Life cycle assessment of milk production systems in south Queensland

Amanda Hamilton[1], **Malcolm Wegener**[2], **Peter Dart**[3] and **Bill Silvey**[4]

1. Queensland Department of Primary Industries, Longreach
2. School of Natural and Rural Systems Management, The University of Queensland, 4072.
3. School of Land and Food, The University of Queenland, 4072, Australia.
4. Waste Management Branch, Queensland Environment Protection Agency, Brisbane.

Abstract

Australian dairyfarmers are efficient by world standards and average farm production has expanded significantly in recent years. This has been achieved through increased use of land for grazing, better pasture and nutritional management, increased use of machinery, agricultural chemicals, and irrigation. Milk yields per cow have increased substantially. With the expansion of milk production, there has been increasing pressure on the environment surrounding dairyfarms. In addition, farms are often located in areas with aesthetic environments that are frequently visited by non-farming members of the community and farms may be located in catchments that feed water into storage areas for potable water supplies for urban areas. Dairy farms therefore rate highly in terms of environmental concern within the community.

Life cycle analysis has been used extensively in Europe, the United States, and Japan for appraisal of industrial production systems and there has been a growing interest in recent years in the application of LCA for agricultural production to assess environmental impact and sustainability.

This paper focuses on the conduct of a preliminary life cycle assessment of the milk production system used on dairy farms in south Queensland. Life Cycle Assessment methods are discussed and methodological issues associated with its application to agricultural production systems raised.

Contributed Paper presented to Annual Conference, Australian Agricultural and Resource Economics Society, University of Sydney, 23-25 January, 2000.

Introduction

Although Australia will not sign the Kyoto protocol by which economic entities will be expected to limit their environmental emissions until it is ratified by the United States, and that will not happen until major developing countries like China and India move to limit their emissions, there are good reasons why companies and other economic units should address greenhouse issues. Indeed companies who cannot show that they are working to reduce their greenhouse emissions can expect to suffer economically (Hordern, N., *Australian Financial Review*, 25 June 1999). While it remains unclear whether greenhouse issues come under the new environmental reporting responsibilities for companies which have been made mandatory by the new section 299 (1) (f) of the Corporations Law (Reinehr *et al.* (1999), they conclude that it would be prudent for companies to cover greenhouse issues in their environmental reporting.

Even in the absence of binding obligations to reduce greenhouse emissions on Australia, companies should not ignore the issue. There are obligations on directors under the common law to act in the best interests of their companies and the principals of other organisations should act similarly. Reinehr *et al*. argue that directors should respond to the Australian government's National Greenhouse Strategy where the focus is clearly on reduction of greenhouse emissions. While the National Greenhouse Strategy does not create legal obligations, companies will be expected to operate within the overall framework of measures specified in it. If companies do not respond voluntarily to reduce greenhouse emissions, in all likelihood, the Australian government will eventually legislate to ensure emission targets are met. It is clear that the pursuit of more energy efficient ways of producing our commodities and switching to more "green" sources of energy supply is a production strategy that Australian industries will have to follow. This applies to primary and tertiary industries just as much as it does to secondary industry which is seen as the major contributor to greenhouse gasses.

This initial application of Life Cycle Analysis in the dairy industry highlights some of the implications of greenhouse issues for one of Australia's major primary industries.

If Australian dairy farmers are to maintain efficient farming practices, and do so in a sustainable manner, they must ensure that environmental impacts are minimised through better environmental management. Life cycle assessment (LCA) is an environmental management tool which evaluates the environmental impacts of a product, process or activity through its whole life-cycle. This method was developed originally for industrial production systems, but has more recently been applied to agricultural production systems and this raises several methodological issues that need to be addressed. If the methodological constraints associated with life-cycle assessment of agricultural production systems are overcome, and LCA software is customised to Australian conditions, life-cycle assessment has great potential to make a valuable contribution to sustainable production in agro-industrial farming systems. The example of milk production in South Queensland is examined in this case study.

