On-farm Energy Use in the Grain and Horticultural Industries

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ABSTRACT

Agriculture and the related primary industry requires energy as an important input. Energy is needed to a differing extent in all the stages of the agri-food chain. In this paper, on-farm energy use in the grain and horticultural industries is evaluated. It is found that the energy use varies significantly with the farm enterprises and also the farming systems, including irrigation and heating/cooling methods. The total direct on-farm energy use for grain grown under dryland conditions with no tillage may be as low as 0.35 GJ/ha, while for horticultural products, the direct on-farm energy use may reach up to 20000 GJ/ha for tomatoes grown in greenhouses. The large variation of energy uses may indicate the significant opportunities for reducing energy use in these industries.

Keywords: Energy, Benchmark, Grain, Horticulture

1. INTRODUCTION

Farming is often an energy intensive operation. Within highly mechanised agricultural productions systems such as the Australian agricultural and horticultural industries, energy inputs represent a significant cost to growers [1].

Energy is used both on-farm and off-farm. It can be further divided into direct energy used, ie. the fuel and electricity consumed, and the indirect energy (embodied energy) involved in the manufacturing of all other inputs such as equipment and agro-chemicals [2]. Direct energy may be consumed in three major forms on most farms: 1) general electricity usage for lighting, appliances, irrigation; 2) fuel use for machinery, tractors and vehicles; and 3) heating/cooling for industries such as dairy, horticulture, piggeries and poultry.

Life Cycle Assessment (LCA) is an internationally recognised approach for evaluating the environmental impacts of products and services [2]. It analyses and quantifies the environmental impacts of the whole process of making, using and disposing a product. LCA is often used to compare the environmental damages assignable to products and services, and further to choose the least burdensome one. The quality of a LCA project is strongly dependent on the quality of inventory data, including the on-farm energy use data [3].

The aim of this paper is to review the energy use data for the grain and horticultural industries in Australia. This is the first step in reducing energy use and the associated greenhouse gas emissions of these industries.

2. GRAIN INDUSTRY IN AUSTRALIA

The grain industry plays a vital role in Australia's economy. The grain industry operates in all states of Australia and makes a major economic contribution at the national and state levels. Australia produced over 48.5 million tonnes of grain in 2011-12 (Figure 1). However, in 2012-2013, this fell to 38.7 million tonnes [4], because of increased climatic variability and volatility of grain prices [5].

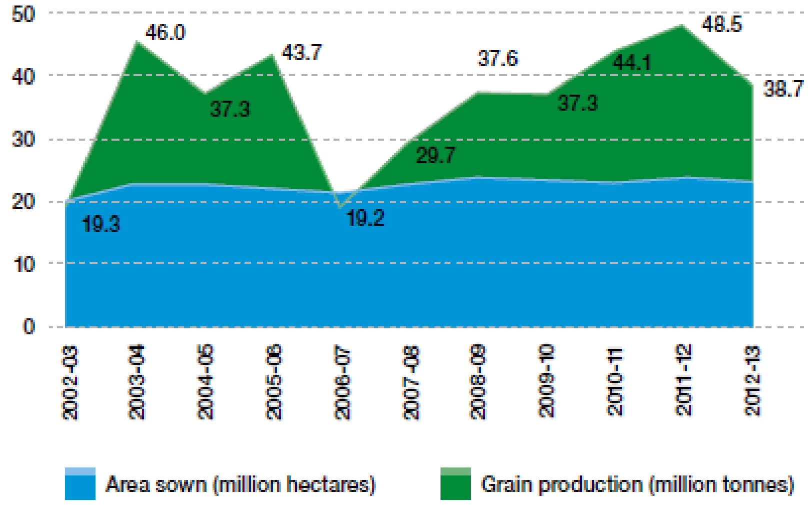

Figure 1: Total grain production and cropping area, 2002–03 to 2012–13 [4]

The grain industry in Australia can be broadly divided into three agro-ecological regions: 1) The Southern Region covers south-eastern Australia, including central and southern New South Wales, Victoria, Tasmania, and south-eastern South Australia. Soils in this area are generally poor (low fertility) with many subsoil constraints, such as salinity, sodicity and toxic levels of some elements; 2) The Northern Region covers Queensland and northern New South Wales. This region has relatively good soils but relatively high variability of seasonal rainfall and therefore the production; and 3) The Western Region covers Western Australia. This region has poor soils and crops yields largely depend on winter and spring rainfall [5].

Depending on the availability and price of water for irrigation, grains in these regions are produced either on irrigated or dryland (rain-fed) conditions. Similarly, for various reasons, many grain growers under dryland farming method are also moving from the conventional tillage system to reduced or zero tillage systems, often for the purpose to hold more moisture in the soil. Under drought conditions, minimum tillage is recognised as being a more resilient farming practice [6]. Most (about 80%) of grains produced in Australia is by dryland farming method. However, irrigation generally produces significantly higher (up to 3 times of dryland farming) yield per hectare.

