6 Environmental supply chain management in Australian grain industries: a life cycle assessment approach

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INTRODUCTION

Australia faces major environmental and natural resource management challenges including shortages of clean and accessible water, degradation of terrestrial and aquatic ecosystems, increasing soil erosion, changes in the chemistry of the atmosphere and the possibility of important changes in climate (Rodriguez et al., 2003; Gunningham, 2007). These changes are generally a direct result of economic activities. Many are recent and profound, and many are accelerating. Given its use in food, fodder and industrial raw material applications, grain production is one of the most important agricultural activities of Australia. The Australian grain industry[1] produces 30–40 million tonnes per annum (CRC Plant Bio-security, 2007) of which approximately 65 per cent is exported. Earning around $6 billion per annum, Australian grain exports are expected to double in the next 10 years (CRC Plant Bio-security, 2007). Furthermore, opportunities for the production of ethanol for fuel is expected to increase dramatically (Webb, 2007), creating further challenges for the Australian grain industry to meet increasing food demands.

The grain industry is a major contributor to Australia's economic growth, however, the environmental externalities are seldom accounted for. The main greenhouse gases (GHG) emitted from agriculture are methane (CH_4) and nitrous oxide (N_2O). Both are major greenhouse gases with 21 times and 310 times the global warming potential of carbon dioxide (CO_2) respectively. Nationally, agriculture is the dominant emitter of both methane (60 per cent) and nitrous oxide (85 per cent). Anthropogenic activities, including farm mechanization and the application of chemicals are the main cause of these GHG emissions. The application of nitrogen fertilizers contributes over 30 per cent of the nitrous oxide emission from farming (de Klein et al., 2003).

In a global context, the emissions of GHGs will have considerable impact on climate change including (US Environmental Protection Agency, 2007):

- rising sea levels that may flood coastal and river delta communities;
- shrinking mountain glaciers and reduced snow cover that may diminish fresh water resources;
- the spread of infectious diseases and increased heat-related mortality;
- possible loss in biological diversity and other impacts on ecosystems; and
- impacts on agricultural crop yields and productivity.

In the case of Australia, some urban residential, industrial and nature conservation areas will be affected and weather events such as storms are also likely to be more intense (Aplin, 2002). There is also a considerable potential for these impacts to result in declining agricultural production (ABARE, 2007).

The objective of this chapter is to discuss the role of life cycle assessment (LCA) as an environmental management tool to facilitate the reduction of environmental emissions from Australia's grain production. Firstly, the chapter discusses the major stages of the grain supply chain. Secondly, it reviews the LCA tool, which applies a 'cradle to grave' approach in assessing the environmental impacts of the different stages of the supply chain for grain and grain based products. Thirdly, the chapter discusses the application of cleaner production techniques for improving the product life cycle. Discussions then review the responsibilities of stakeholders and the role of Environmental Management Systems (EMS) in restructuring supply chains to promote cleaner production techniques, to reduce the ecological footprint of the grain supply chain in Australia.

AUSTRALIA'S GRAIN SUPPLY CHAIN

The grain industry supply chain involves many steps including input suppliers (raw materials), producers (farmers), grain marketers, bulk handlers, shipping agents, manufacturers, wholesalers, retailers, consumers and waste management. Each of these contributes to the ecological footprint[2] left by that stage of production or consumption. Understanding the full supply chain can facilitate better management of environmental impacts associated with grain production.

The five main components of the grain supply chain in Australia are pre-farm, on-farm, storage and processing, retail and consumption, and transportation. Transport components associated with broadacre grain production in Australia result in major environmental costs given the distances involved in transporting the grain from the farm to the final consumer, and then transportation to dispose of the associated product packaging. The National Greenhouse Gas Inventory (NGI) only measures on-farm GHG emissions and does not include the entire supply chain (ABARE, 2007). Australia's agricultural sector accounted for 16 per cent of Australia's total GHG emissions in 2005 and was the second highest GHG emitter after the stationary energy generating sector (AGO, 2005). If the total spectrum of emissions associated with each stage of the agricultural supply chain is considered, the contribution of the agriculture sector to the total national emissions is likely to be much higher than that shown in the national inventory.

