Wheat yield trends in the northern grains region - a sustainable industry?

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Abstract

There is concern that wheat yields in Australia may not be increasing, despite improvements in technology. However, there have been few rigorous studies to determine regional and local trends and to ascertain the causes underlying any apparent failure of the grains industry to capture the benefits of research. We found that in only two of 39 significant wheat-producing Shires in the northern grains region had yields increased significantly since the introduction of semi-dwarf wheats. The poor result was not associated with declining rainfall or shifts in cropping systems that might cause wheat yields to decline whilst increasing overall farm productivity. In closer studies of 7 Shires, there was considerable difference in wheat productivity between farms. Those with better productivity used rainfall more efficiently, which seemed to be associated with better soil fertility and/or history of fertiliser use. Regions with positive yield trends were characterised by technical and social infrastructure that supported learning, innovation and the implementation of new technology.

Key words: Yield trend, productivity, wheat, soil fertility, socioeconomic, extension.

Yield trend analysis provides insight into industry competitiveness, as well as providing a springboard to evaluate impacts of new technology or resource degradation. It can also highlight rewarding research opportunities. There has been doubt about the magnitude and direction of any national wheat yield trends since the introduction of semi-dwarf genotypes in the 1970's. All attempts to determine the long-term yield trend have been dogged by high inter-annual rainfall and yield variation, which masks a small yield trend. Most of these attempts have also been limited by the aggregation of yields into national or state averages, hiding potentially important regional or local differences.

Whitwell and Sydenham (5) showed that the national average yield increased from around 0.7 t/ha in the early 1940's to about 1.2 t/ha by the late 1950's, with little evidence for an increase from then until the late 1980's. They concluded that "sustained improvements in yield (have) eluded Australian farmers despite considerable research effort and expenditure".

Shortly after Whitwell and Sydenham released their finding, Hassall and Associates (2) showed that the rates of yield increase in a range of cereals were much lower in Australia than in almost any other country. They argued the need for Australian farmers to increase land productivity (yields per hectare) to remain competitive. (Put simply, when products are sold into competitive markets, the benefits of technological advances are inevitably passed on to buyers in lower prices. So producers must continue to increase productivity at least as quickly as their overseas competitors in order to maintain returns).

In 1993, Hamblin and Kyneur (1) analysed Shire yields to produce the best evidence yet for poor wheat yield trends. They also pointed to protein declines. They concluded that yields were failing to increase with technological advances because improved cultural practices were not being widely adopted, especially those related to maintaining soil fertility. They also pointed to marked contrasts between adjoining Shires and across State borders, leading to speculation about the apparent failure of farmers to adopt sustainable technology. Their analysis led to serious questions about the sustainability of grain growing in significant parts of Australia, including much of the northern grains region, as well as to questions about the value of research and extension. The Grains Research and Development Corporation then commissioned a study (4) of total factor productivity, not simply land productivity, which revealed essentially the same story of zero (statistically significant) growth in productivity across the nation from 1982/3 to 1992/3.

The Hamblin and Kyneur analysis was based on two important but largely untested assumptions: (i) that declining rainfall or unfavourable seasonal distribution of rainfall was not a factor contributing to the poor recent trend; and, (ii) that cropping systems had not changed in any way that could prejudice wheat yields but raise overall farm productivity (*eg* less use of long fallow and increased cropping intensity).

This paper provides an overview of the methods and results of extensive research to re-analyse long-term yield trends in the northern grains region. The work accounts for or tests the important assumptions underlying Hamblin and Kyneur, and analyses the biophysical and socioeconomic reasons for the dismal long-term trends we found. The underlying objective was to assess the long-term future of cropping in the region and suggest the work which may be required to secure that future.

Methods

In order to reveal underlying yield trends, the effects of seasonal variation in rainfall on yield were removed by the use of a crop water stress index model (3). The model was adapted to estimate a seasonal moisture stress index (SI) for wheat for each year from 1975-93 at each of 460 meteorological stations in the study area. These were integrated to provide an index for each Shire and year. ABS yields were then used as the independent variable (*y*) in the regression:

y = bo + bsi*SI + byr*year. (i)

where the significance and magnitude of any time trend is given by the coefficient byr. Significant byr ($P<0.15$) were mapped to highlight the spatial distribution of yield trends over time.