3. GRAIN ENERGY USE BENCHMARKS – OVERSEAS RESEARCH

Recent international literature on energy use by the arable cropping industry is relatively limited (Table 1). Research in references [7, 8], while dated, may still offer one of the most comprehensive breakdowns of energy consuming activities on an arable cropping farm.

Pellizzi et al. [9] found that in Europe, for wheat-like cereals, 55-65% of the direct field energy consumption was attributed to soil tillage, while harvesting took about 25%. They also reported that the range of field energy consumption for wheat-like cereals varied from 2.5 GJ/ha to 4.3 GJ/ha. For maize (corn), this was estimated to be between 4.7 and 5.0 GJ/ha, including drying which alone required 50-60% of the field fuel consumption.

Cormack [10] compared the energy inputs in organic farming with similar conventional systems in the UK. It was found that organically grown crops require only around 30% of the energy input per unit area of conventional crops, largely because of lower, or zero, fertiliser and pesticide energy inputs. However, the generally lower yields of organic crop systems reduce the advantage of organic methods when energy input is calculated on a unit output basis.

In Greece, the total life cycle energy inputs for soft winter wheat production were found to be between 16 and 26 GJ/ha [11]. Extra energy inputs of 3 GJ/ha were required for straw harvesting. The major energy inputs were found to be fertilizers and fuel, amounting to 81–84% of the total inputs. Wheat yields ranged between 2.5-6 t/ha. Pimentel et al. [12] found the energy use for winter wheat production in America was 16.4 GJ/ha, of which 4.0 GJ/ha was the on-farm direct energy use.

Safa & Samarasinghe [13] and Barber [14] investigated the energy demands of irrigated arable and dry arable cropping systems in New Zealand. It was found [14] that the main direct energy inputs were liquid fuels, most of which were consumed during field operations, and electricity, especially where irrigation was undertaken. Total energy intensity ranged from around 5 GJ/ha for dry arable farms growing cereals to 34.2 GJ/ha for irrigated wheat [15]. Wheat yields in the NZ dryland operation were 4.3 t/ha. The yield of irrigated wheat was 7.2 t/ha.

Crops	Direct Energy Input (GJ/ha)	Indirect Energy Input (GJ/ha)	Total Energy Input (GJ/ha)	Country	References
Wheat	2.5~4.3			Europe	[9]
Maize (corn)	4.7~5.0			Europe	[9]
Conventional arable	5.8	15.0	20.8	UK	[10]
Organic arable	3.8	2.3	6.1	UK	[10]
Wheat			16~32	Greece	[11]
Wheat	4.0	12.4	16.4	USA	[12]
Wheat (irrigated)	10.9	14.7	25.6	NZ	[13]
Wheat (dryland)	3.2	14.3	17.5	NZ	[13]
Wheat (irrigated)	24.4	9.8	34.2	NZ	[14]
Wheat (dryland)	6.9	13.3	20.2	NZ	[14]
Barley			9.0	NZ	[14]
Maize (corn)			15~36	NZ	[14]

Table 1: Grain energy performance data from the published overseas literature

4. GRAIN ENERGY USE BENCHMARKS – AUSTRALIAN RESEARCH

Similar to other parts of the world, energy use data is also limited in Australia. However, energy use for the production of wheat and barley production was investigated by Khan et al. [15], based on the farm survey data in Coleambally Irrigation Areas (CIA) and Murrumbidgee Irrigation Area (MIA) of New South Wales. It was found that the total life cycle energy inputs for wheat and barley are respectively 3028 and 2175 kWh/ha (or 10.9 and 7.8 GJ/ha respectively).

Crops	Direct Energy Input (GJ/ha)	Indirect Energy Input (GJ/ha)	Total Energy Input (GJ/ha)	References
Wheat	5.8	5.1	10.9	[15]
Barley	5.7	2.1	7.8	[15]
Wheat	0.8			[16]
Wheat	0.35			[17]
Wheat, Barley, Sorghum	0.9~2.5			[18, 19]

Table 2: Grain energy performance data published from Australian research

Sandell et al. [16] investigated the energy saving opportunities for various farming enterprises in Western Australia. The energy use data is based on the published data of Western Australian Agriculture enterprises from the Planfarm Bankwest Benchmarks 2011/12. This was further complemented by seven case studies of "typical" farming enterprises. It was shown that diesel was by far the largest (85-90%) on-farm energy source and cost for all enterprises. The average on-farm energy use was 0.83 GJ per hectare, consisting of 20 L diesel, 1.5 L petrol and 2.4 kWh of electricity. Biswas [17] found that this can be as low as 0.35 GJ/ha in south-western Australia.

