THIRTY YEARS OF CHANGE IN SOUTH AUSTRALIAN BROADACRE AGRICULTURE: TREND, YIELD AND PRODUCTIVITY ANALYSES OF INDUSTRY STATISTICS FROM 1977 TO 2006

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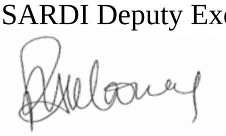
Signed: 

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Thirty Years of Change in South Australian Broadacre Agriculture: Trend, Yield and Productivity Analyses of Industry Statistics from 1977 to 2006

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Glossary of Terms

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
APSIM	**A**gricultural **P**roduction **S**ystems s**IM**ulator
CPI	consumer price index
$2005	value expressed in terms of the value of the Australian dollar in 2005, using the Adelaide consumer price index
DSE	dry sheep equivalent
HRZ	the ABARE SA high rainfall zone
IFP	input factor productivity
K	potassium
MLA	Meat and Livestock Australia
N	nitrogen
OFP	output factor productivity
OLS	“ordinary least squares” statistical analysis
Oz-Wheat	A program that predicts region crop area and production based on historical records, APSIM predictions and using 1993 crop growing technology
P	phosphorus
PISA	Primary Industries South Australia
PIRSA	Primary Industries and Resources South Australia
R&D	research and development
R&E	research and extension
RD&E	research, development and extension
SA	South Australia(n)
SARDI	South Australian Research and Development Institute
Settled areas	the ABARE SA HRZ and WSZ
TFP	total factor productivity
TOT	terms of trade
WSZ	the ABARE SA wheat-sheep zone

These terms are defined in the text at first use only, except where used in headings.

Abstract

This report

- presents a review of important trends in the Australian Bureau of Agricultural and Resource Economics (ABARE) data on South Australian (SA) broadacre agriculture, concentrating on the settled areas (the ABARE wheat-sheep zone and the high rainfall zone) for the period 1977 to 2005[1, 2],
- estimates total factor productivity (TFP) increases in various sectors of SA broadacre agriculture,
- provides a detailed analysis of the determinants of wheat yield,
- provides statistical analysis of the elements of input factor productivity (IFP), output factor productivity (OFP) and TFP in the sectors examined, as well as cash costs, in order to determine which factors were most influential in productivity growth,
- discusses the impact of the dry seasons in the last three years (2006-2008) on the evolution of broadacre farming, as well as the future evolution of farming, and
- discusses the implications of the results, particularly in relation to R&D management.

Prices for farm outputs

In terms of prices indexed to a particular year, in this case 2005, trend analysis shows that within the major commodities <u>wool prices</u> have fallen the most from 1977-2005 (45 percent). They are also the most volatile. <u>Sheep and beef prices</u> are now (2005-2008) approximately the same as they were in 1977 in real terms. They started to trend upwards from around 1995. At their worst in the early 1990s sheep prices were 60 percent lower than in 1977 and beef prices 20 percent lower. In 2005 <u>wheat prices</u> were 40 percent lower than in 1977 in real terms and <u>barley prices</u> 25 percent lower. However, both started to trend upwards from around 2000. <u>“Other grains”</u> prices have trended upwards steadily, and were 100 percent higher in 2005 compared with 1977, mainly but not exclusively due to the increasing canola component in this category.

Farm numbers and average farm size

SA broadacre farms became fewer between 1977 and 2005, from 11,500 to 8,000, at an average rate of 145 a year, so average farm size has increased by close to 30%. Increasing farm size, resulting in increasing economies of scale, is one of the ways surviving farmers have maintained viability.

<u>The sheep, sheep/beef and mixed crop/livestock categories</u> of properties each behaved in a similar manner: in the reduction in property numbers over the period and the increase in average property size. The decline in both the numbers of sheep and sheep/beef properties can be ascribed to low wool prices since the early 1990s. The decline in crop/livestock properties is probably due mainly to a switch to specialised cropping.

While there are relatively few properties in this category, <u>beef property numbers</u> increased and farm size decreased considerably – from a 139,000 ha average in 1977-

[1] Note that other data in this report cover the period 1977-2008

[2] ABARE data covers financial years. The crop production reported in each financial year is for the earlier year. I.e. crop production for 1983-1984 was for the 1983 growing season. The convention of awarding the data to the earlier year has been adopted in this report, including livestock outputs.

1980 to a 26,000 ha average in 2002-2005. This appears to be mainly attributable to an increase in beef properties in the high rainfall zone.

There was an increase of 25 percent in the number of properties in the crop category. There was no increase in average property size, however. The fact that there was no significant increase in property size in the crop specialist category indicates that productivity improvement was the most important way that cropping properties remained viable.

Revenue and production

Total revenue from the major outputs of SA broadacre agriculture trended downwards in real terms between 1977 and 1990. Since then it has increased. In 1977-1980 livestock products contributed around 60 percent of total farm revenue. Between 1996 and 2005 they contributed around 40 percent. In particular, wool revenue has markedly declined as a proportion of the total since 1990. After a relative decline in the middle years (1985-1995), cattle and sheep sales have undergone a minor revival in terms of their proportional contribution. Wheat and barley revenues contributed an increasing proportion of total revenue until around 1997-1998, as have the "other grains" category from a low base.

Wheat and barley production increased by over 100 percent, largely through a combination of increasing yield (see below) and an increase in cropping intensity. "Other grains" increased by over 700 percent, the latter consisting of increases in grain legume production up until the early 1990s and canola production increases since then. After increases in production to around 1990, sheep meat and wool then declined and sheep meat then stabilised to similar levels at the end of the period as at the beginning. Prime lamb has been an increasing proportion of sheep meat production since the mid 1990s. Wool production was less than at the beginning. Beef cattle production decreased and then recovered strongly so that it was greater at the end of the period than at the beginning.

Wheat and barley yields

Both wheat and barley yields have tended to plateau from the late 1990s until the present (2007-2008) but, overall, barley has achieved a higher annual yield gain (2.3 percent p.a.) than wheat (1.8 percent p.a.). The plateauing may be due to a declining average seasonal rainfall trend.

In a more sophisticated analysis, wheat yield efficiency improved by an estimated average 1.7 percent p.a. with a slight, but significant, negative curvilinearity towards the end of the period. In a longitudinal analysis, significant positive explanatory variables for improved yield efficiency were increased fertiliser use and improvements in wheat price compared with canola from time to time. Significant negative explanatory variables included wheat terms of trade, wheat area sown and the combined area of grain legumes and canola. The systems components of annual wheat efficiency improvements were divided into varietal yield gain and improved farming systems, with farming systems further partitioned into earlier sowing times and "other" changes. Wheat varieties have contributed an estimated 0.5 percent p.a. to efficiency improvement and hence, by difference, 1.2 percent p.a. is attributed to farming systems improvement. Under our assumption for the change in average sowing time over the period, the farming systems components that have enabled this change (e.g. larger and more efficient machinery, more effective and efficient use of better herbicides, etc) have contributed 0.7 percent p.a. Hence, again by difference, other factors of improved systems (e.g. more effective crop nutrition, effective rotations, etc) have contributed 0.5 percent. The annual improvement due to farming systems (1.2 percent p.a.) comes at a cost of 0.1 percent p.a. increase in farm inputs.

Sheep and cattle stocking rates and net turnoff, and wool production

Overall, per grazed ha, wool production in the settled areas decreased by 1.0 percent p.a. over the 1977-2005 period. In the high rainfall zone (HRZ), stocking rate increased by 1.1 percent p.a. and net turnoff by 1.8 percent p.a. In the wheat-sheep zone (WSZ) the corresponding figures were 0.1 percent p.a. and 0.4 percent p.a.

Over the settled areas the wool production trend was composed of an increase in production per grazed ha until around 1988-1990, which coincided with high wool prices, followed by a decrease in production until the late 1990s, and has leveled off thereafter. Average stocking rate followed similar trends. However, net turnoff has increased steadily over time. Relating the stocking rate and net turnoff trend lines, it seems that broadacre farms in the settled areas have become progressively more efficient in turning animals off for market. This, in turn, is related to the sheep industry becoming progressively more oriented towards prime lamb production.

The large differences in stocking rate and turnoff improvements between the WSZ and HRZ reflect the fact that the HRZ is still largely comprised of livestock specialist properties, and there is adequate rainfall to allow intensification of grazing industries. By contrast, in the WSZ there has been a large increase in cropping intensity, relegating animal production to the less productive land.

Change in farm inputs

From 1977 to 2005 the quantity of fertiliser per ha applied to cropping land increased approximately three and a half fold and that of chemicals increased approximately six-fold.

The amount of fertiliser applied to pastures fluctuates widely over time. It is strongly related to livestock revenue per ha – a 1 percent increase in revenue produces a 1.3 percent increase in the index of fertiliser applied.

The quantity of livestock materials (drenches, dips/jets, vaccines, livestock tags) used per dry sheep equivalent (DSE) increased steadily from 1977 to 2000, despite decreases in livestock and wool prices between 1990 and 2000. Since then the use of livestock materials has increased dramatically, probably due to the enforced use of electronic ear tags for cattle and the progressive adoption of expensive slow release worm drench capsules.

Owner/operator, family and hired labour per ha, in total in the settled areas has progressively declined since the mid 1980s and is now roughly 75 percent of what it was in the 1977-1985 period.

Machinery in use per cropped ha and per DSE has dropped by 20-25 percent over the 1977-2005 period.

Paid advisory services per farm increased by nearly nine-fold between 1989 and 2005, from $64 to $560, in real terms.

Farm financial performance and family income in the settled areas

The equity ratio is quite high in both the WSZ and the HRZ, and is currently around 90 percent. If anything, it has risen since 1990. This high level may reflect a conservative approach to debt in the face of fluctuating incomes, and may also reflect the relative success of farmers who operate at high equity ratios. A one percent increase in rate of return results in an increase in equity of 1.3 percent in the high rainfall zone and 0.9 percent in the wheat-sheep zone.

Property rate of return (profit plus imputed labour value plus capital gain) has stabilised at around 10 percent per year in the WSZ and has recently increased to around that same figure in the HRZ. This increase in the HRZ was probably due to the increase in beef and sheep meat prices translating into higher prices for livestock sold. The 29-year average rate of return in the HRZ is 8.0 percent and that in the WSZ is 10.8 percent. If it is accepted that farmers take a holistic view of income, and most of the ownership in a property is that of the farm family, then these averages seem reasonable compared to a risk-free real rate of return of 5 percent. The additional 2.8 percent return in the WSZ can be viewed as a risk premium for farming in a zone where drought years strongly impact on yield from grain crops. Most of the income is in the form of capital gain: the farm profit plus imputed labour return on capital measure is 2.9 percent for the HRZ and 3.9 percent for the WSZ. Average family income from the farm, inclusive of capital gain, in the HRZ zone is now around $80,000 per year and in the WSZ it is around $100,000. Off-farm wages have increased markedly and now contribute a significant amount to total family income in both zones: averaging $13,000 in the WSZ and $23,000 in the HRZ.

Productivity improvement and cash costs

TFP growth was not significantly different from zero on sheep properties and only marginally significantly different from zero on beef-sheep properties (0.8 percent). It was only 1.1 percent per year on beef properties. These results are disappointing, particularly in relation to those achieved by cropping properties (3.2 percent) and, to a lesser extent, mixed crop-livestock properties (1.9 percent).

There is no lack of research in SA devoted to livestock and pasture systems, as well as interstate and overseas. This research should translate into usable technology and, if attractive to farmers, eventually be measured as TFP gains. Unfortunately, these results show little evidence for substantial productivity gains in the livestock, particularly sheep, industries.

Crop yield increases are the major cause of the superior TFP performance on crop and crop-livestock properties compared to livestock specialist properties (inputs per cropped ha have remained relatively constant). However, yield increases in wheat and barley, the predominant crops in SA, have plateaued from the late nineties until the present (2006-2008), causing a plateauing of productivity growth in these property categories.

There was a considerable degree of commonality in the drivers of cash costs for both zones and property types, except in the case of the crop specialist properties. These included, variously, livestock purchases, hired labour, machinery in use, cropping contracts, fertiliser, purchased fodder and livestock materials. The best model for predominantly cropping properties included only machinery in use, chemical usage and cropping contracts, although fertiliser was a near perfect substitute for chemicals. This near perfect substitution suggests that, in any given year, crop farmers cannot afford to increase both at once to the desired level, and thus they alternate the necessary increases over time.

Possible adverse climate change and the recent run of poor seasons

If potential wheat yields, as predicted by a 10 mm sowing rule (sowing occurs after 10 mm has fallen within 3 days after April 1st) in the Agricultural Production Systems Simulator model (APSIM), at Minnipa and Turretfield are taken as a guide, 5-year rolling mean analysis indicates that the broadacre farming community has faced a recent set of growing conditions that are as difficult as they have been in the historical record since 1900. If high order polynomial analysis, which subtly admits the possibility of adverse climate change because of the downward trend this century, is taken as a guide, current SA broadacre growing conditions are indicated as being worse than they have ever been in the historical record since 1900.

Current and Future Broadacre Farming Evolution

The dominant features of the 2006-2008 growing seasons were (a) a drought in 2006 and dry seasons in 2007 and 2008, and (b) large increases in important input prices and grain prices, but not livestock prices except wool. The consolidation into larger properties is likely to have accelerated, because drought and dry seasons, exacerbated by high input prices, will have made the smaller and less efficient producers increasingly less viable, particularly in low rainfall regions where crop yields are lower.

Kingwell (2008) forecasts trends towards 2020, including:

- increasing property size
- farmland as a supplier of renewable energy and source of greenhouse gas emission offsets
- biotechnology increasingly underpinning productivity improvement and new product development
- greater dependence on electronic technologies, and
- the effects of climate change largely addressed through incremental technological improvement, plant breeding and design of novel farming systems.

1 Introduction

Our initial motivation for analysing the historical statistics used to derive this report was to elucidate trends of significance for RD&E. However, it became evident that a report of our analyses would be of wider interest, especially for those who are industry participants. We hope that readers will find the contents interesting and useful.

It is worthwhile emphasising to those readers from broadacre properties that this report deals with industry averages and trends over time in order to identify average industry behaviour. An individual farmer's tactics over time may have differed considerably from the norms shown in this report.

It is in the best interests of producers to minimise farm inputs for a given level of output (which, over time, is a simple definition of productivity improvement), in order to maximise profit[3]. Even when the prices of outputs are increasing, such as during recent surges in grain and meat prices, this principle applies. Productivity improvement in Australian broadacre agriculture is of paramount importance in the face of declining terms of trade (TOT), i.e. when prices of farm inputs (labour, capital, other inputs such as fertiliser) are increasing faster than the price of its outputs (grains, sheep, wool and beef sold). Apart from short-term fluctuations, for the second half of the 20th century there was an inexorable long-term decline in Australian farmers' TOT. There are signs that this trend has ended, however (Figure 1), in sympathy with a recent, seemingly longer-term upward trend in food prices (FAO 2007). On the basis of a fixed farm size and mix of outputs, the only way an average farm will remain viable when TOT are declining is to improve productivity at a rate that is at least equal to the decline in TOT[4]. Australian farmers' TOT have declined by an average of 1.7 percent per year in the period 1977-2005, whereas SA broadacre farm TFP has increased by an average 2.5 percent over the same period (Figure 2).

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[3] Because of the nature of farming, this principle does not necessarily apply in any given year – for example a good season that produces good returns may allow farmers to apply more fertiliser to pastures in the next season, which may turn out to be a drought year. Hence the statement is probably more correct if the phrase "in the medium to longer term" is added.
[4] Technically, this statement is also dependent on a lack of "supernormal" profits in the industry.

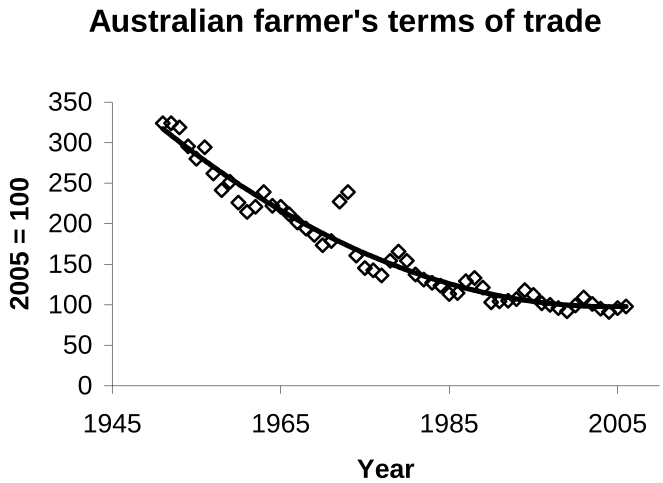


Figure 1: Terms of trade for Australian farmers from 1977 to 2006. Source: ABARE (2007)

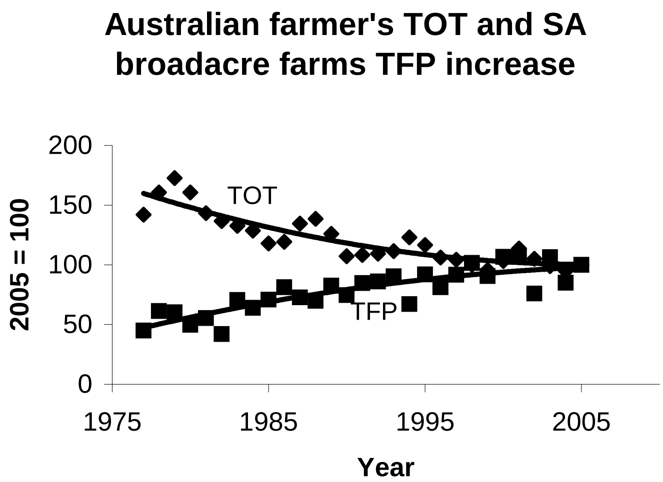


Figure 2: Decline in Australian farmers' terms of trade and increase in SA broadacre total factor productivity from 1977 to 2006.

A rate of change in the TFP[5] of an industry sector over time is defined as the rate of change in its outputs less the rate of change in its inputs[6]. This report examines the determinants of TFP growth in SA broadacre agriculture from 1977 to 2005 by statistically analysing the composition of output factor productivity (OFP) growth and input factor productivity (IFP) growth, to determine the factors that were most influential in their growth.

It is well recognised that improvements in available technology, together with their innovative use, bring about improvements in TFP. R&D produces these new

[5] Sometimes the term multi factor productivity (MFP) is used instead of TFP. The reason is that the MFP term implicitly recognises that the measure of inputs into a production system cannot reasonably be exhaustive. For example the practice of agriculture may be subtly degrading or improving the soil on the farm, thus altering the status of this input over time, and this remains generally unmeasured.
[6] More strictly, the rate of change in TFP is the rate of change in OFP less the rate of change in IFP.

technologies, and these come from research institutions, such as South Australian Research and Development Institute (SARDI), and firms servicing the rural sector, such as machinery and agrichemical companies. Typically these "technologies" might consist of increasingly cost-efficient machinery and herbicides in the case of private sector companies, and higher yielding crop varieties and more sustainable farming methods in the case of research institutions. Therefore, the importance of individual factors that contribute to TFP increases are of interest for agricultural R&D management and strategy, because these factors may provide an indication of the effectiveness of different types of R&D.

ABARE (2007, 2000) provides a comprehensive data set of statistics for broadacre agriculture in SA (and for other States and Australia as a whole). These data show inputs and outputs in a range of categories over time. Hence statistical analyses can be carried out to determine categories that are significant determinants of changes in IFP and OFP[7]. While these categories of data, broadly described in *2.7*, are highly imperfect measures of the impact of particular technologies, they have the potential to provide useful indications of such impacts.

ABARE data do not include sub-categories of outputs and output prices (for example wheat produced is not disaggregated into the standard grades with accompanying values for each grade). This means that it is not possible to incorporate quality improvements into the OFP measures using ABARE data alone. Quality improvement has been incorporated into the measures for the main broadacre outputs – wheat, barley, sheep sold, wool and beef cattle sold. An outline of the technique used is shown in Appendix 1.

For the period 1977 to 2005[8], this report

- Presents a review of important trends in the data,
- Estimates TFP increases in various sectors of SA broadacre agriculture,
- Provides a detailed analysis of the determinants of wheat yield,
- Provides statistical analysis of IFP, OFP and TFP in the sectors examined, as well as cash costs, in order to determine which factors were most influential in growth,
- Discusses the impact of the dry seasons in the last three years (2006-2008) on the evolution of broadacre farming, as well as the future evolution of farming, and
- Discusses the implications of the results, particularly in relation to R&D management and future funding emphasis.

ABARE publishes its data for broadacre agriculture in various categories. Some of these categories were not suitable for statistical analyses and are not therefore included in this report. The choice of some categories for analysis and rejection of others is discussed in detail in the following section. The categories chosen for analysis were:

- SA broadacre agriculture as a whole

Characterisation by major output

[7] i.e. Rates of change of physical inputs (IFP) and physical outputs (OFP) over time.

[8] ABARE data covers financial years. The crop production reported in each financial year is for the earlier year i.e. crop production for 1983-1984 was for the 1983 growing season. The convention of awarding the data to the earlier year has been adopted in this report, including livestock outputs.

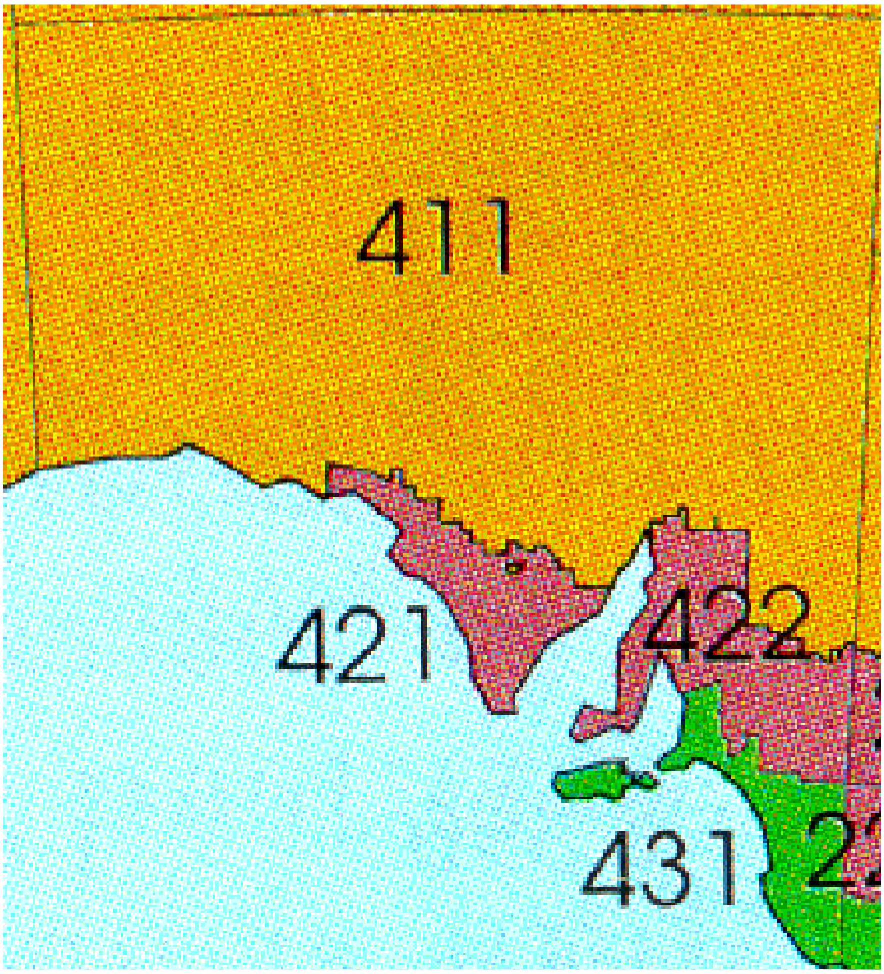
- Grain production enterprises (the predominant output, in terms of value, from these properties was grain),
- Mixed grain/livestock production enterprises,
- Sheep production enterprises,
- Beef production enterprises,
- Sheep/beef production enterprises,

Characterisation by geography (Map 1)

- The WSZ, and
- The HRZ[9].