LCA can assist in a more comprehensive and inclusive calculation of GHG emissions from the agricultural supply chain, resulting in the identification of 'hot spots' including point and non-point sources[3] and those stages resulting in high levels of GHG emissions compared with the other stages of the grain supply chain.

ENVIRONMENTAL LCA OF SUPPLY CHAIN MANAGEMENT

LCA is an analytical method used to evaluate the resource consumption and environmental impacts associated with the production of a specific product or activity (ISO, 1997). LCA provides a system-based accounting of material and energy inputs and outputs at all stages of the life cycle of grain products, including the acquisition of raw materials, production, processing, packaging, use and retirement (disposal and recycling). LCA provides a holistic assessment of the environmental profile of the total grain system. Life Cycle Inventory Analysis (LCIA) deals with the collection and synthesis of information on the major physical, material and energy inputs and outputs in the form of pollution in the various stages of the grain life cycle.

The grain supply chain includes many stages with associated emissions:

- The pre-farm stage results in environmental emissions from agricultural machinery, fertilizer and pesticide production.
- The on-farm stage results in environmental emissions from diesel use, liming and nitrous oxide (N_2O) emissions from N fertilizer applications.
- The post-farm stage includes grain storage, flour milling, starch

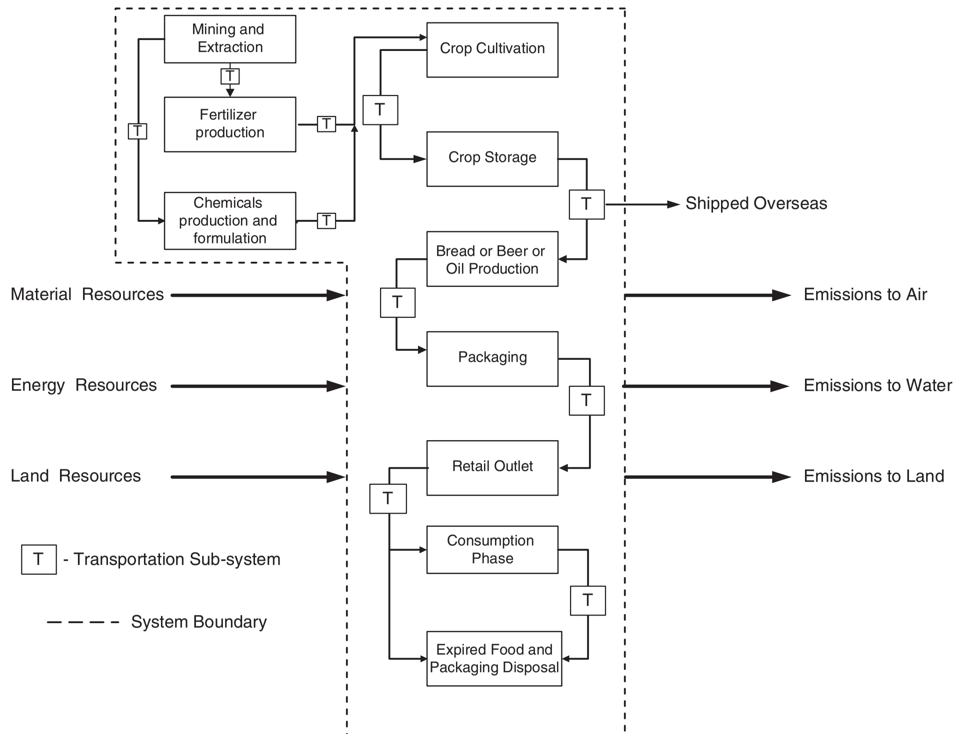
production and starch end-use with emissions created by energy production, transportation and waste management.

Life cycle assessment can provide a 'cradle-to-grave' approach, which involves analysing all inputs and (non) product outputs that are extracted from the environment or disposed of to the environment across all stages of the grain supply chain. LCIA provides the data upon which the LCA can proceed.

