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Environmental impacts and resource use of Australian beef and lamb exported to the USA determined using life cycle assessment

Stephen Wiedemann [a, *], Eugene McGahan [a], Caoilinn Murphy [a], Ming-Jia Yan [a], Beverley Henry [b], Greg Thoma [c], Stewart Ledgard [d]

[a] FSA Consulting, PO Box 2175, Toowoomba, Qld 4350, Australia
[b] Institute for Future Environments, Queensland University of Technology, Brisbane, Qld 4000, Australia
[c] Ralph E. Martin Department of Chemical Engineering, University of Arkansas, Fayetteville, AR 72701, USA
[d] AgResearch Ruakura Research Centre, Private Bag 3123, Hamilton 3240, New Zealand

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ABSTRACT

Australia is one of the two largest exporting nations for beef and lamb in the world and the USA is a major export market for both products. To inform the Australian red meat industry regarding the environmental performance of exported food products, this study conducted the first multi-impact analysis of Australian red meat export supply chains including all stages through to warehousing in the USA. A large, integrated dataset based on case study farms and regional survey was used to model beef and lamb from major representative production regions in eastern Australia. Per kilogram of retail-ready red meat, fresh water consumption ranged from 441.7 to 597.6 L across the production systems, stress-weighted water use from 108.5 to 169.4 L H_2O-e, fossil energy from 28.1 to 46.6 MJ, crop land occupation from 2.5 to 29.9 m^2 and human edible protein conversion efficiency ranged from 7.9 to 0.3, with major differences observed between grass finished and grain finished production. GHG emissions excluding land use and direct land use change ranged from 16.1 to 27.2 kg CO_2-e per kilogram, and removals and emissions from land use and direct land use change ranged from −2.4 to 8.7 kg CO_2-e per kilogram of retail retail ready meat.

Process based life cycle assessment shows that environmental impacts and resource use were highest in the farm and feedlot phase. Transportation contributed ≤5% of greenhouse gas emissions, water and land, confirming that food miles is not a suitable indicator of environmental impacts for red meat transported by ocean shipping. The contribution of international transportation to total energy demand was higher, ranging from 14 to 23%. These beef and lamb supply chains were found to rely on small volumes of water from stressed water catchments, and occupied only small amounts of crop land suited to other food production systems. Production of high quality protein foods for human consumption used only small amounts of protein from human edible grain.

1. Introduction

Agricultural systems such as livestock production face the challenge of maintaining and increasing production in the future with constrained natural resources and pressure to reduce environmental impacts. Globally, meat demand is expected to increase 74% by 2050 because of expanding global population and increased wealth (FAO, 2009). However, global targets also exist to reduce greenhouse gas (GHG) emissions (Stocker et al., 2013) and concerns exist regarding the use of scarce water resources (Rockström et al., 2007; WHO, 2009) and arable land (UNEP, 2014). Australia is one of the two largest exporting nations for beef and lamb in the world, closely following Brazil in total volume of beef and New Zealand in lamb (FAO, 2011). The United States of America (USA) is a major export market for both products (DFAT, 2012). Product life cycle assessment (LCA) is an important method for understanding the impacts associated with food products and particularly for determining what stages in the supply chain contribute to impacts. Despite long transport distances, LCA studies of red meat have shown that transportation distance, or 'food miles' (Paxton, 2011) is not a good indicator of environmental impacts in several instances (Webb et al., 2013; Weber and Matthews, 2008). However, 'food

* Corresponding author. Tel.: +61 (0)7 4632 8230; fax: +61 (0)7 4632 8057.
E-mail address: stephen.wiedemann@fsaconsulting.net (S. Wiedemann).

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List of acronyms:

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
CSF	case study farms
GHG	greenhouse gas
GWP	global warming potentials
HEP-CE	human edible protein conversion efficiency
LCA	life cycle assessment
LF	long fed
LU	Land Use
dLUC	direct land use change
MF	mid fed
NSW	New South Wales
QLD	Queensland
RAF	regional average farms
SA	South Australia
VIC	Victoria
WSI	water stress index

miles' is still taken as a proxy indicator for environmental impact in popular media communications and a greater understanding of the relationship between impacts and transport distance is sought by the users of Australian beef and lamb in the USA.

