EFFICIENT IRRIGATION BY APPLYING A WATER BALANCE

Felix Reinders

ARC • LNR -Institute for Agricultural Engineering
South Africa

COMING UP.....

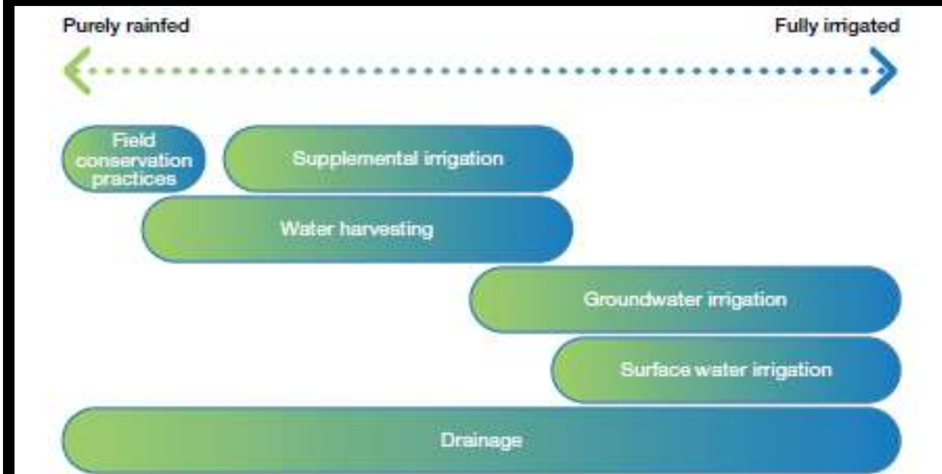
- INTRODUCTION
- THE WATER BALANCE APPROACH
- APPLICATION OF THE WATER BALANCE APPROACH
- RESULTS
- CONCLUSION

The importance of water:

- **Water is the key to food security**
  - without water, crops simply
- **Water is not just for primary production**
  - it plays a vital role at all stages along the agricultural value chain
- **Water for agriculture connects us all together**
  - In times of scarcity we all have a responsibility to use water wisely, efficiently and productively.

We need to be more 'water smart'

The spectrum of agricultural water management



(Delany, 2012)

Water balance framework

The water balance for an irrigation project is a complex set of inflows, outflows, consumptive use, and recycling of water.

Withdrawal for irrigation use:
Water abstracted from streams, groundwater or storage

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Storage change	Consumed fraction	Non-consumed fraction

Water balance framework

Withdrawal for irrigation use:
Water abstracted from streams, groundwater or storage

Storage change: (SC) Flow to or from aquifers, in-system tanks, reservoirs, etc. With no significant change in water quality between the in and out flows

Consumed fraction:

- **Beneficial consumption: (BC)** Water evaporated or transpired for the intended purpose – eg. crop transpiration
- **Non-beneficial consumption: (NBC)** Water evaporated or transpired for purposes other than the intended – eg. evaporation from dams, riparian vegetation.

Non-consumed fraction

- **Recoverable fraction: (RF)** Water that can be captured and re-used – eg. drainage water from irrigation fields
- **Non-recoverable fraction: (NRF)** Water that is lost to further use – eg. flows to saline groundwater aquifers, flow to the sea.