LCA Methodology

Typically, the methodological framework of LCA is comprised of four steps (ISO, 1997; Guinee et al., 2001): goal and scope definition; life cycle inventory (LCI) assessment; life cycle impact assessment; and life cycle interpretation.

- The goal and scope definition establishes the functional unit, system boundaries and quality criteria for inventory data. For example, the goal and scope for grain industries can be the assessment of the environmental performance of the production of a grain product, or to assess the performance of grain products like flour or feedstock. The functional unit determines whether it should be the environmental performance of one tonne of wheat production or one loaf of bread. The LCA, with a functional unit of 'one loaf of bread', has a bigger system boundary (paddock to bread): that is, it consists of more stages than a LCA with a functional unit of 'one tonne of wheat production' (paddock to harvested grain).
- Figure 6.1 shows a grain product LCI from an LCIA, consisting of inputs and outputs for the different stages of production. Inputs and outputs are assigned to environmental impact categories and characterization models are used to calculate the contribution of each of these inputs and outputs to category indicators.
- A Life Cycle Impact Assessment Profile of category indicators scores each environmental impact category.
- Finally, the Life Cycle Interpretation deals with the interpretation of the results from both the Life Cycle Inventory Analysis and Life Cycle Impact Assessment. It includes the identification of issues and the evaluation of results. Once potential environmental improvements have been identified and assessed, appropriate cleaner production strategies can be considered to improve the environmental performance of the grain supply chain.



Source: Narayanaswamy et al. (2004).

Figure 6.1 Life cycle flow chart

LCAs of the Australian Grain Industries

There are a few published research references on LCA, which have identified 'hotspots' or stages requiring the implementation of cleaner production strategies in Australia's grain production.

Biswas et al. (2008) conducted an LCA of one tonne of wheat transported to Fremantle port in Western Australia, where pre-farm, on-farm and post-farm stages accounted for 45 per cent, 44 per cent and 11 per cent of GHG of the total emissions from the supply chain, respectively. Fertilizer production at the pre-farm stage was the major contributor (35 per cent) to GHG, followed by the on-farm CO_2 emissions (27 per cent) and the emissions from the transportation of inputs (12 per cent) (Biswas et al., 2008). However, the functional unit of a LCA analysis has a large bearing on the conclusions drawn. LCA outcomes change when the functional objective is the environmental impact assessment of one loaf of bread compared to one tonne of wheat. Narayanaswamy et al. (2004) found that the retail and consumption stage contributed 55 per cent of the total greenhouse gases in the bread supply chain. The same study also found that the post-farm activities, including storage and processing, accounted for 70 per cent of the total greenhouse gas emissions for producing beer from barley. Overall, pre-farm and on-farm stages produce more GHG emissions (64 per cent) than other stages in the life cycle of oil production from canola. The variation of 'hot spots' in the life cycles of canola and wheat may vary with inputs, technologies and processes used.

For the production of chips from corn, post-farm, pre-farm and on-farm stages accounted for 57 per cent, 37 per cent and 6 per cent of the total GHG emissions during the product life cycle (Beer et al., 2003). In the pre-farm stage, the production of fertilizer contributed the highest portion of GHG (52 per cent): N_2O emission from the applied fertilizer accounted for the highest emission in the life cycle of corn chips. After N_2O emissions from applied fertilizers, oil for frying the corn, boxes for transporting the corn chip packets, transporting the corn chips to market and water pumping contributed to GHG emissions during the corn chip product life cycle. Some overseas studies that included all stages of the crop life cycle from 'paddock to plate', found that the manufacturing process for the finished product or the use of the finished product, contributed more to GHG emissions than pre-farm and on-farm stages (Heller and Keoleian, 2000).

Whilst the manufacture of fertilizer is a major contributor of GHG in agriculture, Riedacker (2007) reviewed the impact of increasing inputs in crop production to increase yields relative to GHG emissions. He concluded that increasing inputs was a beneficial option for GHG mitigation in spite of the fact that increasing inputs (in particular N) increase N_2O emissions. Riedacker noted that increasing yields with better applied inputs can avoid the conversion of virgin forestland, bushland or grassland into crop land – thereby assisting with CO_2 reduction and climate change challenges, increasing food security and reducing the energy intensive importation of food.

