the annual water requirements of the crops are met by the annual volume of water applied (irrigation plus rainfall), and is expressed as a percentage. The other is an annual water balance equation which expresses the applied water excess (drainage) or deficit (under-watering) as a volume and a depth (Meissner et al., 1995).

Assumptions

The following calculations are based on a number of assumptions.

Firstly, because only annual figures of water use are available, it is not possible to assess how well irrigation and rainfall have met water requirements during any particular portion of the season. In reality there is often much variation in adequacy of water application, with crops experiencing periods of both excess and deficit water supply, this method cannot capture that variation.

As a result, the figures calculated by the formulae below assume that irrigation scheduling was practiced by the grower, and that the grower's approach to irrigation management over the season was consistent.

It is also assumed that the crops on the property are healthy and representative of their age in terms of water use. This also will obviously not always be the case, and less healthy crops will require less water.

Annual Water Balance Efficiency

Annual Water Balance Efficiency (AWBE) = $(CWR + Evap) / (Irr + Rain)$

where:

CWR = Volume of crop water requirement for the growing season, summed for all planting units of all crop types on the property over their growing seasons.

Evap = Volume of evaporation from bare soil and evapotranspiration of cover crops during the non growing season for planted

areas with limited growing seasons.

Irr = Volume of irrigation applied for the year (July to June).

Rain = Volume of total rainfall for the year (July to June).

The left hand half of the equation incorporates the estimated water extractions from the site, assuming full availability of water for evapotranspiration and soil surface evaporation. The right hand side of the equation calculates the total water applied to the site, by both irrigation and rainfall (total). Total rainfall is used in order that all water applied to and extracted from the site is accounted for.

The resultant figure is a measure of the efficiency with which the volume of water applied from all sources over the year has matched the total water requirement. A low efficiency figure indicates that the volume of water applied was well in excess of requirements, whilst an efficiency near 100% indicates good matching of gross volume applied with the gross requirements. Efficiency over 100% is possible, and indicates that the volume applied was less than the calculated requirement, but this situation raises concerns regarding adequate leaching of salt from the rootzone.

In reference to the figure of 85% efficiency proposed by RMWRC (The River Murray Water Resources Committee, 1995), their figure is based only on the irrigation water applied to the crop, such that drainage was restricted to 15% of irrigation. The annual water balance methodology incorporates all water applications, both rainfall and irrigation, and gives a much better picture of the true extent of drainage.

Annual Water Balance

Annual Water Balance (AWB) = **Irr + Rain - (CWR + Evap)**

This equation uses the same terms as the first equation, except that it calculates the actual size of the difference, be it positive or negative. Whilst Annual Water Balance is calculated on the basis of volumes of water required and applied over the whole farm, the final figure can be expressed as an average depth in millimetres over the planted area, to allow direct comparison between properties of different sizes.

A positive water balance indicates the application of excess irrigation and rainfall over and above the annual crop and evaporative requirements of the property, and is an estimate of the amount of drainage past the rootzone on the property. Actual drainage is likely to be greater than the figure calculated here, due to inconsistencies in irrigation across the season, as discussed under Assumptions.

A negative water balance indicates overall under-irrigation, but by the reason above could still hide the production of drainage at certain times during the year.

Limitations of the Method

The prime limitation of this method has already been discussed, the problem of knowing how water was applied, and when over the year, information that is not available from an annual water meter reading. In reality, more drainage is likely to be produced than will be estimated by this method.

Having said this, the method still has value as a means of analysing gross annual performance, and highlighting those sites or districts where clearly excessive volumes of water have been applied, and for comparing different years to evaluate long term trends in water applications. As annual application approaches annual requirement, however, this method becomes less able to distinguish good irrigation management from poor irrigation management.

The other major limitation to the method has to do with the reliability of data. Because of the large volumes of data being collected, it is very costly to check the data for each property to identify data problems. As a result, incorrect water meter readings or inaccurate crop areas can dramatically affect the calculations.

