Farm productivity

The influence of resource quality
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Productivity, profitability and resource quality

Productivity gains have been a major determinant of farm profitability over the past twenty years (Knopke, Strapazzon and Mullen 1995). However, there is increasing evidence that the land resource base has been degraded over this period and that productivity gains achieved historically may not be sustainable.

Land degradation has been defined by Crabb (1997) as any change in the land that reduces its condition or quality and therefore its productivity or productive potential. Key degradation problems affecting the quality of the land resource on Australian farms include salinity, soil structure decline and rising watertables. One of the most serious, land salinisation, has been identified by the Prime Minister’s Science, Engineering and Innovation Council as an economic and social issue of high priority (Department of Industry, Science and Resources 1998).

The influence of soil degradation and other problems on farm productivity is investigated in this article by calculating farm level productivity indexes using ABARE farm survey data. The geographic location of farms is collected as part of ABARE’s farm surveys which enables the mapping of productivity indexes across farms in a region. The impact of resource quality on farm productivity is likely to be reflected in geographic patterns in the productivity measures.

Measuring productivity

There are a number of ways in which farm productivity can be measured. Previous ABARE work has used a total factor productivity measure to estimate productivity.
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growth over time for various broadacre industries (Knopke, Strapazzon and Mullen 1995).

More recently however, data envelopment analysis techniques have been used in ABARE to calculate farm level productivity indexes (Harrison and Chapman 1999; Chapman, Boero Rodriguez and Harrison 1999). This technique is more suited to investigating the relationship between productivity and resource quality because it enables farms within a region or industry to be compared on the basis of relative farm level productivity indexes.

Data envelopment analysis uses mathematical programming techniques to define a productivity frontier which represents the smallest amount of each variable input required to produce a given quantity of output. Relative measures of productivity can then be calculated based on the different amount of inputs each farm uses to produce one unit of output.

Farms close to the frontier use fewer inputs per unit of output and are therefore given higher productivity scores compared with farms further away from the frontier.

Differences in measured productivity across farms may reflect differences in the quality of inputs used to produce a particular output, with farms that have poorer quality inputs obtaining lower productivity scores relative to farms with inputs of a higher quality.

By mapping the farm productivity indexes and comparing them with maps of groundwater contours, salinity levels and soil types it is possible to investigate the relationship between productivity and resource quality.

However, variations in productivity are also likely to be influenced by a number of other factors. These include differences in the use of farm technologies and the adoption of better farm management practices by individual farmers as well as differences in climatic conditions between farms.

A case study of rice farms

Farms surveyed in ABARE’s 1996-97 Australian agricultural and grazing industries survey that grew rice in New South Wales were chosen as a case study for this preliminary investigation into the relationship between productivity and resource quality.

An extended survey of irrigated agriculture across the Murray Darling Basin in 1996-97 (ABARE 1998a) resulted in the collection of detailed financial and physical data for 74 farms producing rice in the Murrumbidgee and Murray Valleys in New South Wales, facilitating calculation of the productivity indexes (see box 1 for the model specification).

The majority of Australian rice production occurs in the Murrumbidgee and Murray Valleys, located in the southern Murray Darling Basin (figure A). Rice has become an increasingly important source of income for these regions, with Australian exports of rice valued at almost $400 million in 1997-98, more than double the value of exports in 1990-91 (ABARE 1998b). The easing of rice growing area restrictions in the early 1990s to farms beyond the Murrumbidgee Irrigation Area (MIA) assisted in this expansion.

1 Model specification

Productivity indexes are calculated by comparing the different amount of inputs individual farms use to produce the same level of output. The inputs and outputs used in the model are as follows:

- **variable inputs**: volume of water used (megalitres), quantity of fertiliser used (kilograms) and other variable costs incurred ($);
- **fixed inputs**: area planted to rice (hectares), other farm area (hectares) and other fixed costs incurred ($); and
- **outputs**: total rice receipts ($) and receipts from other farm activities ($).