The last two categories encompass most properties in the five enterprise categories. The pastoral zone, which encompasses the remaining properties, was not included in the analyses because the basis of the ABARE sampling in this zone gave data that were not indicative of "pastoral" properties in general[10].

Map 1: ABARE Zones of SA (411 = pastoral zone, 421 and 422 = wheat-sheep zone, 431 = high rainfall zone)



[9] Mount Lofty Ranges, Fleurieu Peninsula, Kangaroo Island and Southeast.
[10] This issue is discussed in detail in the next section.

An early comment on this report was that it did not reflect what might be happening to broadacre farming systems in the light of the recent run of poor seasons (the ABARE statistics ended in 2005-2006), as well as how they might evolve in the future. In *3.9* the issue of poor recent seasons is addressed, through the prism of the historical record of potential wheat yields at Minnipa and Turretfield, particularly in the light of possible adverse climate change. In **4** the authors' suggestions on the continuing and future evolution of SA broadacre agriculture are given.

One of the largest transformations in the broadacre production industries in the past 30 years has been the decline of the wool industry and the change in the structure of the sheep industry as a whole. The period saw a number of changes relating to the deregulation of the wool industry in particular and broadacre industries in general. The removal of the minimum price for wool, dismantling of the wool stockpile, removal of the guaranteed minimum price for wheat, the floating of the Australian dollar and subsequent high interest rates for a number of years all had a profound effect on on-farm decisions relating to choice of industry in which to participate. The collapse of wool prices in the early nineties, coupled with more recent difficulties in the live sheep trade, has seen the financial incentives to grow merino wool and sell mature sheep, except as a necessity, diminish markedly. While this report is predominantly about trends, with a focus on productivity improvement, it needs to be noted that political decisions, translated into deregulation, have contributed to price-induced structural changes in SA broadacre agriculture.

2 Data and Methods

2.1 Data sources

ABARE (2008, 2000) data come from two electronic sources: ASPIRE: 1977-1999 and AGSurf: 1990-2005, and ongoing. They are presented in the form of property averages in each category. In summary, these databases contain statistics on physical production and its value (e.g. tonnes of wheat produced and wheat receipts), area of crops and farm costs (e.g. payments for repairs and maintenance)[11].

These two databases were joined by the authors to form a coherent series from 1977 to 2005 inclusive – 29 years of data. The ASPIRE data are in nominal terms, i.e. the value in the year of production/purchase. Hence the appropriate index was applied (ABARE 2007, and back copies) to recalibrate these values to 2005 dollars.

Unfortunately, some cash cost variables of particular interest in terms of R&D impact were categorised together in the ASPIRE data early in the period. In particular the value of "crop and pasture chemicals", "fertiliser", "seed" and "fodder" were bundled together for the 1977-1989 period. For the 1977-1989 period the proportions of variables in the integrated category were "back cast", based on the proportionate trends in the 1990-2005 data. In addition, the "advisory services" category did not appear in the ASPIRE data. This category was dropped from the analysis. The alternative was to guess the 1977-1989 data for this category, based on a back cast methodology. This was deemed to be too compromising for analytical purposes.

There was some change in other categories of data between the two databases. In particular, subsections of the capital categories changed.

ABS (7000 series) and PIRSA (2008 and back copies) data were also used for the detailed wheat yield increase analyses.

2.2 Choice of industry sectors for analysis

ABARE offers data in the following SA broadacre categories:
1 By dominant product - grain, mixed crop/livestock, sheep, beef, sheep/beef;
2 By geographical zone - pastoral, wheat-sheep, high rainfall;
3 By value of annual production - < \$100K, \$100-200K, \$200-400K, > \$400K.
4 By region – However in SA only the wheat zone is divided - into 2 regions: Eyre Peninsula and the remainder

Category 3 is offered only on the AGSurf database. Hence there is only a 15-year time series. The constituent populations of enterprises falling into these categories may change significantly between drought years and more normal years. Finally, as time elapses there is likely to be a strong trend towards the higher value categories. For these reasons – a markedly reduced time series and unstable populations within categories – it was decided not to perform statistical analyses on the basis of "value of annual production".

[11]There are also incomplete longitudinal data on physical amounts of fertiliser purchased and area fertilised.

Data from the pastoral zone in category 2 showed a large and statistically significant increase in the contribution of grain to the output. This is incompatible with production from the vast majority of land within the SA pastoral zone, where viable cropping is not an option. There is a small area where cropping is economically viable which is included in the Pastoral zone because of local government boundaries. In addition to a general increase over time in cropping across the state in areas where this activity is economically viable, changes in local government boundaries resulted in more area where cropping is viable included in the pastoral zone. Because of these influences, it was decided not to include pastoral zone statistical analysis in this report.

Category 4 does not differ from the zone classification except for the WSZ, which is divided into two. However this zone division may add little value to an analysis because both regions encompass areas of relatively high and relatively low seasonal rainfall. In SA, differences between regions whose boundaries are based on average rainfall appear to be those of greatest significance in terms of productivity differences (Black 1998, 2004).

Broadacre SA as a whole, the Category 1 enterprise divisions, and the WSZ and HRZ were therefore those subjected to detailed statistical analysis.

2.3 Estimates of quality improvements in outputs

Qualitative estimates of quality improvements were used for wheat, barley, wool, sheep and beef cattle sold. These were based on interviews of persons with a long experience and deep knowledge of the quality changes in these products[12]. The reason for this approach was that the statistics available only provide average data – e.g. tonnes of wheat sold and its value. Such undifferentiated data do not lend themselves to capturing product quality increases. Details of the methodology and the individual quality index multipliers for each commodity are shown in Appendix 1.

2.4 Analyses of trends in the data

A range of important trends in these data will be presented in Section 3 without recourse to sophisticated analysis, but trend analysis will be used, quantitatively, in some cases.

2.5 Statistical analyses of TFP and cash costs[13]

An econometric approach to statistical analysis of these types of data is to choose a procedure that is consistent with microeconomic theory. Under conditions approaching perfect competition, microeconomic theory predicts that producers

[12] Mick Deland, SARDI, in the case of the cattle industry and Guy Wheal, sheep producer, in the case of the sheep industry helped provide the qualitative data via interview. Ken Saint, ABB Grains, helped provide the qualitative barley data via interview. Note, however, that the final estimates are the responsibility of one of the author's (Black) alone.
[13] This section draws heavily on Alston, Norton and Pardey (1995) pp 121-125.

choose minimising levels of inputs for a level and mix of outputs that maximises profits[14].

In Figure 3 Q_{t0} represents the attainable quantity of output using a given state of technology where X_1 and X_2 represent varying quantities of two physical inputs, in a hypothetical situation where only these 2 inputs are required to produce Q. The value W_{t0} represents the price of X_2 relative to X_1 at time t0, and cost minimising producers will use the combination of inputs, $X_{1,\,t0}$ and $X_{2,\,t0}$ at point A. By time t1, technology has changed and Q_{t1} represents the quantity of output with the new technology. W_{t1} represents the price of X_2 relative to X_1 at time t1 (not necessarily different from W_{t0} but expected to be), and cost minimising producers will use the combination of inputs, $X_{1,\,t1}$ and $X_{2,\,t1}$ at point B.

Technical change, price change and input substitution

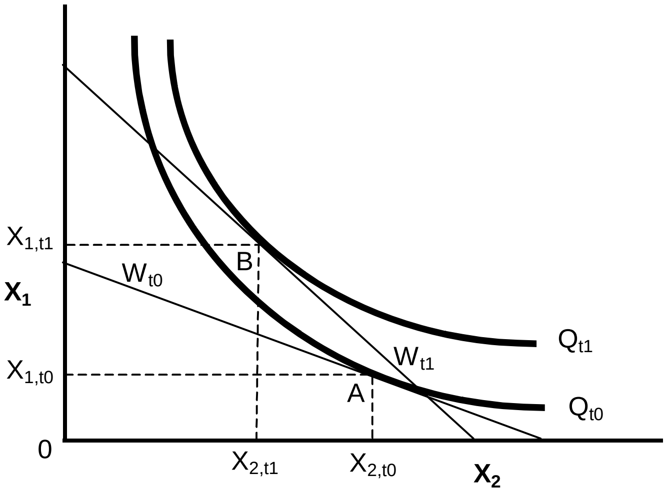


Figure 3: Diagrammatic representation illustrating the relationship between technical change, price change and input substitution.

Various complications arise when attempting to accurately measure changes in use of inputs, because of the relative price changes of X_1 and X_2 between t0 and t1. The method commonly used to minimise the impact of these price changes is to use a *Divisia* indexing procedure when forming aggregate quantities of inputs. In this case the *Fisher ideal* approximation was used.

An analogous situation is shown in Figure 4, for outputs. PPF_{t0} represents a production possibility frontier at time t0, composed of two outputs, Q_1 and Q_2. Given the relative price of Q_1 and Q_2, shown by P_{t0}, $Q_{1,\,t0}$ and $Q_{2,\,t0}$ will be produced at A. At time t1 technology has changed, and PPF_{t1} represents the new production possibility frontier, and the relative price of Q_1 and Q_2 has changed, and is represented by P_{t1}. Under these new conditions, $Q_{1,\,t1}$ and $Q_{2,\,t1}$ will be produced at B. Again, various complications arise when attempting to accurately measure changes of outputs, because of the relative price changes of Q1 and Q2 between t0 and t1. Again, the

[14] Or, alternatively, they minimise costs for a given level and mix of outputs. In microeconomic theory the two behaviours are equivalent.

method commonly used to minimise the impact of these price changes is to use a *Divisia* indexing procedure when forming aggregate quantities of outputs.

Technical change, price change and output substitution

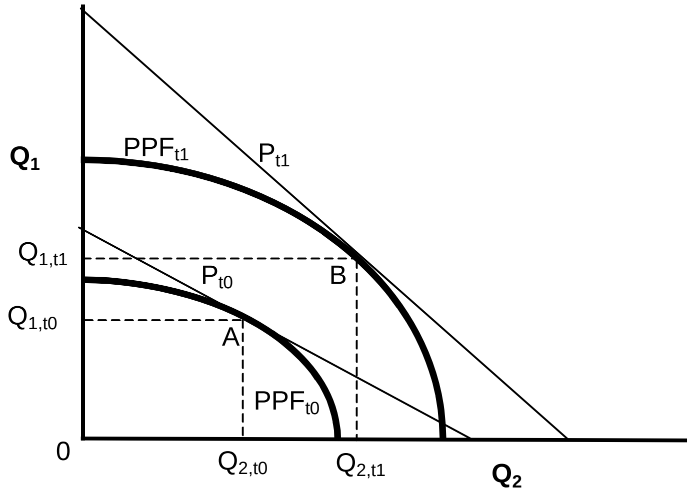


Figure 4: Diagrammatic representation illustrating the relationship between technical change, price change and output substitution.

<u>Total factor productivity (TFP)</u>
Microeconomic theory does not provide a framework for support of statistical analyses that directly link changes in inputs and outputs to total factor productivityTFP change. The static situations presented in Figures 3 and 4 reflect this **(**notice that in the description of Figures 3 and 4, it simply states that Q (Fig. 3) and PPF (Fig. 4) have shifted between t0 and t1). The reason is that technical change is treated as exogenous, occurring outside of the factors – price and quantity of inputs and outputs - that drive the production system in the short-term. However, this lack of accepted theory does not necessarily invalidate a statistically significant link between such categories and TFP growth. In other words, correlation is principally interpreted as causal, not merely association. In addition, “exogenous” is a matter of degree. Most agricultural R&D is ultimately aimed at producing new technology that improves farm productivity or safeguards the physical agricultural environment. Hence, in a more dynamic framework for economic behaviour, technical change derived from agricultural R&D becomes an important part of evolving production systems and, in that sense, is therefore embedded in the production system. Therefore results of statistical analyses of input and output explanatory variables regressed against TFP are presented.

<u>Cash costs</u>
Cash costs, appropriately indexed, represent the most important contributor to the various inputs that comprise the IFP index. Therefore, once a statistically significant relationship between IFP and cash costs has been demonstrated, it is appropriate to examine statistically those constituent factors within this general IFP variable that have driven its change through time.

2.6 *Indexes*

Fisher ideal IFP, OFP and TFP indexes were derived for the categories of broadacre agriculture stated in *2.2.* The ABARE data are presented in terms of the “average” farm in each category, and these data were used without aggregation (i.e. not multiplying the data by the estimated number of farms). In addition to being widely recognised as perhaps the most sophisticated of the *Divisia* index approximations, the *Fisher ideal* index was also chosen because it is capable of dealing with zeros in the data. For example, in some years barley was not produced on the “average” farm in the beef farms category.

The *Fisher ideal* input factor index aggregation is

$$XI_t = XI_{t-1}\left(\frac{\mathbf{W}_{t-1}\mathbf{X}_t}{\mathbf{W}_{t-1}\mathbf{X}_{t-1}}\right)^{\frac{1}{2}}\left(\frac{\mathbf{W}_t\mathbf{X}_t}{\mathbf{W}_t\mathbf{X}_{t-1}}\right)^{\frac{1}{2}}$$

Where:

XI_t is the input index in period t,

W is the vector of input factor prices, and

X is the vector of input factor quantities

The TFP is compiled using

$$TFP_t = \frac{QI_t}{XI_t}$$

Where:

TFP_t is the TFP index in period t, and

QI is the output factor index (compiled in the same manner as the input index, using output factor prices, **P**, and quantities, **Q**).

<u>Output factor productivity (OFP)</u>

Wheat, barley, and other grains (grain legumes, oilseeds and oats) production, as tonnes produced, wool production (kg produced) and sheep and beef cattle sold, adjusted for increasing carcase weight over time, were the physical outputs entered into the calculations. The relevant prices were also entered into the calculations, according to the formula for the index. In some cases, sheep and beef numbers were combined as DSEs according to the formula of one sheep equals 2 DSEs and one cattle beast equals 10 DSEs (White and Bowman 1985, adjusted for the large frame of the SA merino).

<u>Input factor productivity (IFP)</u>

The imputed value of owner/operator and family labour, cash costs (both indexed to 2005) and area of property were the measures of input factors. The “prices” used were the annual ratio of the relevant category of price index and the consumer price index for the first two factors, and 5 percent of the total capital value of the representative property[15] for the third factor.

[15] This percentage was chosen as representative of a market-based risk-free rate of return on capital.

2.7 Statistical analyses methodology and explanatory variables

An ordinary least squares methodology adjusted for autocorrelation was used, via the econometric statistical package SHAZAM V8.0. Both the subject and explanatory variables (regressors) series were logged, after setting the relevant 1977 values equal to 100. Where the 1977 quantity for some commodities was rather atypical (1977 was a drought year), sensible adjustments were made to the actual 1977 value before it was normalised to 100. The log-log configuration acceptably normalises inter-year variability, which is particularly desirable when dealing with samples from populations where variability can be quite high. It needs noting that some econometricians believe that the log-log configuration provides an inadequate framework to allow expression of <u>marked</u> technological change. However, broadacre agriculture at large did not undergo radical technological change over the 1977-2005 period.

There are 29 years in the data set. A rule of thumb is that the number of regressors included in an investigative, yet robust, model should be no more than approximately the square root of the number of entries in the data set. Hence it was decided to limit the number of investigative regressors in the final analyses to six. An exception to this rule was growing season rainfall, included in the IFP and “cash cost” analyses. It was expected that growing season rainfall could prove significant in these analyses, so it was additional to six other regressors. The reason was that growing season rainfall is regarded as an obvious, dominant year-by-year influence on input decision-making in broadacre enterprises, not an “optional” variable.

Analyses proceeded by working through the list of potential regressors in initial analyses, as outlined below, and progressively reducing their number. The final analyses included only those regressors that were significant at P (probability) < 0.1. This level is not very stringent but it was thought preferable to include factors that may be important rather than risk excluding them by using $P < 0.05$.

<u>OFP explanatory variables:</u>
Sheep sold
Beef cattle sold
DSEs sold
Wool produced
Wheat produced
Barley produced
Other grains (oilseeds, grain legumes, oats) produced
Total grains produced (in the case of beef, beef/sheep and sheep properties)
Other grains area*
Machinery in use

*In addition to reflecting “other grains” production, this variable reflects the well-known value of a break crop in a rotation in terms of reducing disease and weed loads in subsequent cereal crops.

An accurate measure of machinery in use would have been very useful for this exercise. The cost-effective use of efficient machinery is critical for modern broadacre farming. However, depreciation did not contribute as an explanatory variable when regressed against IFP in the WSZ - the zone where a contribution would be most likely. Considerable discretion in the timing of machinery purchases is possible – for example, in times of low cash flow, machinery purchases can be delayed for a year or two if necessary. In hindsight, it was not surprising that depreciation was not significant. A "machinery in use" variable was compiled by the addition of the "fuel, oil and grease", "repairs and maintenance" and a proportion of "depreciation" categories in the ABARE data. The proportion of the "depreciation" category depended on the industry sector – for example it was 90 percent for the specialised crop properties category and 70 percent for the specialised beef properties category. This ratio is a guess about the "mobile machinery" to "new buildings and fixed machinery" ratio for the different property categories.

<u>Cash costs</u>
ABARE provides data for a range of cash cost variables that did not enter into the analyses. These costs include accounting; electricity; fuel, oil and grease; insurance; telephone; other administrative costs; other services; council rates; freight; shearing/crutching; and handling and marketing. Producers were deemed to have little year-to-year control over these variables, as they are part of the inevitable costs of doing business. Their impact was not examined because the essential objective of the report was to examine discretionary behaviour of producers over time.

In addition, it was obvious by inspection of the databases that some other potential explanatory factors exhibited far too much inter-year variation to have any chance of showing a statistically significant relationship with cash cost growth. Hence they were not included as explanatory variable candidates. These cost factors include: land rent; leasing charges; water charges; stores and rations; veterinary fees; produce purchased for resale; agistment; livestock transfers inwards; other livestock (i.e. not sheep or beef cattle) purchased; sharefarmer payments; and livestock contracts. While some farms in each sector examined may show considerable activity in these cost factors, ABARE surveys are based on samples, with independent samples from year to year. Hence, if a significant portion of the randomly sampled population shows little or no activity in these cost variables, considerable inter-year variation will result.

<u>IFP explanatory variables:</u>
Land
Imputed owner/operator and family labour cost
Cash costs
Growing season (April-October) rainfall

<u>Cash costs explanatory variables</u>
Hired labour
Broadacre chemicals (herbicides - mainly, fungicides, insecticides)
Fertiliser
Fodder
Seed
Beef cattle purchases
Sheep purchases
Combined beef and sheep purchases (as an alternative to their use as individual items)
Livestock materials (e.g. drenches, dips, vaccines)
Cropping contracts

Growing season (April-October) rainfall
Machinery in use[16]

2.8 Wheat yield analyses methodology and explanatory variables

<u>SA wheat yields and longitudinal efficiency gains</u>
Oz-Wheat (Potgieter *et al*. 2005) predictions over the 1977-2006 period were used to provide seasonal estimates of SA wheat yields. The program uses mid 1990s technology with a basket of then current varieties, depending on the season. Hence Oz-Wheat provides a reference point in terms of technology in use. ABS (7000 series) and PIRSA (2008) data were used to provide actual seasonal wheat yields over time. It was ensured that these data were from equivalent SA constituent regions to those used in Oz-Wheat. The actual seasonal yields were divided by the Oz-Wheat predictions, and then the estimates were converted to a longitudinal series with 1977 yield[17] = 100.

<u>Estimating efficiency improvements through time</u>
An average estimate was achieved by logging the derived longitudinal series and fitting a linear relationship, with the slope thus representing the average efficiency gain. Curvilinearity was assessed through the use of orthogonal polynomials, representing year, year squared and year cubed, regressed against the logged efficiency longitudinal series. SHAZAM v 8.0 (1997) was used in this and other ordinary least squares (OLS) regressions.

<u>Deriving and assessing the impact of explanatory variables as drivers of yield improvement</u>
ABARE (2000, 2008), ABS (7000 series) and PIRSA (2008) data were used to derive 1977 = 100 logged longitudinal series for wheat terms of trade, wheat/canola price ratio, wheat/grain legumes price ratio, (no. of crop specialist farms)/(no. of crop specialist + mixed crop and livestock farms), wheat area, total crop area, oilseeds area, grain legumes area, grain legumes and oilseeds area, crops other than wheat area, wheat/(wheat and oilseeds + grain legumes area), (wheat area)/(total crops area), proportion of cropping area containing herbicide resistant weeds, fertiliser per ha cropped quantity index (QI), chemicals per ha cropped QI, fertiliser plus chemicals per ha cropped QI. Stepwise OLS analysis, using second order autocorrelation, proceeded until all non-significant explanatory variables were eliminated. In addition to using the derived efficiency series, actual longitudinal wheat yields (1977 = 100, logged) was also used as the dependent variable, with the Oz-Wheat series included as an additional explanatory variable.

<u>Modelling wheat yield increase component contributions as percent annual increases</u>
The following equations represent our modelling assumptions.
(A) Wheat yield increase = genetic gain component + farming systems improvements component
(B) Farming systems improvements = improvement due to earlier sowing + other sources of improvement
(C) Wheat enterprise TFP increase per ha = OFP increase per ha – IFP increase per ha = wheat yield increase – changes in farming systems inputs per ha

[16] Note that the “depreciation” portion of this explanatory variable is not a cash cost.
[17] Sensibly adjusted, as necessary, to take account of the fact that 1977 was a drought year.

Estimating varietal yield gain

To estimate the contribution from cereal breeding for yield, annual comparisons in the same variety trials in SA among the better-performing (‘reference’) varieties that were released in different years establish relative yields in identical situations in the seasons in question. Because relative performance can vary under a range of climatic conditions, representative sites at which the comparisons were made were nominated to cover major regional differences and the comparisons are based on several years of testing. The results from the relative experiments are reported in annual reports of SARDI’s varietal testing.