Dairy farming in Queensland

Australian dairy farmers are efficient producers by world standards, and average farm production has continued to expand. This has been primarily achieved through increased use of land for grazing, better pasture and nutritional management, increased use of machinery and agricultural chemicals, and the expansion of irrigation[1]. With the expansion and development of milk production comes increased pressure on surrounding environments. In addition, dairy farms are often located in aesthetic environments that are frequently visited by non-farming members of the community. Further, farms may be located in catchments that feed into water storage areas for potable water supplies for urban areas. Dairy farms therefore rate highly among the environmental concerns of the community at large.

Queensland dairy farmers have a General Environmental Duty of Care under the Environmental Protection Act (1994) to implement farm management practices that improve economic well-being and also maintain the quality and integrity of the environment. Under the act, they must take all reasonable and practicable measures to conduct their activities and practices in a way that minimizes environmental harm.

Dairy farms have a large flux of materials on and off farm associated with the milk production process. These materials have energy and environmental costs associated with their manufacture, transport, and use in milk production. Life Cycle Assessment (LCA) is a concept and method developed to evaluate the environmental impacts of a product, process or activity throughout its life cycle. This includes identifying and quantifying energy and materials used and wastes released to the environment, assessing their environmental impact, and evaluating opportunities for improvement[2].

Life cycle assessment is being used extensively throughout Europe, the United States, and Canada, and in Japan for process improvement, product design, strategic planning, marketing, and in deciding government policy. Australian companies have been slower to adopt LCA than their northern hemisphere counterparts. However, as pressure from government and the community to provide information on the environmental impact of production practices increases, LCA is being recognised as a useful environmental management and improvement tool.

Life cycle assessment has been developed primarily for appraisal of industrial production systems. The past several years have seen growing interest in the application of LCA to agricultural production systems to assess environmental impact and sustainability. Agricultural production systems differ somewhat from industrial production systems and require new methodological developments for all phases of LCA[3]. Once such methodological difficulties are overcome, LCA may be useful as an environmental management tool for south Queensland dairy farmers and other intensive producers of animal and crop products.

This paper focuses on the conduct of a preliminary life cycle assessment of milk production in the dairy industry in South Queensland. Life cycle assessment methodology is discussed, and methodological issues associated with application to agricultural production systems are raised.

---

[1] QDPI (1996) Environmental Guidelines for Queensland Dairy Farmers. Information Series Ql 96052. DPI, Brisbane.

[2] Mitchell, B. (1997) *Resource and Environmental Management*. Addison Wesley Longman Limited. Harlow, England

[3] Cowell, S.J. and Clift, R (1996). "Impact Assessment for LCAs Involving Agricultural Production" International Journal of Life Cycle Assessment 1997 (2) pp. 99-103.

Dairy production and ecological sustainability

Local, national, and international concern has grown in recent years regarding the efficient use and management of natural resources, particularly those used in agriculture. The potential for environmental impact from agricultural production on rural lands and adjacent ecosystems is gaining increased attention. Community values which once focused on economic development have now shifted to demand a balance between economic development and environmental sustainability. Today, landholders are expected to act as stewards of their land, and to ensure that management is conducted in a manner that maintains the quality and integrity of soil and water resources, and avoids damage to downstream environments.

While the principle of ecologically sustainable development is not clearly defined, it has become a topic of great debate in Australia[4]. The concept of ESD (ecologically sustainable development) grew out of the definition of sustainable development provided in the report of the World Commission on Environment and Development (WCED 1987) entitled *Our Common Future* (also referred to as the Brundtland Report). Sustainable development is founded on the notion that economic development and environmental well-being are not conflicting but mutually enhancing goals[5]. The National Strategy for Ecologically Sustainable Development[6] defines ESD as 'development which aims to meet the needs of Australians today while conserving our ecosystems for the benefit of future generations'.

