Economics, productivity and natural resources in agricultural systems

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Abstract
Existing research that is focussed on increasing the productivity (and production) of the agricultural sector, makes the implicit assumption that the current farming system is operating at close to optimal in an economic sense. However, this is unsupported. Data show that the profitability of farming in Australia has been declining consistently and significantly for at least the past 40 years, despite a 250% increase in production and estimated productivity growth of up to 2.5% per annum in the grains sector.
There are significant free inputs provided to agriculture, principally in the form of rainfall and solar energy. To maximise profitability in farming enterprises, it is a requirement that the use of free inputs is maximised. The amount of purchased inputs required to achieve a given amount of production depends on how well land managers use these free inputs. Rainfall use efficiency (RUE) is used as a measure of how effectively the free inputs are being used. A number of factors influence the ability to use these free resources and therefore RUE. These include levels of runoff, deep drainage, evaporation, as well as possible physical or chemical properties of plants and soil.
This paper will present a number of agronomic principles that minimise the ineffective use of rainfall and solar energy and that could be used to define the boundaries of resilient farming systems.

Introduction

The microeconomic theory of the firm with regard to production is based on three important concepts by Henderson and Quandt (1971).

1. The producer wishes to maximise profits.
2. To maximise profit, each input should be used to the point where the value of its marginal product (MVPa) equals its cost (Pa) or MVPa/Pa = …………. = MVPn/Pn = 1 for all n inputs (MVP is the additional production achieved from the addition of another unit of input multiplied by the market price of that product). This determines optimal output volume.
3. Input mix should be varied until the ratios of their marginal products equal their price ratios, i.e. MPa/MPb = Pa/Pb or MPa/Pa = …….. = MPn/Pn for all n inputs into a production process. MPa/MPb is also known as the rate of technical substitution (RTS) and measures the amount of one input (a) that can be substituted for another input (b) and leave total quantity of production unchanged. This measures relative input intensity.

For the purposes of this analysis, consider the two input case. The two inputs are defined as purchased and free. The only input that is free to farmers is the weather. Weather is defined as rainfall, solar energy and wind run and its net effect can be measured as rainfall use efficiency (RUE) or the amount of rainfall that is utilised, in situ, for production of plant material. The components of RUE are crop production, livestock production, litter and positive or negative change in plant mass. It is possible to utilise different combinations of weather and purchased inputs to achieve the same amount of output.

Because the weather is effectively free, it should be utilised up to the point where its marginal product is zero or production from the available weather is maximised (condition three above. If Pi = 0 then MP must also equal zero). For any level of production, weather should be substituted for purchased inputs to the point where the rate of technical substitution between the weather and purchased inputs is zero, i.e. where purchased inputs for that level of production are minimised and utilisation of the weather is maximised.

At one end of the spectrum, a given amount of production could be achieved by utilising most of the available weather and few purchased inputs or by using more purchased inputs (e.g. feed supplements) and less efficient use of the weather. The most appropriate mix of inputs is determined by tangency between an isoquant (RTS) and the price ratio of the inputs. Profit is maximised **under existing management** when MP =Pi/Po from an individual's production function. This does not imply that existing management - the combination of the various inputs to achieve this level of output - is optimal.

Rainfall use efficiency

RUE work undertaken by Gardiner and Browne (unpublished), as part of the Property Management Planning courses delivered by Farming for the Future, found that RUE on 1700 farms across northern NSW varied from 6% to 70%. Similar research undertaken south of Tamworth by the same researchers showed that RUE for different paddocks on the same farms varied from 9% to 74%. Average RUE across all farms was about 21%. Because we know that it is possible to achieve RUE of >60%, it is highly unlikely that RUE of 21% reflects an optimal use of available weather. We also know that the paddocks and farms with the highest RUE are the most profitable. Tables 1 and 2 give an indication of the amount of rainfall that is converted to production by different commodity groups in NSW and Australia.

Table 1. Rainfall Use Efficiency of NSW Farms

Farm Type	Rainfall Used (2002-03)	RUE (2002-03)	Rainfall Used (2003-04)	RUE (2003-04)
All Broadacre	68mm	19%	73mm	18%
Specialist Cropping	57mm	14%	94mm	19%
Mixed Livestock and Cropping	83mm	21%	81mm	16%
Specialist Sheep	28mm	11%	45mm	15%
Specialist Beef	185mm	21%	138mm	16%

(Source: ABARE 2006)

Table 2. Rainfall Used on Australian Farms

Farm Type	Rainfall Used 2002-03	Rainfall Used 2003-04
All Broadacre	37mm	41mm
Crop Specialists	63mm	104mm
Mixed Crop and Livestock	98mm	102mm
Sheep Specialists	34mm	29mm
Beef Specialists	27mm	28mm

(Source: ABARE 2006)

The data in Tables 1 and 2 clearly show that, on average across NSW, rainfall used in the production of agricultural products is certainly less than 20% of what is available and, for Australia, where the decadal average rainfall for 2001 – 2010 was 500 mm (Bureau of Meteorology 2011), is probably closer to 10%.

If less than 20% of the available rainfall is being converted to production, where does the rest go? There are four causes of rainfall loss.