Estimating wheat growing IFP per ha

See *2.6*, above

Estimating improvement in wheat yields due to earlier seasonal average sowing times

APSIM (Keating *et al*. 2002) was used to model seasonal point estimates of wheat yield at Minnipa Research Centre (a low rainfall cropping environment) and Turretfield Research Centre (a high rainfall cropping environment) for the 1900 to 2007 growing seasons for 15 May, 23 May and 15 June average sowing times. The estimates proved quite stable and second order polynomials were fitted to the results from each site. Our estimate of earlier annual sowing time was a change from a 15 June average to a 31 May average over the 1977-2006 period. There is no readily obtainable data on this variable so it therefore needs to be noted that our estimate is a guess. The Minnipa and Turretfield estimates were combined using the relative mean sowing area in high and low rainfall regions over the review period.

Using APSIM potential wheat yields to estimate climate variability

APSIM (Keating *et al*. 2002) was used to model seasonal point estimates of wheat yield at Minnipa and Turretfield for the 1900 to 2007 growing seasons using a 10 mm sowing rule (sowing occurs after 10 mm has fallen within 3 days after April 1st). The Minnipa and Turretfield estimates were also combined using the relative mean sowing area in high and low rainfall regions over the review period. Five-year rolling means and a combination of 5th and 6th order polynomials were fitted to these data.

3 Results and Discussion

Prices are in 2005-dollar values, i.e. inflation has been removed.

3.1 Prices of outputs

When a farmer has a choice of what to produce, changes in volume of different outputs are dependent to a large extent on the relative prices of those outputs. Likewise farm viability, reflected in farm numbers over time, is also dependent on prices of outputs – if prices of outputs are insufficient to generate a viable income then the least efficient producers will exit the industry and farms will be consolidated into larger units. The discussion on farm numbers and value and volume of production, below, is dependent on relative price changes (in real terms) of the products over the period. Figure 5 shows relative price changes for the major livestock products and Figure 6 shows relative prices for the major grain products, all as fitted trends.

In summary, Figure 5 shows that all livestock output prices declined over the 1977-1992 period, except for a brief and steep increase in wool prices in the late 1980s followed by an equally steep decline in the early 1990s. The pattern in wool prices was repeated early this century. Since around 1995 livestock prices have recovered somewhat. Sheep prices exhibited a greater decline, followed by a greater recovery, than those of beef. In part, this is probably due to the fact that sheep produce two products – wool and meat. Hence sheep price fluctuations could be exacerbated if prices for both products trend in the same direction at the same time. The overall trend in wheat and barley prices has been downward (Figure 6). However, wheat and barley prices have increased a little in the last 5 years to 2005. The trend of barley towards higher priced malting varieties and grades may be the principal reason why the overall drop in relative barley prices is smaller than for wheat. “Other grains” prices have trended strongly upwards, principally due to the high price of canola and the increasing production of this crop resulting in its increasing contribution in the mix. In addition, lentil production increased rapidly from the late 1990s to 2002, and this is the highest price crop in this category. Another reason for the increase in pulse prices is the development of food markets rather than feed markets.

Figure 6 does not indicate the abrupt price rise in grains in 2007-2008, which is outside the scope of this long-term study.

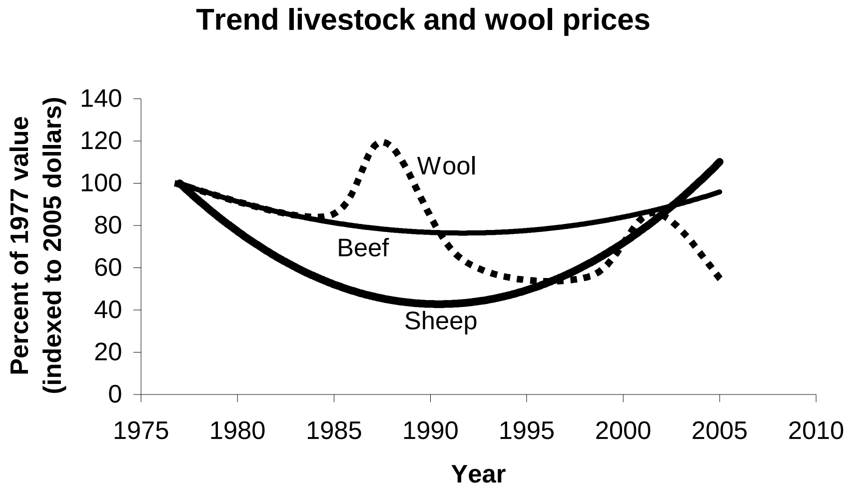


Figure 5: Trends in livestock and wool prices, indexed to 2005 dollars, from 1977 to 2006. The wool price trend line is hand-drawn in order to satisfactorily encapsulate the price changes. For clarity of presentation, original datum points are not displayed.

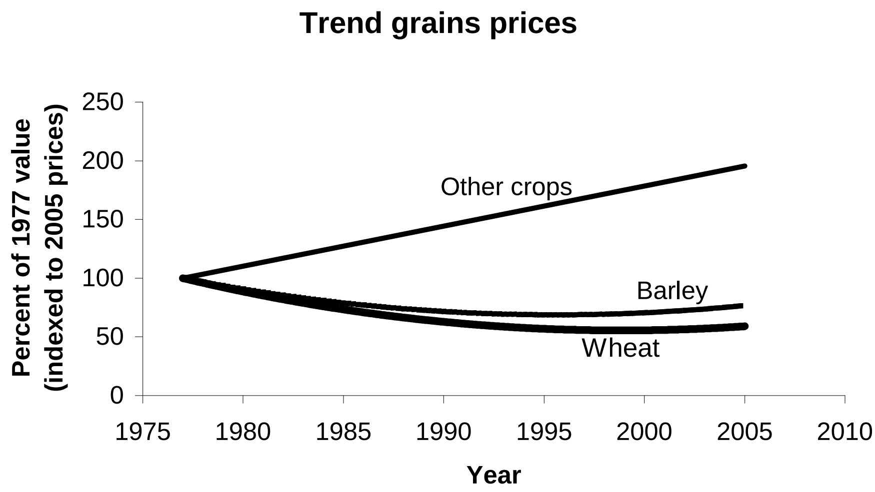


Figure 6: Trends in grain prices, indexed to 2005 dollars, from 1977 to 2006. For clarity of presentation, original datum points are not displayed.

3.2 Farm numbers and farm size

Table 1 shows farm numbers in each of 3 categories of data, as well as for SA as a whole. Overall, and in rounded terms, SA lost 30 percent of its broadacre farms between 1977 and 2005, the numbers being reduced from 11500 to 8000, at an average rate of 145 a year. The results indicate a likely response to a long-term decline in terms of trade. Given that the total area farmed/grazed in SA has remained approximately the same since 1983[18], family incomes have in part been improved by increasing property size.

Broadacre total property revenue and property numbers are shown in Figure 7. Assuming the relationship is causal, the increase in revenue since the mid 1990s has reduced the decline in property numbers[19].

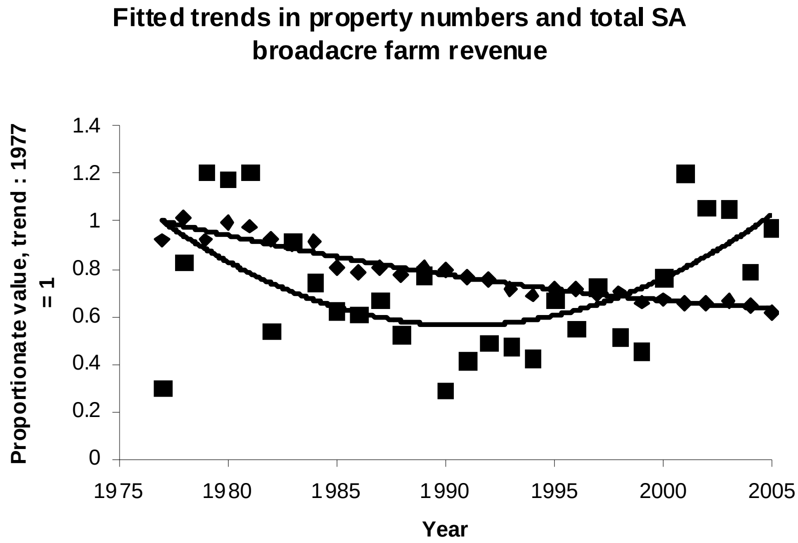


Figure 7: Fitted trends in SA broadacre property numbers and farm revenue, indexed to 2005 dollars, from 1977 to 2005.

[18] From examination of ABARE records, there appears to be a drop in land area available for agriculture around this time. This may have been a result of large areas of the pastoral zone being removed from pastoral leases, or ABARE may have significantly changed their sampling methodology.
[19] A 1 percent increase in total SA broadacre farm revenue produced a statistically significant 0.1 percent increase in property numbers, or around 2 properties a year. Counterbalancing this trend is the effect of time in decreasing property numbers. Time can be considered a proxy for the increasing standard of living expected by Australian communities. Therefore greater individual property size, and hence fewer property numbers, will be necessary to provide an adequate level of income if productivity increases do not keep abreast of increasing standard of living expectations.

Table 1: SA property numbers and summary of average sizes

Year	By predominant product						By zone			By Production value (2004) ($,000)			
	Beef	Sheep	Sheep /beef	Mixed	Crops	All	Past- oral	Wheat /sheep	High rainfall	<100	100-200	200-400	>400
1977	326	1947	1684	4269	2853	11079	401	7485	3192				
1978	274	2410	855	4438	3118	11095	429	7843	3825				
1979	196	1728	1728	4937	2509	11098	421	7771	2905				
1980	409	2007	1457	5827	2192	11892	430	7342	4119				
1981	252	2025	839	5096	3515	11727	427	7465	3835				
1982	254	2146	1269	4795	2698	11162	283	7360	3519				
1983	415	2301	757	4453	2957	10883	328	7003	3553				
1984	408	2471	866	3760	3526	11031	275	7181	3575				
1985	176	2147	597	4327	2570	9817	306	6518	2994				
1986	199	1936	681	4282	2484	9582	310	6366	2907				
1987	277	2289	745	4945	1568	9824	394	6441	2989				
1988	431	2118	785	5108	1069	9511	388	6172	2951				
1989	530	2342	682	4727	1548	9829	395	6290	3143	2154	3455	3078	1480
1990	432	2377	949	4296	1650	9704	396	6129	3179	4034	3185	1938	593
1991	441	1703	1032	3844	2340	9360	385	6005	2971	3579	2803	2004	1113
1992	309	1490	1257	3457	2761	9274	392	5865	3016	2863	2803	2651	1137
1993	281	1304	1271	3138	2822	8816	379	5609	2827	2419	2886	2442	1212
1994	368	1585	1359	3108	2113	8533	360	5540	2632	3018	2223	2309	1124
1995	496	1286	1170	2331	3509	8792	370	5766	2655	3040	1913	1860	2272
1996	671	1297	623	2507	3702	8800	344	5805	2651	3293	1719	2554	1290
1997	786	1515	626	2001	3645	8573	373	5559	2640	2632	2230	2210	1997
1998	1012	745	592	2534	3778	8661	433	5389	2840	3401	2385	1643	1546
1999	771	994	498	2304	3636	8203	392	5398	2414	3235	1522	2513	1365
2000	571	1516	710	2025	3498	8320	420	5309	2593	2840	1893	1413	2319
2001	893	872	688	1686	4030	8169	406	5123	2642	1935	1546	1906	2974
2002	876	1443	520	1933	3391	8163	363	4856	2943	2335	1466	1561	2944
2003	906	2214	450	1172	3481	8223	363	4997	2863	2403	964	1589	3306
2004	916	1305	753	1819	3290	8083	372	4882	2829	2780	1163	1891	2249
2005	736	1523	762	1504	3200	7725	351	4879	2496	1786	1058	2400	2481
	Annual property loss/gain												
	25	-37	-22	-142	34	-145	0 (NS)	-107	-38	-57	-141	-44	125
	Annual percent property loss/gain												
	5.0	-2.4	-2.4	-4.7	1.2	-1.5	0.1	-1.7	-1.2	-2.1	-7.2	-2.1	7.3
	1977-1980 average size (ha)									**1989-1992 average size (ha)**			
	139066	9109	7125	1264	1564	6619	149355	1432	716	604	2016	2978	34659
	2002-2005 average size (ha)												
	26016	10157	5327	1567	1629	6039	94803	2057	1449	1520	2706	3524	13379

NS: Non significant trend, P>0.1; all other trends significant P<0.1, or less

3.2.1 By predominant product:

Distribution of properties

Most sheep, beef and sheep/beef properties are in the pastoral zone or HRZ. This makes number and size data somewhat difficult to interpret, because of the large disparity in the rainfall environments of these zones. In addition, they are likely to be relatively more numerous in areas of the WSZ where rainfall is marginal for cropping enterprises, or topography precludes cropping. In contrast, most mixed crop/livestock and cropping properties are in the WSZ and some areas of the HRZ.

Beef properties

While there are relatively few properties in this category, beef property numbers increased (Table 1) and farm size decreased considerably – from a 139,000 ha average in 1977-1980 to a 26,000 ha average in 2003-2005. This appears most likely to have been the result of an increase in beef properties in the HRZ. There are two influences that may explain the result. Firstly, the plunge in wool prices in the early 1990s caused some predominantly livestock property owners to concentrate on beef production. Secondly, beef production requires less labour per DSE than sheep, allowing a greater dilution of labour across the enterprise. This second factor is relevant if owner/operator/family labour for off-farm income, and/or managing a property of increasing size without additional paid labour, become factors of importance.

Sheep, sheep/beef and mixed crop/livestock properties

These three categories of properties behaved in a similar manner to SA as a whole: a reduction in property numbers over the period and an increase in average property size. The decline in sheep and sheep/beef properties can be ascribed to low wool prices since the early 1990s. The decline in crop/livestock properties is due to a switch to specialised cropping.

Crop

There was an increase of 25 percent in the number of properties in the crop category (Table 1). There was no increase in average property size, however. The increase in crop specialist properties compared to the decline in the other categories can be explained by generation of greater income per ha from cropping, in areas where seasonal rainfall allows cropping to be a viable option. The fact that there was no significant increase in property size in the crop specialist category is important. It indicates that productivity improvement was the most important way that cropping properties remained viable.

It needs noting that long-standing crop specialist properties, as a sub-category, may have grown in size over the period, taking advantage of economies of scale resulting from the dilution of machinery and labour costs over a larger area of cropping. Some of the contribution towards keeping the size of properties in the crop specialist category constant may have come from the entry of mixed crop-livestock properties of relatively small size into the category, as livestock revenue decreased to the point where they qualified as crop specialists in the ABARE categorisation (80 % of revenue derived from crops).

3.2.2 By Zone:

The WSZ lost 107 properties a year over the period (2.2 percent) and the HRZ lost 38 a year (1.4 percent) (Table 1).

3.2.3 By production value (1989-2005)

The most significant trend was the increase in properties with income greater than $400,000 (2005 values) (Table 1). Property numbers in this category increased by 150 a year. Allowing for a general overall reduction in property numbers, there were corresponding decreases in the $100-200,000 and $200-400,000 classes. Clearly, many farms have remained viable by the ability to increase income (while minimising costs at the same time, and aided by the increasing average area of properties in the

WSZ and HRZ). There was no statistically significant trend in the number of properties earning less than $100,000. Given declining terms of trade, it is unlikely that properties in this category could now support families without their income being supplemented by off-farm jobs, share farming, work contracts, or Government welfare payments. Hence, in this category the financial viability of farm families has probably been maintained through off-farm income in many cases.

3.2.4 Property category areas

Most properties in the WSZ and HRZ have increased in area, and this is reflected in average property sizes at the beginning and end of the period (Table 1). This trend to increased property size accords with a prior expectation that increasing property size will assist in maintaining farm viability through more efficient use of machinery and labour. It would also be expected if the agricultural area in SA remained roughly constant over time and the number of properties has diminished, as Table 1 shows. However, in some categories property size has actually decreased over the period (Table 1) and, as this is counter-intuitive, it requires some explanation.

Overall: As stated in footnote 18, from examination of ABARE records, there appears to be a drop in land area available for agriculture around 1983. This may have been a result of large areas of the pastoral zone being removed from pastoral leases, or ABARE may have significantly changed its sampling methodology.
Pastoral zone: As stated above, large areas of the pastoral zone may have been removed from pastoral leases. As stated in *2.2*, changes in local government boundaries included more area where cropping is viable in the Pastoral zone. Properties on which cropping is an option are much smaller than exclusively livestock properties, which are in areas of the pastoral zone where average rainfall is lower and less reliable.
Beef: As stated in 3.2.1, the marked decline in property size appears most likely to have been the result of an increase in beef properties in the HRZ where average property size is considerably less than in the pastoral zone. In addition, cattle feedlot properties have come into existence, and these require relatively little land.
By production value: Only the lowest revenue category (less than $100,000) increased in size (Table 1). The three higher revenue categories decreased in size, particularly the “$200-400,000” and the “greater than $400,000” categories. This is most likely the result of an increase in cropping properties in these categories diluting the influence on average property size of larger predominantly livestock production properties in other zones. Table 1 shows that predominantly crop production properties are, on average, considerably smaller than predominantly livestock production properties.

3.3 *Revenue and production*

Total revenue from the major outputs of SA broadacre agriculture trended downwards between 1977 and 1990 in real terms (Figure 8). Since then it has increased. This overall result has masked significant trends in the contribution of individual outputs to the total (Figure 9). In 1977-1980 livestock products contributed around 60 percent of revenue. Between 1996 and 2005 they contributed around 40 percent. In particular, wool revenue has markedly declined as a proportion of the total since 1990. It is reasonable to summarise the changes as a shift from wool revenue to grains revenue. After a relative decline in the middle years, cattle and sheep sales have undergone a minor revival in terms of their proportional contribution. Figure 9 also shows that wheat and barley revenues contributed an increasing proportion of total revenue until around 1997-1998, as has the “other grains” category from a low base. These trends are partly a result of relative prices between commodities (Figures 5 and 6), taking into consideration production responses as a result of those prices, and partly a result of the ability to generate more income per unit area from cropping (the latter influence in areas where cropping is a viable option). The high price of oilseeds, and some pulse crops, relative to wheat and barley, was responsible for the very large increase in production (Figure 11), and therefore proportion of revenue (Figure 9), from “other grains”.

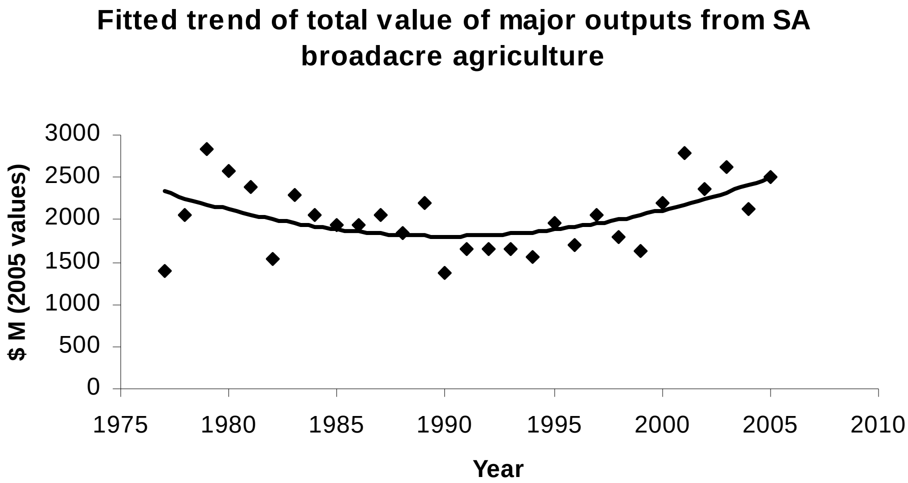


Figure 8: Fitted trends of total values of major outputs from SA broadacre agriculture from 1977 to 2005.

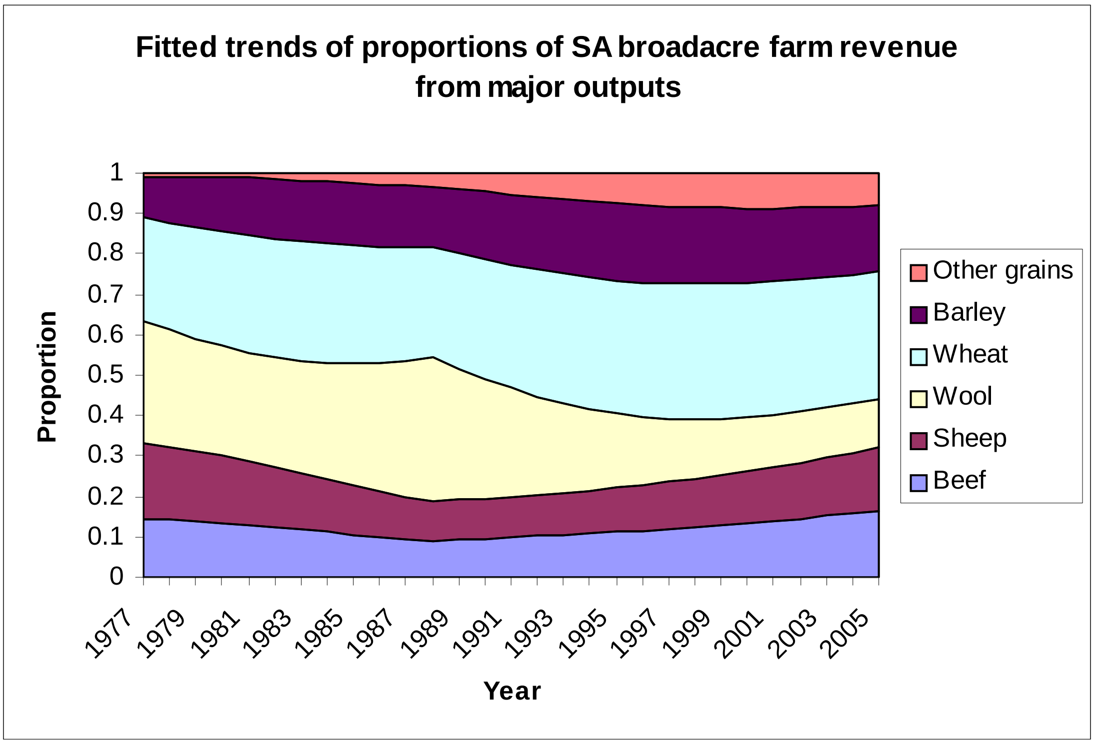


Figure 9: Fitted trends of proportion of SA broadacre farm revenue from major outputs from 1977 to 2005. For clarity of presentation, original datum points are not displayed.

Wool

Since the early 1990s, trend wool prices have been relatively lower than sheep and cattle sale prices (Figure 5). This partly explains the increasing proportions of cattle and sheep sale revenue, relative to wool revenue (Figure 9), when production responses to those prices are taken into account (Figure 10). Three subordinate factors are probably also responsible for the decline in wool production. Firstly, shearing costs and livestock materials (e.g. drenches, dips, vaccines) have continued to increase approximately in line with the consumer price index, thus increasing pressure on the viability of wool production enterprises. Secondly, there has been an increase in the number of crop specialist and beef specialist properties (Table 1). This increase has come at the expense of specialist sheep, sheep/beef and mixed crop/livestock properties (taking into account, the overall decrease in property numbers). Hence the area available for sheep enterprises has decreased. Thirdly, on mixed crop/livestock properties there has been an expansion of cropping. Therefore, even on these properties the area available for sheep production has decreased and it is likely that the extra land used in cropping is the better land on the property in terms of carrying capacity.