In addition to LCA of GHG emissions, other environmental impacts (for example soil condition, air pollution, water quality) need to be taken into account in order to assess the sustainability of grain industries in South-western Australia. For example, diesel had more global warming impact than biodiesel (Sheehan et al., 1998), but De Nocker et al. (1998) found that diesel has more impact than biodiesel on soil and water acidification, eutrophication and radio active waste type (that is, other environmental impact categories).

LCA analysis, therefore, can identify 'hotspots' in grain production or a grain product supply chain, which subsequently may benefit from the introduction of cleaner production strategies to improve production efficiency (eco-efficiency) and reduce negative environmental impacts. For example, the retail and consumption stages are hotspots for bread and corn chips, while storage and processing are major hotspots for the beer supply chain, and pre-farm and on-farm for canola oil (Narayanaswamy et al., 2004; Grant and Beer, 2008).

Limitations of the LCA Methodology

LCA is a useful methodology for assessing the environmental impacts associated with a product, process or activity by identifying, quantifying and evaluating all the resources consumed and all the emissions and wastes released into the environment (Brentrup et al., 2001). However, a number of methodological issues still need further evaluation and assessment in order to more fully account for the positive and negative environmental impacts of grain production, including the carry over between crops (nutrient cycling), human, eco-toxicity and land use impacts (that is, dryland salinity and the biodiversity issues associated with broadacre grain production in Australia) (van Berkel, 2000). For example, any real or potential impacts of dryland salinity on GHG have not been found in the existing LCA frameworks and software databases. The most common impact categories in LCA frameworks and databases are global warming, photochemical oxidation, euthrophication, carcinogens, land use, water use, solid waste, fossil fuels and minerals.

Dryland salinity (that is, salinity on non-irrigated land) is seen as one of

Australia's most serious environmental and natural resource management problems. There has been considerable government investment in salinity management programs for over a decade that aims to increase farmers' adoption of management practices for salinity prevention (John et al., 2005). Therefore, an additional impact category for salinity effects, including increased fertilizer application, land use change and deep drainage effluents, would be beneficial in taking account of the GHG production associated with salinity management and broadacre grain production in Australia.

While dryland salinity and associated land degradation impacts on grain production are well known, land use and practice impacts from land degradation or changes in land use have not been appropriately considered in modern LCA analysis. This is because there are few, if any, impact assessment methodologies currently available. However, in agricultural production, land use is one of the most significant impact areas, particularly in relation to soil erosion, hydrology, soil organic matter, soil structure, nutrient balance, soil pH and landscape aesthetic value (Mattsson et al., 2000). Mattson et al. suggest that for the impact category for land use, both qualitative and quantitative information is necessary, which makes aggregation into a single LCA-based data input difficult. They suggest that land use impact assessments should be provided together with LCA results to provide further environmental information for decision-makers. Riedacker (2007) also examined the land use impacts in relation to wheat production in France in order to more fully assess the impacts of changes in land use, land use intensity, primary GHG mitigation potential of wheat, payback periods for deforestation and wheat production versus afforestation (land use change) on various environmental parameters. This research took account of a much broader array of environmental impacts than is normally possible with LCA analysis.

Similarly, a detailed and comprehensive LCA methodology could be developed in Australia for addressing the impacts of climate change, land degradation (salinity, soil acidification), land use and production practice change on GHG emissions.

POTENTIAL CLEANER PRODUCTION BENEFITS FROM A LCA OF THE GRAIN SUPPLY CHAIN

Once environmental hotspots in the grain supply chain are identified, appropriate cleaner production techniques can be applied to these hotspots, in order to improve environmental performance. Cleaner production initiatives involve the continuous application of an integrated preventative strategy to processes, products and services to increase efficiency and reduce negative human impacts on the environment. van Berkel (2007) highlights some of the prevention practices to reduce undesirable impacts:

- good housekeeping – to improve operation, maintenance and management procedures;
- input substitution – the use of environmentally preferred and 'fit-for-purpose' process inputs;
- technology modification – improve the production facility;
- product modification – change product features to reduce its life cycle environmental impacts; and
- re-use and recycling – on site recovery and re-use of materials, energy and water.