Water meter problems are common, unfortunately, and little can be done about them. On the other hand, some crop area data is collected with the use of aerial photographs to identify patches of different crop types, and the area is then estimated directly from the aerial photograph. Most of the rest of the crop area data is from grower surveys, with no quality control whatsoever, such that, while some of this may be very accurate, some of it could also be extremely inaccurate.

It is very time consuming and expensive to collect data by the aerial photograph method, especially when, ideally, data should be collected every year to ensure that changes to plantings are incorporated. What is required is a standard protocol for the collection and storage of such data, to ensure a minimum standard of reliability.

Comparisons across the Riverland and Sunraysia

Data was collected from irrigation areas in the Riverland region of South Australia, and the neighbouring Sunraysia region along the border of Victoria and New South Wales. A range of comparisons are presented to illustrate the possibilities of this methodology.

Predominant Crop Type

Figure 1 presents Annual Water Balance Efficiency for properties which contain predominantly (>80%) one crop, either citrus, pasture, stonefruit/nuts, vegetables or vines.

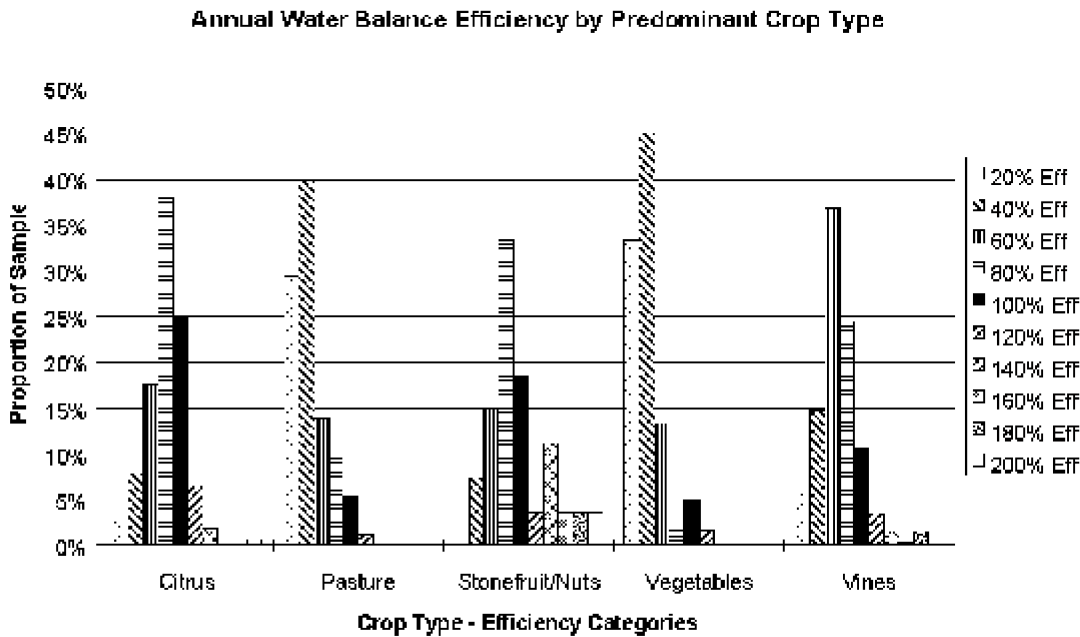


Figure 1: Annual Water Balance Efficiency by Predominant Crop Type

Whilst the crop water requirements of these crops are all different, a good irrigation manager should match that requirement fairly closely. The figures show that citrus growers and stonefruit/nut growers had the highest proportion of properties in the 80% efficiency category and above, whilst vegetable and pasture growers have a far larger proportion of properties in the low efficiency categories.

Predominant Irrigation System Type

Figure 2 presents Annual Water Balance Efficiency for properties with predominantly (>80%) one type of irrigation system, either centre pivot, drip, flood, furrow, low level or overhead sprinkler.