Production

Figures 10 and 11 show wheat and barley production increases over the period in excess of 100 percent and "other grains" increases in production over 700 percent, the latter consisting of increases in grain legume production and, since the early 1990s, canola production[20]. After earlier increases in production, sheep and wool declined

[20] It also needs noting that hay production, particularly for export, has increased markedly in the past decade.

and then stabilised to similar levels at the end of the period as at the beginning. Beef cattle production decreased and then recovered so that it was greater at the end of the period than at the beginning[21].

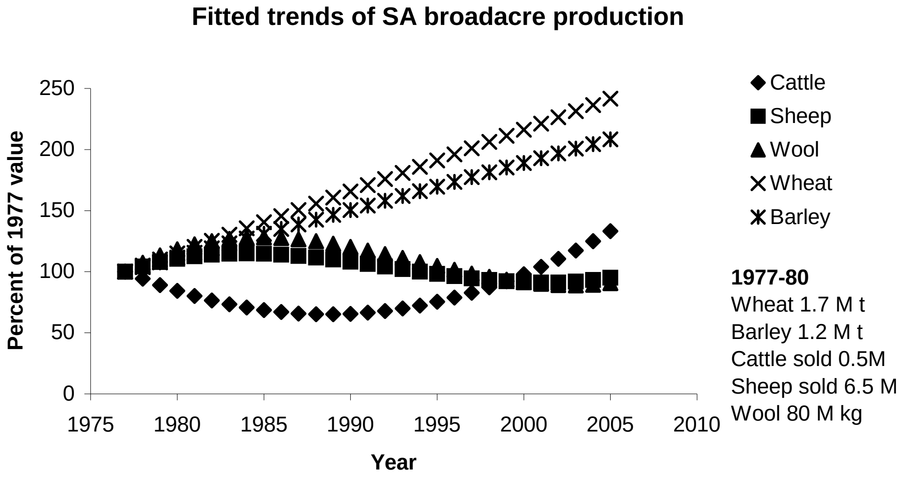


Figure 10: Fitted trends of SA broadacre sector production from 1977 to 2005. For clarity of presentation, original datum points are not displayed.

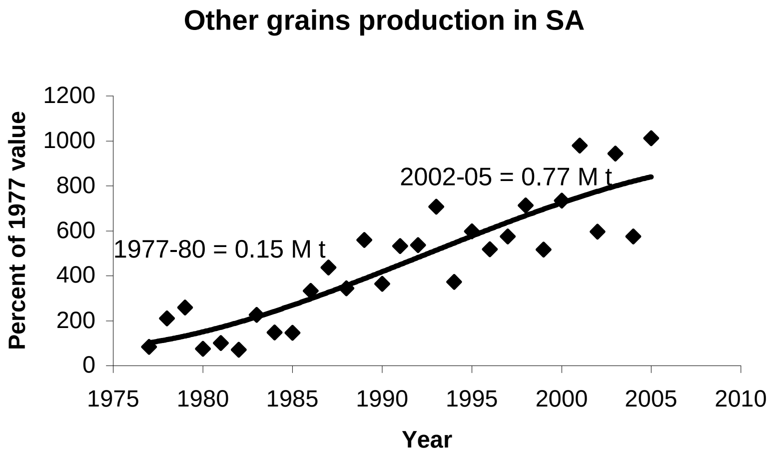


Figure 11: Non-cereal grains production in SA from 1977 to 2005.

[21] Beef cattle and sheep sales are not particularly accurate indexes of livestock production on an annual basis, being influenced by inter-property trade, market conditions and drought. However, in an overall time series, these influences become less important. On balance, these measures were chosen rather than beef and sheep meat production, which are also influenced by market conditions, drought, interstate slaughter, live beef and sheep exports and shipping through Portland rather than Adelaide. Hence there may be little to choose between the two types of measure in terms of amplitude of annual variation around a “true” production figure. In addition, cattle and sheep sales come from the same ABARE database as the other commodities whereas ABS data would have to be used for sheep meat and beef production.

3.4 *Wheat and barley yields*

Over the 1977-2006 period, wheat yields have increased by 31 kg/ha/year and barley yields by 44 kg/ha/year (Figure 12)[22], according to forced-fit straight lines. Using the fitted value of the 1977 season as a base, this translates to an average rate of yield increase of 1.8 percent per year and 2.3 percent per year, respectively, via logarithmic transformation. Barley yields appear to have levelled off from around 1997 (Figure 12, best fit curvilinear functions). This may be due to the earlier impact of the release of Galleon barley, a feed variety that markedly increased yields. In addition there has been an emphasis on early sowing of wheat to maximise yields, as well as markedly increased cultivation of oilseed and grain legume crops on the better quality cropping land on properties. These choices and emphases may have resulted in feed barley receiving a lower priority in overall farm crop management, together with barley being grown after barley and/or after several wheat crops. Figure 12 trendlines emphasise that neither wheat nor barley yield increases are as great in the second half of the period. The reduction in rate of yield increase in both wheat and barley may be due in part to a trend decline in average seasonal rainfall over the review period (Figure 13). One viewpoint is that performance has been reasonably encouraging over the last decade, given the incidence of poor rainfall years. Increasing, or even maintaining, yields while increasing the intensity of cropping could be considered a moderately good achievement.

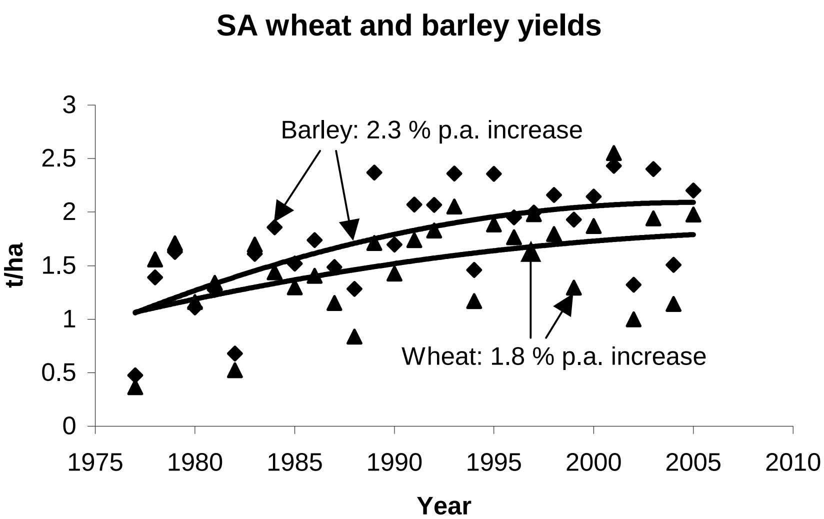


Figure 12: Trends in SA wheat and barley yields from 1977 to 2005.

[22] ABARE data has been used as the basis for analyses in the first part of this section, as with other sections in this report. It needs noting that other reliable data sources could have been used for cereal yield analyses (ABS, district agronomists monthly reports). Overall, these data will be very similar to those from ABARE, but may differ significantly in particular instances.

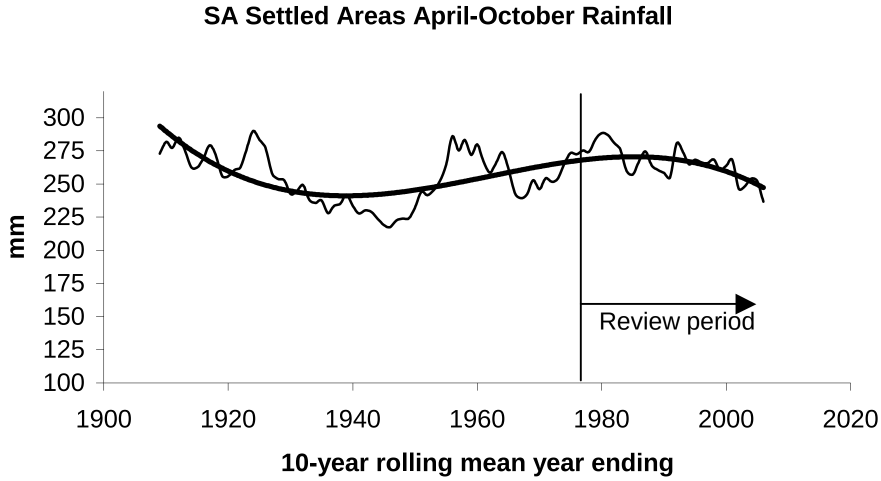


Figure 13: Long term and recent trends in rainfall between April and October in SA settled areas. Source: Bureau of Meteorology.

A detailed analysis of SA wheat yields was recently undertaken by Black *et al.* (2008, in press). The methodologies used for these analyses are shown in *2.8*, above, and the results reported here.

Estimates of yield efficiency annual gain and longitudinal curvilinearity

The estimate of SA wheat yield efficiency gain was 1.7 percent p.a., which agrees well with the estimate of 1.8 percent p.a. derived in Figure 12. Longitudinal log regression analysis using orthogonal polynomials showed that the fitted curve had significant linear and third order polynomial trends, resulting in negative curvilinearity towards the end of the time series.

Farm management drivers of wheat yield improvement

Table 2 presents the results of the final stepwise OLS longitudinal analyses for wheat yield efficiency improvement (measured against Oz-Wheat predictions) and wheat yield improvement. Elasticity provides a percentage measure of how far the dependent variable shifts for a 1 percent shift in the explanatory variable.

Table 2. Statistically significant farm management drivers of improvements in SA wheat yield from 1977 to 2006**.**

Explanatory variable	Dependent variable			
	1. Logged yield efficiency (1977 = 100)		**2. Logged yield** (1977 = 100)	
	t value	elasticity	t value	elasticity
(Oz-Wheat simulated yield)	not used	not used	17.38***	1.34
Wheat area	-2.86**	-0.47	-2.09*	-0.29
Fertiliser per ha cropped quantity index	5.34***	0.48	5.61***	0.35
Grain legumes and oilseeds area	-1.87+	-0.11	NS	NS
Wheat terms of trade	-4.11***	-0.87	-4.83***	-0.39
Wheat/canola price ratio	4.34***	0.90	2.15*	0.32
Model adjusted R^2	0.75		0.95	
Durbin-Watson autocorrelation statistic	2.56 (NS)		2.45 (NS)	

+, *, **, *** Statistically significant at < 0.1, 0.05, 0.01, 0.001 respectively. NS: not significant

Despite the relative R^2 values, Model 1 should be viewed as the superior, more sensitive model because Oz-Wheat yield is embedded in the dependent variable measure, therefore allowing a greater role for other explanatory variables. The dominance of seasonal rainfall in predicting annual wheat yields is displayed in Model 2 by the very high t value and high elasticity for Oz-Wheat, which adjusts for seasonal rainfall in its predictions. The following explanations are suggested for the significance of the explanatory variables. Additional wheat area has a negative impact on efficiency increases because the expansion is onto less suitable cropping land on-farm. Despite the fact that grain legumes and oilseeds have a strong, positive impact on a following wheat crop (Norton 1999, Schultz 1995), the more sensitive Model 1 shows that they have an overall negative impact on efficiency increases. This may be due to these crops expanding in the more suitable high rainfall areas and onto higher yield potential land within a farm. For agronomists, the impact of increased fertiliser use in increasing wheat yields is self-explanatory. In this category, chemicals (mainly herbicides) proved to be not significant, indicating that they have more of a “maintenance of yield” role. For agronomists, the negative effect of wheat TOT may appear counter-intuitive. TOT shows a historically consistent negative trend (Figure 1). This means that the TOT trend provides a positive incentive to increase wheat yields. The effect has been demonstrated before in a TFP context (Mullen and Cox 1995, Black 2004) and probably relates to farmers feeling less pressure to maximise yields when wheat prices are relatively higher and therefore wheat farming is more profitable. In addition, negative TOT probably means that the less efficient producers exit the industry at a faster rate. An increase in wheat price compared to canola has a positive impact on wheat yield increases, probably because relatively more farm system inputs (fertiliser, chemicals, resources for more timely sowing) are diverted to wheat relative to canola.

Wheat yield efficiency increase component contributions

Table 3. Estimates of R&D sector contributions to increased SA wheat yield efficiency from 1977to 2006.

Contributing factor	**Average annual percent change**
Estimated varietal yield gain (VG)	0.5
Farming systems improvement (FSI) (Total – VG)	1.2
Estimated total annual improvement	1.7
Farming systems improvement contributions	
Estimated earlier average sowing times (EAS)	0.7
Other farming systems contributions (FSI – EAS)	0.5
Estimated input factor productivity growth (IFP)	(-) 0.1

Estimated varietal yield gain has been approximately constant over the period. Therefore, the slight curvilinearity in the longitudinal percent increase function is due to a decreasing farming systems improvement effect. This may be due to the fact that the fitted curves to the time of sowing APSIM results showed slightly decreasing impacts as sowing becomes earlier. Also, the fertiliser volume index showed curvilinearity (as well as that for chemicals). An alternative approach is to consider the relative amount of R&D contributing to varietal yield gain compared to farming systems R&D. At least in SA in recent years, we have observed that local R&D for wheat breeding and pre-breeding has increased considerably in public institutions compared to farming systems research. On the basis that there is a strong causal link between lagged R&D and productivity improvement, this relative change in public institution R&D resources may have caused the observed efficiency curvilinearity. The earlier average sowing time contribution is a proxy for all the farming systems components that have contributed to this effect, which was first demonstrated in SA by R Holloway on Eyre Peninsula and then E Braunack-Mayer in the mid North, in the early to mid 1980s. These components include larger and more effective machinery, better use of more effective herbicides, etc. If our suggested estimate of average sowing time changes is reasonable these evolutionary innovations, derived mainly through commercial R&D for machinery and herbicides, have had the dominant impact on SA wheat yield improvements. Other farming systems contributions, such as increased fertiliser use, better disease control through rotational biofumigation and precision farming have had an impact similar in size to varietal yield gain.

3.5 Settled areas per ha livestock stocking rates, net turnoff and wool production

Data on sheep and beef held on the property at the end of June were converted to DSEs according to White and Bowman (1985), adjusted for increasing carcase size (ABS data) over the period from 1977 to 2005, the large frame of the SA merino and improvements in the quality of animals (Appendix 1). These DSEs were then converted to a stocking rate per grazed ha. Grazed hectares were calculated on the basis of property size minus two thirds of the area under crop[23]. Likewise, net sheep and beef sold (net turnoff) (i.e. sheep and beef sold less sheep and beef purchased[24]) were converted to DSEs per grazed ha, and similarly wool produced per grazed ha was calculated.

For the settled areas (the WSZ and the HRZ) Figure 14 shows the carrying capacity, turnoff (both in DSEs/ grazed ha) and wool production per grazed ha over the 1977-2005 period. Over the settled areas the wool production trend was composed of an increase in production per grazed ha until around 1988-1990, which coincided with high wool prices, followed by a decrease in production until the late 1990s, and has levelled off thereafter. Stocking rate followed similar trends. However, net turnoff has increased steadily over time. Relating the stocking rate and net turnoff trendlines, it seems that broadacre farms in the settled areas have become progressively more efficient in turning animals off for market. This probably reflects the fact that sheep meat and beef production have formed a progressively greater share of livestock revenue in the second half of the period (Figure 9), particularly prime lamb production (Figure 15). Net turnoff has increased by 1.0 percent per grazed ha per year over the period whereas, overall, stocking rate has remained constant. Overall, wool production has decreased by 1.0 percent per year.

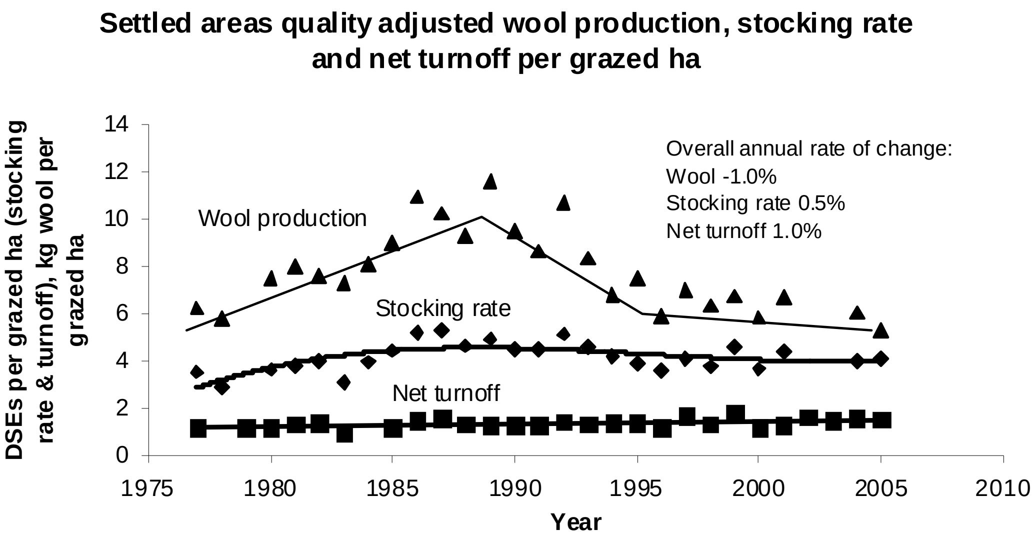


Figure 14: Wool production, stocking rate and net turnoff, all adjusted for proportional quality improvements, per grazed ha from 1977 to 2005.

Notes: Clearly, the rate of change in wool production has not been uniform over the 1977-2005 period. Hence an overall rate of change may not be meaningful if the reader is concerned with change in shorter periods. Notably outlying data points (1979, 2001, 2002) were dropped from the wool production and stocking rate presentation and analysis.

[23] Sheep and cattle graze cereal stubbles; hence an allowance is made for this practice.
[24] This adjustment provides a better indication of those animals sold for slaughter or for the overseas live export trade.

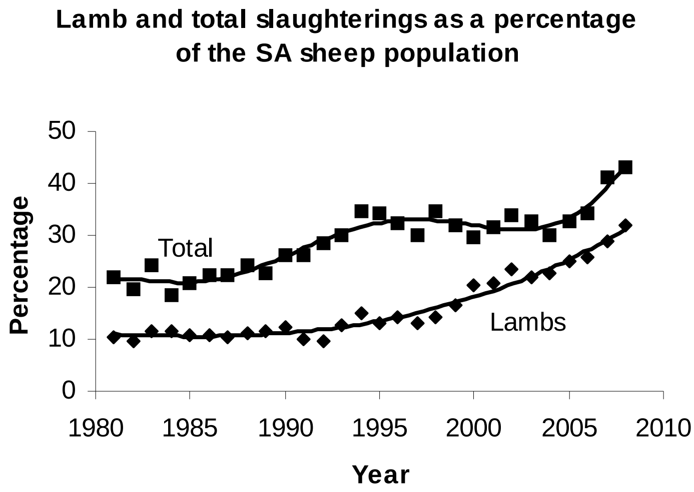


Figure 15. Lamb and total slaughterings each as a percentage of SA sheep population from 1977 to 2005. Source: G Trengove, drawing on ABS, ABARE and Meat and Livestock Australia (MLA) data.

Table 4: 1977-2005 Quality adjusted livestock per grazed ha averages and annual rate of change measures

	High rainfall zone	Wheat-sheep zone	Combined
Averages			
Wool production (kg)	14.6	5.6	7.8
Stocking rate (DSEs)	9.4	2.6	4.2
Net turnoff (DSEs)	3.2	0.8	1.3
Actual annual rates of change			
Wool production (kg)	-0.11	-0.04	-0.054
Stocking rate (DSEs)	0.11	0.00	0.015
Net turnoff (DSEs)	0.058	0.002	0.012
Percent annual rates of change			
Wool production	-0.8	-0.8	-1.0
Stocking rate	1.1	0.1	0.5
Net turnoff	1.8	0.3	1.0

Note: The inconsistency apparent in wool production percent annual change between the zone and combined results is due to separate curve fitting procedures.

The average stocking rate in the WSZ is only 30 percent of that in the high rainfall zone: 2.6 DSEs/grazed ha and 9.4 DSEs/grazed ha, respectively (Table 4). The difference reflects annual rainfall averages between the two zones. There was no statistical difference between percent turnoff in the two zones over the period (around 32 percent). Wool production averaged 6 kg/ha in the WSZ over the period, compared to 15 kg/ha in the HRZ. There was a statistically significant increase in both stocking rate and net turnoff per ha over the period in the HRZ, but not in the WSZ, and a significant decrease in wool produced per ha in both zones (Table 4).

The large differences in stocking rate and turnoff changes between the two zones reflects the fact that the HRZ is still largely comprised of livestock specialist properties, and there is adequate rainfall to allow intensification of grazing industries. By contrast, in the WSZ there has been a large increase in cropping intensity (Figure 17), relegating grazing enterprises to less productive land. In addition, for conservation purposes many farmers no longer graze stubbles, aided by minimum/no-till cropping systems, even though their properties may carry sheep on non-arable land.

3.6 Rates of change of selected inputs

<u>Fertiliser and agrichemicals per cropped ha</u>

ABARE data does not allow an exact assessment of agrichemical inputs to cropping – statistics are only collected on a "whole property" basis (i.e. crop, pasture and other areas in total). In addition, detailed fertiliser use statistics have not been collected for the last 3 years of the data set. However, a reasonable approximation probably can be made by use of data from crop specialist properties. It is likely that almost all fertiliser and chemicals used on these properties are applied to cropped land. It is known that little fertiliser is applied to pasture on these properties. Likewise little herbicide and other chemicals, except in relation to spray topping in preparation for cropping in the following season, are applied to pasture paddocks.

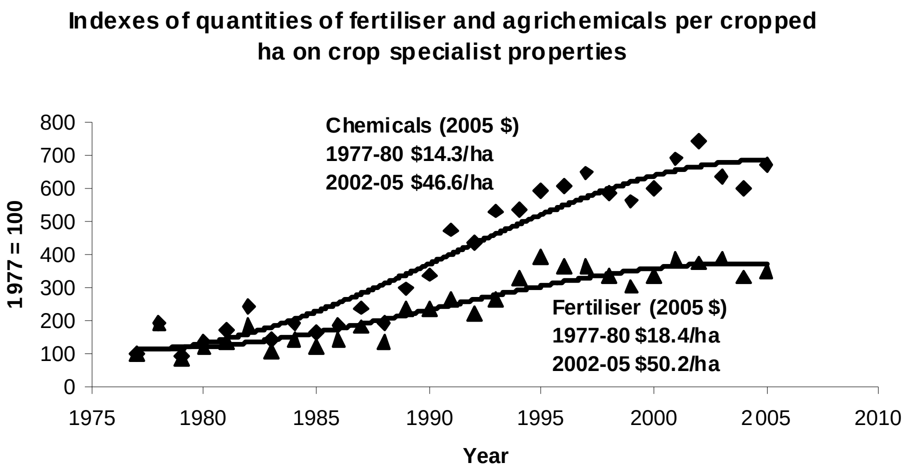


Figure 16. Indexes of quantities of fertiliser and agrichemicals per cropped ha on crop specialist properties from 1977 to 2005.