The calculation of productivity indexes using data envelopment techniques is usually specified in terms of quantities of inputs and outputs. However, the number of inputs and outputs specified in this model was limited by the relatively small sample of 74 rice producing farms surveyed which required the use of aggregate cost and receipt variables as dollar value surrogates for input and output quantities.
As is the case in many parts of Australia, degradation of the resource base has occurred in the southern Murray Darling Basin as agricultural production has intensified. Specifically, land salinisation has increased because of rising watertables. Deep rooted native vegetation has been removed and replaced by shallow rooted annual crops and pastures which use less water, resulting in the watertable being maintained closer to the surface. In irrigation areas this has been compounded by the application of water to crops, often without sufficient drainage facilities to remove excess water.

The incidence of this degradation as well as the inherent quality of the natural resource base is highly variable — not only between regions but within regions. The extent to which the production of rice is affected by these issues is therefore expected to vary significantly between farms, with rice growing likely to be more productive where certain soil types are prevalent and both the land and water resources are of a sufficient quality (box 2).

Results
Productivity indexes were calculated for all rice growers surveyed in the Murrumbidgee and Murray Valleys; however, only results for selected regions are reported in this article.

The Coleambally, Wakool and Murrumbidgee irrigation areas were selected because of the availability of information on resource condition.

The development of land and water management plans across these regions to address issues such as rising watertables and subsequent salinity problems has resulted in the collection of data on soil types, the distance of watertables from the surface and salinity levels of both the soil and groundwater. Using this information, it is possible to compare the patterns of productivity with the geographic characteristics of land and water quality in each region.

Interpreting the results
The majority of farms were found to have a productivity index close to one, implying that similar inputs were used to obtain a unit of output. However, there was considerable variability among farms, with indexes ranging between 0.34 and 1.00 across the region as a whole. Mapping the productivity indexes revealed distinct groupings of low productivity farms.

Coleambally Irrigation Area
The Coleambally Irrigation Area is located to the south of the Murrumbidgee Irrigation Area and centres around the township of Coleambally (figure A).

This region had the greatest range of farm productivity indexes. Mapping the indexes revealed a strong geographic pattern, with farms in the north obtaining higher productivity scores compared with farms further south (figure B).
A map of the watertable across the district (figure C) shows that the watertable is within two metres of the surface to the south east of Coleambally (Coleambally Land and Water Management Plan Committee, p. 19). The watertable is closest to the surface in the same areas where measured productivity was lowest.

<table>
<thead>
<tr>
<th>Productivity</th>
<th>Permeability</th>
<th>Soil type</th>
<th>Soil salinity</th>
<th>Water salinity (surface)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Low permeable soils</td>
<td>Transitional red brown soils, medium to heavy clay soils</td>
<td>Class A, A+ and partly B soils (less than 6dS/m)</td>
<td>Salinity levels below 2dS/m</td>
</tr>
<tr>
<td>Low</td>
<td>High permeable soils</td>
<td>Sand, sandy loam, red loam or deep cracking clay soils</td>
<td>Class B and C soils (greater than 6dS/m)</td>
<td>Salinity levels above 2 and 2.5dS/m</td>
</tr>
</tbody>
</table>

Implications for productivity: Impermeable soils such as transitional red brown earths and medium to heavy clay are particularly suited to rice growing. Moisture is retained in these soil types and then used by the crop rather than draining into the watertable. This improves on-farm water use efficiency which contributes to higher productivity scores. Rice is relatively tolerant to salt levels both in water and soil. However, increased salt concentrations in the soil, irrigation water and even shallow watertables can decrease yields resulting in lower productivity scores.

*a* Electrical conductivity in deciseimens per metre is a measure of electrical conductivity which is used to measure salt content of soil.

Source: M. Lattimore and D. McCaffrey, District Agronomists, NSW Agriculture, personal communication, April 1999.
There are a number of ways of interpreting the relationship between productivity and the depth of the watertable. The quality of both the groundwater and soils provide two possible explanations. If this groundwater is highly saline, rice yields — and the corresponding level of output per unit of input — are likely to be lower. Farms affected by this condition are therefore likely to be less productive.

Alternatively this relationship may be explained by differences in soil types across the region. If soils to the south of Coleambally are more permeable than soils in the north, then farms in the south may be applying larger volumes of irrigation water. The greater use of inputs will mean that these farms appear less productive. In addition, the application of higher volumes of irrigation water is likely to result in the watertable rising closer to the surface.

Wakool Irrigation District

The Wakool Irrigation District is one of two irrigation areas in the western part of the Murray Valley. The district is predominantly located to the west of the Wakool township (figure A). As in Coleambally, productivity indexes in the Wakool district varied significantly across farms, ranging from 0.54 to 1.00.