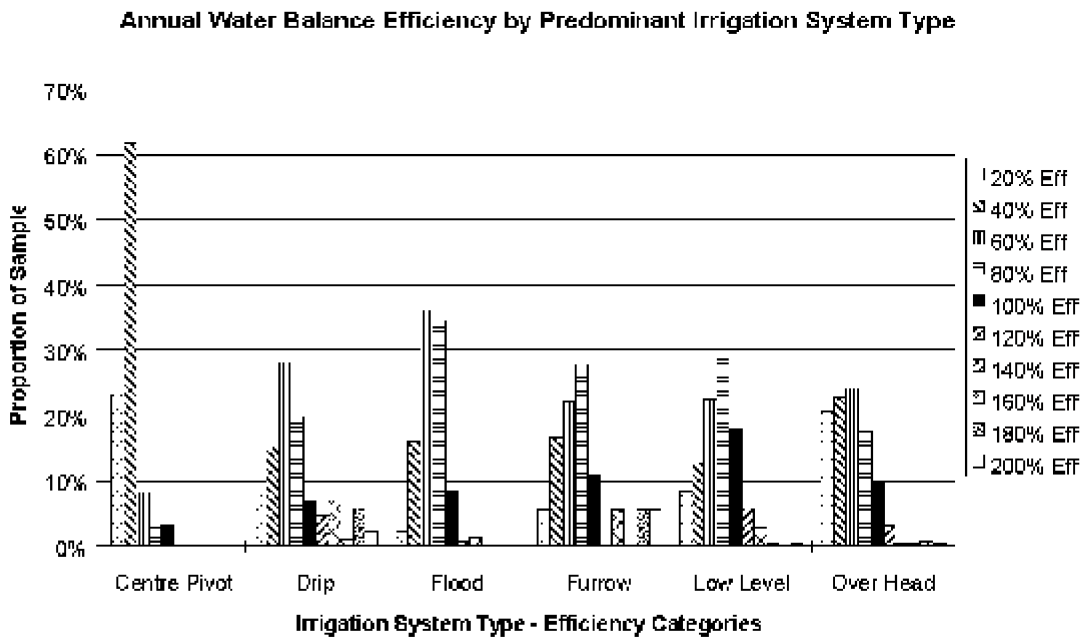


Figure 2: Annual Water Balance Efficiency by Irrigation System Type

Perhaps surprisingly, the lowest overall efficiency was found amongst Centre Pivots, indicating that the management of these systems is leading to larger volumes of water being applied than is required. Drip and Furrow both show significant areas of

very high efficiency (greater than 100%). Significantly, however, drip also shows over 50% of properties with efficiencies less than 80%, indicating that reputedly efficient irrigation systems (ie. drip irrigation) can be managed in an inefficient manner.

Private Diverters vs Irrigation Districts

Figure 3 presents data for private water diverters and irrigators in irrigation supply districts. The distinction can sometimes be blurred, but in general, private diverters pump water direct from the river or a backwater, whilst irrigators in irrigation supply districts have water supplied to their property boundary by the irrigation supply authority. There is generally a charge for the delivery of water, but pumping costs are often very low, and in some cases entirely absent.

On the other hand, private diverters generally have complete control over when they can irrigate, and are limited only by the ability of their pumping and distribution system to deliver sufficient water when it is required. Irrigators within supply districts face various degrees of restriction on when they can obtain irrigation water, according to the capabilities of the supply infrastructure, and the irrigation rostering protocol in use by the authority. Rehabilitation (pipelining and metering) of many supply infrastructure systems in recent years has enabled the introduction of water-on-order procedures, which has greatly improved the level of direct control each irrigator has over when they can irrigate.