It is possible to derive crude[25] indexes of physical quantities of herbicides and chemicals from ABARE farm expenses data, by use of the appropriate price indexes. Figure 16 shows that from 1977 to 2005 the quantity of fertiliser per ha applied to

[25] The indexes are crude in the sense that the corresponding price index relates to a general mixture of fertiliser or chemicals purchased in Australian agriculture; hence it is clearly not possible to account precisely for volume of the particular mix of fertilisers or chemicals applied in SA broadacre agriculture in any given season. In addition, there is no tight correlation between these indexes and physical volumes of product. For example in the 1980s in many cereal crops sulfonylurea herbicides, which are applied at the rate of 5-25 g/ha, supplanted phenoxy herbicides, which are applied at the rate of 500 ml - 2 L/ha.

cropping land increased approximately three and half times and that of chemicals has increased approximately sixfold.

Fertilisers

In the late 1970s to early 1980s, cropping land generally only received single superphosphate and a significant proportion of such land did not receive any regular fertiliser applications at all, relying on residual nutrition from prior pastures. From the early to mid 1980s, increasing volumes of fertiliser were applied to cropped land, including fertiliser with a nitrogen component. This coincided with increased cropping intensity and the adoption of residual sulfonylurea herbicides. Farmers have increased nitrogen fertiliser use in crops, for four reasons. These are: greater cropping intensity, which reduces legume pastures in the rotation; manipulation of grain protein content; residual sulfonylurea herbicide use in cereals which reduces the legume component in following pastures on neutral-alkaline soils; and a desire to increase crop yields resulted in farmers increasingly using more fertiliser and particularly more nitrogen fertiliser. In addition, increasing grain legumes production required high levels of phosphate fertiliser on those crops. During the 1990s, canola cultivation rapidly expanded. Canola requires large quantities of phosphate, nitrogen and sulphur fertiliser. Since the late 1990s fertiliser volume applied per cropped ha has levelled off. Deteriorating TOT for cereals have influenced the general run of farmers to adopt the practice of applying only maintenance applications of phosphate fertiliser to ensure a minimum level of available soil P. Nitrogen fertiliser is likewise only applied at maintenance levels to ensure adequate growth of the crop. In addition, the area sown to canola in SA has stopped expanding. Assuming a causal connection between fertiliser application and cereal yields, the levelling off of wheat and barley yields shown in Figure 10 could be explained partially by the current plateau in fertiliser levels applied to cropping areas, since nutritional reserves in soils are generally not extensive, apart from potassium in certain soils.

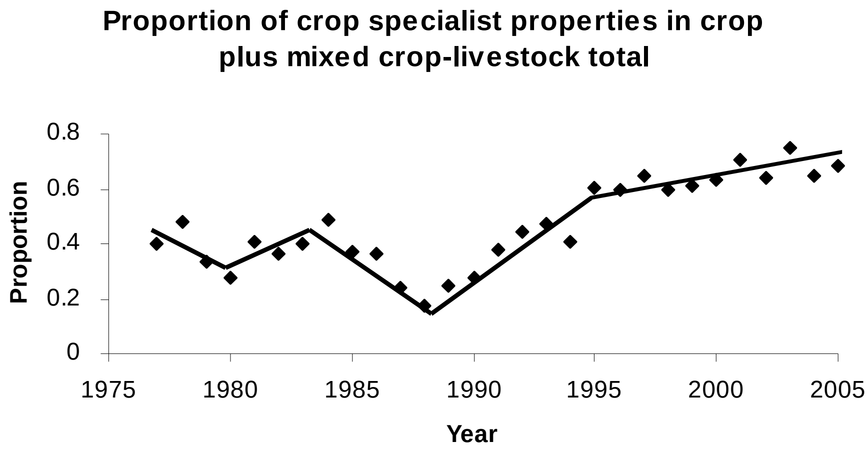


Figure 17: Crop specialist properties as a proportion of the total of crop plus mixed crop-livestock properties from 1977 to 2005.

The decline of legume pastures in crop rotations

The detailed fertiliser statistics to 2001 (no data in this category has been collected since then) from crop specialist properties show that the principal component of the increase was in fertiliser that provided nitrogen. The amount of phosphorus applied was stable, and there was virtually no potassium applied, by virtue of high soil K levels in many SA cropping soils. These data indicate that there has been a marked decline on reliance of nitrogen from legume pastures in crop rotations. Data from mixed crop-livestock properties indicate that the proportion of pastures fertilised compared to the total is stable. This indicates that legume pastures still play a part in crop rotations on these properties. However, the marked increase in the proportion of crop specialist properties compared to the total of crop and mixed crop-livestock properties since the crash in wool prices in the early 1990s (Figure 17) indicates that the hitherto key role of legume pastures in crop rotations in SA has declined markedly. This was being noted as early as 1990 (D Reuter, addressing farmer groups).

Agrichemicals

In terms of broadacre agriculture purchases, by far the largest component in the agrichemicals category is herbicides. Since the late 1970s, a large range of effective and efficient herbicides has been introduced. These augmented and to a large extent supplanted the main broadacre cereal herbicides then in use – trifluralin, phenoxy herbicides and diquat/paraquat. These new herbicide groups, including glyphosate, the sulfonylurea group and the “fops” and “dims” groups, facilitated the trend to minimum cultivation and reliance on herbicides for weed control within the crop, spray topping in the year prior to cropping and stubble weed control by herbicides prior to sowing. This trend towards minimum tillage facilitated by effective herbicides largely accounts for the enormous growth in per ha chemical use over the 1977-2005 period. Chemical usage in the new century appears to have levelled off (Figure 16). This may be caused by the trend to minimum tillage actually falling short of no tillage. Secondly, the advent of herbicide resistance, particularly in annual ryegrass, may have resulted in less, and more strategic, use of herbicide in some cropping situations.

Fertiliser per grazed ha

As stated above, detailed fertiliser use statistics have not been gathered by ABARE in the last three years of the data set. However, a reasonable approximation probably can be made by use of data from sheep and sheep-beef specialist properties[26]. It is likely that most fertiliser used on these properties is applied to grazing land, because crop revenue forms a very low portion of the total farm revenue. Therefore the proportionate area of land under cash crop is very low. Overall, fertiliser use on grazing land is very low compared to that on cropped land (see note on fertiliser value per ha in Figure 18, below, compared to the equivalent note in Figure 16). Owners of sheep and sheep-beef properties in the pastoral zone are unlikely to use fertiliser on grazing land at all. Although few in number, these properties are of such size that per ha statistics are seriously diluted. In addition, there is probably a significant amount of marginal land in the settled areas on sheep and sheep-beef properties that receives little or no fertiliser. Nevertheless, the values shown in Figure 18 may indicate that fertiliser on relatively productive pastures is either selectively applied or applied at a low rate, or both.

[26]Beef specialist properties were not included in this trend analysis. Much of the total area involved in this category is in the pastoral zone, on land that is never fertilised. Exclusion of this category may therefore have avoided compromising the results.

Figure 18 shows that the amount of fertiliser applied to these properties has fluctuated widely over time. It is strongly related to livestock revenue per ha – the statistically significant analysis shows that a 1 percent increase in revenue produces (assuming a principal causality – fertiliser is applied to increase, or maintain, revenue) a 1.3 percent increase in the index of fertiliser applied. The causality assumption is plausible because fertiliser is generally applied to pasture in late autumn-early winter, and ABARE statistics are collected on a financial year basis. Hence ABARE data records livestock income at a time when farmers are considering whether they have sufficient income from the year’s transactions to afford fertiliser application to pastures.

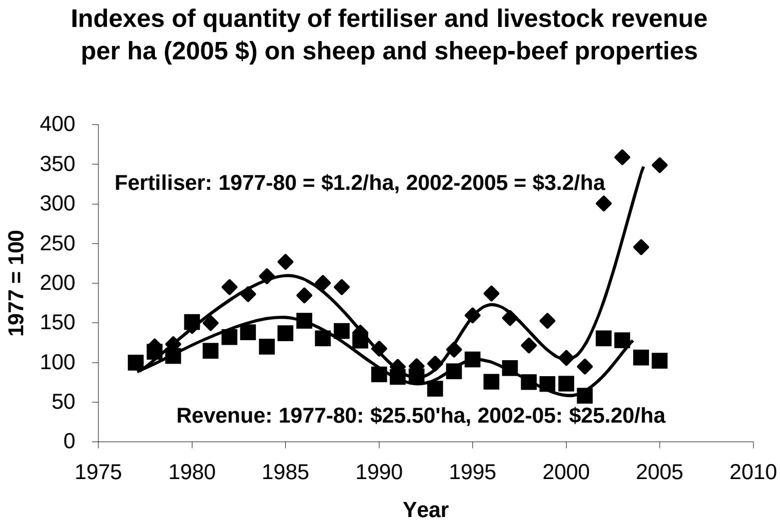


Figure 18: Composite index of quantity of fertiliser and index of livestock revenue, indexed to 2005 dollars.

This pattern of behaviour is contrary to normal advice that pasture fertiliser should be applied on a regular basis, in roughly equal amounts from year to year. Given that the practice appears to be so ingrained that it overcomes many years of extension and consultant advice, those who make recommendations on pasture fertiliser should perhaps alter their advice to minimise the damage to pasture productivity that results from this farmer behaviour.

<u>Livestock materials per DSE in the settled areas</u>

Livestock materials refer to drenches, dips/jets, vaccines, livestock tags, and similar materials. Figure 19 shows the amount of such material per DSE. It is interesting to note that, despite a long period of relative decline in livestock prices in the 1980s and 1990s (Figure 5), livestock materials per DSE continued to increase steadily, taking into account the year-to-year variation in these data.

Since 2000 there appears to be a greater increase in the quantity of livestock materials per DSE. The four data points shown, 2000 to 2003, as well as the artificially inflated 2004 point (not shown, see note to Figure 19) are consistent enough to indicate that the effect is not the result of random sampling of the population. There may be both economic and technical reasons for this growth since 2000. Firstly, the increase in sheep meat and beef prices has allowed growers to spend more on livestock materials because they now generate more income from livestock systems. Technical reasons[27] certainly include the now mandatory electronic ear tagging of cattle. These ear tags are much more expensive than tail tags ($3 vs. 15c). In the lead-up to the time when such ear tagging became mandatory (January 2004), there was probably a gradual increased in use of such tags, particularly for beef cattle destined for slaughter for the European Community market. Other technical reasons could include progressive adoption of worm drench capsules, a delivery technology that is considerably more expensive than traditional drenches. Also, the demand by retailers such as Coles and Woolworths to purchase large individual batches of uniform cattle and prime lambs may have increased the pressure on growers to purchase and apply livestock materials that ensure a more uniform product.

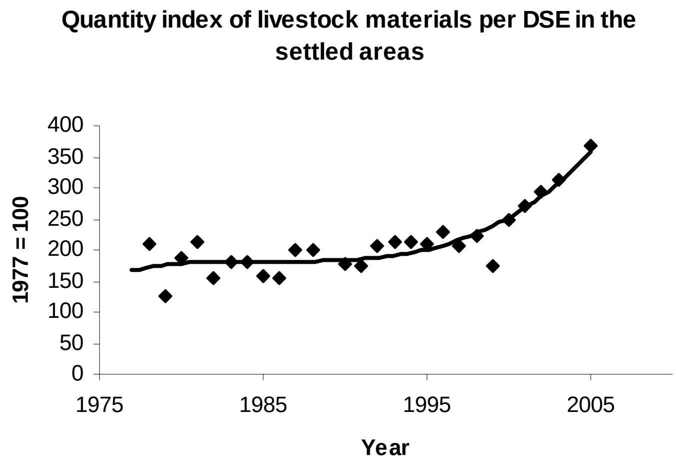


Figure 19: Composite index of quantity of livestock materials (drenches, ear tags, etc.) per DSE in settled areas from 1977 and 2005.

Note: 1977 (low), 1989 (high) and 2004 (very high) data points removed, as they are considered unrealistic. In 2004 the index was artificially inflated because of stockpiling by growers of State Government subsidised cattle electronic ear tags (D Rendell, pers. comm.).

Labour per ha in the settled areas

In the index shown in Figure 20 imputed owner/manager and family labour, hired labour and half the value of crop and livestock contracts is included. Figure 20 shows that labour per ha has progressively declined since the mid 1980s and is now roughly 75 percent of what it was in 1977-1980. The explanation seems straightforward: as property size has increased, farmers have made more effective and efficient use of machinery and other labour saving devices.

[27] The authors are indebted to Forbes Brien, Ian Carmichael and Denice Rendell (PIRSA/SARDI) for their discussions and assistance in providing these explanations.

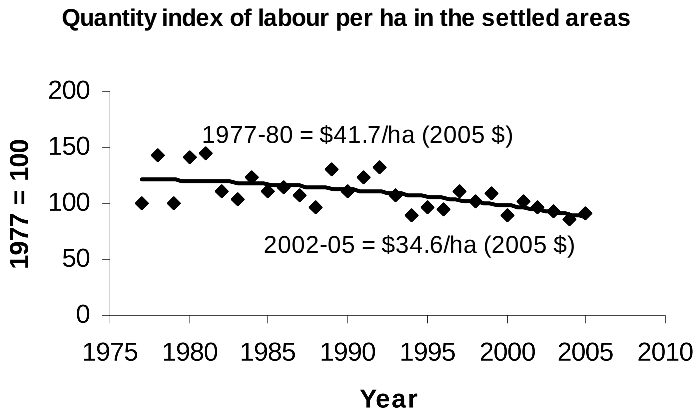


Figure 20: Composite index of quantity of labour per ha in the settled areas from 1977 to 2005.

<u>Machinery in use per cropped ha on crop specialist properties; and</u>
<u>Machinery in use per DSE on sheep and sheep-beef specialist properties</u>

This variable comprises 75-90 percent[28] of the "Depreciation", and 100 percent of the "Repairs and maintenance" and "Fuel, oil and grease" categories in the ABARE database. Figure 21 shows that machinery in use per cropped ha and per DSE has dropped by 20-25 percent over the 29-year period. This result is probably counterintuitive for the average reader, who may envisage ever-larger and more expensive tractors and harvesters on cropping properties as well as larger and more expensive general utility vehicles and other equipment on all properties. However, these data show that such machinery and other equipment have been more efficiently used than the equipment it has replaced. Therefore such equipment has been a good investment.

[28] 75 percent was used in the case of the sheep and sheep-beef specialist properties and 90 percent in the case of the specialist crop properties. The difference reflects the belief that there is a higher vehicle and mobile machinery component of depreciation on the specialist crop properties, due to the expense of cropping related machinery. Other components of depreciation include buildings, fixed machinery (for example in shearing sheds) and fencing.

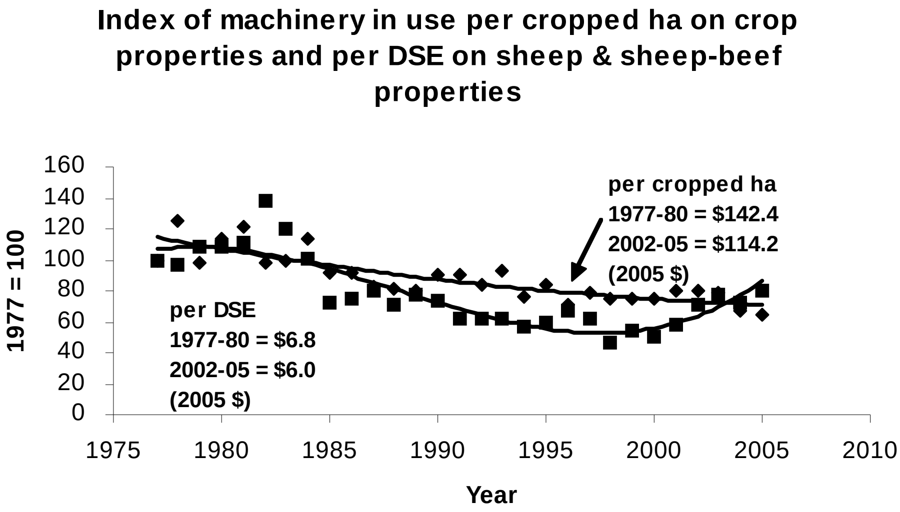


Figure 21: Composite indexes of quantity of machinery in use both per cropped ha on crop properties and per DSE on sheep and sheep-beef properties from 1977 to 2005.

Note: 1982 datum deleted from the DSE data (unrealistically high).

<u>Paid advisory services per property 1989-2005</u>

This category was not available in the 1977-1999 ABARE databases. There was an eightfold increase in paid advisory services, from $64 to $560 (2005 dollar values) in trendline terms or 13.6 percent p.a., in the 1989-2005 period (Figure 22) (data were not collected in the 1977-1988 period and the value is presumed to be low). PIRSA's (at that time PISA's) policy from the early 1990s was to charge for individual consultancy services rather than provide them free, and this change in policy accounts for some of the increase early in the period. However, the continuation of the trend in these data beyond the mid 1990s indicates that farmers perceive that increasing paid advisory services is worthwhile.

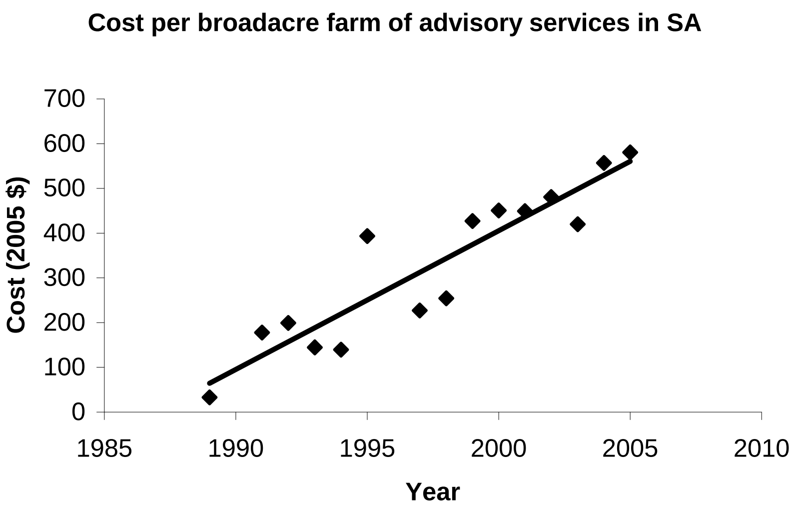


Figure 22: Cost per broadacre farm, in 2005 dollars, of advisory services in SA from 1989 to 2005.

Note: 1990 and 1996 data deleted (unrealistically high)

3.7 Property financial performance and family income in the settled areas

The equity ratio is quite high in both the WSZ and the HRZ and is currently around 90 percent. If anything, it has risen since 1990. This high level may reflect a conservative approach to debt in the face of fluctuating incomes, and may also reflect the relative success of farmers who operate at high equity ratios. Given that the equity ratio remains high in the face of declining farm numbers, successful farmers may have 100 percent equity plus off-farm investments, and they buy out those exiting the industry by converting their investments into extra land, together with a minimal loan[29].

Figures 23 and 24 show a relationship between equity and return on capital in both zones (return is measured as profit plus imputed labour plus the value of capital gain), and the relationships are statistically significant. A further statistical test[30] indicates that increased return results in increased equity, not the other way around. A 1 percent increase in rate of return results in a 1.3 percent increase in equity in the HRZ and a 0.9 percent increase in the WSZ. Using this rate of return measure, Figure 25 shows that the rate of return has stabilised around 10 percent in the WSZ and has recently increased to around that same figure in the HRZ. This increase in the HRZ was probably due to the increase in beef and sheep meat prices translating into much higher prices for livestock sold.

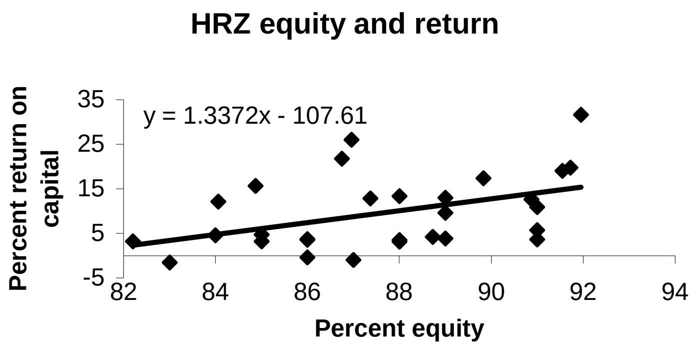


Figure 23: Average equity of property owners and rate of return on capital employed in high rainfall zone over period 1977 to 2005.

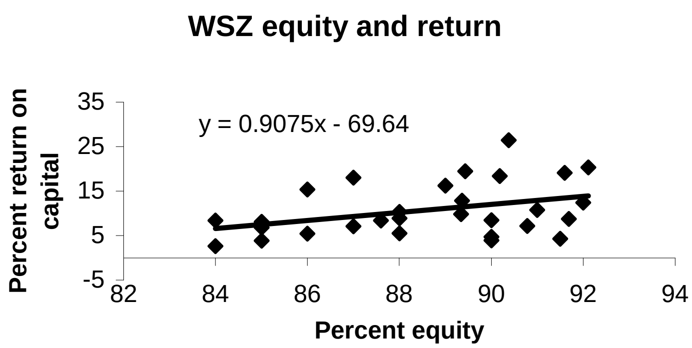


Figure 24: Average equity of property owners and rate of return on capital employed in wheat-sheep zone over period 1977 to 2005.

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[29] A pessimistic interpretation of these data is that cash flow is not sufficient to service debt at less than 90 percent equity.

[30] The “Granger causality” test.

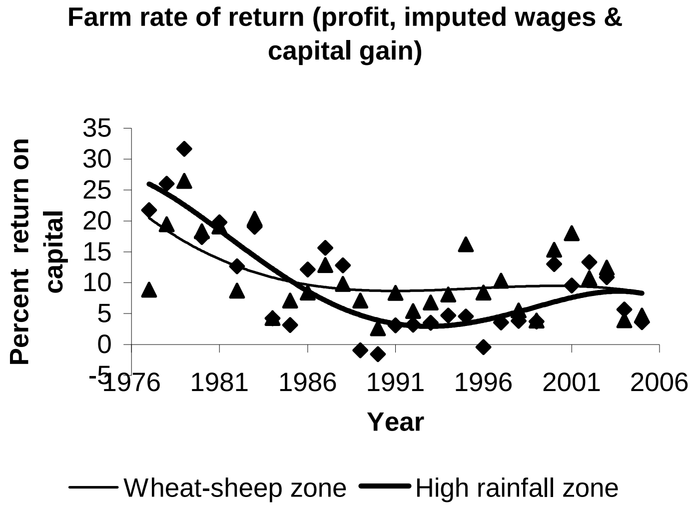

Figure 25: Farm rate of return (profit, imputed wages and capital gain) in the wheat-sheep zone (diamonds) and high rainfall zone (triangles) from 1977 to 2005.

