

Saving More Rain to make Grain – Measuring Your WUE (Water Use Efficiency) the CSA WAY

Right from the start – Note the big difference in the WUE formulas

- Standard WUE (kg/ha/mm) = **Crop Yield (kg/ha) / Water Supply mm** (= Stored Water mm + Growing Season Rainfall mm - Water Loss Factor mm)
- CSA WUE (kg/ha/mm) = **Crop Yield (kg/ha) / Fallow Rain mm** (3 months prior to month of Sowing) + **Growing Season Rainfall mm** (month of Sowing to month of Haying Off inclusive)

Water drives the functions of all life and ‘makes things happen’. No more Water – No more Life. Lack of water is the greatest, single, limiting factor in all pursuits of agriculture. Water timing, conservation and efficiency will be the greatest, single, determining factor in Yield Outcome.

WUE can explain 50%-80% of why yields will vary from year to year. That makes WUE a valuable tool to benchmark how well we are conserving and converting the rain we get - to grain. However – WE HAVE A MAJOR PROBLEM – Not everyone uses the ‘Standard’ WUE calculation the same. So you have to set the ground-rules for yourself AND if you want to compare WUE numbers with others you have to check how they conducted their calculations as well. CSA has a real problem with this permitted fudge factoring in the Standard WUE Formula that also seems to be acceptable to agronomic scientists. You should have a real problem with this too given WUE is such a critical measurement of farm potential and viability.

Understanding the currently promoted ‘STANDARD’ WUE FORMULA Line by Line

- $WUE \text{ (kg/ha/mm)} = \text{Crop Yield (kg/ha)} / \text{Water Supply (mm)}$

This WUE formula relies on estimations of the amount of water available to the crop. Variance in WUE between crops, years and fields on our farm certainly gives us a means to benchmark and task our own performance and to seek ways to continually improve the farms’ WUE. So how can you benchmark yourself or benchmark against others in the district using this currently promoted formula if you can guess numbers and have no comparable or objective criteria by which your neighbour ‘assessed’ his water supply numbers either.

This is how the currently promoted WUE Formula Works -

Crop Yield - WUE (kg/ha/mm) = **Crop yield (kg/ha) / Water supply (mm)**

- Crop Yield is the Easy Bit of course. Total Tonnes harvested per Hectare expressed in Kilos. No Need to Dwell on that – except to say that in CSA we like to assess the Screenings, Hectolitre Weight and other ‘Quality’ Variables like Protein, Robust Senescence (a CSA calculation relying on Stem Sap EC, Soil Moisture Readings and Stem Sap Brix to determine the weeks left to plant death), Crown/Tiller Profile and Stubble to manipulate our future programs for a better WUE.

Water Supply - WUE (kg/ha/mm) = **Crop yield (kg/ha) / Water supply (mm)**

- Water Supply (mm) = Stored Water (mm) + Growing Season Rainfall (mm) - Water Loss Factor (mm). Water Loss ‘Factor’ - This is the ‘devil in the detail’ that turns science into snake-oil.

Calculating the Water Loss Factor in this Formula is Logically Wrong to CSA – and completely deceptive.

Determining Water Supply is simple enough to estimate; but a very complex and difficult number to determine with high accuracy. Water Loss Factor in the Standard WUE equation is crucial for accuracy, consistency and truly understanding where you are in Water Use efficiency; and yet that number is totally built on guesswork! The Water Loss calculation requires you to make an allowance for general evaporation prior to sowing, in-crop evaporation, run-off and water used in building the crop before grain production – presumably for every paddock because they are all show different water characteristics don’t they? How does a farmer accurately or even ‘reliably estimate’ over so many different paddocks!? How do farmers or scientists ensure we are all comparing the same ‘estimations’ legitimately?

The first estimate of this water loss factor is conventionally (and conveniently) set at 100 mm and as quoted in the literature “with experience this number can be adjusted”. What a load of snake-oil BS! CSA rejects this convention as an excuse to compensate for a number that will never truly be known or in good faith – have any practical means to be accurately measured on any farm at any time – in reality.