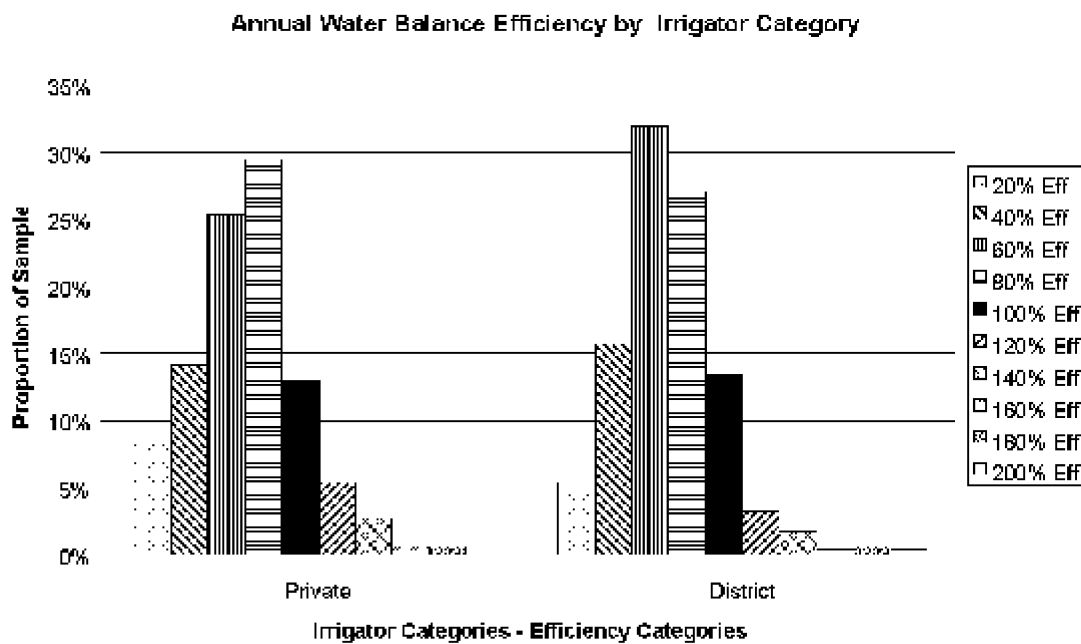


Figure 3: Annual Water Balance Efficiency by Irrigator Category

The graph indicates that there is very little difference in water balance efficiency between private diverters and irrigators in irrigation supply districts. This suggests that the level of flexibility available within an irrigation supply district is now comparable with that of private diverters, and opportunities for improvement of efficiency are similar in both groups. Alternatively, it could be that flexibility of supply is not a major factor in determining efficiency.

State

Figure 4 presents Annual Water Balance Efficiency for all properties on the database, split into the three states which contain the Riverland and Sunraysia regions.