In an effort to address concerns about environmental impacts from agricultural sources and to meet sustainable development objectives, the Queensland Government has developed new environmental laws, and in particular the Environmental Protection Act (1994) which places responsibility on all Queenslanders to meet a general environmental duty of care. Queensland farmers, including dairyfarmers, have a legal obligation imposed by the *Environmental Protection Act (1994)* to protect natural resources and waterways from the effects of farming practices. As defined in the *Act*, 'primary producers must take all reasonable and practicable measures to conduct their activities and practices in a way that prevents or minimises environmental harm.'[7] To show that the General Environmental Duty of Care has been met, primary producers have to be able to show 'due diligence'. Due diligence is when the person responsible for the property can demonstrate that they have assessed the potential risk to the environment from a farming or grazing activity and have taken reasonable and practical measures to minimise that risk[8]. Under the *Environmental Protection Act (1994)* the Minister has approved an Environmental Code of Practice for Agriculture that provides a way for primary producers to show 'due diligence' and to meet their legal requirements under the General Environmental Duty of Care. An approved code of practice is not a regulation under the *Act*, however it does have legal standing. A court may decide that a producer's failure to follow advice provided in the Environmental Code of Practice for Agriculture is evidence of failure to meet the General Environmental Duty unless

[4] Christainsen, I (1999) "The Code of Practice for Sustainable Cane Growing in Queenlsand - It's Developments and Future Directions". Proc.Aust.Soc.Sugar Cane Technol., 21.

[5] Ecologically Sustainable Development Working Groups (1991) *Ecologically Sustainable Development Working Groups, Final Report - Agriculture*. Australian Government Printing Service.

[6] Commonwealth of Australia (1992). *National Strategy for Ecologically Sustainable Development*. Australian Government Publishing Service.

[7] QFF (1998) *Queensland Farmers' Federation Environmental Code of Practice for Agriculture*

[8] ibid.

the producer can prove to the court that alternative actions were adopted which achieved the same environmental outcomes as those management options described in the Code[9].

Due to Queensland dairyfarmers' quest to achieve efficient farming practices, average milk production per farm and per cow has increased over time. If such productivity improvements are to be continued, and dairy farm viability secured, it is imperative that dairy farmers take action to protect the agricultural resource base from deterioration, through sound environmental management. In doing so, farmers will be better equipped to comply with the Environmental Protection Act and may move positively towards achieving ecologically sustainable development.

Life cycle assessment and environmental management

Evolution of the principle of ecologically sustainable development has resulted in the parallel development of a new discipline in environmental management. Modern society now demands a "preventative" approach to environmental management rather than a "prescriptive" approach. Life cycle assessment (LCA) is one of a new generation of environmental management tools contained within the international standard ISO 14000 which have emerged in response to increased environmental awareness on the part of communities, industry, and governments. LCA is designed to prevent rather than control or treat environmental damage by providing useful information on production processes while, at the same time, offering cost savings through improved resource management.

LCA is defined by the Society of Environmental Toxicology and Chemistry (SETAC) as:

"a process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment, to assess the impact of those energy and material uses and releases to the environment; and to identify and evaluate opportunities to effect environmental improvements. The assessment includes the entire life-cycle of the product, process, or activity, encompassing extracting and processing raw materials; manufacturing, transportation and distribution; use, re-use, maintenance; recycling and final disposal."[10]

LCA provides a holistic, cradle-to-grave approach to impact assessment rather than focusing on single issues. It is objective as scientific methods are used to collect and analyse data. LCA can be used to compare alternative products, processes or activities, to compare alternative life cycles for a product, or to identify components of a life-cycle where greatest improvements can be made. LCA aids better understanding of the impact that products and processes have on the environment, and hence, identification of areas requiring improvement. LCA has been used internationally for the past two decades as an environmental management tool. Its applications include product improvement, process engineering, strategic planning, eco-labelling, and policy development[11].

LCA methodology is not limited to one specific form, but is rather a framework for a systematic and comprehensive environmental assessment of product life-cycles. The Society

---

[9] ibid.
[10] SETAC (1991) *A Technical Farmework for Life-Cycle Assessments*. SETAC Foundation, Washington DC.
[11] Demmers, H (1996) "Life Cycle Assessment and Environmental Management" *Australian Journal of Environmental Management* 1996 (3).

of Environmental Toxicology and Chemistry (SETAC) developed the first international code of practice for LCA in *A Technical Framework for Life-Cycle Assessments (1991)* and the draft international standard (ISO14040) has been developed to specify the general framework, principles and requirements for conducting and reporting LCA studies[12]. As recognised in the draft international standard, LCA methodology is still at an early stage of development with some phases of the LCA techniques still in their infancy.