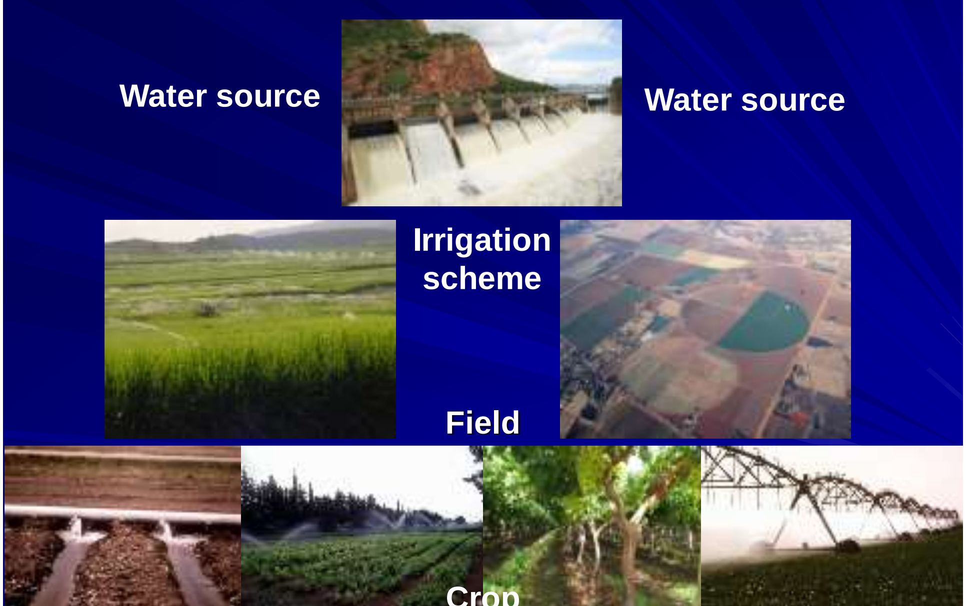
(Perry 2007)
Endorsed by ICID

Four levels of water management infrastructure

Water management level	Infrastructure system component		
Water Source	Dam/Reservoir		Aquifer
Bulk conveyance system	River	Canal	
Irrigation scheme	On-scheme dam		
	On-scheme canal		
	On-scheme pipe		
Irrigation farm	On-farm dam		
	On-farm pipe / canal		
	In-field irrigation system		

(Reinders, et al,2010)

Defining efficient use of irrigation water:



Efficient use of Irrigation water

Defining efficient use of irrigation water:

Water source

“On-scheme losses” ← **Irrigation scheme**

“On-farm losses” ← **Farm**

“In-field losses” ← **Field**

Crop

Ensuring that most of the water taken from the source reach the intended target

– the crop –

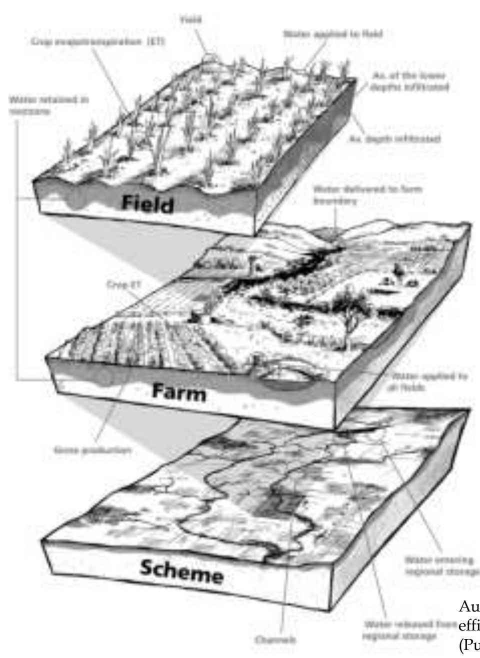
by minimising losses along the way.

By using……

A water balance approach

Implementing the water balance approach

- Applied at different levels
- During design AND management



Australian water use efficiency framework (Purcell and Currey, 2003)

Unfortunately, historically reporting of irrigation efficiencies (such as "application efficiency", "system efficiency", "distribution efficiency", "transportation efficiency", etc.) have resulted in the diminished understanding and scrutiny of the source or causes of losses. There is a widespread illusion that efficiency is fixed by the type of irrigation infrastructure used rather than to the way a particular system has been designed and managed. In the past, improving performance and efficiency was, incorrectly, only associated with an upgrade in infrastructure or change in irrigation system.