Annual Water Balance Efficiency by State

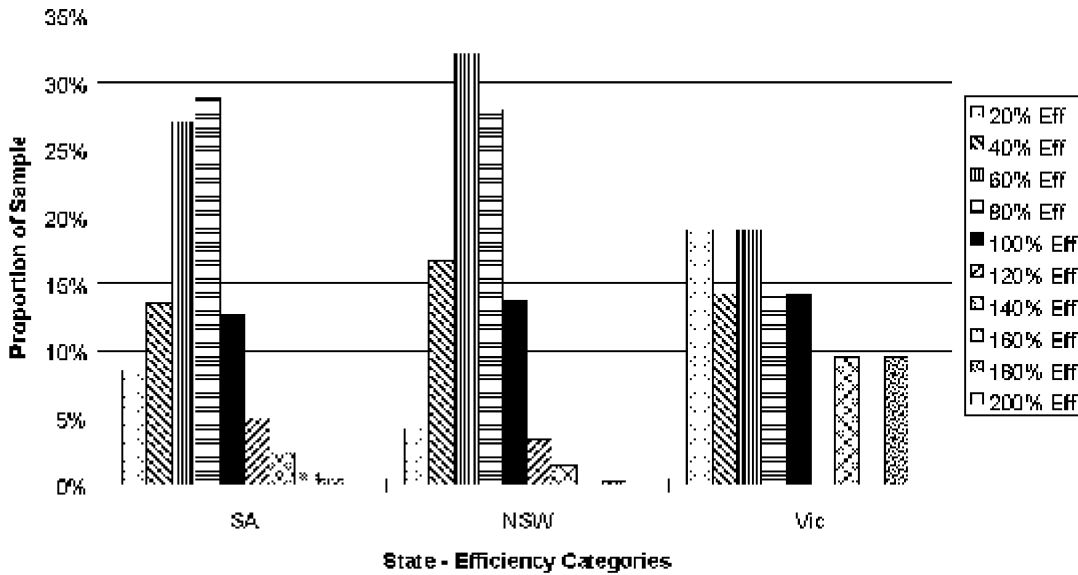


Figure 4: Annual Water Balance Efficiency by State

There is little difference between SA and NSW. For Victoria, the small number of properties in the sample (21) has produced a rather even distribution by chance. By logic, there are very few factors which would be likely to produce a difference in irrigation efficiency between irrigators in the three states, and it is therefore not surprising that there are few differences.

Land and Water Management Plan Areas

Figure 6 presents summed Annual Water Balance for each of these regions. Some of the regions are not represented in the sample, and others are represented by only a few sites. The Victorian and New South Wales data is presented by Irrigation Area rather than Salt Action Plan or Water Management Area. FMIT is within the Sunraysia Salt Action Plan Area, and the NSW Irrigation Areas are all within the Lower Murray Irrigation Areas Land and Water Management Plan Area.

Summed Annual Water Balance was calculated for each region by summing the volumes of drainage calculated for individual properties, and dividing the total drainage by the total area of all irrigated properties within the sample for that region. The same process was followed for deficit, to calculate total deficit. The resultant figures are the average depth of drainage and deficit over the whole region. Both drainage and deficit are presented for each region, because one does not cancel out the other.

Figure 5 illustrates how information can be extracted for any designated area, and information such as presented here will be invaluable in the development and review of Land and Water Management Plans and similar programs, and for the purpose of reporting to Catchment Management Boards.

Summed Annual Water Balance by Region

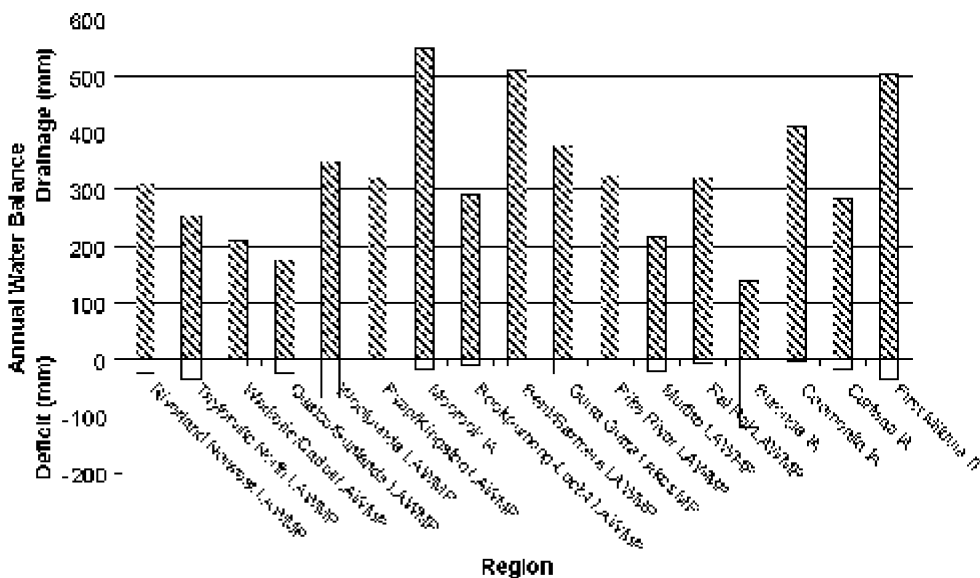


Figure 5: Summed Annual Water Balance by Region

Changes Over Time

Most exciting, however, is the potential to track changes over time. As an illustration, figure 6 presents data for two separate years for 16 private diverters in South Australia (the only sites for which two years of data are currently available).