SETAC and the draft International Standard define four distinct stages in LCA methodology:

(i) *Goal definition* to identify the purpose for the study and its intended application(s), and *scoping* to define the boundaries, assumptions and limitations of the study.

(ii) An *inventory* of materials and energy used and environmental releases (e.g., airborne, waterborne and solid waste) arising from all stages in the life of a product or process, from raw material acquisition to ultimate disposal.

(iii) An *impact assessment* of potential and actual environmental and human health effects related to the use of resources (energy and materials) and environmental releases; and

(iv) An *improvement assessment* of the changes needed to bring about environmental improvements in the product or process under study[13].

Limitations of life-cycle assessment

While LCA is considered useful and is becoming a more popular environmental management tool, like all techniques, this methodology has limitations. LCA is not yet a fully developed methodology because some phases remain in relative infancy. A common criticism is that LCA is too complex, time-consuming, and expensive to be of practical use in environmental management. Computer software tools such as Sima-Pro 4 and GaBi3 have been developed to overcome these problems (***Reference ????***). These software packages have been developed to reduce problems associated with data collection and impact assessment and to ensure that assessments are transparent. They contain process and impact databases which facilitate the comparison and analysis of production system life-cycles.

LCA studies are data-intensive and therefore hindered by problems with data availability and accuracy. Intensive data collection also involves considerable time, expense and effort. Practitioners are often forced to compensate for missing data, and by doing so may fail to reach conclusions where data are inadequate, make qualitative judgements, or use average emissions data or maximum legal limits where actual production data are not available[14]. The data intensive nature and related problems with LCA indicate that the scientific accuracy and subsequent objectivity of an LCA may be compromised. Caution must therefore be exercised when interpreting possible ‘subjective’ results of a study. Researchers in the United States and Europe have endeavored to overcome data collection

[12] ibid.

[13] SETAC (1993) *A Conceptual Framework for Life-Cycle Impact Assessment.* SETAC Foundation, Washington DC.

[14] op.cit Demmers (1996).

limitations through the development of public databases and emission registration programs requiring companies to publish environmental information. Where studies are carried out for private organisations, data can be obtained by giving a guarantee of confidentiality within the chain of life-cycle producers. In Australia, however, data availability remains a major issue, as data collected by individual companies remains confidential and very little published data exists in a form suitable for use in LCA[15].

Defining system boundaries is an important element of the goal definition and scoping stage as this determines which activities will be included within an LCA. A common problem for LCA practitioners is to define system boundaries that yield results that are meaningful and achievable within a realistic time frame and financial constraint. In making decisions about which unit processes to include in a system, several issues arise. For example, a practitioner must decide if an LCA should consider the environmental impacts involved in making the capital equipment to produce a product or provide a service. They must also determine product durability and hence the time horizon covered by the LCA, and whether personnel requirements and emissions are included in the production process[16]. Such issues may lead to a more subjective definition of system boundaries. In an effort to guide practitioners in defining system boundaries, attempts have been made to formulate "decision rules", however these still allow for subjective decision making. The draft International Standard (ISO 14040) states that all criteria used in establishing the system boundaries shall be identified and justified in the scope of the study[17].

Difficulties often arise in linking physical processes contained within the life cycle inventory to environmental impacts and valuing the relative importance of such impacts. Models used for inventory analysis are still under development, are limited by their assumptions, and may not be available for all potential impacts. Impact assessment therefore calls for a high level of professional judgement, becoming a rather subjective procedure. Despite often generating inconclusive answers, it is argued that the impact assessment stage should not be avoided on this premise. Provided all assumptions and value judgements are clearly documented in the final report, the impact assessment may still be useful.

LCA is often perceived as a complex, time-consuming and expensive procedure, and consequently doubts arise concerning its practicality as an environmental management tool. Provided the practitioner recognises the "point of diminishing returns", that is, the point at which further investment of time or money is not justified by the likely benefits[18], this problem may be controlled. A detailed, quantitative LCA may not be necessary or suitable for all cases. A simplified, less quantitative, but cost effective method of LCA may be beneficial.