These practices can potentially be implemented through the grain supply chain. An introductory review of some examples of cleaner production initiatives in relation to the grain supply chain are noted below.

Good Housekeeping

Good housekeeping activities, including on-farm management practice and the maintenance of farm machinery, can help reduce the overall consumption of agricultural inputs, the production and application of which can cause harmful environmental emissions.

Precision agriculture (PA), for example, can reduce the use of energy and chemicals by applying monitoring and mapping techniques to supply exact amounts of fertilizer, water or chemical control agents to crops, at exactly the right time and place. Targeted root zone application and drip irrigation can also help reduce water consumption.

As in other broadacre cropping regions in the western world, interest in PA, machinery guidance systems, yield monitors and remotely sensored soil data have increased rapidly within the traditional wheat growing areas of Australia (Jochinke et al., 2007). Substantial increases in the cost of agricultural inputs and a steady decline in the prices received by farmers in real terms over past decades has led to the uptake of PA (ABARE, 2006). Conversely, the availability and affordability of guidance systems, yield monitors, variable rate applicators and an array of data collection tools including satellite imagery and electromagnetic soil surveys have improved in recent years (White, 2006).

The implementation of crop rotation plans to maintain the availability of crop nitrogen and organic matter can avoid the overuse of N and other chemical fertilizers. While increased use of nitrogen fixing leguminous plants improves soil condition and reduces nitrate leaching, it also decreases the fallow periods, which results in the reduction of soil carbon content and CO_2 production. Wheat yields are often higher in wheat–lupin and wheat–subterranean clover rotations than in continuous wheat cropping systems, which has been attributed to improved nitrogen availability after the legume crop, as well as lower disease and weed pressure (Bunemann et al., 2006).

Integrated Pest Management (IPM) provides an economically and environmentally acceptable method of pest control through the judicious use of pesticides. Pesticide production accounted for 9 per cent of the total greenhouse gas emissions in the life cycle of one tonne of wheat production in WA (Biswas et al., 2008). IPM programs are based on a careful assessment of local conditions, including such factors as climate, crop characteristics, the biology of the pest species, agricultural practices, soil quality and government regulations. Common IPM strategies include inter-planting of different crop varieties; the introduction of beneficial insects that prey upon the target species; and mechanical tools such as vacuums that physically remove insects from crops.

Finally, preventative maintenance of farm machinery to ensure running efficiency and productivity can reduce fuel consumption and therefore mitigate greenhouse gas emissions during on-farm operations.

Input Substitution

Substitution of chemicals by 'greener' or more natural products can reduce energy usage and environmental emissions. For example, the introduction of earthworms can reduce the use of chemicals for grain production (Baker, 1998). Fields trials have shown that some exotic earthworm species now found in Australian agricultural soils can substantially improve the availability of soil nutrients and consequently the quality and quantity of pasture and crop production. A wide range of agricultural management practices including tillage and stubble management, pesticide use, drainage, irrigation and lime application, have been shown to influence earthworm abundance in soils in southern Australia (Baker, 1998).

Pre-farm activities which cause CO_2 emissions from the manufacture of fertilizers and chemicals can be minimized through industrial symbiosis, where industries collaborate to exchange products, by-products and wastes to reduce their collective environmental footprint. For example, CO_2 is produced by CSBP at their ammonia plant in Kwinana WA. About 1000 tonnes of the CO_2 is sold to a nearby Alcoa plant as an input in alumina processing, thereby mitigating the emission of GHG.

Alternative fuel and renewable energy sources can be produced by delivering grain products to energy (co-generation), bio-fuel and bio-refineries/bi-products for on-farm operation and transportation purposes. Irrigation pumps run by solar panels can substitute for the fuel required by a conventional fossil fuel powered pump.