Distinct geographic patterns within the region were found, with the areas of highest productivity concentrated to the north of Wakool (figure D). Productivity was lowest across farms in the western most part of the district.

In 1994 the watertable was within four metres of the surface across more than half of the western Murray Valley, and the groundwater was generally very saline (Wakool Land and Water Management Plan Working Group 1995).

In the district, the watertable was closest to the surface to the west of Wakool (figure E). However, a subsurface drainage scheme involving groundwater pumping has assisted in some of the worst affected areas in recent years. The watertable was furthest from the surface along the northern border of the district where productivity was found to be highest.

A map of groundwater salinity across the district shows that the groundwater is least saline to the north of Wakool (figure F). This occurs in the same area where productivity was highest.

The association between farms with the highest productivity and regions with less saline groundwater located furthest from the surface suggests a relationship between farm productivity and resource condition. These lower salinity levels may have enabled farms to obtain higher yields and therefore higher productivity scores relative to farms in regions with more saline groundwater.

Soil salinity levels are also likely to affect farm productivity. A large proportion of soils in the district were naturally saline before agriculture was introduced. The
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A majority of soils across the region are either grey soils subject to inundation or grey and brown soils of the treeless plains which have a naturally high salt content. The soils more suited to rice growing (see box 2), are located to the north west of Wakool (Wakool Land and Water Management Plan Working Group 1995), where some of the most productive farms in the region were observed.

Murrumbidgee Irrigation Area and Districts

The Murrumbidgee Irrigation Area and Districts is located around Griffith and Leeton (figure A).

The MIA and Districts is itself made up of a number of small irrigation districts not referred to specifically in this article, with the exception of the Wah Wah Irrigation District which is situated to the west of Barren Box Swamp (figure G).

As with Coleambally and Wakool, productivity across the MIA and Districts varied considerably, with productivity generally lower in the Wah Wah Irrigation District.

Irrigation water across the Murrumbidgee and Murray Valleys is generally of a similar quality, with one exception being water quality in the Wah Wah Irrigation District. The irrigation water used in this region is typically drainage water collected in Barren Box Swamp from irrigation occurring further upstream and is more saline (MIA and Districts Land and Water Management Plan Working Group 1997). This is likely to have an impact on the rice yields achieved by farms in the region compared with farms further upstream using less saline irrigation water.

Soils in the MIA and Districts generally consist of transitional Mallee soils with few areas of clay. Larger areas of deep cracking clay soils less suitable to growing rice are located in the Wah Wah Irrigation District, and soils in general across the district are more naturally saline compared with the rest of the MIA and Districts (Wah Wah Land and Water Management Plan Working Group 1997).

The lower productivity observed in the Wah Wah Irrigation District is consistent with the saline deep cracking clay soils in the region as well as the poorer quality irrigation water.

Influence of other factors on productivity

While these results suggest a relationship between farm productivity and the condition of soils and water on-farm, other factors such as climate, technology and farm management practices might have influenced the results to some extent.

Given the geographic concentration of production in the southern Murray Darling Basin, rice farms were identified as an ideal case study for this preliminary work into the influence of resource quality on productivity. In particular, the concentration of the
industry limits variation in climatic conditions between farms and may also reduce the differences in farm technology and management practices compared with industries spread over more geographically diverse areas. Despite this, the influence of these other factors is likely to contribute to the observed variation in productivity between farms.

**Summary**

This preliminary work suggests that differences in resource quality are likely to explain some of the observed variations in productivity. For farms producing rice in the case study regions, factors such as surface and ground water quality, soil types and salinity levels appear to contribute to variations in productivity.

Notwithstanding these findings, differences in other factors including climatic conditions, farm management practices and technology are also expected to influence farm productivity. Further work investigating these relationships is required to establish and quantify the impact on productivity of each different factor.

The application of data envelopment techniques to other industries or regions is likely to lead to an improved understanding of the relationships between productivity and resource quality. Further refinement of the technique may also enable the analysis of related issues such as valuing the cost of land degradation.

Research into these topics may provide valuable insights for current government initiatives — such as the National Land and Water Resources Audit — which aim to facilitate improved decision making in land and water resource management.

**References**