Despite the problems associated with LCA, the methodology is developed enough to still prove useful as an environmental management tool. Much effort and funding is being invested in research and development to resolve these methodological issues. More qualitative, streamlined alternatives exist to the detailed, quantitative LCA framework, including a simplified LCA framework developed by SETAC[19]. Such methods are attractive when simpler methods are suitable for analysis of environmental problems.

---

[15] ibid.
[16] ibid.
[17] op.cit. ISO (1997).
[18] op.cit Demmers (1996).
[19] SETAC (1997) *Simplifying LCA: Just a Cut?* SETAC - Europe, Belgium.

Life cycle assessment for agricultural production systems

Life cycle assessment was initially developed as an environmental management tool for industrial production systems. In striving towards ecologically sustainable development, there has been growing interest in developing LCA as a tool for assessing the environmental implications of agricultural production systems. Application of such a management tool to agricultural systems seems sensible when considering the magnitude of environmental impacts linked with current farming practices including pollution, deterioration of the landscape, reduction in biodiversity, and animal welfare. However, agricultural production systems differ significantly from industrial production systems. Application of LCA to agricultural systems therefore requires a systematic approach to existing methodology and new methodological developments[20]. Until recently, the application of LCA to agricultural production systems had not been explored systematically, and the extent to which the general approach would have to be modified and adapted for agriculture was unknown[21]. A concerted action "Harmonisation of Environmental Life Cycle Assessment (LCA) for Agriculture" was conducted by thirteen European groups from six countries to investigate how LCA might be applied in general to agricultural production and to identify methodological difficulties which required further research. Three alternative methods of growing wheat were used as case studies. They were defined in a way that introduced as many as possible of the LCA issues requiring harmonisation and resolution. Publications from Cowell and Clift (1995;1996) also identify problems in developing LCA methodology for agricultural systems, and these are summarised below.

While some environmental issues related to agricultural production systems are encompassed in LCA methodology, other important issues are not addressed. LCA is based on a systems approach to environmental management that is amenable to mathematical analysis and therefore has limitations when attempting to incorporate factors like landscape degradation, animal welfare, and bio-diversity into an analysis. These issues are concerned with the state of the farming system itself, rather than with inputs and outputs that merely cross the system boundary. As these issues are more qualitative in nature, they become more difficult to assess.

Agricultural production systems also present a number of new challenges for current LCA methodology. Cowell and Clift (1995) discussed the key challenges as being geographical boundaries, allocation among co-products, crop rotations, and functional units.

The definition of system boundaries, that is, boundaries across which flows of inputs and outputs are quantified, is generally straight-forward for industrial production processes. In agricultural production systems, the boundaries are less obvious. The most prominent issue is whether or not soil should be included within the farming system boundary. Cowell and Clift (1995) recommend that farmed soil be included within the system boundary as it is an integral part of the production system. In doing so, a further issue is raised. This is whether a change in the soil quality resulting from farming activities should form part of the analysis. Cowell and Clift (1995) advise that as LCA has been developed to assess the environmental impact of inputs that cross the system boundary, a change in soil quality is not

[20] op.cit (1996) Cowell & Clift.
[21] European Commission (1996) Harmonisation of Environmental Life Cycle Assessment for Agriculture - Final Report, Concerted Action. Silsoe Research Institute, UK.

relevant for inclusion in an LCA where soil is within the system boundary. It is noted however, that impacts of farming systems on soil quality should not be ignored as soil quality is a vital component in defining sustainable farming systems. They therefore recommend that an indicator of soil quality should be developed and included within the Inventory Analysis to document changes in soil structure, texture, and fertility resulting from the farming system.

It is common in agricultural production systems for more than one product to be produced, for example, the production of grain and straw from a wheat crop. In such instances, there is a problem about how inputs and output should be allocated between co-products. Allocation of total inputs and outputs among co-products is generally carried out on the basis of mass or some other physical property or in relation to economic value.

Crop rotation is often undertaken in farming systems to maximise overall productivity from any given area of land. However, when an LCA study focuses on a single crop, the existing methodology fails to account for the interactions between the current crop, and preceding and subsequent crops. Cowell and Clift (1995) therefore raise the question of whether it would be more appropriate to draw a system boundary around a crop rotation rather than a particular crop.