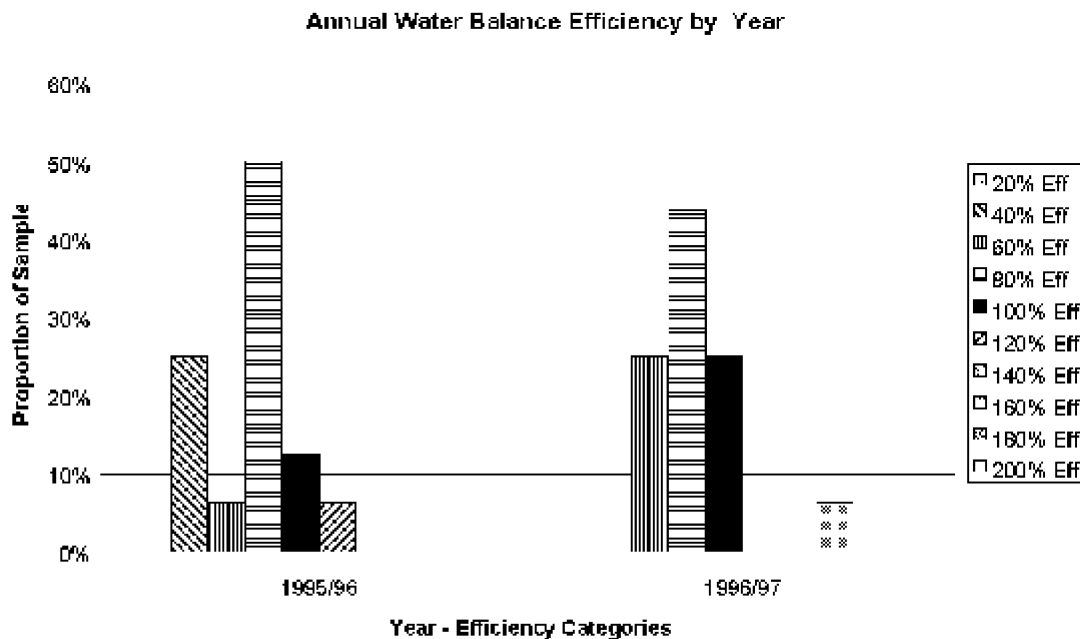


Figure 6: Annual Water Balance Efficiency by Year

The graph illustrates how changes over time can be evaluated, giving feed back on the effectiveness of education programs, or the impact of events such as rehabilitation of supply systems. It can be seen from the graph that there has been a general improvement in efficiency over the period evaluated, but it is not possible to determine whether the improvement seen is part of a long term trend, or is perhaps merely an artefact of weather conditions in the two seasons represented.

Long term monitoring is required to assess long term trends, and this methodology is an ideal way to conduct such long term monitoring. It is important that the methodology used to collect data and evaluate performance remains the same over time, otherwise long term comparisons will not be valid.

Conclusion

The figures above illustrate only some of the possibilities of this methodology. Linking with a GIS platform would allow presentation of mapped information, which would facilitate the identification of geographical areas of particular concern or interest.

Overcoming some of the data problems, particularly with the crop survey data, will assist in building up a valuable resource, which will enable ongoing monitoring of changes in irrigation efficiency.

The methodology described here can be applied to any region, and any range of crops, as long as the relevant data is available. In a climate of active concern about the impacts of irrigation on the environment, and the need to improve efficiency to sustain both the river and the irrigation industry, the potential value to resource managers, policy makers, irrigators, as well as LAP and other community groups is immeasurable.

References

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