Technology Modification

Through the supply chain, technological improvements can take place in farm machinery, the production of insecticides, fertilizers and other inputs, transportation and manufacturing processes for grain products. In addition to cost savings and the improved efficiency with which fuel, pesticides and fertilizers are used (and their attendant application and supply chain input reductions), environmental benefits can be achieved from a reduction in GHG emissions and off-site impacts from pesticides or fertilizers (losses to the atmosphere and leaching). The uptake of minimum/zero tillage by Australian farmers has been found to be productive and profitable and potentially may lead to a more sustainable cropping system. Minimum/zero till farms use less fossil fuel since tractor usage is dramatically reduced (Zentner et al., 2004). This can reduce the emissions of greenhouse gases and other pollutants. Furthermore, under zero tillage, soils can build up increased levels of organic matter made up of decomposing plant material, insects and earthworms. Whilst there are initial costs in upgrading machinery for minimum/zero tillage systems, in the long term, savings are possible through reduced labour and machinery costs, reduced operational time and lower GHG emissions.

While increased efficiency through accurate machinery guidance systems can deliver quantifiable returns to farmers, White (2006) estimated that accurate auto-steer systems could save farmers 5–15 per cent on input costs (fuel, pesticides and fertilizers) by reducing over or under lapping and by increasing the timeliness of operations, for example facilitating the application of chemicals at night. Jochinke et al. (2007) postulate that a reduction in input costs alone indicates that the cost of accurate auto-steer systems can be justified on farms cropping more than 1000 ha annually, with further benefits from reduced soil compaction from controlled traffic farming systems.

Product Modification

Product modification involves the development of product type/categories that require less processing inputs and/or transport steps to consumers. For example, on-site processing of grains (for example canola to oil) can reduce GHG emissions from the transport sector. The use of genetically engineered plants may not only increase crop yields, but may also reduce pesticide application (Baker, 1998).

Reuse and Recycling

This includes recycling of nutrients and water for on-farm activities and the re-use of environmentally friendly packaging materials for grain products in the post-farm stage. Biodegradable polymers offer the potential for addressing a wide range of environmental concerns associated with conventional polymers (Bohlmann, 2004).

Re-use of waste water can supplement the irrigation scheme by combating salinity and therefore mitigating climate change. In Adelaide, South Australia, highly treated and disinfected wastewater is being injected into a brackish confined aquifer that has become more saline due to overdraw and ingress from more saline aquifers. Extensive trials have focused on the microbiological quality and the technical feasibility of injection, with regard to clogging of the injection bores and water quality changes during aquifer storage and recovery (Blair and Turner, 2004).

RESTRUCTURING SUPPLY CHAINS

Once the appropriate cleaner production (CP) techniques have been identified for treating environmental 'hotspots', stakeholders in the grain supply chain, including farmers, food processors, retailers, government, research organizations and consumers, will be able to implement appropriate strategies to enhance their environmental performance. In order to assess the environmental performance of supply chains, each stakeholder can develop an environmental management system (EMS).

An EMS is a methodological system-based approach to implement and review an organization's attempts to manage its positive and negative impacts on the environment. The main components of an EMS are to plan; implement; check and correct; verify; and improve production processes.

Planning assesses the current environmental performance, identifies environmental impacts and evaluates cleaner production options for improvement. It can also determine how stakeholders in the supply chain collaborate with each other in order to improve the overall performance of grain production. Planning consists of actions and control measures linked to key performance indicators (KPI) and targets. Actions include training programs, human resource development, alternative technology and farm management practices to apply CP strategies. Examples of KPIs are tonnes of GHG per tonne of grain produced or kg of GHG per litre of canola oil. Targets for achieving certain levels of GHG emissions need to be set, which depends, among other things, on the accessibility of information and technology, skilled labour and resources.

Implementation is the application of CP options to achieve environmental targets by reducing chemicals, energy and ecological footprints. Checking and corrective action supports regular monitoring and the use of KPIs to verify whether appropriate CP strategies have been correctly implemented to enable targets to be achieved. Reviewing of plans and goals ensures continuous improvement in developing an 'eco-grain' product. An 'eco-grain' product can impose less burden on the environment throughout the production life cycle.

