Spatial and Temporal Scale of Eco-label for Agricultural products - case study of milk production

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ABSTRACT

Eco-labels serve as a means to narrow the information gap between producers and consumers with regard to the environmental impact of consumer choices. Whether they are successful is open to debate because of credibility issues, one of which is the specificity of the label: is the label specific to the particular item labelled (e.g. a cut of meat from a specific cow, milk from a particular farm) or the class of items (e.g. beef produced in a country in general, milk from a co-op). Most eco-labels do not provide consumers with information about the specific food products they choose because tactical and operational management decision are not captured in the life cycle inventory collection process, and are usually a historical snapshot from a time in the past. This paper reviews the spatial and temporal aspects of current eco-labels, and assesses the potential to decrease the producer-consumer information gap as farm ICT is developed as part of routing farm management.

Keywords: Eco-label, credibility, ICT, LCA

1. Introduction

In recent decades consumers have started to demand more information about the environmental impact of food products, especially in developed countries represented by organisations such as OECD. Consumers are increasingly willing to buy "environmentally friendly" food products, even if they are more expensive than the market norm (Brécard et al. 2009). At the same time, national policies are driving producers to reduce environmental impacts. Together these have driven demand for informative labelling. Early studies on "environmental labelling" found a wide range of labels with very different meanings and validity (OECD 1991). In 1993, the General Agreement on Tariffs and Trade (GATT) Secretariat differentiated between 'environmental labelling' that reflected any type of claim and 'eco-labelling' that used life cycle methods (GATT. 1993). Eco-labels are usually voluntary and convey information to consumers about the full life cycle environmental implications of their choices, but the specificity in terms of impact, product and geography can be unclear.

Life Cycle Assessment (LCA) is a tool to assess the potential environmental impacts and resources used throughout a product lifecycle, i.e., from raw material acquisition, via production and use phases, to waste management (ISO14040:2006). As a comprehensive assessment, LCA considers all attributes or aspects of natural environment, human health, and resources (ISO14040:2006), and avoids problem-shifting. There are an increasing number of eco-labels using life cycle methods, though many of them do not follow the LCA standards (ISO 14040/14044). For these eco-labels, the spatial and temporal scale over which they apply is not clear, as is the case for many LCA studies. This can be important in terms of both the impacts and the activity data.

Emerging EU research on deployment of Information and Communication technology (ICT) for agriculture is investigating whether massed sensor technology combined with cloud data sources (sometimes known as the "Internet of Things", IoT) can provide real-time data for decision making to optimize profit, environmental impact and welfare (for example the ERA-net, Agri-ICT project 'Sustainable Integrated Livestock Farming', SILF). SILF is evaluating the concept of using data from sensors with a high spatial and temporal resolution, combined with national databases and life cycle methods to define algorithms for real-time decision support based on the environmental impact of the decision. As such technology develops from concept to application, the question arises whether eco-labelling convey appropriate spatial and temporal information about the specific product being labelled.

This study investigated the how spatial and temporal scale is considered by current eco-labels and evaluated whether integrating the ICT systems and life cycle assessment at farm level may have implications for future eco-labels and the information they convey.

2. Methods

The investigation used three evaluations: (i) review of eco-label types and assessment of scale specificity at the macro level, (ii) evaluation of some example labels commonly used in Europe, and (iii) evaluation of an example farm system, low-cost, grass-based, rotational milk production, for scale specificity and the potential of IoT to permit more specific label information.

2.1. Review of label types

The current status of eco-labels was reviewed. There are three types of eco-labels defined: Type I, Type II and Type III. A comparison with respect to criteria, metrics, standards, verification processes, and spatial and temporal considerations was undertaken. Key issues were identified.

2.2. Evaluation of example eco-labels

Three Type I eco-labels used for food and agricultural products in OECD countries and the Type III international EPD system were evaluated. The selected labels claim to contribute to improved agricultural sustainability. The labels used were:

a) the ***Carbon Reduction label*** was developed by the Carbon Trust, based on the PAS2050 standard and Footprint Expert(TM). The certification uses life cycle assessment including production, use and disposal. The certification must be undertaken every two years and prove that real reductions have been made.
b) the ***MK*** (the abbreviation for Milieukeur) label, was developed in 1995 by Stichting Milieukeur (SMK) using a credit system with points to reward some actions and penalize others. To be eligible to use the MK label, a producer is obliged to have a positive score at the end of the season, both for the company and for each product. The label is based on life cycle methods but not LCA as such.
c) the ***KRAV*** label was first used in 1985 based on IFOAM (International Federation of Organic Agriculture Movements) Basic Standards to fulfil EU regulation (EC) No 834/2007. It is based on life cycle thinking, including environmental impacts and energy consumption.
d) an ***EPD*** (Environmental Product Declaration) is a Type III environmental declaration in accordance with ISO 14025. The EPD system is international, compatible with all types of goods and services, third party verified and a flexible source of information. It is LCA based with defined Product Category Rules (PCR) defined for classes of products that can then be used for the LCA modelling of a specific product.

2.3. Farm system example

Low-cost, grass-based, rotational milk production was taken as an example of a farming system in which tactical and operational decision can have significant influence on the environmental impacts that occur. The system diagram from (Casey & Holden 2005) was evaluated with respect to spatial and temporal specificity.

