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A longitudinal analysis of some Australian broadacre farms' greenhouse gas emissions, farming systems and efficiency of production

Ross Kingwell *, Rose Marie Jeanne, Atakelty Hailu

Dept. of Agriculture & Food & University of Western Australia, School of Agricultural & Resource Economics, 3 Baron-Hay Court, 6151 South Perth, WA, Australia

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ABSTRACT

This study tracks the emissions of 250 rainfed broadacre farms in south-western Australia from 2002 to 2011. Relationships between their emissions, farming systems, their productive efficiency and profit efficiency are examined. Emissions varied greatly among the farms, ranging from 0.02 to 2.49 CO_2-e tonnes per hectare, and averaged 0.43 CO_2-e tonnes per hectare. The distribution of emissions was rightwards skewed due to a small proportion of the sample being livestock dominant farms that generated high levels of emissions per hectare. The mix of enterprises on farms and the regional location of farms led to large differences being observed regarding farm aggregate and per hectare emissions. The trajectory of the farm emissions over the ten years was quadratic, with the diminution of emissions being attributable to the increased crop dominance of farming systems over the study period, an associated reduction in sheep numbers and the impacts of drought. The lessening in emissions towards the end of the decade occurred despite there being no policy incentive to lessen farm emissions. If these farms had to pay for their emissions then livestock farms in particular would have little capacity to pay. Across the decade, improvements in profit efficiency were significantly associated with only small increases in emissions per hectare. A 1% improvement in profit efficiency resulted in only a 0.10% increase in emissions per hectare. The implication is that improvements to the productive and profit efficiency of farms, although important for the commercial success of farming, are unlikely to cause large increases in farm emissions. Choice of the farm's enterprise mix and farm location are the more important decisions affecting farm emissions.

1. Introduction

Global climate change is chiefly considered to have an anthropogenic cause whereby increasing emissions of greenhouse gases (GHGs), attributable to human activity, lead to higher temperatures (Garnaut, 2011; IPCC, 2013). In response to the challenge of climate change many governments, corporations and organisations have committed to reduce their GHG emissions.

Agriculture is an important source of GHG emissions. In Australia, for example, agriculture currently accounts for 15% (84 Mt. CO_2-e) of net national emissions (DIICCSRTE, 2013), with enteric fermentation being the main source of agricultural emissions. In spite of the acknowledged importance of agriculture as a source of GHG emissions in Australia, there are few studies that track the emissions from different farming systems or that explore the longitudinal relationships between farming systems' emissions, profitability and productive efficiency. Some studies such as Maraseni et al. (2007) compare the GHG emissions from different farming systems in one region of Australia but do not explore the productive efficiency and profitability of those systems. Another study by Galbally et al. (2005) compares nitrous oxide emissions from fertiliser use in irrigated dairy and rain-fed winter wheat in Australia against emissions in similar northern hemisphere enterprises and found emissions were less in Australia. However, these authors did not investigate the productive efficiency and profitability of those systems.

Other studies such as Lawes and Kingwell (2012), Hughes et al. (2011), Sheng et al. (2011) and Kingwell et al. (2013) report on the productivity and profitability of different farm enterprises but exclude any reporting of the enterprises' GHG emissions. This study seeks to fill a gap in the farming systems literature by reporting on the GHG emission profiles, productive efficiency and profitability of different farm enterprises. A sample of 250 broadacre farm businesses in Australia's southwest is examined over the period 2002 to 2011. This region is acknowledged to be particularly affected by recent climate change (Kingwell et al., 2013).

The region has experienced a 20% decline in rainfall over the last several decades, more than any other wheat-growing region in Australia (Asseng and Pannell, 2012). These authors also note that the region's average temperature has increased by 0.8 °C over 50 years and that there has been a disproportionate increase in the frequency of hot days during grain filling when cereal yields can be adversely affected

* Corresponding author.
E-mail address: ross.kingwell@agric.wa.gov.au (R. Kingwell).

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(Asseng et al., 2011). In addition, frost risk at flowering also has increased (GRDC, 2012), reducing grain yield in some years.

In this study the annual GHG emissions, profit efficiency and productive efficiency are measured for the 250 farms from 2002 to 2011. Relationships between farming systems, emissions, profit efficiency and productive efficiency are investigated and reported.

The next section describes the region's farming systems, the farm data, the GHG emission measurement methods and productive efficiency assessment methods. A presentation and discussion of results then follows, before conclusions are drawn.

2. Data and methods

2.1. Study region

The study region is the broadacre farming region of south-western Australia (Fig. 1). In the northern parts of the region the growing season is typically shorter, lasting from April to September; whilst in the southern parts the growing season lasts from May through to November. Greater extremes in daily minimum and maximum temperatures occur with movement inland away from the coast and annual and growing season rainfall also declines.

The region has a Mediterranean-type climate with hot, dry summers and cool, wet winters. Summer rainfall is highly variable, and is more frequent along the south coast parts of the study region. By contrast winter rainfall is greater and much more reliable, making the region mostly suited to annual crops and pastures. The region's farming systems are rain-fed mixed enterprises (Kingwell and Pannell, 2005). Most farms run crop-dominant farming systems with wheat being by far the principal crop grown and sheep are the main livestock enterprise (Bankwest-Planfarm, 2013).