Distinguish between

WATER USE EFFICIENCY & WATER PRODUCTIVITY

Water Use Efficiency (WUE)

Efficiency of any process = (useful output/total input) x 100
Note: output an input need to have the same units

Water use efficiency in agriculture = the % of water supplied to the plant that is effectively taken up by the plant, i.e. that is not lost due to drainage, bare soil evaporation or interception.

If, for example, 10mm water is added to the plant and the plant uses 8 mm through root water uptake and transpiration while 2mm water is lost through drainage below the root zone or via bare soil evaporation from the surface then the water use efficiency is:

(8 mm / 10 mm) x 100 = 80%

Water Productivity (WP)

Productivity, in general, refers to what you can produce from a unit of input
Note: Input and output don't need to have the same units

Water productivity in agriculture:
is the crop yield produced per unit of water supplied, e.g. 50 kg grains per 1 m^3 of water.

Modern agriculture aims to increase yield production per unit of water used.

Efficient use of Irrigation water

- The water balance approach is more flexible than calculating ratios
- It takes into account:
  - the intended destination of water taken from a resource, and
  - how the water is used along the way.
- It encourages a better understanding of water management at all levels
- The water balance framework are recommended by the ICID as published in an article by Chris Perry in 2007

Water balance framework allocation of typical irrigation system components

Water balance framework system component	Inflow of water into system component
Dam / reservoir	Total amount of water released from storage
River bulk conveyance system (from on-river dam to scheme / farm edge) (if applicable)	Total amount of water entering the river
Canal bulk conveyance system (from on-river dam to scheme / farm edge) (if applicable)	Total amount of water entering the main canal
On-scheme surface storage	Total amount of water entering a scheme dam
Shared (scheme-level) groundwater aquifer compartment	Total aquifer recharge
On-scheme canal distribution system (if applicable)	Total amount of water entering the on-scheme canal distribution system
On-scheme pipe distribution system (if applicable)	Total amount of water entering the on-scheme pipe distribution system
On-farm surface storage	Total amount of water entering a farm dam
On-farm distribution system	Total amount of water entering the on-farm pipelines or canals
In-field system (from field edge to root zone) *Intended destination of the water released.*	Total amount of water entering the irrigation system (Gross Irrigation Requirement (GIR) plus precipitation)

Water balance framework allocation of typical infield irrigation system components

Possible water destinations within the in-field irrigation system component	Framework classification	Desired Range, % of inflow
Increase soil water content	SC	
Transpiration by crop	BC	
In-field evaporation (beneficial)	BC	
Frost protection irrigation water	BC	
Leaching (intended, beneficial but non-recoverable)	BC	
Interception (unavoidable)	NBC	<1
In-field evaporation (non-beneficial, excessive)	NBC	0
In-field deep percolation (non-intended, non-recover)	NRF	0
In-field run-off (uncontrolled)	NRF	0
Drainage water (surface & subsurface, recoverable)	RF	
Operational losses (unavoidable)	NRF	<5

Application of the water balance approach

Compiling the water balance there are a few steps that must be followed to achieve an improved water use efficiency

1. Identify the appropriate level of application
2. Identify the water management infrastructure
3. Identify the boundaries
4. Define the inflow
5. Finalise the list of possible water destinations
6. Set the allowable range or threshold values

Example of compiling a water balance

The Gamtoos Irrigation Scheme is located in the Eastern Cape and has 7 431 ha of scheduled irrigation area. Water allocations are 8 000 m^3/ha and there are approximately 170 farmers on the scheme, receiving water from the Kouga Dam. Water is distributed with a canal network with automatic gates and water meters are used to measure water distributed through pipelines to the farmers from the canal network. Irrigation systems used include centre pivot, drag lines, micro, drip, and travelling guns to irrigate a range of crops but mostly citrus (30%), vegetables, pastures, coffee, tobacco, soya beans, and canola.

