WATER USE EFFICIENCY

Why water use efficiency matters

Improving water use efficiency has been a driving force for government and commercial endeavours for several decades but the term can mean different things to different people. For example, to governments water use efficiency may be a key to optimising production from water resources, while for irrigators it may contribute to optimal profit for their business.

There may also be confusion about what is being measured and differing perceptions of the implications of measured changes in water use efficiency.

To address that confusion the National Program for Sustainable Irrigation has promoted uniform terminology and definitions. They are detailed in its Irrigation Insights Number 5 'Water Use Efficiency' and summarised here.

Having a common language allows easier communication and a more informed discussion of some important concepts.

The emphasis in this document is on water use efficiency and the productive use of water in an agricultural context. Other uses (e.g. the maintenance of wetlands) are important, but are better assessed by other indicators.

Measuring efficiency

Even when terminology and definitions of water use efficiency are agreed, there can be misunderstandings arising from other factors.

Perceptions of efficiency and saving

'Efficiency' can mean using less water to grow a crop or pasture for optimal yield so that surplus water is available for other uses, i.e. 'saving water'. Alternatively, it can mean increasing the amount of crop or pasture produced from the same volume of water, i.e. more output from the same amount of water; but no actual 'saving' of water.

Scale matters

The scale of assessment can influence the measurement of efficiency. Inefficiencies at one scale may disappear when a larger area is considered. For example, 'inefficient' use of water in the upper reaches of a catchment may mean that more water drains back into the river. If it is of acceptable quality, this water can be used for environmental benefits or by downstream irrigators. Its use downstream for irrigation would improve the apparent efficiency of the system overall.

In that scenario downstream irrigators, urban centres and the environment could 'lose' water on which they rely if up-stream water use efficiency was improved and all gains were channeled into increased production.

TERMINOLOGY

Water use efficiency (WUE) is a generic label for any performance indicators used to study water use for crop production.

The indicators may be either:

- efficiencies – derived by dividing figures in the same units, e.g. the volume of water used (output in ML) divided by the volume of water supplied (input in ML); or
- indices – where inputs and outputs are measured in different units, e.g. crop production (output in tonnes) divided by the volume of water supplied (input in ML).

Whichever is used, it is important that it is comprehensively defined and specifies the area and the period of time over which inputs and outputs are measured, e.g. ML/ha/year.

NATIONAL PROGRAM FOR
Sustainable Irrigation

Published by: National Program for Sustainable Irrigation

Contact: Guy Roth, guyroth@roth.net.au

Title: Water Use Efficiency

Product code: NPSI-4-09

ISBN: 1 921025 22 0

December 2009

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About this NPSI Knowledge Harvest document

The NPSI Knowledge Harvest brings together information from across the National Program for Sustainable Irrigation (NPSI) projects, highlighting key findings and promoting wider understanding.

Key themes within the Harvest are:

- Irrigation Overview – facts, figures and key concepts about irrigation.
- Water Delivery Systems – the efficient storage and distribution of water for irrigation.
- On-farm Irrigation Essentials – principles for efficient irrigation.
- Recycled Water – recycling treated effluent and stormwater for irrigation.

This document is part of the Irrigation Overview theme. It explores issues likely to affect the future of irrigation in northern and southern Australia, especially those related to ecology and natural environments, and provides tools for planners to address them.

Other documents in the series may be downloaded from www.npsi.gov.au

WATER BALANCE

A water balance measures the volume of water moving into a defined boundary (such as a dam or river), changes within that boundary (e.g. evaporation and seepage) and the volume leaving the boundary (e.g. extraction or flow), in a specified period.

A water balance is necessary before calculating where efficiencies may be improved. The accurate measurement of as many variables as possible will give decision-makers more confidence before committing to a course of action.

Timing counts

The period of time over which measurements are taken can affect the calculated efficiency.

If a property is 'inefficient' in water use in individual irrigation events but captures all the run-off and later re-uses it, its long-term efficiency will be much higher.

Similarly, if a second crop (e.g. wheat) uses water stored in the soil from a preceding irrigated crop (e.g. rice), the total efficiency for the paddock will be higher than that of the original crop alone. The efficiency of a 12-month period will be higher than that of individual irrigations or seasons.

Assessments over different time periods (e.g. a year, a growing season and a single irrigation event) and between years of differing rainfall, will provide different insights about water use efficiency. Assessments over several years will provide useful information for irrigators.

Rainfall matters

Parts of Australia receive significant amounts of rain during the irrigation season, which affects the amount of irrigation water required. When making water use comparisons it is important to be clear on whether rainfall has been included in the calculations.

Storage, delivery and application

To understand efficiencies and where they can be achieved, it is important to consider the whole irrigation system as well as its individual parts:

- water storages;
- water distribution systems;
- field applications and crop agronomy; and
- the system overall.