Difficulties often arise when defining an appropriate functional unit and the service provided by the product, process, or activity under analysis. When comparing alternate production systems, each useful final product may have different properties. It is imperative therefore that an appropriate functional unit be defined which allows a standard comparison of alternatives.

Application of LCA to agricultural production systems is still in its infancy and extensive research is being conducted to overcome some of the associated challenges to current LCA methodology and to identify new methodological developments. If such issues are addressed accordingly, and consensus is achieved among LCA practitioners and users, LCA has the potential to make a valuable contribution in defining pathways to more sustainable agricultural production.

Life Cycle Assessment of the Dairy Milk Production System in South Queensland

The intention of this paper is to determine whether life cycle assessment is an appropriate environmental management tool to assess the sustainability of dairy production systems using a typical South Queensland dairyfarm as an example. Through a study of literature concerning life cycle assessment methodology and its more recent application to agricultural production systems, it is believed that LCA holds much potential as a tool to evaluate the environmental impact of dairy production systems. Consideration has therefore been given to how a life cycle assessment of the dairy industry production system in South Queensland should be conducted. In this case, LCA would be most useful if employed to compare alternative dairy production systems used throughout South Queensland. By doing so, the most environmentally responsible system could be identified. Also, the relationship between economic and environmental impact for various dairyfarming systems could be examined.

Smith and Wegener (1997)[22]undertook an economic study of dairy farms in south Queensland and northern New South Wales which identified five different dairying districts with the survey region, northern New South Wales, Sunshine Coast, Moreton Plains, South Burnett and Darling Downs, with quite different production systems in each. In addition, the farms were divided according to herd size (<110 milking cows, 110-150 cows, and >150 milking cows) as well as the area of the farm that was irrigated (less than or more than 20 percent of farm area irrigated).

The QDPI in collaboration with the CRC for Waste and Water Technology at the University of New South Wales is currently conducting a life cycle assessment of the Australian Dairy Processing industry which is funded by the Dairy Research and Development Corporation (DRDC). It focuses on environmental impacts from the farm-gate to the factory warehouse. A meeting was held with one of the members of the technical advisory committee for this project, Mr. Michael Jones (DPI - Centre for Food Technology, Toowoomba) to discuss how this LCA is being conducted. This discussion provided a better understanding of how an LCA of the dairy production system should be conducted. The initial intention of this project was to conduct a detailed LCA study for all manufactured milk products. However, it was soon realised that completion of an LCA for all twenty products would be a most expensive and difficult task. An early milestone report indicated that the environmental burden resulting from milk powder production was more significant than other manufactured milk product processes. A decision was taken to refine the LCA study, and conduct a streamlined LCA of skim milk powder production processes and the study was confined to the Darnum Park milk powder factory operated by Bonlac foods[23]. An LCA software tool, Sima-Pro 4.0 has been used for the inventory and impact assessment stages.

It was recommended that a life cycle assessment of the South Queensland dairy production system be conducted in a similar manner. Life cycle assessment methodology should be applied according to both the guidelines of the draft ISO 14040 standard and the framework developed by the Society of Environmental Toxicology and Chemistry. The study should therefore commence with the establishment of goals and scope definition. Flow charts should be constructed which depict alternative dairyfarming system processes. An inventory of materials and energy used throughout the production process and subsequent environmental releases should be compiled from primary and secondary data collection. Data sources could include existing literature, previous research projects, any industry surveys, and on-site data collection. Once comprehensive and valid data are collected for each production system identified, an impact assessment can be carried out. The results generated will quantify environmental burdens resulting from each dairy production system and will allow a comparison to be made between the systems. The most sustainable production system can then be identified and an assessment made of changes required to bring about environmental improvements in the remaining systems. An LCA software tool such as Sima Pro 4.0 or GaBi 3 should be employed to facilitate the LCA.