It is often argued that broadacre farming is a poor investment. However the 29-year average rate of return, as defined, in the HRZ is 8.0 percent and in the WSZ it is 10.8 percent. If it is accepted that farmers take a holistic view of income (profit plus imputed labour plus capital gain), and most of the ownership in a property is that of the farm family, then these averages seem reasonable compared to a risk-free real rate of return of 5 percent. The additional 2.8 percent return in the WSZ can be viewed as a risk premium for farming in a zone where drought years strongly impact on yield from grain crops. Most of the income is in the form of capital gain (against which borrowings can be made, particularly in the short term). The farm profit plus imputed labour return on capital measure is 2.9 percent for the HRZ and 3.9 percent for the WSZ.

Overall, there were two distinct trends in farm income (profit plus the value of the owner/manager and family labour – the ABARE definition of profit deducts the value of this labour) in the settled areas. Before the early 1990s, property and family income tended to decline and since then it has increased. The curves shown in Figures 26 and 27 are somewhat misleading in that farm income can vary enormously between years, due to drought and fluctuations in commodity prices.

Off-farm wages have increased markedly and now contribute a significant amount to total family income in both zones ($13,000 in the WSZ and $23,000 in the HRZ – 2002-2005 averages). Off-farm wages have increased at a greater rate and are much higher in the HRZ compared to the WSZ, which may be due to locational effects: greater opportunities for employment because farms are closer to significant population centres. Off-farm wages, presumably mainly from spouses, as well as other off-farm income, obviously now play a significant part in helping farm families through drought years and low commodity prices.

On a fitted curve basis, and assuming the farm family owns around 90 percent equity, average family income from the farm, exclusive of capital gain, in the HRZ zone is now around $80,000 per year and in the WSZ around $100,000 (Figures 26 and 27). This is significantly better than the state average for households ($54,000 – ABS

6523.0, 2005). However, this extra income comes at a considerable cost in terms of locking up very large quantities of equity in the farm, especially compared to the average SA household net worth, and particularly given the fluctuations in farm income caused by prices and low rainfall seasons. Figures 26 and 27 also show that farm family income has improved very considerably since the early 1990s. On the basis of current family incomes, there appears to be no need for general government assistance to farm families, except perhaps in times of exceptional circumstances such as severe droughts.

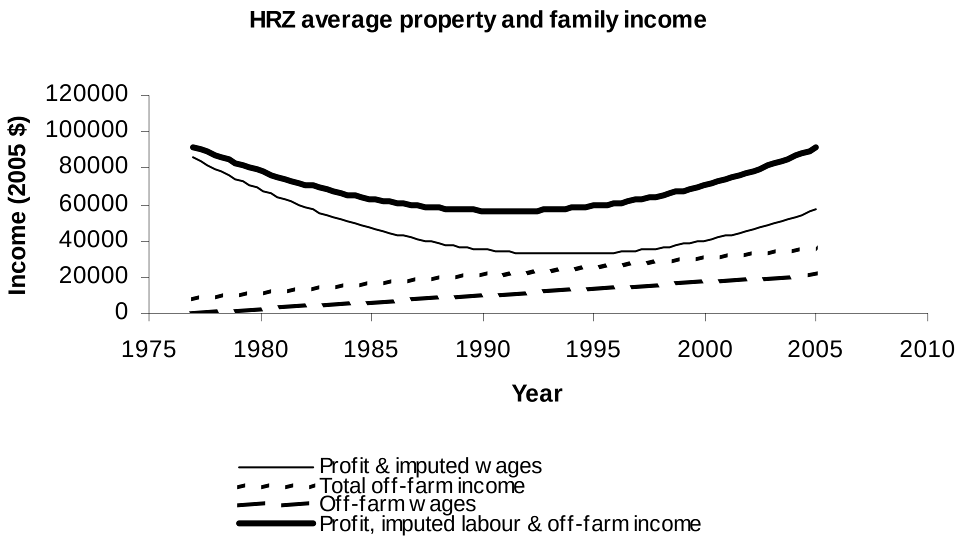

Figure 26: Breakdown of the average farm family income, in 2005 dollars, in the high rainfall zone from 1977 to 2005.

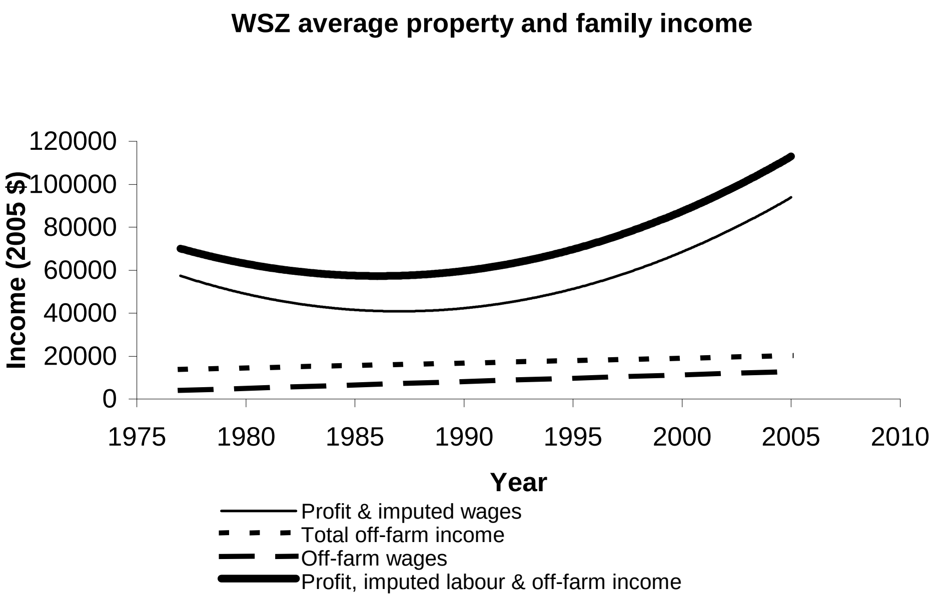

Figure 27: Breakdown of the average farm family income, in 2005 dollars, in the wheat-sheep zone from 1977 to 2005.

Note: For clarity of presentation, original datum points are not displayed.

3.8 Productivity and cash cost statistical analyses

Section *3.8* is probably challenging for the general reader. See the "Abstract: Productivity improvement and cash costs" (p.4) for a summary for those who have little interest in the details discussed here.

<u>Introduction</u>

Discussion of the results has been structured first by TFP, and the cash cost analyses follows this. The industry property analyses have been grouped into livestock specialists (beef, sheep-beef and sheep as separate industries), mixed crop-livestock and crop. This is followed by discussion related to the two settled area zones – the HRZ and the WSZ.

There are four elements of the results that are covered in the TFP results and discussion: (1) the OFP, IFP and TFP measures; (2) the statistical significance of the explanatory variables in the TFP measure; (3) the impact of the explanatory variables, measured as elasticities; and (4) the explanatory power of the models, measured in terms of adjusted coefficients of determination (*R* squared).

For readers who are not familiar with the elasticity measure, an example explanation of it may be helpful at this point. An example from Table 2 is that sheep sold recorded an elasticity of 0.39 relative to TFP on sheep properties. This means that for an increase of 1 percent in sheep sold TFP is increased by 0.39 percent. Likewise, for readers who are not familiar with the adjusted coefficient of determination (adjusted *R* squared), an example explanation is worthwhile. In Table 2, the adjusted *R* squared for the sheep property TFP model is 0.69. This means that the explanatory variables have been estimated to account for 69 percent of the variation in the 29 years of TFP data.

It is expected that model adequacy (adjusted *R* squared) would be high for the TFP models, as the significant explanatory variables, plus any possible statistically non-contributing variables, actually make up the OFP and IFP measures that in turn determine the TFP measure (by definition). The prime objective of the analyses was therefore the determination of the elasticities of the contributing variables, and thus their relative impact, by maximising adjusted R square rather than simply estimating it[31]. Rainfall variability, sampling error and random error are the principal other factors that could contribute to the variation in these empirical models. However, rainfall variability is somewhat correlated with input (management) and output (production) explanatory variables (such variables often tend to move in sympathy with seasonal rainfall), and hence it did not contribute as a separate explanatory variable in most models tested.

The point of the cash costs analyses shown here is to determine, on the basis of the time series statistics, what were the key determinants driving changes in cash costs. The "hired labour" category contributes a relatively small amount to total cash costs in all property categories, yet it contributes significantly in four of the five specialist

[31] Subject to the Durbin-Watson statistic for autocorrelation being within the satisfactory range. The autocorrelation parameter in the analysis was altered to achieve this.

property categories. This needs to be interpreted from the viewpoint that it is probably an indicator of increased costs in a range of other activities. If there is a need for increased hired labour on a property then there is probably a need for an increase in a range of other cash costs, but these changes are not as consistent within each category as they depend on seasonal and other influences. The hired labour category can therefore be interpreted as a "lead indicator" for a range of other cash costs.

The livestock properties

Table 5 shows the significant explanatory variables for TFP and for changes in cash costs for the beef, sheep-beef and sheep industries in SA, over the 1977-2005 period.

The relatively poor explanatory model (low adjusted R squared value of 0.69) for the sheep properties, compared to the other property categories, is first partially explained by the low, non-significant TFP measure together with the random variation around the best-fit estimate. Secondly, an examination of the individual year data indicates considerable divergence among yearly measures in years following the wool boom in the late 1980s. From the early 1990s the underpinning data became less secure, possibly due to different tactics among sheep properties in handling the collapse in wool prices (taken together with the fact that the data come from a sample rather than a full census of properties). Together these suggestions help explain why the TFP model for sheep is less robust than the models for other property types.

Beef properties seem far more specialised than the other two livestock production property categories. The evidence for this comes from two sources. Firstly, there were so few outputs other than cattle that these other outputs had to be combined into a single "other outputs" category, comprising sheep sold, wool produced and grain produced (wheat, barley, other grains). Individual "other output" categories recorded zero in particular years, from time to time. Secondly, changes in property numbers in this category over time were fairly steady from year to year (Table 1). This contrasts with the other two categories – sheep and sheep-beef – where a marked increase in property numbers in the former resulted in a marked fall in the latter (Table 1). That behaviour in the sheep and sheep-beef categories seems related to relative price changes between sheep and cattle, and therefore revenue from sheep and cattle. The highly specialised nature of beef properties firstly is probably related to some being located outside the dingo fence in the pastoral zone, where sheep grazing is not a viable alternative. Secondly, some properties in the lower southeast are located on land that becomes swampy in winter. This precludes sheep grazing because of footrot and wool rot problems. Finally, as more farm family income in the form of wages is derived from off the property in the HRZ (see Section 3.7, above) there are time-related pressures to stock only cattle, because they require less maintenance than sheep.

TFP was not significantly different from zero on both on sheep and beef-sheep properties, and was only 1.1 percent per year on beef properties. These results are disappointing, particularly in relation to those achieved by cropping properties (3.2 percent) and, to a lesser extent, mixed crop-livestock properties (1.9 percent) – Table 5. There is some circumstantial evidence that farmers are increasing the quality of sheep and beef animals turned off – see Figure 17 (quantity of livestock materials per DSE) and related discussion as well as Appendix 1 for quantification from interviews of these quality improvements, and the methodology used (note that these estimates of quality improvements have been incorporated in the OFP measures). It may be that owner/managers of livestock properties are, to some extent, traders. The behavioural focus is to maximise profitability by taking advantage of price changes, opportunistically selling lambs, sheep and cattle at a time that takes advantage of relatively high prices. Such relatively high prices can come about either because of market fluctuations or because of seasonal conditions. Seasonal conditions dictate the quality and quantity of pasture. If pasture is of low quality or is heavily stocked the condition of livestock will deteriorate and therefore their unit value will drop. Both these behaviours – improving the quality of the lambs and cattle turned off because of market demands, turning lambs, sheep and cattle off at a time that takes advantage of relatively high prices – means that the focus is not on maximising the utilisation of pastures, which would generate productivity increases particularly if the quantity of pasture was increasing per unit area over time. Circumstantial evidence for farmers not placing a high priority on pasture growth comes from Figure 16, which shows that fertiliser is applied to pastures on sheep and sheep-beef properties only at low rates overall, and fluctuates according to farm income. Another major reason for a lack of productivity growth on sheep and beef properties could be the downturn in growing season rainfall in the settled areas (Figure 13). A reduction in growing season rainfall will reduce pasture production, and hence carrying capacity. Finally, the carrying capacity of land available for grazing has probably been reduced as more and more of the better quality land in the settled areas has been subject to cropping each year.

The OFP and IFP measures show that each property category arrived at its poor TFP figure in different ways. Both OFP and IFP were significantly negative for beef properties. In other words, property owners in this category placed an emphasis on cost minimisation (the IFP measure) but this came at the price of reduced output (the OFP measure). The results indicate that the increased price of cattle turned off from the mid 1990s, together with reduced costs, were the primary factors in maintaining viability on beef properties. While the “area” sign was negative, as expected – the average area of beef properties has actually decreased. This means that increased area on beef properties has a positive impact on TFP. The size and sign of the elasticities for cash costs and beef sold were as expected. “Imputed labour” did not contribute as an explanatory variable in the TFP analysis and “other outputs” contributed only in a very minor way. In the case of “other outputs”, this was not unexpected, given the very small size of their contribution to output. The imputed labour of the owner/manager and family is a relatively constant figure from year to year, as it is for all property categories. In the beef property category the analysis shows it does not make a significant impact. In other words, there may be little of importance to do at particular times during the year on these properties.

On sheep-beef properties, OFP increased significantly, at 2.6 percent p.a., and IFP increase was estimated at 1.8 percent p.a. TFP was not significant, at 0.8 percent p.a. The reason why there was a significant increase in OFP on the sheep-beef properties but not on the other two categories can only be a matter of conjecture, given the similarity of the type of operations in the three property groupings. On sheep-beef properties, Table 2 shows both cattle sold and wool production had high elasticities, but sheep sold had a relatively low elasticity. These figures indicate that the main contributors to TFP change on these properties were cattle turnoff and wool production, rather than prime lamb production.

Table 5: Livestock properties econometric analyses results

	Beef				Sheep-beef				Sheep			
2002-05 av. no of properties	840				657				1548			
OFP annual change (adj. R^2)	-0.97 NS (-0.01)				2.60 *** (0.46)				0.17 NS (-0.03)			
IFP annual change (adj. R^2)	-2.11* (0.14)				1.78 * (0.15)				0.20 NS (-0.02)			
TFP annual change (adj. R^2)	1.14 ** (0.20)				0.82 + (0.06)				-0.04 NS (-0.04)			
(A) TFP analyses significant	**(A)**	**(B)**	**(C)**	**(D)**	**(A)**	**(B)**	**(C)**	**(D)**	**(A)**	**(B)**	**(C)**	**(D)**
explanatory variables (P < .05)	Outputs:				Outputs:				Outputs:			
(B) Elasticity	Cattle sold	0.86***	-1.9	93	Cattle sold	0.45***	2.2	42	Cattle sold	0.09**	-0.9	10
(C) Actual % annual change	Other outputs	0.01*	-1.1	7	Sheep sold	0.09***	1.5	21	Sheep sold	0.39***	0.0	27
(physical units)					Wool	0.30***	1.3	31	Wool	0.23*	0.3	49
(D) Average % value of					Grains	0.02***	9.4	3	Grains	0.13***	3.6	8
contribution to outputs or	Inputs:				Inputs:				Inputs:			
inputs (5 % of total capital	Cash costs	-0.45***	-0.3	63	Cash costs	-0.46***	1.3	58	Cash costs	-0.30**	-0.2	58
value for "area")	Area	-0.35***	-6.6	26	Area	-0.32***	1.7	30	Area	-0.33***	1.6	27
					Imputed labour	-0.18***	1.0	13	Imputed labour	-0.27*	0.2	15
(Non contributing explanatory	(Non contributing)				(Non contributing)				(Non contributing)			
variables in the TFP analysis)	(Imputed labour)				(Hay sold)				(Hay sold)			
Model explanatory power: adj. R^2	0.88				0.99				0.69			
(A) Cash costs analyses	**(A)**	**(B)**	**(C)**	**(D)**	**(A)**	**(B)**	**(C)**	**(D)**	**(A)**	**(B)**	**(C)**	**(D)**
explanatory variables	Cattle purchases	0.29***	2.2	23	Cattle & sheep purchases	0.19***	1.6	16	Cattle purchases	0.03**	0.2	3
(B) Elasticity									Sheep purchases	0.05**	-1.8	9
(C) Actual % annual change	Hired labour	0.30***	-4.7	7	Hired labour	0.17***	-0.9	5	Hired Labour	0.08***	-1.7	5
(2005 $ values)	Livestock materials	0.21***	2.4	2								
(D) Average % value of												
contribution to cash costs	Purchased fodder	0.05*	5.7	4	Purchased fodder	0.06*	0.0	5				
					Fertiliser	0.12*	2.4	9	Fertiliser	0.19***	2.6	6
					Machinery in use	0.15*	0.2	24	Machinery in Use	0.46***	0.2	27
					Cropping contracts	0.07***	12.6	2				
									(Rainfall)	0.08*		
Model goodness of fit: adj. R^2	0.94				0.95				0.94			

NS The partial regression coefficient was not statistically different from zero, +, *, **, *** Statistically significant, P< 0.10, 0.05, 0.01, 0.001 respectively (TFP: one-tailed test).

[a] Includes both grain and sold hay

On sheep properties, IFP, OFP and TFP growth were all not significantly different from zero. Strategies for minimising inputs resulted in zero input growth (IFP) but also resulted in zero output growth (OFP), and hence zero TFP growth. In a situation of low wool and sheep prices such a strategy is probably worth pursuing, particularly if property circumstances are such that sheep enterprises are more profitable than cattle enterprises, but there is little scope for expansion into cropping. The relatively low value of sheep and wool enterprises is also reflected in the fact that both cattle sales and grain production contributed significantly to TFP as explanatory variables (Table 2), despite the fact that the properties were classified as predominantly sheep and wool production. The elasticity of cash costs was only two-thirds that in the sheep-beef industry grouping (-0.46 vs. -0.30). These negative elasticities provide further evidence that the emphasis was on cash cost minimisation on sheep properties.

There was considerable commonality in the cash costs models (Table 5). Livestock purchases (cattle only in the case of cattle properties) contributed as an explanatory variable in all three models, as expected. However the elasticity estimate varied widely between property types. Judging by the elasticities, livestock purchases were considerably more important in driving cash costs on beef properties than on sheep properties, with sheep-beef properties intermediate. This suggests that beef properties were much more dependent on livestock trading and finishing than sheep properties. Similarly, although hired labour contributed as an explanatory variable in all three models its elasticity was much greater for beef properties than for the other two categories, suggesting a greater dependence on the use of hired labour on beef properties at critical times in the production cycle. The use of hired labour has decreased in all of these property categories (Table 5 column C).

Both fertiliser and "machinery-in-use" contributed as explanatory variables in the sheep and beef-sheep property categories cash cost models. The sensitivity of fertiliser application to fluctuations in property revenue on these properties has already been noted (Figure 17 and related discussion). It is therefore not surprising that fertiliser costs should be a significant explanatory variable for fluctuations in cash costs. The fact that fertiliser costs were not significant in the beef properties model is probably due to the number of beef properties in the pastoral zone, as well as their relative size. Such properties would not have fertiliser applied to them. In addition, properties with feedlots may apply little fertiliser because nutrient-rich feedlot waste is applied to pastures on these properties. There are only about 30 properties in SA that feedlot, however (Australian Lot Feeder's Association, pers comm.). Machinery-in-use forms a considerable portion of cash costs: 25 percent in both sheep and sheep-beef categories. However, the elasticity is markedly different in these two property categories. The emphasis on reducing cash costs on sheep properties compared to sheep-beef properties (cash costs elasticities in the TFP analyses of –0.32 and –0.46, respectively) may mean that inter-year fluctuations in machinery-in-use costs played a larger part in explaining the cash costs fluctuations on sheep properties. In addition, a larger proportion of the value of output is derived from grain production on sheep properties compared to sheep-beef properties. Therefore machinery-in-use costs associated with variations in cropping costs, in turn influenced by seasonal rainfall, played a larger part on sheep properties. Despite its large contribution to cash costs on beef properties (24 percent), machinery-in-use did not contribute as an explanatory variable. Especially on beef properties in the pastoral zone, there may be little discretionary use in this category, because routine trips by vehicles around properties and to population centres are necessary for their viability. In addition, it is noted that there is little production of anything other than beef cattle, which may additionally reduce linkages between the category and fluctuations in total cash costs.

Livestock materials contributed as an explanatory variable in the cash costs models for beef properties, but not for sheep and sheep-beef properties. As noted in *3.6* in the discussion on livestock materials, electronic ear tagging of cattle has played a significant part in recent cost increases in livestock materials for cattle. Electronic ear tagging is not, as yet, used for sheep. In addition, it appears from these results that the use of livestock materials (drenches, dips, etc) is more tactical on beef properties than on sheep and sheep-beef properties.

The fact that purchased fodder was a significant contributor in the beef and beef-sheep enterprises, but not the sheep enterprises, indicates that sheep enterprises are more reliant on feed produced on the property, as well as the possibility that there is a greater need to supplement beef cattle during feed shortages. Purchased fodder contributed little to cash costs (Table 5), but may be an indicator of other cash purchases in the same way that hired labour is (see the discussion in the "Introduction" to 3.8).

<u>The crop and crop-livestock properties</u>

The 2002-2005 number of crop properties was more than double those categorised as mixed crop-livestock (Table 6). Crop specialist properties constituted 44 percent of the total SA broadacre farms in 2002-2005. As a generalisation, they are also situated on the best land in the WSZ. They have easily outperformed the other property categories in terms of TFP increase (3.2 percent vs. 1.9, 1.1, 0.8 and 0 for the crop-livestock, beef, sheep-beef and sheep categories, respectively). Their productivity has increased by a factor of 2.7 in the 1977-2005 period, whilst that of the crop-livestock category has increased by 1.8 times. However, TFP growth has levelled off in both category types in the last few years (Figure 28). Crop yield increases are the major cause of the superior TFP performance on crop and crop-livestock properties compared to livestock specialist properties (inputs per cropped ha have remained relatively constant). Yield increases in wheat and barley, the predominant crops in SA, have plateaued in the last few years. See *3.4* for a detailed discussion on this topic.

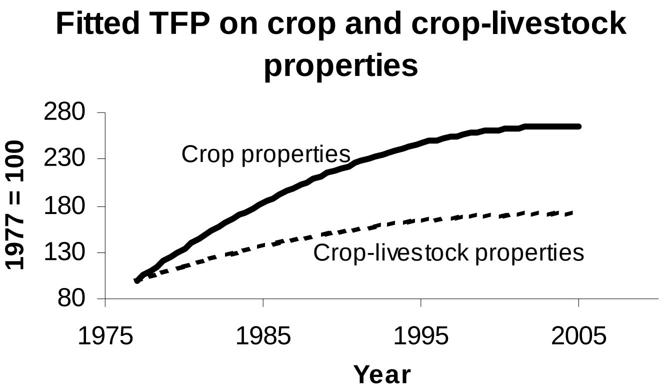

Figure 28: Fitted total factor productivity, with 1977 = 100, for crop and crop-livestock properties from 1977 to 2005.