Storage efficiency

Dams and reservoirs lose water through:

- evaporation, influenced by climate (sunlight, temperature, wind and humidity), storage design (e.g. surface area relative to total volume) and management (e.g. if it is kept full over summer); and
- seepage, influenced by linings, soil type, geology, depth of stored water, depth to groundwater and storage management (e.g. wetting and drying cycles).

A storage water budget requires information on:

- inflows (from streams and rainfall);
- losses (from evaporation, seepage and overflow); and
- outflows (as regulated releases or extractions).

To measure the efficiency of a storage over a season or year (storage efficiency) the amount of water released is divided by the amount of water entering the storage.

Measure	Input / Output
Storage Efficiency	Water released / Water entering

The management of storages, distribution systems and on-farm irrigation are all linked and there may be efficiency trade-offs between the components: savings in one area may affect efficiency in another.

How water is held and released and how it is accounted for in storages (e.g. continual accounting versus 'use it or lose it') can influence the decisions of irrigators.

Distribution (conveyance) efficiency

Water may be 'lost' on the way to the farm (a 'conveyance loss') or during distribution on the farm (including any temporary storage in on-farm dams).

Distribution systems (pipes and channels) lose water through:

- leakage and seepage;
- evapotranspiration (evaporation from water and soil and the transpiration of water by plants, including weeds); and
- operational losses (e.g. surplus delivered water that cannot be used).

Contamination (e.g. by salt, chemicals or nutrients) can also make water unsuitable for use.

It is often difficult to account for all these factors. For example, the volume of water initially entering the system may not be known accurately, let alone the volume of drainage waters re-entering the system. There may also be significant variability within a system and some factors will have to be calculated (based on informed assumptions) rather than measured.

'Conveyance efficiency' measures how efficiently water is delivered to farms. It is calculated by dividing the amount of water delivered to farms by the amount of water originally released into the supply system. Factors such as the adequacy of the water supply, its reliability and the consistency of supply are also of importance to end-users when considering the performance of a water delivery system.

Measure	Input / Output
Conveyance Efficiency	Water supplied to farms / Water released to the supply system

Moving large volumes of water and meeting the differing supply needs of numerous end users is inherently difficult and requires skilled management. System performance is a factor of system design and management. A simple, low-tech system with sound management can be more efficient and effective than a high-tech system with inadequate management.

Leaching fraction

Every time irrigation water is applied, so is salt. Repeated irrigation may cause salt to build up in the soil profile. If that occurs, a 'leaching fraction' – water applied to wash the salt through the profile and beyond the reach of the crop roots – will be required to maintain healthy soil and plant vigour.

The need for a leaching fraction depends on the salinity of the irrigation water and the amount of water moving beyond the root-zone from irrigation (the efficiency of the irrigation) and/or rainfall. The need to leach salt out of the crop root zone is one of the factors that can reduce water use efficiency.

For more information on monitoring and managing salinity, see other Knowledge Harvest papers regarding On-Farm Irrigation Essentials.

Improving crop WUE

Generally, to improve crop water use efficiency requires:

- optimising the amount of applied water taken up and used (transpired) by the crop; and
- minimising the losses as water moves to the plants.

However, sometimes it is desirable to limit the amount of water a plant transpires, e.g. to improve fruit quality or stimulate yield ('regulated deficit irrigation'). For more information see other Irrigation strategies in the report Irrigation Essentials.

On-farm – field efficiency

Water is lost when it is applied to paddocks as a result of:

- evaporation;
- surface runoff that isn't recycled;
- deep drainage beyond the root zone; or
- 'off-target' application, e.g. sprinklers affected by wind drift.

Uniform distribution of irrigation water in a field helps improve water use efficiency.

The biggest challenge in determining efficiency is measuring all the components for a water balance:

- Deep drainage is particularly difficult to measure and is usually estimated by calculating what is left over after all the other water uses and losses have been estimated.
- Evaporation and crop transpiration are usually calculated from other information, not measured.
- Soil water (moisture) levels, before and after irrigation, are also often estimated.
- Accounting for rainfall should focus on 'effective rainfall' – the amount that is ultimately available for use by a crop. This may be rainfall during just the growing season, or a variation of it such as rainfall from events above a certain volume (i.e. excluding light showers) or excluding storm run-off.

Efficiency trade-offs

It can be difficult, though not impossible, to maximise different efficiency measures at the same time. Trade-offs may have to be made. It is therefore useful to employ several different indicators in order to gain a true appreciation of overall 'efficiency'.

For example, although some advanced 'regulated deficit irrigation' techniques deliberately under-water plants, in most circumstances under-watering will result in lower yields. Usually with under-watering, water use efficiency (as measured by Water Input Efficiency – water consumed / water applied), would be high, but the Water Use Index (kg produced/ML applied) may be low. There may also be environmental consequences to consider, such as increasing salinity because salt is not being leached from the root zone.

To prepare a water balance for a paddock requires measures or estimates of:

- water stored in the soil before irrigation begins and at the end of the water-use period;
- irrigation water applied and the area it was applied to;
- rainfall during the water-use period;
- water transpired by the crop or pasture;
- water that left the area as run-off; and
- water lost in deep drainage, below the rootzone.