Until recently the market demand for 'eco-grain' products was largely unknown and uncertain. While there is increasing community awareness of and concern about the degradation of natural resources as a result of agriculture (Ridley, 2007), Pahl (2007) believes that consumers often over-estimate their desire to purchase 'environmentally friendly' products because of strong social pressure for them to support the environment, even though very few consumers trust or understand what 'environmentally friendly' actually means. Furthermore, while 'environmental friendly' products are not always available, invariably they are an important consideration. Many consumers are suspicious about the environmentally friendly products. Hence, environmental considerations are the primary motivator for only small groups of highly committed consumers in their decision to purchase food (Pahl, 2007). Not unexpectedly, WA's largest grain handler and marketing company has recently instigated processes to enable certification against market requirements for environmental assurance (Noonan, 2008).

Cary et al. (2004) concluded that due to the low profit margins, high production costs, diseconomies of scale and low consumer demand, the production and marketing of 'eco-grain' products was not commercially viable. From the storage and handling company's perspective, the cost of segregating various grains at the bulk handling storage facilities is not economic, for because the quantity of EMS-based grain available is insufficient to cover the increased costs (Noonan, 2008).

The adoption and diffusion of EMS has been slow in the absence of substantial market demand. Nonetheless, producers have indicated that the uptake of an EMS has enabled them to counter negative community perceptions (Huhn et al., 2007; Seymour, 2007; Noonan and Brindal, 2008). Other potential benefits from the adoption of an EMS can include improved productivity, increased efficiency, less exposure to risks and a greater capacity to meet market requirements (Carruthers et al., 2005).

Improved productivity and increased efficiency of grain production as a result of the application of an EMS may reduce the overall production cost in the long term by reducing the amount of energy and materials consumed. However, the benefits arising from the implementation of an EMS are not always obvious or certain for farmers who cite a lack of immediate and tangible benefits, particularly financial and market incentives (Pahl, 2007).

In order to become more environmentally sustainable, farmers may need to use inputs with lower ecological footprints, which in turn places additional pressures on the 'up stream' supply chain to adopt measures for reducing environmental impacts. The Fertilizer Industry Federation of Australia (FIFA), as part of its obligations to the Greenhouse Challenge Plus program, has started providing up-to-date information to FIFA members about greenhouse challenges, and some of the national and international responses – including ways to minimize the industry's GHG 'footprint' (FIFA, 2008).

Farmers will also face increased environmental scrutiny from international customers with an increasing demand for 'clean and green' grain coming from abroad (MIG, 2003; Noonan and Brindal, 2008). 'Clean' is generally interpreted to mean that food is free of contamination (for example chemical residues), while 'green' means that food is produced and processed through environmentally acceptable means. This can be extended to packaging and the distribution of products, freedom from genetic engineering and other ethical considerations including fair trade and worker welfare. Quality Assurance (QA) schemes address food safety and product specifications such as the consistency of product and supply. However, there is little doubt that customers will increasingly demand 'environmentally safe' products in the future (Batt, 2007).

In Australia, community concerns are reflected in policy debates at both the Federal and State level (Ridley, 2001). Farmers' groups, such as the Mingenew-Irwin Group (MIG, 2008), as well as catchment management bodies, are taking an active role in the development of EMS. Producers are being asked to be more accountable by the government, which provides a key driver for the implementation of EMS (Ridley, 2001). Since 2002/3 the Australian Government has assisted the development of and encouraged the uptake of EMS through its various EMS Pilot and Pathways Programs (DAFF, 2008). In the future, an operational EMS might be necessary before farmers are eligible for land stewardship payments for the provision of eco-system services.

The Australian Corporations Law, Section 299(1)(f) requires that companies operating under any environmental legislation must report on their performance (Ridley, 2001). Retailers are reacting to this pressure for 'clean and green' products by requiring their suppliers to verify that the food they purchase is safe and, increasingly, produced in an environmentally sustainable manner (Newton, 2007). This not only influences grain farmers but also the food processors to reduce their ecological footprints. This trend is most apparent in Europe and Japan and is being led by large supermarket chains such as Sainsbury's and Tesco in the UK (Currey, 2000). The reasons for multinational companies to become involved in 'green' interests is largely out of 'enlightened self interest' in response to global concerns on climate change (Ellyard, 1998). Therefore, for corporate farms, given that they have to report on environmental performance, this provides an additional motivation compared to small individual farms (Ridley, 2001). It would be appropriate to postulate that climate change and corporate social responsibility (CSR) are now strong drivers for retailers.

