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Resource use and greenhouse gas intensity of Australian beef production: 1981–2010

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ABSTRACT

Over the past three decades major changes have occurred in Australia's beef industry, affecting productivity and potentially the amount of resources used and environmental impacts from production. Using a life cycle assessment (LCA) approach with a 'cradle-to-farm gate' boundary the changes in greenhouse gas (GHG) emission intensity and key resource use efficiency factors (water use, fossil fuel energy demand and land occupation) are reported for the 30 years from 1981 to 2010, for the Australian beef industry. The analysis showed that over the three decades since 1981 there has been a decrease in GHG emission intensity (excluding land use change emissions) of 14% from 15.3 to 13.1 kg CO_2-e/kg liveweight (LW). The improvement was largely due to efficiency gains through heavier slaughter weights, increases in growth rates in grass-fed cattle, improved survival rates and greater numbers of cattle being finished on grain. However, the increase in supplement and grain use on farms, and the increase in feedlot finishing, resulted in a twofold increase in fossil fuel energy demand for beef production over the same time. Fresh water consumption for beef production dropped to almost a third from 1465 L/kg LW in 1981 to 515 L/kg LW in 2010. Three contributing factors for this dramatic reduction in water use were: (i)an increase in the competitive demand for irrigation water, resulting in a transfer away from pasture for cattle to higher value industries such as horticulture, (ii) an initiative to cap free flowing artesian bores in the rangelands, and (iii) an overall decline in water available for agriculture compared to industrial and domestic uses. While there was higher uncertainty relating to estimates of land occupation and emissions from land use (LU) and direct land use change (dLUC), an inventory of land occupation indicated a decline in non-arable land occupation of about 19%, but a sevenfold increase in land occupation for feed production, albeit from a low base in 1981. GHG emissions associated with LU and dLUC for grazing were estimated to have declined by around 42% since 1981, due largely to legislated restrictions on broad-scale deforestation which were introduced progressively between 1996 and 2006. This paper discusses the prospects and challenges for further gains in resource use efficiency and reductions in greenhouse gas intensity for Australian beef production.

1. Introduction

The major global challenges of food security and climate change have generated greater interest in understanding and monitoring the environmental impacts and resource depletion from food production systems. To address these challenges, there has been an increased focus on sustainable intensification – the production of more food from fewer resources with lower impacts. However, the capacity to monitor the impacts of food systems on the environment has been hampered by the lack of practical methods of assessment, and the lack of suitable data to quantify these impacts over time and identify impact hotspots for improvement. Life cycle assessment (LCA), initially a tool for the industrial sector ISO (2006), has increasingly been applied to agricultural products to quantify environmental impacts, to meet this need. In this paper, an LCA approach is used to assess the change in key environmental impacts and resource use efficiency of Australian beef production over the past three decades (1981–2010). This period covers a period of significant change in beef production systems in Australia and coincides with availability of more reliable data on animal numbers, their movements and productivity than in earlier years.

The Australian beef industry has evolved from meagre beginnings with European settlement in the late eighteenth century to a national herd of approximately 26.5 million head of beef cattle

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for a broad spectrum of markets and climatic conditions. Australia is now the world's 8th highest beef producing country and third largest beef exporter. These developments have inevitably been accompanied by changes in the interaction of beef production with the environment. The industry continues to develop in response to market, climate and policy drivers, improved production technology and changing socio-cultural values (Bindon and Jones, 2001). These changes influence, and are affected by, environmental impacts and resource constraints. The beef industry in Australia remains characterised by relatively low input production systems utilising native or naturalised grasslands in the extensive rangelands and woodlands. Australian beef producers also operate within a high degree of climatic variability, driven largely by the El Nino-Southern Oscillation (McKeon et al., 2004). Low input management and a high degree of flexibility are management strategies employed to manage the influence of high climate variability, particularly in the north where frequent droughts limit pasture growth and, in turn, cattle productivity (Herrero et al., 2013). An example of change in the industry over the last 40 years has been the move in the northern subtropical and tropical regions to *Bos indicus* breeds which are favoured for their capacity to handle heat, poor quality feed and parasites. In the extensive north, these breeds have lower mortality rates but also lower weaning rates than *Bos taurus* breeds. In the southern part of the continent, the temperate climate and Mediterranean weather patterns have historically delivered more reliable rainfall and better feed conditions. The southern regions are more productive in terms of weaning rates, growth rates and beef produced per unit area of land, though inputs such as fertiliser are significantly higher than in the north. Other major structural changes influencing the interaction of beef cattle in the Australian environment over the past half century have included advances in animal genetics and the rapid expansion of the feedlot industry from 1980 onwards. The influence of these changes on resource use and environmental impacts across the industry has not been assessed to date.