- In the CSA practice we view this Standard WUE Water Loss Formula as logically wrong. It is worse than just an 'Achilles-heel' in the Formula because it does not reward a truly better soil WUE.
- A truly better WUE would require us to lower our Water Loss Factor in the Water Supply figure each Year – say by becoming more-efficient in storing Fallow Rain and Growing Season Rainfall in the soil and if we change the benchmark performance level for ourselves – compared to previous years; for making these improvements - the Standard WUE Formula punishes us for it.
- Under this formula; we end up having to rely on getting higher and higher Yields each year to improve our WUE Score whereas farmers who ruin their soil leading to greater and greater Water Loss Factors can conceivably keep increasing their WUE (via their Water Loss Factor) under this formula - until they go broke!

Given all practice-inputs being equal - If you grow the same Yield on Lower Rain compared to the previous year the CSA WUE Formula increases your WUE but in the currently promoted Standard WUE formula there are no clear ways to reward this better performance in lower rainfall years – in fact you will likely be deemed worse even though you actually performed better!

The “Worse than an Achilles Heel” Example –

WUE/Ha	Crop Yield kgs	Fallow	+ Growing	- Loss =	Adj Rain	WUE	
Year 1	3200	110	250	360	100	260	12.3
Year 2	3400	110	250	360	75	285	11.9
Year 3	3000	90	210	300	50	250	12.0

- Year 2 - 200kg Higher Yield with Same Rain and better Water Storage creates a lower WUE.
- Year 3 - 200kg Lower Yield with 60mm Less Rain and better Water Storage creates a lower WUE.

The Standard formula fails to reward true WUE and is effectively dysfunctional. It expects you to account for 'impossible to measure' variables; it allows individuals to make up their own 'water loss numbers'. Have you noticed how little anyone talks, uses or benchmarks with the Standard WUE? That in fact we don't know how to properly use this most important tool for farm performance and profitability – because it is inherently flawed and logically wrong! What scientific tool tells a user to assume a number like 100mm for such a critical measure as Water Loss and then guess your way past that?! How can we possibly compare each other or ourselves year to year with such a critical but out-of-control variable?

We have another problem with the Standard WUE Formula – Water Supply Calculations

When calculating Water Supply in the currently used WUE Formula, only a percentage of Fallow rainfall is included. 20% is typical. Seasonal conditions and management skill will raise or lower this figure. A fallow efficiency of 25% is commonly used where high levels of stubble are maintained. Drier hotter areas typically have poorer fallow efficiencies than cooler wetter areas. Run-off on sloping country is reduced by maintaining stubble and or using zero tillage. Typical run-off on bare Fallow is around 10% of rainfall. This can be reduced to around 5% by maintaining stubble.

Tighter crop sequences will increase fallow efficiency and open cracks will allow the capture of storm rainfall. Effective management of fallow weeds is also critical to fallow efficiency. CSA finds the problem of properly quantifying these variables as simply too hard and prone to serious error. How does a farmer know what his fallow efficiency really is across all the paddock variables of the farm?

Unfortunately there does not seem to be a common or objective method to apply in the Standard WUE formula – so in that model we are all at liberty to create the WUE numbers we think are right – and that is definitely not acceptable to CSA practices.

All farms and all the numbers used in calculations must be measured in the same way.

To simply capture the true efficiency of all the possible variables on farm CSA takes the opposite position and we count every Fallow Rain mm in the 3 months prior to Sowing as a known sum. If all your different farming practices end up accumulating more moisture in various ways across all the soil conditions then that will contribute to the total Water Supply for the year. If that in turn improves your Yield then an increased WUE will result – which is the only outcome that will make the farm more viable, robust and profitable. If it doesn't – you have lost a connection between soil-water-plant and you need to find out why. Rotation changes? Frost? Storm? Chem-Damage? Variety? Nutrition? Look for the factors that make a soil or a plant less efficient – other than water.

There is no 'devil-in-the-detail' of the CSA WUE formula – but there is plenty of pondering about why and how the numbers are what they are. That type of complexity we can account for to make sense of the results. The Stored Water number in the CSA WUE Formula becomes far more transparent, robust and independently checkable against anyone else's numbers. CSA uses the 3 months of Fallow Rain prior to sowing plus Growing Season rain, (CSA defines the Growing Season period as the month of Sowing to the week of CSA Confirmed Haying Off). District Rainfall records provide a source of historical water supply data for WUE calculations of this seasons and past seasons' crops; including your neighbours.

LETS GET BACK TO REALITY! Principles First! Let's get rid of the un-measurable.