The World Trade Organization (WTO) is increasingly focussing on trade rules that relate to environmental protection policies (Mech and Young, 2001). Along with Canada, the US and Europe, the United Nations Environment Program (UNEP), the World Bank and World Conservation Union (IUCN) are becoming more active in the environment and trade debate (WTO, 1999). For example, the US government stresses that members should exercise a high level of environmental protection and the Canada government wants an environmental review included in the next round of trade negotiations (Ridley, 2001). According to the European Common Agricultural Policy, much of the EU's increased biofuel production would take place on 'set aside' land, which was taken out of production due to surpluses of cereals in the EU (European Commission, 2007). Expanded planting of grain producing crops almost certainly requires additional chemical, energy and fertilizer inputs, the use of which can cause harmful environmental impacts. In Western Australia, *Moringa oleifera* and *Pongamia pinnata* are perennial species which are highly tolerant to dryland salinity, water logging, frost and drought, and can be planted and harvested for biodiesel production on land not suitable for grain cropping (Brockman, 2007). This land would otherwise be 'set aside' by the landholder or used for less productive purposes.

While primary producers will face considerable additional costs in compliance, failure to comply is likely to result in exclusion from the market. To reduce the costs associated with environmental assurances, Seymour et al. (2007) discuss the need for and the means by which an EMS can be 'bolted on' to existing quality assurance or food safety programs. This not only allows farmers to identify, understand and manage the hazards and risks in their business that might impact on food safety, product consistency and the environment, but potentially, it may reduce the cost of record keeping and third party certification (Batt et al., 2006).

Finally, a key role for the government is to promote a greater awareness of EMS to the wider, non-agricultural community and to promote cleaner production strategies in the supply of 'eco-grain'. This will enhance the community's awareness of the environmental efforts being undertaken by their agricultural counterparts and may increase the demand for 'eco-based' products, without increasing the need for legislation. The provision of incentives for farmers practising EMS is largely contingent upon identifying an appropriate mechanism to identify 'eco-grain' products in the market and reward those farmers who have environmental management plans in place. Finally, interaction with research organizations has the potential to provide new ideas and technical expertise to manage and improve agricultural productivity and efficiency.

CONCLUSIONS

In the last five years more attention has been given to reviewing grain supply chains in order to better understand the environmental implications of agricultural production and consumption. LCA is an environmental management tool that provides a framework for analysing and evaluating environmental impacts in the different stages of the life cycle of grain products. LCA also provides a strong basis for targeting cleaner production initiatives in, for instance, an 'eco-grain' supply chain. This chapter identifies the potential role of cleaner production initiatives in increasing the efficiency of grain production and associated supply chain management, whilst reducing their environmental impacts.

The substantial contribution by agriculture (including grain production) to environmental emission warrants an investigation of cleaner production strategies to assist farmers and industry to both reduce their ecological footprint and improve grain production efficiency.

Finally, the grain supply chain needs to evolve, or in some instances radically change, its production practices through the implementation of cleaner production strategies with a consequential improvement of environmental performance at the 'hotspots'. In order to assess the environmental performance of supply chains, each stakeholder should develop a system-based approach, for such an approach can foster and consequently lead to the implementation of cleaner production initiatives. Government policies and supporting initiatives, international trade requirements, carbon trading schemes, and capacity building have all been and will potentially continue to be, the major drivers for implementing EMS in Australian grain supply chains.

NOTES

1. Collectively, this industry includes wheat, barley, sorghum, oats, oilseeds (canola, cottonseed, sunflower seeds, soybeans) and pulses (field peas, faba beans, chickpeas, lupins and lentils).
2. The ecological footprint measures how much land and water area a human population requires to produce the resource (for example electricity) it consumes and to absorb its wastes (for example solid waste), using prevailing technology.
3. The example for a point source would be the emission from a factory chimney, while N_2O emission from a paddock is the emission from a non-point source.

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