In 7 Shires with contrasting yield trends in (i), multiple linear regression was used to relate ABS Shire wheat, sorghum and barley yields to rainfall from 1975-1990 (ie prior to the drought), seasonal estimates of potential transpiration and May SOI. 'Potential transpiration' included 20% of fallow rainfall plus two-thirds of in-crop rainfall (the 2/3 adjustment to account for soil evaporation and runoff). These regressions provided independent estimates of the yield trend in the regression:

y = bo + bt*t + bsoi* SOI + byr*year. (ii)

Regression was also used to explore/develop hypotheses related to rainfall use and overall farm productivity. For this, $WUE was calculated as the gross dollars received from each 100 mm of incident rainfall ($/ha/100 mm), from all crops assuming prices for wheat, barley and sorghum of $170/ha, $140/ha and $130/ha. $WUE is an index of total cropping system performance.

Local silo wheat yields (Qld Wheat Board) within the 7 Shires (above) were then related to local rainfall and estimated potential transpiration by regression to provide an additional yield trend analysis for more localised regions, where crop yield was likely to be better known and rainfall more relevant This part of the study was also intended to establish whether there might be differences in yield trend between 1960-75 and 1975-90.

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Twenty-two case study farms across five Shires were visited to collect long-term rainfall and yield data and information on crop and farm management, and to gather soil samples. Again, yield trends were analysed. The case studies allowed us to test hypotheses arising from the yield trend analyses.

Finally, four focus group meetings were conducted in northwestern NSW and through Queensland grain growing areas to validate our general findings regarding yield trends. The technique was also used to determine the underlying reasons for the observed yield trends.

Results and discussion

Evidence for yield trends was sought from 3 independent sets of yield data (ABS-Shire, silo, farm records) analysed in two alternative ways to remove effects of inter-seasonal rainfall variation (SI model, regression based on potential transpiration). Overall, we found little evidence for any strong positive wheat yield trend from 1975-1993, regardless of analytical approach, with the exception of two Shires. Importantly, in the focus group meetings, farmers in only one area (North Star) thought that yields had improved in the last 25 years. Farmers in Bungil Shire were optimistic that technology had recently changed and they were well placed to enjoy higher yields 'once seasons returned to normal'. Two other groups expressed no such optimism.

Yield trend analysis

The analysis based on ABS yield data and Equation (i) revealed that only two of 39 major wheat producing Shires in the northern grains region, Bungil (Roma, Qld.) and Yallaroi (North Star area, NSW), had a significantly positive yield trend over the 1975-93 period, even with a relaxed significance level (P<0.15) for the coefficient byr. This result is substantially worse than reported by Hamblin and Kyneur. The difference reflects the more rigorous removal of rainfall variability and its effects, as well as a shorter time period. Hamblin and Kyneur studied 1950-1991, which included a likely step-up in yield following the introduction of semi-dwarf wheats. We could not detect the contrasts in adjoining, agroclimatically similar, Shires reported by Hamblin and Kyneur, except for the adjoining cross-border areas of north-eastern NSW (Yallaroi) and southeastern Queensland (Waggamba) which had strongly positive (20 kg/ha/yr) and zero yield trends, respectively. Hamblin and Kyneur drew heavily on such Shire differences to draw conclusions about soil fertility decline, conclusions which required closer scrutiny in the light of our analysis. The northern region was in marked contrast to southern NSW where yields had increased in most Shires.

Further analysis was undertaken for 7 Queensland Shires using ABS data and multiple regression (Equation (ii)). This revealed a positive and statistically significant yield trend in 2 of the 7 Shires (one of them Bungil) and a negative trend in one. Equation (ii) resulted in more statistically significant trends than Equation (i), but no difference in overall result.The area sown to wheat had trended up or down, depending upon the Shire, and the area of sorghum had increased in some Shires, but there was little evidence that cropping systems had changed and their productivity increased as determined by the $WUE.

It is important to note that the positive yield trends amongst these 7 Shires were only significant when May SOI was included in the regression equation, and that the trends were greater (40-50 kg/ha/yr) than Equation (i) had indicated for much the same period (1975-93) or for 1950-91 (1). This suggests that seasonal effects associated with the SOI were stronger for winter crops in the 1975-90 period than in the period 1950-1975. Accounting for SOI effects provides a more sensitive test for yield trends over time.

The effect of May SOI was also significant in 6 of the Shires. The May SOI appears to be acting as a surrogate for seasonal effects in addition to those already accounted for in rainfall or potential transpiration. These effects could include frost, opportunities to plant on time, and temperature and vapour pressure deficit during grainfill. It was notable that May SOI was significantly correlated to the areas of both winter and summer crop sown. It appears that grain growers have historically read this climate signal and adjusted crop areas accordingly. We suggest that further gains from formal use of seasonal forecasts based on SOI, to determine areas to plant, may be small.