Gamtoos Irrigation Scheme

Kouga Dam
7 431 ha
8 000 m^3/ha
170 farmers

The Board is continuously upgrading the scheme and has in the last 9 years succeeded in improving the management of the main canal. There is an on-going process of repairs to siphons on the main canal in conjunction with Department of Water Affairs, as the scheme is strategically important in its role as co-water provider for Port Elizabeth, a metro city in the Eastern Cape.

Identify the appropriate level of application

Agricultural water infrastructure usually includes the following components, applicable at different levels of water management.

- An in-field irrigation system to apply the water to the crop.
- An on-farm water conveyance system to convey the water to the field edge.
- An on-scheme water distribution system such as a canal or river, shared by a number of water users to convey the water to the farm edge

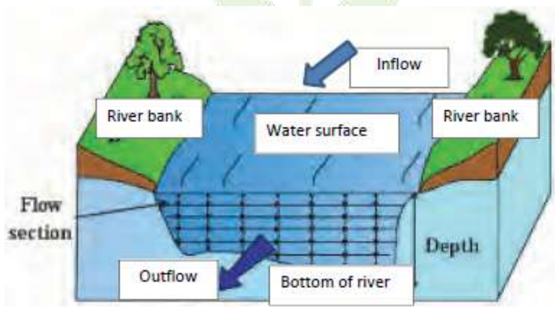
Identify the water management infrastructure

The applicable infrastructure is identified according to the water management infrastructure – the water source and bulk conveyance system, the irrigation scheme, the irrigation farm and the irrigation field. Although a water balance can cover more than one infrastructure component, a separate water balance is compiled for each component.

Identify the boundaries

When defining boundaries for water balance areas, it is necessary to define both

- spatial (related to area) and
- temporal (related to time) boundaries.



Spatial boundaries

Area	Upper boundary	Lower boundary	Horizontal boundary
In-field application systems (from field edge to root zone)	Crop canopy	Bottom of root zone	Field edges
On-farm distribution system (from farm edge to field edge)	Water surface	Bottom of canal / pipe walls / drainage system	Farm edges
On- scheme conveyance system	Water surface	Bottom of canals / pipe walls	Scheme edges
River system (from on-river dam to scheme / farm edge)	Water surface	Bottom of river	All river inflows, outflows and sides

Temporal boundaries

The temporal boundaries of the water balance are determined by the purpose for which the balance is done.

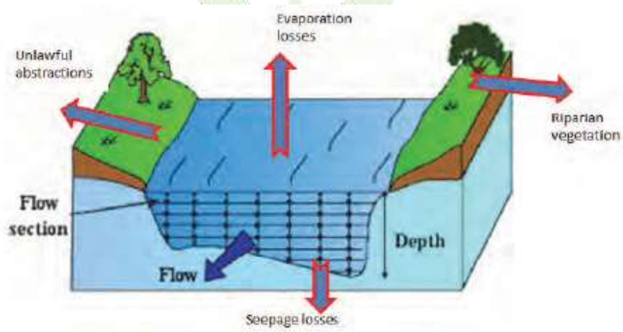
- As water is allocated for irrigation use on an annual basis, a one-year period is used as a temporal boundary.
- In some cases, such as at field level, the time scale may be reduced to the length of a season for a specific crop.
- A daily soil water balance can also be done for specific reasons such as irrigation scheduling, as an annual balance at this level will be useless.

Define the inflow

The source of the water entering the system component must be specified, as this is usually the parameter which is being scrutinised by compiling the water balance. In order to compile a credible water balance, the flow volume or flow rate at the entry point of the system component must be measured and quantified. The more often this can be measured, the greater the accuracy and reliability of the data. Continuous measurement should be the aim of any measurement system.

Finalise the list of possible water destinations

When drawing up the water balance, all water entering the water management level as “Inflow”, should be allocated to a specific destination within or exiting the water management level boundaries.



The specific situation must be inspected for which the water balance are being compiled and all the possible water destinations must be identified.