As LCA software tools have been traditionally designed for industrial production processes, databases may not account for some inputs and environmental releases associated with agricultural production systems. The Cooperative Research Centre for Waste and Water Technology at University of New South Wales has two LCA software packages, Sima Pro

[22] Smith, AG and Wegener MK, Comparative analysis of dairy farm returns in south east Queensland and northern New South Wales, Final report on DRDC Project UQ024, University of Queensland, February 1997.
[23] M. Jones, QDPI Toowoomba (*pers. comm.* May 1999) and A. Feitz CRC for Waste and Water Technology, UNSW, (*pers. comm.* July 1999)

4.0 and GaBi 3, and also has the expertise to conduct computer software aided LCAs. To assess whether an LCA software tool would generate meaningful information for a study of this nature, a preliminary LCA was conducted for a case study South Queensland dairy production system using Sima Pro 4.0. The cooperation of the UNSW - Centre for Waste and Water Technology was sought to assist in this preliminary exercise.

A flow-chart was designed representing the input and output flows of a typical dairy production system (See Appendix 3). Data was collected from a single dairy farm in the Lockyer Valley, South Queensland, and entered into Sima Pro 4.0 to assess the software package's ability to model the production system (See Appendix 4). While the data collected may not be completely accurate or representative of typical South Queensland dairy production systems, it was merely compiled and used to gain an indication of the data requirements of an LCA software package, as well as the style and usefulness of output generated. A more complex flow-chart of the dairy production system was generated by Sima Pro 4.0, as the program was able to compile information regarding the production processes for inputs (See Appendix 4). The nature of data required by Sima Pro 4.0 to execute an LCA can be understood from a summary of inputs. Graphical output from the program shows the relative contribution to various environmental sustainability indicators (eg. greenhouse gases, ozone gases, acidification, eutrophication, heavy metals, carcinogens, winter smog, summer smog, pesticides, energy and solid waste) from the dairy production system (See Appendix 4). In the chart in Appendix 4, the relative contribution to the various environmental indicators from each farm and transport activity involved in milk production and delivery to the factory gate are shown. These results demonstrate that pasture production is the main contributor to greenhouse gas production, acidification, eutrophication, heavy metals, energy usage and solid waste production. Electricity used in the process, mainly for irrigation, contributes equally with pasture production to greenhouse gases and acidification and is the major contributor to carcinogens and winter smog. Transport of farm inputs and milk contributes a relatively minor amount to greenhouse gases, acidification, carcinogens, winter smog, energy and solid waste in comparison with pasture and electricity, but it is the most important contributor to winter smog. However, an actual estimate of the level of each environmental impact is not provided in this case, and whether or not these exceeded a critical level is not discussed. A lack of information during data entry resulted in the omission of pesticides used in the farming system. Consequently, pesticide contribution to environmental impacts was not described. Information contained within the Sima Pro 4.0 database was not sufficient to model agricultural pesticide and fertiliser manufacture, transport, and use. The software was also unable to model the hay, silage and feed grain components of the production system and it is unclear whether Sima Pro 4.0 was able to model an effluent pond waste management and recycling system. These components are all integral to a dairy production system and must be modelled correctly if a true representation of production systems is to gained to perform an accurate LCA. Despite these problems, the results generated indicate that the dairy production process does have significant environmental implications.

Sima Pro 4.0 software was designed in The Netherlands for industrial production systems. LCA experts from the Centre for Waste and Water Technology feel that it is unlikely that the software designers, Product Ecology Consultants, will adapt Sima Pro 4.0 for assessment of agricultural production systems. It is believed however, that the German designers of another LCA software tool, GaBi 3, would be interested in customising software to Australian conditions, so that product may be more suitable for modelling agricultural production systems.

An LCA round table discussion was held on 1 July, 1999 at the UNSW - Centre for Waste and Water Technology. At this discussion Mr. Andrew Feitz presented an outline of the LCA study of the Darnum Park milk powder case study for the Australian Dairy Industry. The preliminary dairy farm data collected for the South Queensland case was incorporated into a hypothetical LCA of a milk production and dried milk powder manufacturing system. The results suggest that the environmental impacts associated with on-farm milk production may be significantly larger than those from milk powder manufacture (See Appendix 5).