Crops, primarily wheat (*Triticum aestivum L.*), barley (*Hordeum vulgare L.*) and canola (*Brassica napus L.*), are typically sown in late autumn through to early winter due to low levels of summer rainfall and mild winter conditions. The crops are harvested mostly in November and December. In some parts of the study region frost risk can greatly affect grain production.

Most farms are owner-operated, relying on family labour and employing no more than one permanent labourer. However, during seeding, harvesting and sheep shearing, casual and/or contract labour is usually required (Doole et al., 2009). The main products from the farms are mostly exported.

Crops and pastures are grown as land use sequences rather than in strict rotations. The allocation of land to different products is altered each year in response to expected commodity prices, seasonal weather, and weed and rotational considerations (Kingwell, 2006). Canola (*Brassica napus L.*) was introduced into farming systems, especially in the higher rainfall parts of the study region, in the late 1990s. Its popularity has increased over the last decade due to its relative yield improvement, attractive prices and the ease of weed control it provides.

Crop yields are improved by the application of phosphate and nitrogenous fertilisers to most crops. Crops benefit from integrated weed management that includes chemical spraying using pre- and post-emergence herbicides and harvest weed seed collection. During the 2000s more farmers adopted direct-drill cropping technologies and purchased machinery that offered higher work-rates.

Harvested grain is usually transported by the farmer or contractors to on-farm and off-farm silos. A fraction of grain harvested is reserved for seed and supplementary feed for sheep in the autumn feed gap when pasture feed is in limited supply and usually of poor quality (John, 2004).

Pastures grown in the region vary by soil type and quality. On the acid sands, the species grown are yellow serradella (*Ornithopus compressus*), volunteer annual grasses, herbs, and native legumes. On sandplain, gravelly sands and duplex soils, pasture species are pink and yellow serradella, volunteer annual grasses, herbs, native legumes and various varieties of subterranean clover (*Trifolium subterraneum*). On the sandy loams and clays, pastures are mainly based on burr medics (*Medicago polymorpha*). Over the last decade a growing proportion of farmers have introduced the practice of liming to reduce the soil problem of acidification that has limited pasture and crop pasture production (Andrew and Gazey, 2010).

The quantity and quality of pasture produced is mainly influenced by weather-year, rotation, soil type, grazing pressure and fertiliser effects. Pasture production is typically initiated with autumn or early winter rains and biomass is greatest in spring. Pastures senesce in October and November yet can remain a valuable source of feed for sheep for some months, provided they are not degraded by heavy rains in that period. Pasture supplies feed for sheep and provides a disease break for crops. Pasture phases also facilitate control of herbicide-resistant weeds, and leguminous pastures biologically fix nitrogen for the benefit of subsequent crops.

Sheep are run on annual pastures during winter and spring. In summer months, livestock feed is mainly pasture residues and crop stubbles. In late summer through to early winter, there is often a feed gap when

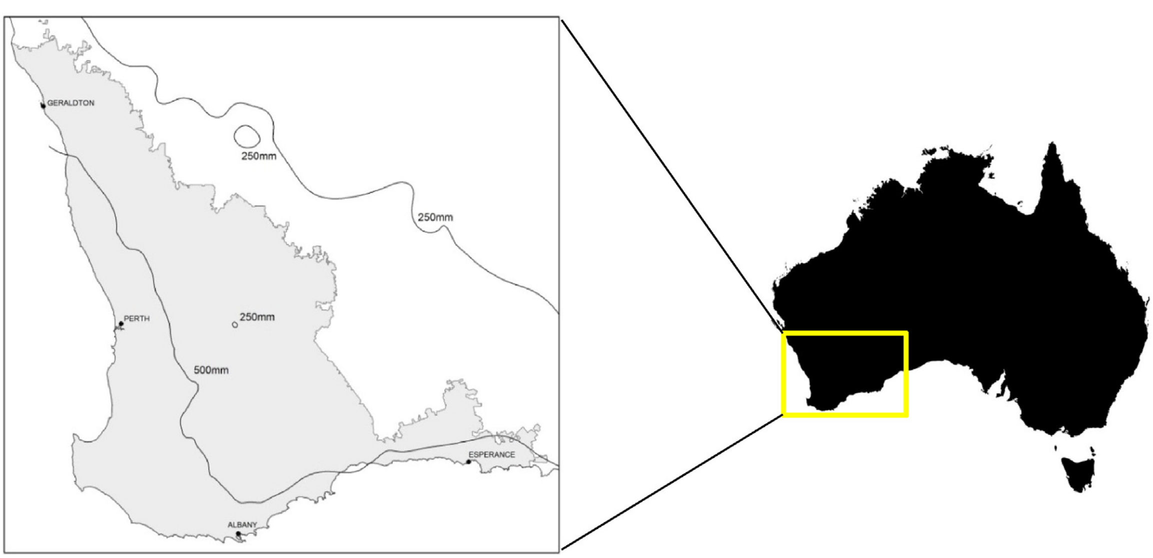

Fig. 1. The study region of south-western Australia. Sample farms are located in the light grey shaded region between the 250 and 500 mm isohyets of average annual rainfall. The region ranges from Geraldton [28.77° S, 114.61° E] south-easterly down to Esperance [33.86° S, 121.89° E].