To date, there has been no holistic environmental analysis of Australian beef and lamb supply chains to the USA. Life cycle assessment studies of Australian production have focussed on case study farms (Eady et al., 2011; Peters et al., 2010a, 2010b), theoretical production systems (Ridoutt et al., 2012a) or controlled production systems found on research farms (Brock et al., 2013) that could not be considered representative of markets that draw from large production regions. These studies predominantly focussed on one or two impacts only. Recent farm gate studies of beef (Wiedemann et al., 2015c) and lamb (Wiedemann et al., 2015d) cover larger regions representative of Australia's export markets through to the farm gate, and were the basis for this expanded supply chain analysis. The present study aimed to determine major environmental impacts and resource use from the production, processing and transport of Australian beef and lamb to the USA by extending two existing farm-gate LCA studies by the same authors, which used large, integrated datasets based on case study farms and regional survey datasets. The study aimed to report on major environmental impacts and resource use indicators with new methods and to provide a robust assessment of impacts and hotspots in the supply chain, with particular attention to the role of transportation.

2. Materials and methods

The study included beef and lamb production from major representative production regions in eastern Australia, through the whole supply chain to the point of distribution to retail in the USA. The functional unit was chosen as one kilogram of retail ready cuts of Australian beef and lamb, at the regional storage centre in the USA. The system boundary included all stages of production, processing, transport and cold storage on the east coast of the USA, as well as distribution to the point of retail (Fig 1).

2.1. Production system characteristics

Australia's sheep and cattle industries have been developed to utilise some 3.5 M km^2 of native vegetation grazing land (Lesslie and Mewett, 2013), or 46% of continental land area. The majority of sheep are produced in the south-east states of South Australia (SA), Victoria (VIC) and New South Wales (NSW), representing 73% of Australia's sheep flock (MLA, 2013a) and the vast majority of export lamb production. The majority of beef cattle are produced in the states of Queensland (QLD) and NSW. Central and southern QLD, and northern and central NSW represent 35% of Australia's beef herd and the major regions exporting premium beef to the USA market and were the focus of the study. Premium beef and lamb exports to the USA must meet specific market requirements. Export lambs are >22 kg carcase weight (CW) and beef cattle destined for premium markets may be grass-fed or grain-finished. The study investigated beef bred in rangeland areas and finished on pastures (grass-fed), and steers finished on grain for either 115 days (Mid-fed – MF) or 330 days (Long-fed – LF). The LF category is tailored to the production of a high quality, niche beef product, predominantly from Angus or Wagyu breeds, for the USA restaurant trade.

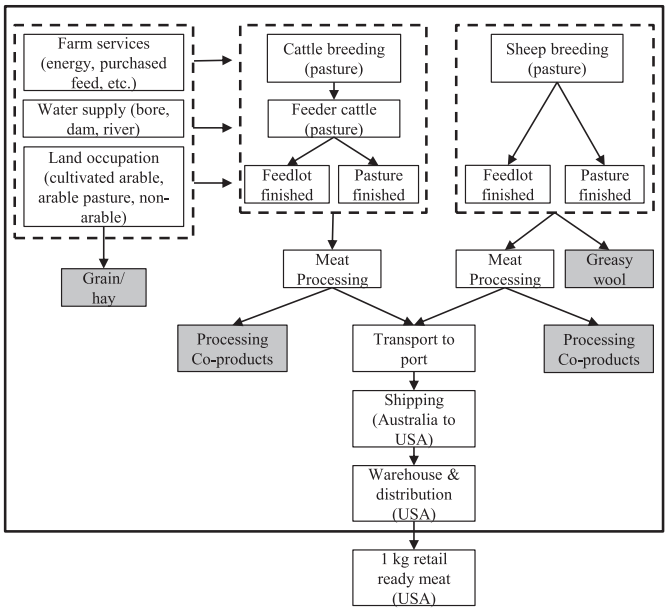

Fig. 1. Illustration of beef and lamb supply chains in the study. Shaded boxes indicate co products.

2.1.1. Indicators

The study investigated GHG emissions using the IPCC AR4 global warming potentials (GWP, 100 years) of 25 for methane and 298 for nitrous oxide (IPCC, 2007). Greenhouse gas emissions associated with land use (LU) and direct land use change (dLUC) were included and reported separately.

Fossil fuel energy demand was assessed by aggregating all fossil fuel energy inputs throughout the system and reporting these per mega joule (MJ) of energy, using Lower Heating Values (LHV). Modelling methods and processes used are described below. Fresh water consumption (an inventory method – Bayart et al., 2010) was assessed, covering all sources and losses associated with livestock production in both foreground and background systems. Fresh water consumption refers to evaporative uses or uses that incorporate water into a product that is not subsequently released back into the same river catchment (ISO, 2014). Stress-weighted water use was assessed using the water stress index (WSI) of Pfister et al. (2009) reported in water equivalents (L H_2O-e) after Ridoutt and Pfister (2010). Land occupation was reported using a disaggregated inventory based on land type and suitability. Four land