According to results generated from the preliminary LCA using Sima Pro 4.0 incorporating the dairy farm case study data into an LCA of milk production and manufacturing, it can be concluded that the milk production process has serious environmental impacts. It is therefore imperative that South Queensland dairy farmers implement better environmental management and using a tool such as life cycle assessment may ensure that these impacts are minimised or kept to a sustainable level.

Conclusions and Recommendations

As a result of conducting this preliminary study into the application of LCA in the south Queensland dairy industry, our experience led us to make several recommendations. It is clear from this preliminary attempt that the LCA methodology can aid an understanding of the environmental impact of farming practices especially those like dairying which combine farm production, transport, and processing activities. It is likewise clear that there is much development work and adaptation of the LCA methodology is needed to cope with agricultural production systems. Databases of information available with the existing software packages are almost exclusively built on European data which may not be relevant in the more moderate, but highly variable climate, of Australia.

There is obviously an opportunity and a need to continue research to develop and adapt this technique to Australian conditions. The dairy industry has already expressed interest in it and a willingness to finance research. It is also an industry with significant environmental impact, is confined to a relatively small part of the Australian farmland, and is often located in areas visited by the urban community so that its environmental impact is under close scrutiny. The dairy industry at both farm and factory level does produce concentrated waste streams that require sensible treatment if they are not to cause environmental problems.

Acknowledgements

The authors would like to acknowledge the funding for this project provided by the Waste Management Branch, Queensland EPA. Christina Dimova, Sven Lundie, Andrew Feitz and Volkers Goebel from the UNSW Centre for Waste and Water Technology, Michael Jones, QDPI, Toowoomba, Don Kerr and Wayne Erlich, QDPI, Mutdapilly Research Station are also thanked for their assistance in providing data, ideas, and assistance with the preliminary LCA without which this project would not have been completed in the successful way that it has been.

References

Christainsen, I., (1999). "The Code of Practice for Sustainable Cane Growing in Queenlsand - It's Developments and Future Directions". Proceedings Australian Society of Sugar Cane Technologists conference, Townsville, 27-30 April 1999, pp 267-273.

Commonwealth of Australia (1992). *National Strategy for Ecologically Sustainable Development*. Australian Government Publishing Service, Canberra.

Cowell, S.J. and Clift, R. (1997). "Impact Assessment for LCAs Involving Agricultural Production", International Journal of Life Cycle Assessment, Vol. 2, pp. 99-103.

Demmers, H., (1996). "Life Cycle Assessment and Environmental Management", *Australian Journal of Environmental Management* 1996 (3).

Ecologically Sustainable Development Working Groups (1991). *Ecologically Sustainable Development Working Groups, Final Report - Agriculture*. Australian Government Printing Service, Canberra.

European Commission (1996). Harmonisation of Environmental Life Cycle Assessment for Agriculture - Final Report, Concerted Action AIR3-CT94-2038. Silsoe Research Institute, Silsoe, UK.

Hordern, N. (1999). Think green, companies told, *Australian Financial Review*, 25 June 1999

Mitchell, B. (1997). *Resource and Environmental Management*. Addison Wesley Longman Limited. Harlow, England.

QDPI (1996). Environmental Guidelines for Queensland Dairy Farmers. Information Series Ql 96052. Queensland Department of Primary Industries, Brisbane.

QFF (1998). *Queensland Farmers' Federation Environmental Code of Practice for Agriculture.* Queensland Farmers Federation, Brisbane.

Reinehr, L., Anderson, S., and Farrands, D., (1999). Greenhouse alert: What should you as a director be doing about your company's greenhouse emission? *Company Director's Journal*, June 1999.

SETAC (1991). *A Technical Framework for Life-Cycle Assessments*. SETAC Foundation, Washington, DC.

SETAC (1993). *A Conceptual Framework for Life-Cycle Impact Assessment.* SETAC Foundation, Washington, DC.

SETAC (1997) *Simplifying LCA: Just a Cut?* SETAC - Europe, Belgium.

Smith, AG and Wegener MK, Comparative analysis of dairy farm returns in south east Queensland and northern New South Wales, Final report on DRDC Project UQ024, The University of Queensland, Brisbane.