Table 6: Mixed crop-livestock and crop properties econometric analyses results

	Mixed crop-livestock				Crop			
2002-05 av. no of properties	1,660				3,341			
OFP annual change (adj. R^2)	3.72 *** (0.73)				4.83 *** (0.64)			
IFP annual change (adj. R^2)	1.83 *** (0.65)				1.62 *** (0.54)			
TFP annual change (adj. R^2)	1.89 *** (0.44)				3.21 *** (0.48)			
(A) TFP analyses significant	**(A)**	**(B)**	**(C)**	**(D)**	**(A)**	**(B)**	**(C)**	**(D)**
explanatory variables, P < 0.1	Outputs:				Outputs:			
(B) Elasticity	Beef sold	0.06***	3.3	5	Beef sold	0.02*	2.4	3
(C) Actual % annual change	Sheep sold	0.09***	3.4	16	Sheep sold	0.08**	1.2	6
(physical units)	Wool	0.27***	2.2	22	Wool	0.06*	0.7	8
(D) Average % value of	Barley	0.14***	2.5	20	Barley	0.10***	5.2	23
contribution to outputs or	Wheat	0.29***	3.1	30	Wheat	0.55***	4.7	52
inputs (5 % of total capital	Other grains	0.12***	9.5	7	Other grains	0.11***	13.0	9
value for "area")	Inputs:				Inputs:			
	Cash costs	-0.51***	2.2	58	Cash costs	-0.48***	2.1	60
	Area	-0.29***	1.8	26	Area	-0.31***	0.6	25
(Non contributing explanatory	(Non contributing)				(Non contributing)			
variables in the TFP analysis)	(Imputed labour)				(Imputed labour)			
Model explanatory power: adj. R^2	0.99				1.00			
(A) Cash costs analyses	**(A)**	**(B)**	**(C)**	**(D)**	**(A)**	**(B)**	**(C)**	**(D)**
explanatory variables	Cattle & sheep	0.08+	3.3	7				
(B) Elasticity	purchases							
(C) Actual % annual change	Machinery in use	0.33**	-0.1	33	Machinery in use	0.50***	0.8	41
(2005 $ values)	Fertiliser	0.21**	2.5	11				
(D) Average % value of	Livestock	0.11*	3.5	2				
contribution to cash costs	Materials							
	Hired labour	0.06+	0.9	3				
					Chemicals[a]	0.17***	5.9	12
					Cropping contracts	0.11**	2.1	3
Model goodness of fit: adj. R^2	0.92				0.88			

+, *, **, *** Statistically significant, P< 0.1, 0.05, 0.01, 0.001 respectively (TFP: one tailed test)

[a] "Fertiliser" was a substitute for "chemicals" in the penultimate crop farms cash costs analyses; however the two were incompatible in an analysis that included both, in terms of signs on the variables (the two were highly negatively correlated), and "chemicals" resulted in a model with a very slightly higher adjusted R^2.

In these two property categories IFP was similar (Table 6). The large difference in the TFP growth rates was due to the difference in the OFP growth. In other words both property categories employed similar expansionist strategies in terms of IFP growth, but the reward for these strategies, in terms of increased OFP growth was markedly different. This OFP growth difference essentially occurred in the crop category (Table 6, TFP analyses, columns C). Growth in all three grains categories was considerably higher on crop properties that on crop-livestock properties, and was not matched by growth in the livestock categories on crop-livestock properties either. The reasons why there was such a difference in the reward from an essentially similar overall IFP strategy may relate to the quality of the land. There is now probably insufficient cropping land on the remaining crop-livestock properties to increase the level of crop production to the extent that they can be classified as crop specialist properties. Evidence for this is the fact that the proportion of crop properties in the totals of crop and crop-livestock properties has started to level off after rapid growth in the 1990s (Figure 16). Imputed labour did not contribute as an explanatory variable in either property category. This suggests that there may be little of importance to do at particular times during the year on these properties. While workflow is highly cyclical for cropping enterprises, it is more constant for livestock enterprises. The result was therefore not surprising on crop specialist properties but was surprising on crop-livestock properties, where it would appear that farmers would divert their efforts to livestock husbandry during periods when cropping tasks did not occupy their time. It may be that the livestock population on crop-livestock properties is relatively small, and therefore the time devoted to livestock husbandry is also relatively insignificant. Assuming property average size is an indication of property viability, the evidence that pursuing a strategy of high TFP growth was successful comes from the fact that average property area has remained essentially unchanged over the 29-year period on crop properties but has increased by 44 percent on crop-livestock properties (Table 1).

Machinery-in-use constitutes a high proportion of total cash costs in both property categories (Table 6, columns D), far higher than on sheep and sheep-beef properties (Table 5). However, it grew faster on crop specialist properties (Columns C, Tables 5 and 6). On crop-livestock properties, there was a great deal of commonality of cash costs explanatory variables with livestock properties (Table 5 cf Table 6). However, there was some departure from these common variables on crop properties. “Chemicals” costs were a near perfect substitute for “fertiliser” costs (see footnote b to Table 6) and “cropping contracts” substituted for “hired labour”. These substitutions are a result of the dominance of cropping enterprises on crop specialist properties.

<u>The wheat-sheep and high rainfall zones</u>

The WSZ and HRZ combine elements from all property types. However, analysis separate from property types is useful because there is a reasonable element of climate homogeneity in the zones. While both experience a Mediterranean type climate with a winter-dominant rainfall pattern, the HRZ is predominantly livestock production, due in part to topography (the Adelaide Hills region), in part to soil types that are prone to waterlogging in winter (particularly in the lower Southeast and on Kangaroo Island) and in part to traditional patterns of use dominated by grazing livestock and dairy production. This is because the higher rainfall and milder average spring and autumn temperatures favours strong pasture growth and a longer growing season. The more marginal lower rainfall areas of the WSZ, and sometimes topography and soil types, dictate the limits of grain production in that zone. Because of these geographic and climate proximity factors, as well as the interplay of the explanatory variables from the different property type analyses, the results in Table 7 are not necessarily a weighted mean of the property types present in the zone.

Table 7: Wheat-sheep zone and high rainfall zone econometric analyses results

	Wheat-sheep zone				High rainfall zone			
2002-05 av. no of properties	4,903				2,784			
OFP annual change	4.29 *** (0.79)				2.16 *** (0.79)			
IFP annual change	2.24 *** (0.79)				0.76 *** (0.31)			
TFP annual change	2.05 *** (0.78)				1.40 *** (0.69)			
(A) TFP analyses significant	**(A)**	**(B)**	**(C)**	**(D)**	**(A)**	**(B)**	**(C)**	**(D)**
explanatory variables, $P < 0.1$	Outputs:				Outputs:			
(B) Elasticity	Cattle sold	0.05***	4.8	4	Cattle sold	0.30***	2.3	29
(C) Actual % annual change	Sheep sold	0.09**	1.6	9	Sheep sold	0.12***	-0.3	23
(physical units)	Wool	0.14+	0.6	15	Wool	0.13**	-0.3	32
(D) Average % value of	Barley	0.19***	4.3	23	Wheat	0.09***	5.7	6
contribution to outputs or	Wheat	0.45***	5.1	43	Other grains	0.09***	6.9	6
inputs (5 % of total capital	Inputs:				Inputs:			
value for "area")	Cash costs	-0.47***	2.5	61	Cash costs	-0.48***	0.7	59
	Imputed labour	-0.15*	0.6	15				
	Area	-0.12*	1.6	24				
(Non contributing explanatory	(Non contributing)				(Non contributing)			
variables in the TFP analysis)	(Other grains)				(Barley)			
					(Imputed labour)			
					(Area)			
Model explanatory power: adj. R^2	0.99				0.98			
(A) Cash costs analyses	**(A)**	**(B)**	**(C)**	**(D)**	**(A)**	**(B)**	**(C)**	**(D)**
explanatory variables	Cattle & sheep purchases	0.10**	4.2	6	Cattle & sheep purchases[a]	0.16***	-0.6	13
(B) Elasticity								
(C) Actual % annual change	Fertiliser[b]	0.13*	4.4	12				
(2005 $ values)	Machinery in use	0.48**	0.9	36	Machinery in use	0.11*	-0.1	24
(D) Average % value of	Cropping contracts	0.10**	2.0	2	Cropping contracts	0.07***	3.7	2
contribution to cash costs	Hired labour	0.09*	0.9	3	Hired labour	0.06**	-0.2	4
					Livestock materials	0.37***	1.7	3
Model goodness of fit: adj. R^2	0.94				0.93			

+, *, **, *** Statistically significant, P< 0.1, 0.05, 0.01, 0.001 respectively (TFP: one tailed test)

a Cattle purchases and sheep purchases both contributed as separate explanatory variables in an alternative analysis. However, their combination resulted in a model with a higher adjusted R^2.

b "Chemicals" was a near perfect substitute for "fertiliser" in the penultimate WSZ farms cash costs analyses. However, the two were incompatible in an analysis that included both, in terms of explanatory variable statistical significance, and "fertiliser" resulted in a model with a very slightly higher adjusted R^2.

Practically all crop specialist properties are in the WSZ and therefore the TFP analyses and cash cost analyses results are likely to mirror the results from these properties, given their high numbers. In addition most of the crop-livestock properties are likely to be in this zone. Therefore, given the number of properties in each category, the results of the analyses are likely to be similar to those from crop properties with some influence from crop-livestock properties and minimal influence from livestock specialist properties.

Despite the relatively small values of the grains categories (Table 7, Column D), wheat and "other grains" contributed to the HRZ TFP analysis. Land area was not significant in the inputs category in contrast to the livestock specialist properties analyses. This suggests that cash costs were the dominant input that contributed to TFP change in the HRZ, reflecting the high livestock output per ha of land. In the HRZ, cattle sold have increased by 2.5 percent per year while sheep and wool production has declined slightly (Table 7 Column C). The reason why wheat and "other grains" categories contributed was likely due to the fact that they expanded rapidly (Column C), albeit from a low base (Column D).

The significant cash costs explanatory variables in the WSZ were the same as those for crop-livestock properties (Table 7 cf Table 6, Columns A) apart from the substitution of cropping contracts for livestock materials. Likewise, the elasticity measures were quite similar, with the exception of the greater predominance of machinery in use. The result is surprising, given that the number of crop specialist properties was double that of crop-livestock properties in 2002-2005. However, the proportions of property types were reversed in 1977-1980, and the result probably reflected this evolution between property types over time.

The unusual aspect about the significant explanatory variables for the cash cost analysis in the HRZ was the high elasticity of livestock materials, given it contributes so little to cash costs in total. It probably reflects the fact that the measure could be associated with a raft of costs related to livestock production.

3.9 Possible adverse climate change and the recent run of poor seasons – an analysis of historical potential wheat yields at Minnipa and Turretfield

This issue was addressed through the prism of historical potential wheat yields as predicted by APSIM at Minnipa, an indicator site of a low rainfall SA wheat growing environment, and Turretfield, an indicator site of a high rainfall environment. In terms of broadacre agriculture as a whole, the heavy reliance of the APSIM predictions on growing season rainfall provides a general indicator of herbage growth in a Mediterranean type environment. Hence the grazing industries, dependent on pastures and forages, face a similar set of circumstances in the SA settled areas.

This analysis is focussed on
- How bad have the recent run of seasons been? and
- Is this an indication of recent adverse climate change (increasing temperatures, lower rainfall, and increasing frequency of drought)?

The recent past

A 40-year time frame was chosen and firstly examined five-year mean yields, using the APSIM predicted yields at Minnipa and Turretfield (10 mm sowing rule: sowing occurs following 10 mm of rainfall within 3 days after the beginning of April) as the basis of the analysis. It seemed logical to work back from the latest available time period (2007). The five-year period was chosen because it is a reasonable convention.

Figure 29, below, shows the results. As stated on the figure, the last five-year mean yield is indicated to be significantly worse ($P<0.1$) than the value predicted by the previous seven five-year means, which cover the period 1968-2002.

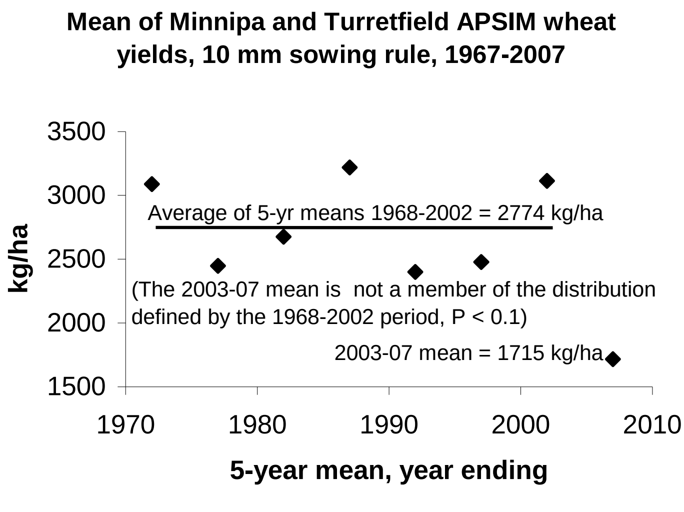

Figure 29: Five year means of Minnipa and Turretfield APSIM wheat yields, using sowing rule of seeding after receiving 10mm rainfall within 7 days after 1st April, for the period 1967 to 2007.

Are there differences between Minnipa and Turretfield in the historical record of potential yield predictions?

Figures 30 and 31 show the APSIM yield predictions at Minnipa and Turretfield respectively, using the 10 mm sowing rule. A mean of 5th and 6th order polynomials were fitted to these data, as well as the 5-year rolling means. The 5-year rolling means can be thought of as a proxy for a "no climate change" scenario - each data point of the means has only a 5-year "memory". They show that the conditions over the last 5 years at both Minnipa and Turretfield are as bad as they have ever been in the historical 1900-2007 record. On the other hand, the polynomial function takes account of the whole data set but cannot, of course, take account of data either preceding or following that set. Hence emphasis is placed on strong trends at the beginning and end of the data. These polynomial functions show that, at both Minnipa and particularly Turretfield, conditions are worse than they have ever been in the historical record. In the sense that these functions emphasise the ends of the data, and they show a worsening recent trend, they can be thought of as admitting the possibility of adverse medium term climate change. In the previous century the fitted polynomials showed different characteristics at Minnipa and Turretfield. Minnipa exhibited a decline in the early part of the last century and a peak of yields around 1965. Since then there has been a decline in potential yields, which has accelerated recently. Turretfield showed a strong increase in potential wheat yields from approximately 1970 through to 1990, followed by a sharp decline since then.

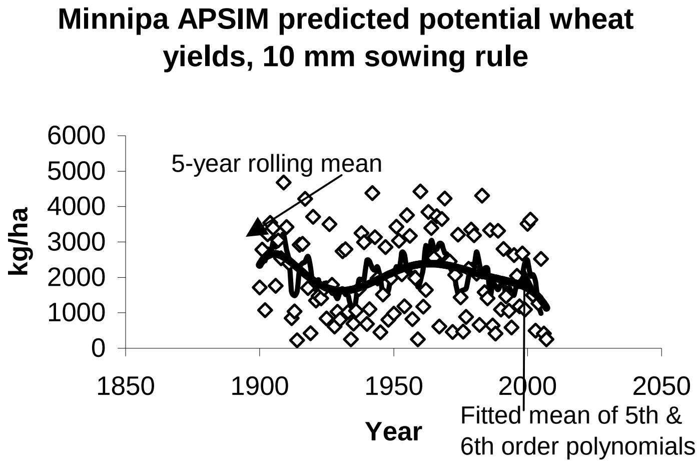

Figure 30: Predicted potential annual wheat yields and fitted trends for Minnipa APSIM using sowing rule of seeding after receiving 10mm rainfall within 3 days after 1st April, for the period 1900 to 2007.

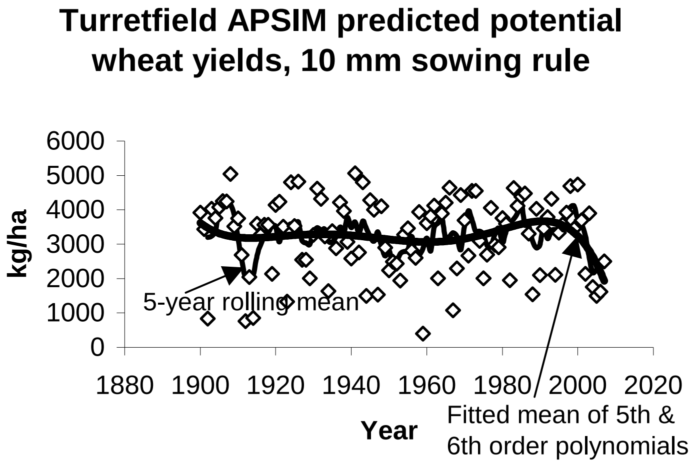

Figure 31: Predicted potential annual wheat yields and fitted trends for Turretfield APSIM using sowing rule of seeding after receiving 10mm rainfall within 3 days after 1st April, for the period 1900 to 2007.

Because Minnipa and Turretfield have both showed a similar recent worsening trend, and the recent years are the focus, the remaining sections combine the data from these sites on a 50:50 basis. That basis crudely reflects the historical area sown to wheat in the high and low rainfall regions of SA.

<u>The historical record: Minnipa and Turretfield combined</u>

For the 10 mm sowing rule, a rule of thumb was applied: "fit polynomial curves up to the 6th order and look at changes in R squared to decide where to stop". The final curve fitted to the full historical record of APSIM yields was suitably summarised by a mean of the 5th and 6th order polynomials. The first significant order was the 3rd. However there was no difference in terms of shape or significance between the 3rd, 4th and 5th order polynomials, while the 6th order produced a marked increase in the R squared figure compared with the 5th, this being attributed entirely to the Minnipa data. The 5th was chosen to join the 6th because they tend to cancel each other out in terms of trend details that are not notable in the Minnipa and combined series. The 6th order, in addition to producing a marked increase in R squared, also emphasises the behaviour in the last 18 years of the series, i.e. from 1990, which clearly is of more immediate interest. It is likely that, in the nature of the process of fitting higher order polynomials, the severe effect observed is exaggerated and certainly subject to a high degree of instability.

Figure 32 shows the results. The curve indicates a strong recent downward trend in yield, markedly exceeding the trough in the 1930s.

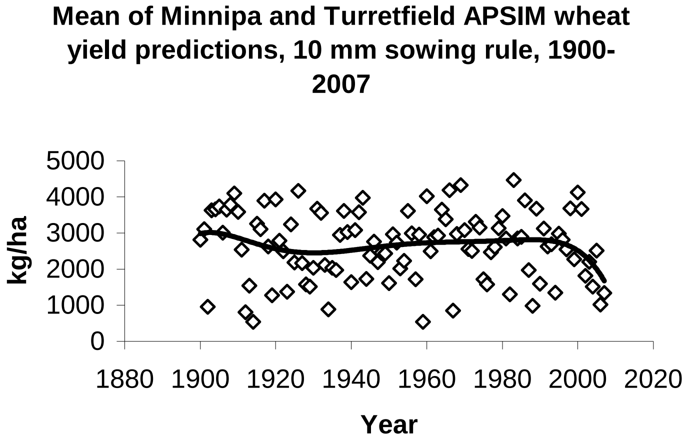

Figure 32: Mean annual wheat yield predictions and fitted trends for Minnipa and Turretfield APSIM using sowing rule of seeding after receiving 10mm rainfall within 3 days after 1st April, for the period 1900 to 2007.

A mean of 3rd, 4th, 5th and 6th order polynomials was fitted to a mean of the May 23rd, 10 mm and June 15th (all sowing occurs by June 15th) sowing rules. The purpose of this exercise was to check that the 5th/6th polynomial/10 mm sowing rule analysis was not anomalous. The results are shown in Figure 33. This procedure clearly shows the influence of the federation drought around 1900 as well as the poor run of seasons in the 1930s. Again, the recent downward trend and rate of descent are indicated as exceeding previous troughs.

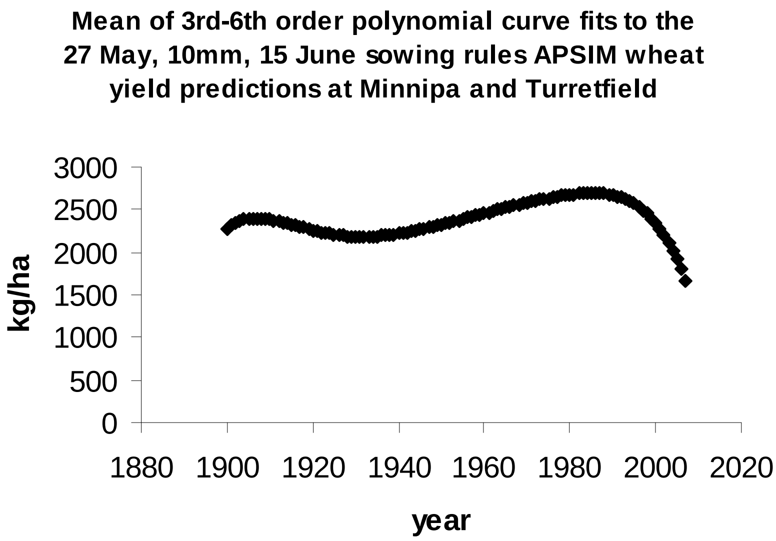

Figure 33: Fitted curve for the APSIM annual mean wheat yield predictions, using sowing dates of 27th May, 15th June and the 10mm rule, at Minnipa and Turretfield from 1900 to 2007.

Finally a better than average season in 2008 (approximately 65th percentile, mean of the sowing rules approximately 3,300 kg/ha) was hypothesised, to see the effect on the curve, as above. The overall effect was, of course, to dampen the downward trend. However there was still around a 0.7t/ha drop between the previous century’s average and the resulting fitted value for 2008.

In light of these analyses we suggest that, while it may continue to be difficult to robustly demonstrate significant negative climate change in the broad sense, APSIM modelling strongly indicates that SA wheat farmers have never faced a more difficult set of climate circumstances than those of the 2002-2007 period.

Tempering the actual predictions to take account of "misleading" randomness in the last 10 seasons

The last 10 years of the APSIM results were re-examined. This includes the run of good seasons with high yield potential in 1998-2000, so it is more than fair if there really has been adverse climate change occurring since 2002.

Figure 32 shows the actual APSIM results with a mean of 5th and 6th order polynomials fitted. As can be seen, the curve plunges dramatically at the end of the series.

The last 10 years of APSIM results were randomised, making sure that the randomisation was not "unfortunate" in the sense that the good and bad seasons were not at each end of the 10 years. Figure 34 shows the results, again with a mean of 5th and 6th order polynomials fitted. The conclusion from this randomisation is that the last few years were not materially worse than the 1930s in terms of yield potential.