Each destination must then also be classified in terms of the water balance framework:

BC: Beneficial consumption
NBC: Non-beneficial consumption
RF: Recoverable fraction
NRF: Non-recoverable fraction
SC: Storage change

Set the allowable range or threshold values

The allowable range or threshold values are the benchmarks according to which the water balance is assessed. By comparing the actual value entered for a specific water destination as a percentage of the inflow with the benchmark, decisions can be made as to whether action is required to reduce water reaching the destination. Setting these values are therefore of great importance.

Collected data

- Seepage was calculated as 1.2 (ℓ/s)/1 000 m² of wetted canal lining
- Evaporation was calculated on the bases of the actual measured daily pan evaporation figures
- Losses were observed but couldn't be quantified. It included canal spills and unlawful use.
- The combined results of the measurements together with estimated confidence intervals (CI) for the various components are shown in the next Table

Results of measurements

	Dec (m³) D	Jan (m³) J	Feb (m³) F	D+J+F (m³)	% of Inflow (%)	CI (%)	
						Min	Max
Inflow	1 261 844	1 487 872	1 158 187	3 907 903		-5	5
Usage	964 380	1 375 510	941 680	3 281 570	84.0	-3	3
Gross losses	297 464	112 361	216 507	626 333	16.0	-5	5
Gross losses detail:							
Evaporation (canal)	2 631	2 898	2 149	7 679	0.2	-15	15
Seepage (canal)	53 120	58 686	53 399	165 206	4.0	-30	30
Evaporation (dam)	3 502	3 493	2 846	9 842	0.3	-15	15
Seepage (dam)	248	248	224	720	0.02	-30	30

Calculating the water balance

By using the spreadsheet based tool, the final water balance was compiled by combining the inflow and water destination values.

Water balance for the Gamtoos canal

Destinations	m^3	CI	% of inflow		Action required?
			Actual	Desired	
Farm edge (on-farm surface storage, distribution system or irrigation system)	3 281 570	3	84.0	N/A	No
Evaporation from canal	7 679	15	0.2	5	No
Seepage in canal	265 206	30	6.8	5	Yes
Unlawful abstractions	0	15	0.0	0	No
Operational losses (unavoidable, eg. filling canal, tailends)	0	15	0.0	8	No
Operational losses (inaccurate releases, spills, breaks,etc.)	0	15	0.0	0	No
Evaporation from dam	9 842	15	0.3	5	No
Seepage from dam	720	30	0.0	5	No
Total	3 565 017	30	91.2		
Unaccounted water*	342 886	30	8.8		
	3 907 903	30	100.0		

System efficiency

The framework was also applied to re-assess the system efficiency indicators typically used by irrigation designers when making provision for losses in a system and converting net to gross irrigation requirement. A total of 75 irrigation systems were evaluated and a new set of system efficiency (SE) values for design purposes was therefore developed.

Default irrigation system efficiency values

Irrigation system	Losses				Default system efficiency (net to gross ratio)	
	Non-beneficial spray evaporation and wind drift (%)	In-field conveyance losses (%)	Filter and minor losses (%)	Total Losses (%)	Min (%)	Max (%)
Drip (surface and subsurface)	0	0	5	5	90	95
Microspray	10	0	5	15	80	85
Centre Pivot, Linear move	8	0	2	10	80	90
Centre Pivot LEPA	0	0	5	5	85	95
Flood: Piped supply	0	0	5	5	80	95
Flood: Lined canal supplied	0	5	5	10	70	90
Flood: Earth canal supplied	0	12	5	17	60	83
Sprinkler permanent	8	0	2	10	75	90
Sprinkler movable	10	5	2	17	70	83
Traveling gun	15	5	2	22	65	78

The Water balance approach of:

"measure; assess; evaluate; improve", promotes an investigative approach to improve irrigation efficiency and the adapted water balance framework assist managers and designers alike to apply it at any level to improve system performance.

Thank you