An overview of crop performance in Western Australia in the 21st century - opportunities and constraints

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Key messages

After a period of stagnant productivity gains in the first decade of the 2000s State level wheat yields and water use efficiencies (WUEs) picked up in recent years with increased nitrogen fertilizer and lime application, a steady trend to earlier sowing and improved genetics.

The regional pattern of yield trends matched spatial patterns in yield variability and nitrogen fertilizer changes, but the changing rainfall distribution through the year and soil constraints such as pH have now emerged as significant. A steeper gradient in yield is developing between dry and wet shires and farm business profits show some resemblance to this, though regions that are not addressing sub-soil constraints appear to have the lowest profits.

There appears to be opportunities to lift crop performance by targeting key constraints in different areas. This includes low pH in the northeast and far southwest, more N fertilizer in higher rainfall areas and earlier sowing with long coleoptile crops in drier areas.

Aims

Whilst impressive crop yield trends and gains in water use efficiencies (WUEs) occurred through the 1980s and 1990s, it has been widely recognised that productivity gains in the first decade in the 2000s dropped off with higher climate variability and more droughts (Stephens et al. 2011). However, since 2010 there has appeared to be a jump in water use efficiency which has produced much more grain than what would normally be expected from the rainfall. The question is: is this a short-term feature based on some better seasons, or should this increase be considered a part of a more sustained upward trend that would put pressure on the supply chain. Therefore, there was a need to calculate the water use efficiencies of crops within a crop modelling framework and examine what factors were driving the temporal and spatial changes observed across the wheatbelt.

Method

Crop Modelling Analysis -Yield trends

A modelling analysis to examine yield trends was carried out with Agrometeorology Australia's STIN wheat yield forecasting model (Stephens et al., 1989). This model calculates a water balance and accumulated stress experienced by the crop through the growing season from excess or deficient soil moisture. CBH shire yields and historical climate data were utilized. Assuming a linear increase in yields with time, model predicted yields (Y) are calculated by:

$$Y = b_0 + b_1*(SI) + b_2*(year) \qquad (1)$$

where, SI is the respective model stress index, b_0, b_1, and b_2 are the population regression coefficients estimated by the method of least squares. By using this approach, the climate variability is removed via the stress index, leaving edaphic and technological factors contributing to the trend term (b_2). Actual yields were converted into de-trended yields using (b_2) and the variability of de-trended yields was examined through the coefficient of variation.

Crop Modelling analysis – Water Use Efficiencies

Water use efficiency is related to the amount of grain produced per millimetre of water used in the crop growing period. To assess water use (or production) efficiency (WUE) of shire yields, actual yields were divided by potential yields (Y_{pot}) defined by French and Schultz (1984) and assuming the latest potential WUE of 24 kg/ha/mm of moisture (note this is higher than the 20 kg/ha/mm used for many years previously).

As a refinement for wetter shires, where considerable water drains through the plant rooting zone or runs off, we utilized the optimised STIN model mean water holding capacity for each shire and removed the excess water. We also removed heavy rainfall events above normal water use in the last three weeks prior to maturity as this rain cannot be used by the crop to produce more yield. A state level average WUE was calculated by adding and weighting the results from each shire based on the proportion of crop grown in each shire.

Exploration of trends and drivers

So as determines what factors were driving yield gains, key inputs and factors that influence yields were examined in a spatial and temporal framework. The analysis thus filtered for fertiliser impacts, pH modification (lime), varietal advances, seasonality factors (sowing dates, rainfall changes through the season) and farm business profits.

Results

State level

At a State level water use efficiencies (WUE's) have more steadily increased over time compared to eastern Australia which was affected by the severe 2006-2008 drought in south-eastern Australia (Fig. 1). In 2015, the Western Australian yield was affected by a very poor start, a late turnaround in the season in the northeast and a dry season in the southwest. In 2016, one of the most severe frost seasons saw another drop in State level WUE compared to the long-term trend. Nevertheless, State WUE has consistently been above 40% since 2010 (keeping in mind the high potential WUE of 24 kg/ka/year that we used in model calculations).