The environmental impact of animal agriculture receiving most attention over recent years has been its contribution to global warming, and quantifying greenhouse gas (GHG) emissions and trends is critical to assessing the environmental performance over time. For beef cattle, GHG emissions arise from enteric fermentation (the rumen digestive process) and from manure management. At a national scale, these direct animal emissions contribute approximately 10% of Australia's total GHG emissions as estimated for Kyoto Protocol reporting (DCCEE, 2013a). In addition, indirect emissions result from fossil fuel energy demand, energy and emissions associated with manufacture of production inputs, soil emissions from nitrogen fertiliser use and emissions associated with land use (LU) and direct land use change (dLUC).

Another prominent concern globally is the stress on fresh water resources (Rockström et al., 2007; WHO, 2009). In Australia, agriculture is attributed with using 65–70% of extracted water, primarily for irrigation (ABS, 2006b), which is similar to the situation globally. Water requirements of cattle vary greatly depending on the moisture content of the feed, the climatic conditions and the physiological state of the animal (CSIRO, 2007; Springell, 1968). Other contributions to water use for beef production include evaporative losses from farm water supply, and irrigation for pasture, fodder and grain production (Wiedemann et al., 2015). Land, particularly arable land, is a limited resource globally and is included in analysis of the environmental impacts of production as the area of 'land occupation' to produce a product. For agricultural products, assessment of the area and type of land (e.g. arable or non-arable) used contributes to reducing the risk of unintended trade-offs in managing environmental impacts (Ridoutt et al., 2011). However, analysis of trends in land occupation over time is complicated by the lack of a consensus method of assessment and the movement of land parcels between production systems or between agriculture and other uses (e.g. conservation reserve or infrastructure). While a number of studies have assessed GHG emission intensity and water use for beef production in Australia (Eady et al., 2011; Peters et al., 2010a, 2010b; Ridoutt et al., 2012) these studies focussed on only one or two case study farms or used theoretical production estimates. The recent study by Wiedemann et al. (2015) studied two major Australian beef production regions, but did not provide comprehensive coverage of the whole industry. Hence, no previous Australian studies have quantified changes in impacts over time or provided broad regional coverage of the beef industry.

Changes in the Australian beef industry undertaken for productivity benefit directly or indirectly affect environmental impacts and resource use efficiency. Improvements in feed quality and quantity using grain finishing or flexible stocking rates to preserve pastures or selection of animals with higher feed conversion efficiency will all increase productivity and, by earlier finishing and heavier slaughter weight, may also decrease the GHG intensity of the product (Capper, 2011; Peters et al., 2010a). However, the trend in GHG intensity or apparent resource efficiency of a product will reflect deliberate management improvements and also factors less under the control of the producer. For example resource use may be influenced by regulation as well as more efficient management, and by seasonal climatic conditions. This study aimed to quantify the trend in GHG emissions, fossil fuel energy demand and water use for the Australian beef cattle industry for the period 1981–2010 using a LCA approach. The study included estimates for LU and dLUC GHG emissions, although data limitations meant the estimates were based on a semi-quantitative approach using best available data. The study identified impact and resource hotspots and considered possible management, policy and natural factors contributing to the trends.

2. Methods

Key sources of data for this analysis included the Australian Bureau of Agricultural and Resource Economics (ABARES) which undertakes independent research and data analysis for agriculture; the Australian Bureau of Statistics (ABS) which provides national and regional scale statistics based on surveys and census data; industry data primarily from Meat and Livestock Australia and the Australian government's National Greenhouse Gas Inventory (NGGI) report to the United Nations framework Convention on Climate Change (UNFCCC) and Kyoto Protocol reporting.

2.1. LCA approach

2.1.1. System boundaries and functional unit

The product system included the national beef herd producing cattle processed in Australia, and specifically excluded beef from dairy cattle and beef from herds supplying the live export market (Fig. 1). Analysis of herd and processing statistics in this study indicated that beef from the dairy herd in Australia contributes only 8–12% to total beef production. Assessment of change in environmental impacts focussed on the beef herd and its changes over the study period. The study excluded not only live export animals but also the herd supporting their production. Australia exports beef cattle from the northern production regions for finishing in feedlots overseas prior to processing, with Indonesia being the largest market. While the live export market is highly relevant to Australia, collecting inventory data for the transport and finishing of these cattle in their country of destination was beyond the scope of the present study.

The study examined the primary production system (i.e. cradle to farm gate) using a functional unit of 'one kilogram of live weight (LW)' on-farm, immediately prior to processing (Fig. 1). The choice