Maraseni and Cockfield [18, 19] also studied the energy use of wheat, barley and sorghum crops grown in the Northern region of Australia (Table 2).

5. HORTICULTURE ENERGY BENCHMARKS

5.1 Nurseries

There is little energy data reported for the nursery sector outside Queensland. By collecting and collating information, energy benchmark was developed for five Queensland nurseries by Schmidt et al. [20] and Chen et al. [21]. A study was also undertaken to determine the energy used for greenhouse heating in the vegetable and flower industry in New Zealand [22]. It was found that average energy use in the North Island is 1,210 MJ/m^2 (12100 GJ/ha) while it is 1,830 MJ/m^2 (18300 GJ/ha) in the South Island (Table 3). Energy use was strongly influenced by management practice, regional location, the type and age of greenhouse, and the type of crop being grown. Generally, smaller operations were less energy intensive, possibly due to capital constraints.

Crops	Direct Energy Input (GJ/ha)	Indirect Energy Input (GJ/ha)	Total Energy Input (GJ/ha)	Country	References
Greenhouse nursery	12100-18300			NZ	[22]
Greenhouse nursery	20000			Italy	[23]
Open-field potato	20.55			Australia	[24]
Open-field potato	21.3	38.7	60	NZ	[14]
Open-field potato	25.6	26.3	51.9	UK	[25]
Greenhouse tomato	10000-20000			NZ	[30]
Greenhouse tomato	25.2	4.1	29.3	USA	[31]
Greenhouse tomato	53.4	53.3	106.7	Turkey	[32]

Table 3: Horticulture energy performance data from the published literature

5.2 Potatoes

The production of open-field potato was studied in [24, 25]. Norton [26] studied the environmental sustainability in the processing potato industry in Australia. It was found that the main emitters of GHG in potato growing were: fertiliser (24.9-55.9% of emissions), diesel use (25.9-39.5%), agri-chemical use (3.5-8.9%), infrastructure (10.7-15.9%) and electricity (0-19.1%). The life cycle energy use ranged between 36.9 to 73.1 GJ/ha.

LCA studies have also been reported on potatoes production in southern Sweden and in the UK [26, 27]. Mattsson and Wallén [26] suggested that organic cultivation is considerably less energy intensive. In contrast, energy input is reported to be the same for organic and conventional production [27]. Mass of the product was used as the functional unit in both studies.

Barber [14] showed that total energy inputs into potato production were similar in NZ with American findings at around 60 GJ/ha, of which 21.3 GJ/ha was on-farm direct energy. The yield was 16.1 t/ha. This was in comparison with a national mean average yield of 36 t/ha in Australia.

5.3 Tomatoes

Tomatoes in Australia are grown either in the field or in the greenhouse [29-32]. Depending upon the level of technology and the yields, three types of greenhouses are identified: the low-technology (low-tech), medium technology (med-tech) and high technology (hi-tech) [29].

When growing tomatoes, energy inputs can vary between 20-45 MJ/kg of produce (or 1-2 GJ/m^2 or 10000-20000 GJ/ha) [30], the range reflecting climatic variations and the need for additional heating, mainly required at night during winter periods, though to maintain optimum temperatures for plant growth at other times. Albright and de Villiers [31] established that producing locally in heated greenhouses in the New York area requires about 49.3 MJ/kg for out-of-season tomatoes and only 3.4 MJ/kg in unheated high tunnels for seasonal production in Mexico whereas the trucking energy over the 4,000 km from Mexico into New York State needs 10 MJ/kg. These figures are also quite comparable to a French study, where 31.6 MJ/kg is required on average for heating only for out-of-season tomatoes and 5.13 MJ/kg for seasonal unheated production [33]. In general, crops grown in glass or plastic cladded greenhouses can have energy intensity demands up to 10 to 20 or more times that of the same crops when grown in open fields [34].

6. CONCLUSION

LCA has been successfully used in various industries to assess the environmental impact and as a tool for product-labelling and marketing. A key component of an LCA project in agriculture and horticulture is the data collection of direct on-farm energy use.

In this paper, on-farm energy use in the grain and horticultural industries has been evaluated. It has been found that the energy use varies significantly with different crops, the farm enterprises and also the farming systems. The total direct on-farm energy use for grain grown under dryland conditions with no tillage may be as low as 0.35 GJ/ha, while for horticultural products, the direct on-farm energy use may reach up to 20000 GJ/ha for tomatoes grown in greenhouses.

The success of a LCA project is dependent on good quality data. It has been suggested by this paper that over-reliance on overseas or even national scale data may not be appropriate for a LCA project because different local climates and farming systems will result in very different energy uses. Thus, there are significant needs to collect more accurate and detailed information on energy use in various farming processes and sub-sectors. A detailed mapping of crop production operations [1, 3] may be adopted so that each major activity of the operations could be characterised and included.

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