Irrigation is not only about achieving maximum plant growth. It may also be managed to control crop quality, plant physiology or health, or soil parameters that create good conditions for root growth. For example, irrigation water may be applied to cool a crop and avoid heat stress – or to ward off frost damage. It may be used to prepare soil for tillage or prevent wind erosion. When assessing irrigation efficiency, it is important to define why the water is being applied.

Indicators such as these may be applied at a paddock, farm or system level. For more information see NPSI Irrigation Insights Number 5 'Water Use Efficiency' or the benchmarking tools available for irrigated cotton and grain farmers at www.cottonandgrains.irrigationfutures.org.au/

Whole-of system efficiency

'Losses' in one part of an irrigation system (such as surface run-off) can become 'inputs' to another part (such as for downstream use).

At a small scale, systems often need to be regarded as 'open': water leaving the system may be re-used elsewhere for a variety of purposes (including environmental). At a larger scale, that re-use is recorded and the system is regarded as a 'closed' system. It can be hard to develop a water balance at that bigger scale, but it will give a different perspective of the efficiency overall.

A whole-of-system analysis is more likely to highlight environmental issues associated with water extraction and water contamination.

Caveats

Some caveats apply to the application of water use efficiency measures.

- Measurement of the components of a water balance is often difficult (and the parameters being measured can be highly variable). Estimates and calculations must often be substituted for measurement, and confidence in the different outcomes will vary. Sensitivity analysis can help expose the relative importance of different components in a water balance and considering the probability of different outcomes can help cater for the variability in natural systems.
- The boundaries applied to measurements are critical and must be specified, in terms of both area (e.g. paddock, farm or district) and time (e.g. annual, seasonal or single event).
- Single measures of efficiency can distort perceptions and expectations. It is important to understand what different measures mean and to use a range of measures to obtain a full picture. The nature of the storage, delivery, irrigation and farming systems must also be understood as there are interactions between them and the purpose and methods by which water is ultimately used.
- Rainfall interpretations need to be clear to understand what, if any, rainfall has been included.

Some common ways to measure water use efficiency on farms are:

Measure	Input / Output	Units
Irrigation Water Use Index	Crop yield / Irrigation water applied	kg/ML
Gross Production Water Use Index	Crop yield / Total water applied (including rainfall)	k g/ML
Crop Water Use Index	Crop yield / Crop evapotranspiration	kg/mm
Gross Production Economic Water Use Index	Gross return / Total water applied	$/ML
Irrigation Rate	Water applied / Area	ML/ha
Water Input Efficiency	Water consumed by the crop / Total water applied	

Conclusion

Water use efficiency is an important and valuable concept. It can be determined at a variety of scales and can help identify ways to improve the productive use of scarce water supplies and the environment.

The analysis necessary to develop water budgets and subsequent efficiency measures is valuable in itself – giving deeper insight to the way in which water is used and stimulating ideas on how that use may be improved.

The work of the National Program for Sustainable Irrigation in developing and defining a set of efficiency measures has been crucial in providing a common language for the discussion of water use efficiency and opening the door to a deeper understanding of all that is involved.

MORE INFORMATION

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Photo source: Peter Day

About NPSI

The National Program for Sustainable Irrigation provides research and innovation to improve the environmental and productive performance of irrigation in Australia.

The program funds and manages research projects across Australia, working at the property level with farmers, at catchment level with policy makers and planners, and at scales that cross state and territory borders.

Our vision

Australian irrigation that is valued for its environmental, economic and social contribution.

Our mission

To invest in research, development and its adoption to improve the productivity and sustainability of irrigation in Australia.

Outcomes

- Improved irrigation water use efficiency and enhanced ability to respond to changing levels of resource availability over time.
- Reduced environmental impacts, more sustainable ecosystems and more prosperous communities.
- Improved skills, knowledge and decision making of end users, which leads to practice change, and more efficient and sustainable use and management of water.
- A national approach to irrigation related to R&D in Australia, which includes a strong focus on a skilled human resource base and enhanced R&D capacity and collaboration.

Our values and guiding principles

- Scientific innovation and excellence.
- Practical knowledge ready for adoption.
- Leadership, integrity and collaboration across the irrigation industies.
- Commitment to sustainable irrigation industries, communities and management of natural resources.

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Partners

NPSI is a collaboration between 14 funding partners. Investment Partners include irrigator groups, water authorities, commodity groups, state government agencies, Research and Development Corporations, Cooperative Research Centres and the Australian Government.

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- Lower Murray Water Authority, Victoria;
- Ord Irrigation Cooperative, Western Australia;
- Grains Research & Development Corporation;
- Sugar Research & Development Corporation;
- South Australian Research and Development Institute; and
- Sunwater, Queensland;
- Western Australian Department of Water.

Resources

To view NPSI research reports and case studies, visit www.npsi.gov.au

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