Take the Total of Stored Water and Don't Fudge (Fallow Rain and Soil Structure Characteristics)

Fallow efficiency varies with the pattern of rainfall received, soil type, slope, soil water profile, infiltration rate, fallow management, temperature, evaporation, stubble cover and tillage. In the vast majority of cropping areas across Australia around 50% of the rain events provide less than 15 mm of rain. These falls tend to remain shallow in infiltration and potentially evaporate without making a significant contribution to sub-soil and stored soil water. Conventionally this limits how much fallow efficiency can be improved.

However in the CSA Practice we are constantly focused on building stored-water capacity regardless of the challenges we face. We are seeking to measure ourselves against a 'Perfect WUE' so our growing efficiency (in comparison to perfection) can be captured by counting 100% of the 3 months prior to sowing and by not allowing any Water Loss deduction or Fallow Efficiency estimation. We seek to store the lot – and any loss that matters will show up in the yield comparisons from year to year across the whole farm – crops, paddocks and our best-practice in managing that is all included. **Our CSA method is to capture any loss or improvement in stored water efficiency – by default – over successive years.** The better we are at keeping fallow rain – the more it will be expressed later in the Yield Outcome compared to whatever the Water Supply was and that calculation will automatically improve our WUE.

USING THE CSA WUE FORMULA -

- **Crop Yield (kg/ha) / Fallow Rain mm** (3 months prior to month of Sowing + **Growing Season Rainfall mm** (month of Sowing to week of CSA Confirmed Haying Off inclusive)

Using the same yield/fallow and growing rain as the previous example

WUE/Ha	Crop Yield kgs	Fallow	Growing	Rain Total	CSA WUE
Year 1	3200	110	250	360	8.88
Year 2	3400	110	250	360	9.44
Year 3	3000	90	210	300	10.00

- 200kg Higher Yield with the Same Rain creates a better WUE.
- 200kg Lower Yield with 60mm Less Rain also creates a better WUE.
- The CSA 'grain versus rain' equation rewards true efficiency for delivering what must be a better WUE in the soil. How that was done becomes the interesting conversation – and how we can do it more in the years to come is what we do because all CSA Programs are designed to increase WUE.

Other reasons for using the CSA WUE formula -

- Months that fall outside of the CSA WUE rain measure are distant to the Yield calculation but they still 'naturally' reflect the trend of the paddocks WUE anyhow. Eg: If soils are poor at holding extra-fallow rain they will lose moisture faster and simply mimic the measure period for a poor in-season performance. If the soils are good at holding extra-water they do the same in season to aid performance. The trend of better or worse will show itself anyhow. It doesn't take many months of no-rain at the end of a season to make a lot of rain 9 months ago useful – or totally meaningless. The trend of the WUE will still show itself.
- Uncontrollable events – like when the rain falls in or out of season – are accounted for. Fortuitous rain helps us all – but it helps the poor-performers more. It doesn't matter how you 'got-out-of-jail' some seasons when the long run will show that if you don't improve WUE you're still going backwards. CSA WUE focus helps us improve for the hard years – not the easier ones.

- CSA focuses on soils that are capable of holding water for longer regardless of when the rain falls. The accounting for all the un-measurable efficiency variables are accumulated in rainfall totals – so the measure of success will always be “water storage for when we want it” and the total efficiency of that outcome, year on year, up or down, is always captured in this CSA formula.
- All the Key Numbers for the formula to make sense are known and are not allowed to be massaged or estimated. The same method of calculating applies to everyone.

USING THE CSA WUE FORMULA TO ASSESS THE FARMS PERFORMANCE

- CSA counts the 3 months prior to sowing through to the week of the crop Haying Off. Haying Off is when the Green Mass/Crown//Roots have committed to senescence; go ‘brown’ and the plant roots system has shut down any further soil water uptake – regardless of further rain. It is a function of Very Low Soil Moisture (Crop specific but usually sub 35%), High Sap EC (Crop specific but usually above 10 us/cm) and Very High Brix Levels (Crop specific but usually above 15 and heavily diffuse @ 20C%) to determine how many days left until shut-off (if there is no more rain). No point in counting anymore rain once the crops root system has shut-down and withers as it sends all the remaining moisture to the end-goal of its life - seeds. Imagine a ‘soup boiling dry’ on the stove. That is the ‘point-of-no-return’ process we are measuring; the end-point of all WUE.