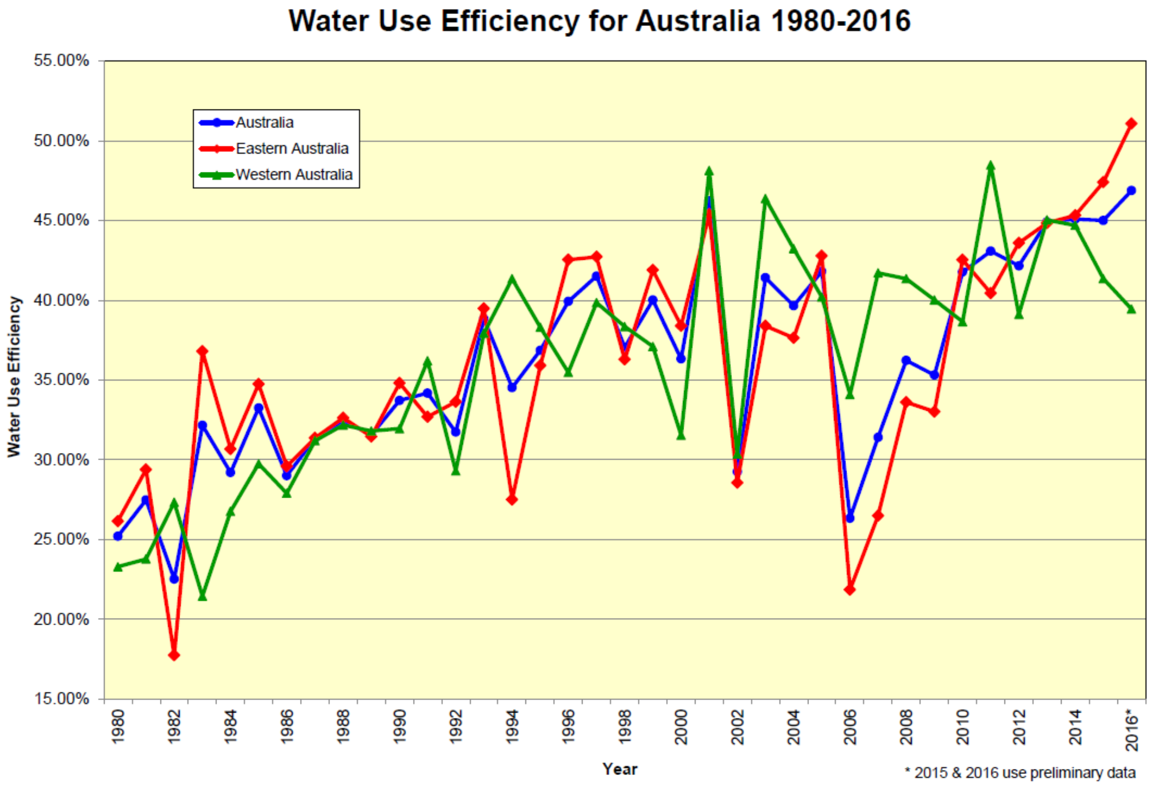

Figure 1 Average weighted WUE across the WA, eastern Australian and Australian wheatbelts from 1980-2016.

Driving factors behind long-term and recent gains at a State level appear to be:

1. Nitrogen fertilizer use steadily increased to 40% more than the previous decade by 2016.
2. The STIN model confirmed a 35-year trend to earlier sowing at a rate of 0.7 days/year which has a suite of yield benefits. A swing to dry sowing enhanced earlier overall plant germination. Spraying of summer weeds brings more subsoil moisture into the crop season which early sown crops can better access, especially with zero tillage.
3. A recent 140% increase in lime application which increases the efficiency of fertilizer application and the extraction of deeper subsoil water (double positive). New soil renovation techniques (spading, deep ripping) work together with liming.
4. steady genetic gains in crop varieties and an apparent increase in the rate of gain from new technologies such as DNA selection, advanced statistics and robotics.

Regional level patterns in productivity gains

When the spatial pattern of productivity growth is mapped across the wheatbelt there is a marked contrast between central eastern areas and other regions. Longer-term yield trends and recent changes in WUE are much lower in central eastern areas compared to the wetter southwest, southeast and most northern shires. Factors which appear to be most influential in explaining the spatial pattern in yields trends and WUE are:

1. A much higher yield (climate) variability in inland central areas. Yield variability explains nearly 40% of the variance in shire wheat yield trends spatially. State yield trends are maximized in periods of low variability (1980-1999) and reached a minimum when yield variability was at a maximum (1998-2012).
2. A decrease in nitrogen fertilizer in the dry and more variable inland areas, while very large increases of 40-100% occurred in the wet southwest, southeast and far north.
3. Subsoil acidity levels are more severe and the lime application is lower in areas such as the northeast where the lowest yield trends are found.
4. The wheatbelt is losing its early Mediterranean peak in rainfall since 2000. This means most of the north and east of the wheatbelt has had a negative change in climate with more seeding and emergence problems. In 2017, crops that were sown early and deep with long coleoptile varieties did much better than other crops. In the wet southwest, crops have benefitted from less waterlogging. In the southeast, a positive change has occurred from more rain being spread more uniformly through the year.
5. Transient salinity is becoming more pronounced in dry inland areas with less fresh water flushing of surface salts with heavy winter rainfall.
6. The lowest farm business profits are in the central eastern areas, while much higher profits occur where nitrogen fertilizer has increased along with higher WUE and yields.

Conclusion

Nitrogen fertilizer application and yield variability play an important role in enhancing the gradient in yields from the dry northeast to wetter shires across the wheatbelt. However, the emerging story here is water use efficiency gains are now being influenced by soil constraints (acidity, salinity) and a changing rainfall distribution which are working in tandem as a couplet to affect productivity. There is very much a “rich are getting richer, the poor are getting poorer” storyline developing. Average farm business profits appear to back this up in key areas, though the lowest farm business profits appear to be in regions of high yield variability where sub-soil constraints like acidity are not being addressed.

References

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Key words

Productivity, Water Use Efficiency, Yield trends, Technology.

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