Run-off

The five main factors that influence run-off are rainfall intensity, soil structure, slope, ground cover and depth to an impermeable soil layer. It is generally recognised that a minimum of 70% ground cover is required to slow run-off and the rate of soil loss (NSW Department of Primary Industries 2005). Incorporation of large volumes of organic material is the long term answer to soil structural decline. This is only possible if there are large surpluses of organic matter regularly available at a whole farm level. High levels of ground cover also modify the effects of high rainfall intensity by slowing the flow of water across the landscape and allowing more time for infiltration.

Deep drainage

The two main factors affecting deep drainage are soil texture and agronomy. Coarser soils with lower clay content drain more freely than fine soils with high clay content. Organic matter performs a crucial role in replicating the nutrient storage and water holding functions of shrink-swell clays in old, highly weathered Australian soils, again reinforcing the need for continuous, large surpluses of organic material.

Agronomic practices that store rainfall in the soil for later crop use can also increase deep drainage. Robinson *et al.* (2010) demonstrated that as much as 28% of fallow rainfall can be lost to deep drainage. Permanent perennials (trees and shrubs) and a mix of perennial and annual grasses that produce whenever rain falls would serve to minimise deep drainage. Prolonged bare fallows, especially in higher rainfall areas, would aggravate this problem.

Evaporation

Evaporation is a function of temperature gradient, ground cover and wind run. Large temperature gradients on bare soil with high wind speeds have the capacity to shift large volumes of water from the soil. Evaporation loss can be controlled, to a large extent by high ground cover (>70%), large volumes of crop and pasture residues (Murphy 2002), and slowing wind speed by incorporating windbreaks into the landscape. Wind run data would suggest that, in northern NSW, wind speeds are sufficient to have a major impact on crop and pasture production on about 30% of days. This is supported by research undertaken by Bird (2003) in the western districts of Victoria, which showed that 30% of the land area could be planted to shelter without affecting overall production.

Inefficiencies

Other factors may limit the capacity of crops or pastures to reach their potential. There are four potential areas of inefficiency.

- **Soil** – physical and chemical soil problems may limit productive potential. Chemical factors that limit RUE include low soil nutrient status, acidity, alkalinity and the presence of toxic elements. Physical barriers in the soil may prevent plant roots from accessing water and nutrients held deeper in the soil.

- **Plant** – not all plants are equally rainfall use efficient. For example, Rick Young (pers. comm.) working on the Breeza Plains found lucerne had a RUE of 4kg/mm/ha/yr while phalaris produced 12kg/mm/ha/yr. Cool season annual grasses in south eastern Australia have reported production levels of up to 28kg/mm/ha/yr (NSW Department of Primary Industries 2009).

  Plant mass is also important in photosynthetic efficiency. The capacity of plants to utilise radiant energy declines rapidly as pasture mass falls below 500kg of green dry matter/ha (Batsima 2011). Much of the rain that falls on such pastures is used getting the plants to the stage where photosynthesis is optimal. Graziers who adjust stock numbers to maintain pasture mass in excess of 1500kg/ha are more resilient in droughts, more profitable and have higher average stocking rates (Batsima 2011).

  Plant physiology has an impact on water use and productivity. C3 and C4 plants have different photosynthetic pathways which affect their capacity to perform under different climatic conditions. Plants with fibrous root systems are generally more efficient at extracting water and mono-valent nutrients than plants with taproots. Symptoms of K deficiency commonly first appear in annual legumes (Baylor 2002).

  Some pastures may be dominated by plants that only produce during a part of the year (annual species). RUE may be seasonally high but, in aggregate, low.

- **Weather** – Temperature and wind run are important considerations. Wheat yields in Australia are determined as much by temperature as rainfall. Wheat is a cool season annual grass which starts to senesce once temperature moves into the 30 – 35° C range. Many of the cool-season annual grasses possess this characteristic.

  Wind run has the capacity to influence the photosynthetic efficiency of plants. Increasing wind speed slows photosynthesis by removing much of the transpired water as evaporation (Bird *et al.* 2003).

- **Animals** – Pasture systems may appear inefficient because of inefficient grazing management. If pastures are continuously grazed to levels below 500kg Green Dry Matter (GDM)/ha, photosynthetic efficiency is affected. Inefficiencies in the animal production system may be the reason for apparent inefficiency in RUE across much of Australia.

The link between profitability and NRM

Micro-economic theory clearly shows that it is not possible to maximise farm profit unless RUE is maximised. To maximise RUE, a number of natural resource management objectives need to be met. Those listed below provide the core natural resource outcomes that would be required to maximise profit and RUE.

- A minimum of 70% ground cover at all times.
- A minimum of 1500kg GDM/ha of pasture mass at all times.
- A diverse range of annual and perennial grasses, shrubs and trees that enable rain to be used when it falls.
- Continuous large surpluses of organic material to improve soil structure and limit evaporation (minimum of 2t/ha litter).
- Wind protection, shade and shelter to improve the performance of both plant and animal production systems.
- Balancing soil chemical, physical and biological constraints.

In short, healthy, bio-diverse ecosystems are required to maximise profitability in agriculture. If RUE is not being maximised, existing management practices are unlikely to be sustainable. Management practices that maximise the utilisation of free inputs also minimise the amount of purchased inputs needed to achieve any given level of production. Minimising the cost of purchased inputs maximises the return from the enterprise being undertaken.

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