Analyses of wheat yield trends were made of Queensland Wheat Board data for silos central to the 7 Shires for which ABS data were analysed. These data , analysed using Equation (ii), yielded no better evidence for positive yield trends than our other analyses. Any weak positive yield trends were in older wheatgrowing Shires where the wheat area was declining, despite rapid expansion elsewhere during the study period. This pro-vides some support for the suggestions that expansion of cropping onto poorer soils could partly explain the poor yield trend in some Shires.

Case studies

Regressions of yield over time on 22 farms failed to uncover any cases of positive trends in wheat yields. An estimate of potential transpiration was used to determine an apparent transpiration efficiency of wheat for each year of the record on each farm. The apparent transpiration efficiency was used as an index of wheat productivity (TEI) through time. The variables which significantly affected TEI are discussed below.

Nitrogen. The TEI of wheat increased significantly in recent years on three of the 22 farms. This appeared to be related to the use of nitrogen (N) fertiliser at rates varying from 20-40 kg/ha N. The associated increase in TEI varied from 2.7 to 3.1 kg/ha/mm. N fertiliser was rarely applied without phosphorus (P) fertiliser, although the use of P fertiliser usually pre-dated the use of N fertiliser. Hence, we cannot confidently isolate the respective effects of these two nutrients on TEI.

Phosphorus. The average TEI of wheat in the last eight years (1989-96) on each case study farm reflected the phosphorus status of those farms. Two measure-ments of soil P were found to be useful for quantifying this effect. One was based on Colwell P (loge transformed) while the other was based on the difference between Lactate P and Colwell P. Our work suggests that the difference between the two tests is most useful in the assessment of soil phosphorus status on alkaline soils low in Colwell P (15 mg/kg). Colwell P was low in 60% of samples derived from case study farms and almost all soils were alkaline. Soil P status accounted for 34% of the observed variation in TEI of wheat on farms extending from Central Queensland to northern New South Wales. This suggests that wheat productivity is limited by a shortage of P across large tracts of the northern region.

Soil biology. The ratio of fungal to bacterial activity as determined by the FAME technique contributed to the explanation of TEI variation between farms. When the inverse of this ratio was introduced into the regression equation that already included soil P status, it lifted the resultant explanatory power of the regression equation, explaining variation in TEI from 34% to 45%. That high bacterial activity relative to fungal activity appears to favour high TEI, suggests that at least some of the fungal activity is pathogenic. We speculate that high bacterial activity may suppress the adverse impact of these pathogenic fungi on wheat productivity. A low bacterial to fungal ratio is normally considered unfavourable (Pankhurst *pers. comm*.).

Focus groups

Farmers agreed that yields had not increased in 25 years, with the exception of the North Star area, as our analysis had shown. These farmers had a long history of fertiliser use, which was related to a particularly strong extension infrastructure. Many North Star farmers had moved to the area from southern Australia and brought with them a culture of fertiliser use. Farmers in the Roma area, whilst not reporting historical yield increases, were optimistic. New technology had recently been adopted and there was strong industry leadership supporting a positive outlook that encouraged investment. These farmers expressed the view that they would enjoy greater productivity growth 'once seasons returned to normal'. This raised questions about 'normality' and the prospects for grain growing, if the pre-1985 period of crop area expansion had occurred in a period of above average rainfall. In two groups the positive outlook needed for investment was lacking.

Whilst all farmers rightly blamed poor winter rain for poor yields during the 1990's, particularly in Queensland, they also recognised that the rainfall which had been received was not being used efficiently. Farmers were receptive to case study results pointing to low fertility as an explanation for poor yield trends. However, they did not generally value alternative crops to wheat for their capacity to restore fertility or manage diseases. Ley pastures were rarely used in rotation with crops.

Conclusions

There was little evidence for wheat yield increases in the last 20 years using analytical approaches designed to remove the effect of interannual rainfall variation on yield, confirming the report by Hamblin and Kyneur. Nor was there evidence that cropping systems had increased in overall productivity as a result of changes in cropping intensity that may have reduced wheat yields. Despite the disappointing overall trend for the northern region, there were significant differences in farm productivity within Shires. From a survey of 22 farms, productivity growth appeared to be related to the use of N fertiliser at rates varying from 20-40 kg/ha N. There was also strong evidence that wheat productivity is limited by a shortage of P across large tracts of the northern region. There was some evidence that high bacterial activity may be suppressing the adverse impacts of pathogenic fungi on wheat productivity in some soils.

Although reduced winter rainfall since the mid 1980's accounts for low yields, the yield trend analysis shows that the rain received has generally been used inefficiently. For most farmers, low soil fertility evidently limits the capacity of crops to utilise the available water. Widespread adoption of technology to restore and maintain fertility in one Shire, with a good yield trend, seemed to be associated with historical and contempor-ary social factors. Sustainability in the region may depend on long-term rainfall.

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