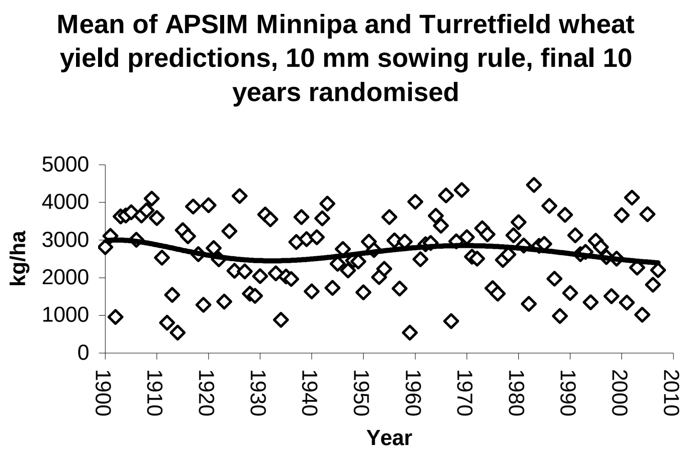

Figure 34: Mean of Minnipa and Turretfield APSIM wheat yield predictions using a sowing rule of seeding after receiving 10mm rainfall within 3 days after 1st April from 1900 to 2007 with the final 10 years randomised.

A mean of the 5th and 6th order polynomials was then fitted to data where the final 10 years consisted of the mean of the actual and randomised results, for purposes of illustration. This reflects a view of possible adverse climate change, accurately reflected by the recent run of seasons, but there is also the possibly that the recent run of seasons was the result of an unfortunate randomisation in a background of no climate change. By implication, we are assigning a 50 percent probability to both scenarios. One advantage of this approach is that we can change the scenario probabilities. Figure 35 shows that, if this approach is taken, the recent run of seasons is worse than it has ever been, similar to, but not as severe as, the result shown in Figure 32.

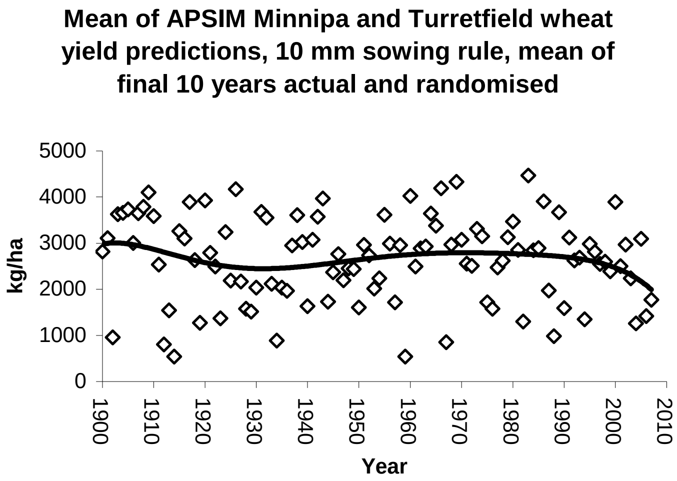

Figure 35: Mean of Minnipa and Turretfield APSIM wheat yield predictions using a sowing rule of seeding after receiving 10mm rainfall within 3 days after 1st April from 1900 to 2007 with the mean of the final 10 years actual and randomised.

4. Current and Future Broadacre Farming Evolution

At the time of publication, most of the statistics on which this report is based are now three growing seasons out of date. This section suggests what impact those three growing seasons, 2006-2008, might have in terms of SA broadacre agriculture evolution, and also suggests future trends through the work of Kingwell (2008).

The dominant features of the 2006-2008 growing seasons: (A) drought in 2006 and dry seasons in 2007 and 2008, and (B) large increases in important input prices and grain prices, but not livestock prices except wool (Table 8).

Table 8: ABARE Commodity Price Indices 2002-2003 to 2008-2009

	Price indices (1998-99 = 100)							**% increase**
Commodity	**02-03**	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**	**08-09** (f)	**04/6-07/9**
Chemicals	108.0	110.0	111.9	114.6	124.7	149.7	172.1	42
Fertiliser	106.9	102.8	108.8	111.6	121.4	220.4	264.5	120
Fuel & lub.	127.0	144.3	167.2	210.6	208.3	243.7	300.2	44
Wheat	*134.4*	*109.1*	*99.6*	*102.5*	*122.4*	*200.2*	*186.6*	*92*
Barley	*159.9*	*105.9*	*100.1*	*93.9*	*153.3*	*167.7*	*135.8*	*56*
Canola	*100.9*	*104.4*	*84.5*	*86.5*	*102.8*	*136.8*	*123.1*	*52*
Cattle	*145.0*	*160.4*	*177.2*	*181.3*	*174.3*	*170.3*	*176.3*	*-3*
Lambs	*176.7*	*190.1*	*184.5*	*177.7*	*165.7*	*164.0*	*173.8*	*-7*
Sheep	*185.4*	*230.3*	*196.1*	*202.7*	*156.4*	*178.9*	*177.0*	*-11*
Wool	*153.2*	*116.5*	*107.4*	*97.7*	*115.5*	*153.9*	*142.1*	*44*
Adel. CPI[(a)]	***139.1***	***144.3***	***148.6***	***151.8***	***157.6***	***160.3***	***167.6***	***9***

(f) ABARE forecasts, except for Adelaide CPI. Note that at the time of publication wheat, barley and canola price indices are below these forecasts
(a) ABS data, June 2002 quarter to June 2008 quarter indices

In a normal run of seasons gross margin analysis shows that these recent wheat price changes would make wheat cropping more profitable despite the increase in fertiliser, chemicals and fuel prices (Trengove and Black 2008). Similarly, compared to livestock enterprises, barley and canola cropping may also be more attractive on suitable areas. However, the last three seasons have been anything but normal - see *3.12* - a drought year followed by two dry seasons with a poor spring finish. The wheat gross margin analysis by Trengove and Black (2008) indicated that, in drought and low rainfall years, it was the farms in low rainfall cropping environments that would come under more financial stress than the farms in medium and high rainfall cropping environments.

Suggested trends in broadacre agriculture in the 2006-2008 seasons:

- The consolidation into larger properties is likely to have accelerated because drought and dry seasons, exacerbated by high input prices, will have made the smaller and less efficient producers increasingly less viable, particularly in low rainfall regions (see above). However, high grains prices would have arrested this trend somewhat in the medium and high rainfall crop growing areas.

- Less fertiliser would have been used, particularly on pastures, because of the enormous increase in the cost of fertiliser. This would have been exacerbated by the fact that livestock prices have declined somewhat (Table 8).
- The increase in wool prices in the last two years would have temporarily arrested its declining contribution to SA broadacre agriculture value. However, unless the recent trend marks a change to more stable and high prices, it is unlikely that the long-term decline in wool production will change. There are two reasons for this:
    - nil or low productivity growth in the industry, making it progressively less competitive
    - historically volatile and declining wool prices, making the industry unattractive as a long-term investment.

<u>The future to 2020</u>
This section has been taken from Kingwell (2008), edited to remove some material. As with all forecasts in broadacre agriculture, it is reliant on continuing general relativities in output prices between, particularly, grain and livestock; continuing trends in the relative size of TFP gains between industries; and no disruptive climate change. The authors see no need at this juncture to disagree with any of the points below. Kingwell presumes deleterious climate change.

"…

- Fewer, larger farms and fewer people employed directly in farming;
- Maintained diversification of business activity (a mix of farm enterprises and off-farm investments). The role of farmland as a supplier of renewable energy and source of greenhouse gas emission offsets is likely to increase . . . . .;
- Increased demand for and supply of animal and aquaculture feeds . . . . .;
- Continued production growth from yield improvement and new technologies. Biotechnology, particularly in the plant sciences, increasingly will underpin productivity improvement and new product development. Market acceptance of GM technologies will further improve with emergence of plants offering environmental and health benefits; . . . . . .
- Broadacre farming will maintain its emphasis on exports, productivity improvement, product and market development. Farmers will continue to invest in technical and scale efficiency, and pursue input and product innovation; . . . . . .
- The relative importance of agriculture in the nation's economy will continue to decline, although towards 2020 its absolute contribution will continue to increase;
- Greater commitment to sustainable farm practices . . . . .; . . . . .
- Greater use of contract services by farmers . . . . .;
- Greater separation of land ownership and management;
- Continuing difficulties in gaining access to reliable and skilled labour. Labour management and purchase of labour-saving technologies . . . . . will be an increasingly important part of farm management;
- Greater dependence on electronic technologies . . . .;
- Effects of climate change largely addressed through incremental technological improvement, plant breeding and design of novel farming systems. However, depending on the severity and rate of climate change, (SA broadacre) agriculture could experience large adjustment costs towards 2020."

5. Implications of these analyses for R&D

Total factor productivity (TFP) growth

TFP was not significantly different from zero on both sheep and beef-sheep properties, and was only 1.1 percent per year on beef properties. These results are disappointing, particularly in relation to those achieved by cropping properties (3.2 percent) and, to a lesser extent, mixed crop-livestock properties (1.9 percent) – Table 3. In making this comment, we distinguish between sheep enterprises, where 'nothing' is happening; and beef-sheep, where the increase in output value is significant, although relatively small. Output quality improvement measures were incorporated into the TFP measure.

Where possible, TFP should take into account any degradation of the stock of environmental, natural and agricultural genetic resources on which farming systems are based (Alston *et al*. 1995, pp 132-133). These TFP measures have not taken such degradation into account. Their possible contribution is widely assessed as small, however. In addition, any such degradation also takes place in crop specialist and mixed crop/livestock properties. If the rate of degradation is similar on all property types, then the comparisons between property types remains valid. It is thought unlikely that the rate of degradation is greater on livestock specialist properties than the other property types.

<u>Livestock enterprises</u>

Livestock specialist properties as a whole have undergone considerable transformation in their mix of products. Quality lamb and mutton production has become much more viable and wool production less viable; hence the sheep production mix has been transformed to reflect market signals. Likewise, beef production has been transformed to accommodate a feedlot sector. The feedlot sector is relatively minor in SA, however. Particularly on sheep and mixed sheep-beef properties, where TFP gain was least, it could be that the transformation in product mix (lamb, mutton, wool) has had a deflective effect on management implementation of productivity improvement. It is known that in some SA broadacre regions heavily influenced by livestock production, an improvement in the terms of trade reduces TFP increases (Black 2004). That is, an increase in profitability reduces the incentive to implement technology that improves productivity. Nevertheless the improvement in meat prices is a relatively recent phenomenon in a 29-year time series; hence in the longer term this explanation has reduced validity.

Although the arguments so far have been couched in terms relating to the poor TFP results from the specialist livestock properties, the poor carrying capacity and turnoff results from the WSZ relative to the HRZ indicate that livestock enterprises on mixed and crop specialist farms have also performed poorly in terms of TFP. For these enterprises the reason for the poor performance may be relatively more straightforward and defensible: as cropping area has expanded livestock enterprises on these properties have been relegated to less productive land that is unsuitable for cropping and/or onto grazing crop stubble of low nutritive value.

<u>Cropping and mixed crop-livestock enterprises</u>

At the other end of the range of TFP increase are the crop specialist properties (3.2 percent p.a.) with the mixed properties intermediate (1.9 percent p.a.). Given the current research intensity ratios (the ratio of R&D to the value of the industry) shown in Table 9 (Black 2009, in preparation), the results suggest that cropping enterprise research is a good investment compared to broadacre livestock enterprise research.

Table 9: Industry R&D intensity, TFP growth and proportion from R&D

Enterprise	Industry value[a] ($M)	R&D value[b] ($M)	R&D intensity (%)	Annual TFP growth (%)	TFP growth from R&D (%)
Cropping enterprises	1,404	50.3	3.6 %	2.0	85 %
Broadacre livestock enterprises	1,061	23.2	2.2 %	0.4	65 %

a 5 year mean 2001/02 – 2005/06, with a 10 percent CPI multiplier.
b all sources of institutional R&D, and allowing for significant spill-ins and spill-outs to SA, 2006.
Sources: Black (2009, 2004)

In work discussed in *3.4* and Black *et al*. (2008 in press) we observed a slight but significant decrease in the trend, corrected for seasonal rainfall, in wheat yield efficiency increases. At least in SA in recent years, we have also observed that local R&D for wheat breeding and pre-breeding has increased considerably in public institutions compared with farming systems research, despite the fact that varietal gain contributed an estimated 0.5 percent p.a. to the wheat yield annual gain of 1.7 percent p.a. and thus farming systems contributed 1.2 percent p.a. On the basis that there is a strong causal link between lagged R&D and productivity improvement, this relative change in public institution R&D resources may have caused the observed negative efficiency curvilinearity.

Specific implications of this study for broadacre R&D

- Annual pasture research for the WSZ should be reviewed because of the movement towards crop specialist properties from mixed crop-livestock properties, together with the relatively poor stocking rate and net turnoff performance in the WSZ compared to the HRZ. Medic pastures are dependent on crops in rotation for continued viability. Given the proportionate decline of annual pastures in crop rotations over much of the WSZ, pasture research for this zone, if it continues, should be directed towards areas that are not suitable for cropping.
- The amount of fertiliser applied to pastures has fluctuated widely over time. It is strongly related to livestock revenue per ha. This pattern of behaviour is contrary to normal advice that pasture fertiliser should be applied on a regular basis, in roughly equal amounts from year to year. Given that the practice appears to be so ingrained that it overcomes many years of extension and consultant advice, those who make recommendations on pasture fertiliser should perhaps alter their advice to minimise the damage to pasture productivity that results from this farmer behaviour.

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Appendix 1: The *ad hoc* incorporation of quality improvements in TFP indexes for SA broadacre agriculture

Rural industry output statistics often do not capture changes in quality – statistics are usually of the “tonnes of sardines caught” and “wharf value of the sardine catch” type – i.e. they refer only to undifferentiated product. Unfortunately, Divisia indexes are reliant on product differentiation by price if they are to lend themselves to the task of capturing changes in the quality of industry outputs. By inspection of the output Divisia index equation shown below, it can be seen that if there is no change in quantity of product between the two periods t and t-1 then there is no change in the index, even though prices between the two periods may have changed. In order to incorporate a measure of quality improvement in industry output, an interview technique was resorted to, followed by incorporation of the estimations into an output Divisia index.

Industry experts were asked the question: “If the industry’s product of the quality produced in (for example) 1994 was placed on the market now, what price would it fetch?” The shorthand was percent quality improvement over the period, with the understanding that the percentage was related to price in a one-to-one ratio. The second question was: “Has the annual rate of change in quality improvement over the period altered, and at what point(s) in the annual series did it alter?”. The shorthand was curvature in quality improvement over the period, and the years when the curvature changed.

Capturing annual changes in quality improvement

Consider a category of industry output that has many quality and corresponding price points, in year *t* and in year *t*-1. For convenience the population discussed below is normally distributed, but the argument is not reliant on this characteristic. However, a depiction of normally distributed populations is convenient for illustrative purposes because the mean of the population is at the apex of the distribution. The hypothetical illustration is for a production of approximately 10,000 tonnes (the same in both years) of a particular product in 60 product-price sub categories, each dependent on the quality of the product. The depictions are shown in Figure A1, with the relevant price and quantity data in Table A1.

Fig. A1: Illustration of data in Table 1: 60 product-price sub categories

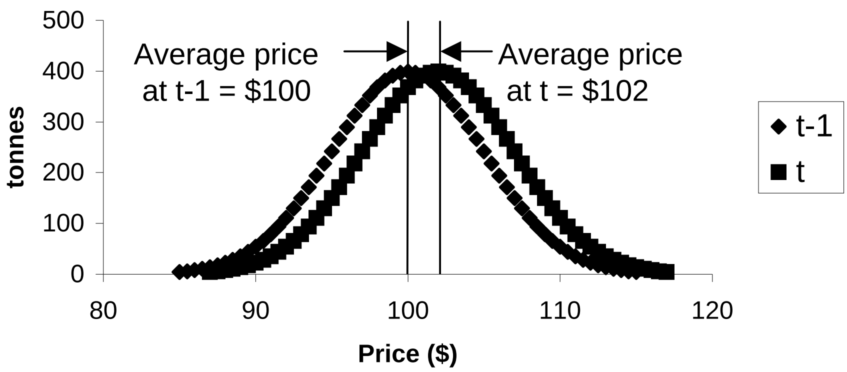

Figure 1 shows that the mean price of the product improved by 2 percent at t compared to t-1 as a result of the 4 worst quality categories at t-1 no longer being populated and 4 new superior quality categories at t being populated (Table A1, below).

The Fisher ideal Divisia approximation of output factor productivity is

$$\mathbf{QI}_t^{DF} = \mathbf{QI}_{t-1}^{DF}\left[\frac{\mathbf{P}_{t-1}^{'}\mathbf{Q}_t}{\mathbf{P}_{t-1}^{'}\mathbf{Q}_{t-1}}\right]^{\frac{1}{2}}\left[\frac{\mathbf{P}_t^{'}\mathbf{Q}_t}{\mathbf{P}_t^{'}\mathbf{Q}_{t-1}}\right]^{\frac{1}{2}}$$

Where

QI^{DF}	is the Divisia Fisher quantity index
P	is a vector of output prices
Q	is the corresponding vector of output quantities, and
t	is time t

For an output where there is only one price and production category the vectors **P** and **Q** become P and Q – where P and Q now represent the quality improvement adjusted industry averages. From Table A1, the relevant quality adjusted average cross products are $P_{t-1}Q_{t-1}$ & P_tQ_{t-1}: \$994,720 and P_tQ_t & $P_{t-1}Q_t$: \$1,017,674. If QI_{t-1} = 1 then, from the above equation, QI_t = 1.02. It is a simple, though laborious, exercise to show that this "average quality improvement" calculation produces the same result as the calculation of the 60 individual quality category and price by year computations – i.e. the vector calculation involving P and Q at $t-1$ and t.

In summary, if differentiated data on product quality by price are unavailable, the only way quality improvement can be captured in an OFP Divisia index is through the external imposition of an estimate; i.e. by multiplying the Divisia index longitudinal series by a quality improvement longitudinal series, for each year. In the example given above, the Divisia index for t is multiplied by 1.02. Table A2 provides the estimates of quality improvement incorporated into the OFP calculations presented in this report.

Table A1

Category prices ($)	t-1 category quantities (tonnes)	t category quantities (tonnes)	t-1 category values	t category values
85	4.43	0.00	376.71	0.00
85.5	5.95	0.00	508.94	0.00
86	7.92	0.00	680.73	0.00
86.5	10.42	0.00	901.41	0.00
87	13.58	4.43	1181.72	385.57
87.5	17.53	5.95	1533.72	520.85
88	22.39	7.92	1970.72	696.56
88.5	28.33	10.42	2506.94	922.25
89	35.47	13.58	3157.24	1208.88
89.5	43.98	17.53	3936.53	1568.78
90	53.99	22.39	4859.18	2015.51
90.5	65.62	28.33	5938.22	2563.59
91	78.95	35.47	7184.46	3228.18
91.5	94.05	43.98	8605.48	4024.49
92	110.92	53.99	10204.70	4967.16
92.5	129.52	65.62	11980.36	6069.46
93	149.73	78.95	13924.64	7342.36
93.5	171.37	94.05	16022.94	8793.58
94	194.19	110.92	18253.47	10426.55
94.5	217.85	129.52	20587.01	12239.40
95	241.97	149.73	22987.19	14224.09
95.5	266.08	171.37	25411.11	16365.68
96	289.69	194.19	27810.36	18641.84
96.5	312.25	217.85	30132.47	21022.71
97	333.22	241.97	32322.75	23471.13
97.5	352.06	266.08	34326.33	25943.28
98	368.27	289.69	36090.43	28389.74
98.5	381.39	312.25	37566.66	30756.98
99	391.04	333.22	38713.18	32989.20
99.5	396.95	352.06	39496.73	35030.46
100	398.94	368.27	39894.18	36826.97
100.5	396.95	381.39	39893.68	38329.43
101	391.04	391.04	39495.27	39495.27
101.5	381.39	396.95	38710.82	40290.64
102	368.27	398.94	37563.51	40692.07
102.5	352.06	396.95	36086.65	40687.59
103	333.22	391.04	34322.09	40277.35
103.5	312.25	381.39	32318.24	39473.59
104	289.69	368.27	30127.89	38300.05
104.5	266.08	352.06	27805.88	36790.78
105	241.97	333.22	25406.90	34988.54
105.5	217.85	312.25	22983.38	32942.75
106	194.19	289.69	20583.70	30707.27
106.5	171.37	266.08	18250.73	28338.05
107	149.73	241.97	16020.82	25890.84
107.5	129.52	217.85	13923.13	23419.08
108	110.92	194.19	11979.44	20972.07
108.5	94.05	171.37	10204.31	18593.47
109	78.95	149.73	8605.56	16320.27
109.5	65.62	129.52	7184.92	14182.16
110	53.99	110.92	5939.00	12201.28
110.5	43.98	94.05	4860.18	10392.41
111	35.47	78.95	3937.68	8763.46
111.5	28.33	65.62	3158.46	7316.15
112	22.39	53.99	2508.18	6046.98
112.5	17.53	43.98	1971.93	4948.15
113	13.58	35.47	1534.87	4008.62
113.5	10.42	28.33	1182.77	3215.12
114	7.92	22.39	902.36	2552.97
114.5	5.95	17.53	681.56	2006.99
115	4.43	13.58	509.66	1562.04
115.5	0.00	10.42	0.00	1203.62
116	0.00	7.92	0.00	918.19
116.5	0.00	5.95	0.00	693.47
117	0.00	4.43	0.00	518.53
Totals	**9977.20**	**9977.20**	**997720.09**	**1017674.49**

t-1 ave P

100.00

t ave P

102.00

t-1: t

OFP full calc	**1.02**
OFP ave calc	**1**
OFP ave calc with t/(t-1) multiplier	**1.02**

Table A2: Product quality improvement assessments

year	barley	wheat	sheep	beef	wool
1977	1	1	1	1	1
1978	1.002474	1	1.000221	1	1
1979	1.004963	1	1.001158	1	1
1980	1.007467	1	1.002789	1	1
1981	1.009986	1	1.005092	1	1
1982	1.01252	1	1.008047	1	1
1983	1.01507	1	1.011635	1	1
1984	1.017634	1	1.015837	1	1
1985	1.020215	1	1.020636	1	1
1986	1.02281	1	1.026015	1.003076	1
1987	1.025421	1	1.031958	1.007011	1
1988	1.028048	1	1.038448	1.010889	1
1989	1.03069	1	1.045469	1.015116	1
1990	1.033349	1	1.053006	1.020043	1
1991	1.036023	1	1.061043	1.025958	1
1992	1.038713	1	1.069565	1.033096	1
1993	1.04142	1	1.078555	1.041634	1
1994	1.044143	1	1.087997	1.05169	1
1995	1.046882	1.0045	1.097874	1.063325	1
1996	1.049637	1.00902	1.108171	1.076541	1
1997	1.052409	1.013561	1.118869	1.09127	1
1998	1.055198	1.018122	1.12995	1.107377	1.01
1999	1.058003	1.022703	1.141395	1.124647	1.02
2000	1.060826	1.027306	1.153185	1.142782	1.03
2001	1.063665	1.031928	1.1653	1.161388	1.04
2002	1.066521	1.036572	1.177717	1.179969	1.05
2003	1.069394	1.041237	1.190415	1.197921	1.06
2004	1.072285	1.045922	1.203371	1.214527	1.06
2005	1.075193	1.050629	1.216559	1.228958	1.06