Sample CSA WUE Farm Chart – Liquid Inject/Solids Program (‘Shadawa Downs’ WA)

- %W/var = Percentage Water Variance = Current Water Total/ Previous Water Total – 1.00X100
- % Y/var = Percentage Yield Variance = Current Year Yield/Previous Year Yield – 1.00X100
- CSA WUE = Total Kilos Yield / Total of Fallow and Growing Season Rainfall

CSA WUE – Fallow (Jan-Mar/Apr) + Growing Apr/May – Oct (2015) Nov (2012/13/14)								
Crop	Year	Fallow	Growing	Total	%W/var	Kg/Ha	WUE	%Y/var
Wheat								
STD	2012	31.6	310.7	342.3		1850	5.40	
CSA	2013	86.2	318.6	404.6	+18.2	2450	6.05	+32.4
CSA	2014	22.6	346.5	379.1	-6.30	2275	6.00	-7.14
CSA	2015	45.0	309.5	354.5	-6.48	2415	6.81	+6.15
Canola								
CSA	2013	86.2	318.6	404.6	+18.2	910	2.25	
CSA	2014	22.6	346.5	379.1	-6.30	720	1.90	-20.8
CSA	2015	45.0	309.5	354.5	-6.48	1060	3.00	+47.2
Lupins								
STD	2013	86.2	318.6	404.6	+18.2	1540	3.80	
CSA	2014	22.6	346.5	379.1	-6.30	1950	5.14	+26.62
CSA	2015	45.0	309.5	354.5	-6.48	2280	6.43	+16.92

This is an actual chart from a CSA Liquid Inject AgroCarbon BroadAcre Cereals property in WA. STD = Not a Ferti-Tech CSA Program.

CSA expects us to study the Variations and Trends between years for explanation. A lot of improvement is explained by WUE – a lot by Farming Practice.

- Best results in terms of WUE occur when %Water/Var is Negative from previous year but %YieldVar is Positive. Less Water but more Yield.
Especially impressive when successive years have less rain but Yield continues to Increase. The strategies in place for WUE on this property must be succeeding.
- Note the drop in 2014 for Wheat and Canola – problems with the seeding program and a very late sowing mid-winter for Canola caused several paddocks to under-perform. Many factors influence outcomes but the accounting of that is sought AFTER the results of the Yield and Water have been tallied – not before.
- Water is the highest determinant for Yield and is accounted for Year on Year by the Numbers. The story in the Numbers is the varied changes, excuses or applied excellence in farming you tally over the season. The Trends are what we want to Chart. Improved Farming Practice can be a two-edged sword! Farms can rape soil fertility and reduce WUE and still improve Yield – until the ‘Flaky overcomes the Robust’ of what they are doing and then the crash is spectacular. Robust – and more Robust is what is happening here in this example.
- What was also clear in 2015 was a massive improvement in circumstances even in conditions of much lower Lower Rainfall. That was also a year when the sowing went far more smoothly than 2014; crops were properly advanced and all the farm practice for CSA foliars was timely.
- Note the exceptional Yield increases in Lupins – some WUE credit is there but a change in Cropping Program that emphasised Liquid Carbon and Carbon buffered Traces like Manganese, Zinc and Copper in furrow made massive differences to Yield in this Soil Profile. Such Comments and Notes on each result should be recorded on the Chart as a permanent record – and a means to manage trials to look for all types of continuous improvement.
- ‘Holding the Fort’ once Yields are above district average is the ultimate CSA WUE goal. Keeping Yields up in the face of lower rainfall events is the test and the Numbers will show how successful we are at that – regardless of what we do. The ‘Scoreboard’ is all that counts.
- Comparing Yield KGS and Water MM across successive Years is also a useful tool. What Yield Increase or Loss is now measured when a similar Water Increase or Loss occurs? Even with Lower Rainfall than 5 yrs ago – and perhaps a lower Yield than last Year: how much higher in Yield are we still - than 5 Years Ago. What changes, fertilisation or other practices have helped?

The CSA WUE Farm Charts can give us real clues for experimentation and finding the maximum effects. It is a tool that gives us an objective measure of the success of our Cropping Programs and the truth of whether we are truly Robust – or increasingly Flaky and ever-reliant on kind weather.

WUE? What Will it Be?

“Because I Farm my Soil is Better” OR “Because I Farm my Soil is Worse”

Ferti-Tech CSA Programs Improve Farm WUE because we Know How Soils & Plants Work.
We Deliver Better Soils, Crops & Profits - You Can Measure and See!



**“To be a Successful Farmer –
One must first know the Nature
of the Soil”**

**Xenophon
The Oeconomicus 400BC**