3. Results

3.1. Label types

Type I labels refer to the environmental quality of a product compared with similar products (or production process) and are meant to encourage a switch towards more environmentally friendly consumption habits. These labels are the result of third party certification programs (usually government supported), and are voluntary. The guiding principles for eco-labels follow ISO 14024, which has more specific requirements than ISO 14020 (ISO14024:1999). Type I labels need to include all stage of the life cycle from resource through extraction, production, distribution and use phase to disposal. Spatial and temporal requirements are not specified in detail, but consideration of relevant local, regional, and global environmental issues when establishing defining criteria and revision period must be specified. ISO 14024 indicates that the ranges and variability of the data obtained for specific products should be analysed to ensure that the selected product environmental criteria are adequate and reflect the differences among and between products. This means that a minimum spatial and temporal resolution should be specified for data quality. Common examples of Type I eco-labels include Nordic Swan and Blue Angle in Europe, but these do not include a specific agriculture or food product category.

Type II labels are self-declarations made by the manufacturers, importers or distributors and refer to specific attributes of the products (like “CFC free”, recyclability, degradability and so on). Since these labels are without third party verification, some assurance of reliability is essential. In addition to the requirements of ISO14021, the Type II labels should also follow the principles set out in ISO 14020. ISO 14021 requires Type II labels to take into consideration all aspects of the product life cycle in order to identify the potential for problem shifting. This does not necessarily mean that a life cycle assessment must be undertaken. There are no clear guidelines with respect to spatial and temporal other than stating that the area should correspond to the expected environmental impact and that for comparative claims the calculation should cover an appropriate period such as 12 months (ISO14021:1999). Common examples of Type II labels include Energy Star and WaterSense.

Type III labels are voluntary programs that provide quantified environmental data about a product, under preset categories of parameters set by a qualified third party, based on life cycle assessment, and verified by users or a qualified third party. A typical example is Environmental Product Declarations (EPD). Type III labels are primarily intended for use in business-to-business communication, but under certain conditions, they can be used for business-to-consumer communication (ISO14025:2006). They specifically use the ISO 14040 series of standards either following a complete LCA including goal and scope, inventory analysis (LCI); impact assessment (LCIA) and interpretation or incomplete LCA restricted to goal and scope, LCI and interpretation. There is no clear requirement for spatial and temporal scale to be addressed except to clarify the scope and to define limits, for example, to a certain geographical area. Since Type III labels are based on LCA, the requirement for spatial and temporal specificity should be applied as in ISO 14040/14044. Any lack of spatial and temporal specificity in the LCI introduces uncertainty in the LCIA results. For example, in a milk production system, changes to animal management or fertiliser and slurry application timing can lead to significant change in impact (as discussed later). Currently, the number of Type III label in market is still small. Use in Europe is increasing through the EPD system.

At present, Eco-labels are poorly specified in terms of spatial and temporal detail (Table 1), but recent ICT advances leading to the concept of the IoT might change this. Traceability and sell-by information for specific packaged items are offered to consumers as reliable information so it should also be technically possible for more specific environmental information to be conveyed on labelling.

Table 1. Comparison of the labels types

	Type I	Type II	Type III
Criteria metrics	Multiple	Single	Multiple
Extent of life cycle	Life cycle considered but need not be complete	Life cycle considered but need not be complete	Life cycle assessment, usually complete
Third party verification	Yes	No	Yes
ISO Standard	ISO14024	ISO14021	ISO14025
Spatial aspects	General product characteristics, not specific to the labelled package	Area of environmental impact not specific to the labelled package	Same requirement in ISO 14044
Temporal aspects	General product characteristics not specific to the labelled package	No clear requirement	Same requirement in ISO 14044

A further consideration is that most eco-labels are designed for a specific region or country, which means for example that eco-labels for the China market can be quite different to eco-labels for Europe (UNOPS 2009). (Cohen & Vandenbergh 2012) suggest that the entire life cycle of a product being labelled should be described according to an international standard for measurement and reporting and that once a product meets set criteria, producers can use the eco-label logo for a fixed period of time. Knowledge gained through use of ICT and IoT is increasingly revealing that management and production process change, thus making the label inaccurate. As the technology exists to capture space and time specific data about food products (from precision agriculture technology, activity reporting for regulators and increased ICT use on farms) this weaknesses of eco-labels should be overcome by developing systems to capture real-time data and link it to mass flow during processing.

3.2. Specific examples

The characteristics of the selected eco-labels (Table 2) indicate that all have a relatively loose consideration of spatial and temporal scale that reflects historical technological competence. EPD, which uses ISO 14044 requires specific consideration of spatial and temporal differentiation of the characterization model relating the LCI results to the category indicator and consistency of the spatial and temporal scales of the environmental mechanism and the reference value, but is not specific with regard to the activity data. The Carbon Reduction label that use PAS 2050 requires the time of coverage (age of data and collection period) and geographical specificity (location of collection) to be specified, but this result is then applied to the class of products rather than being product specific.

Table 2. Characteristics of selected Eco-labels

Name of label	Country	Spatial Scale	Temporal Scale	LCA based
KRAV	Sweden	From regional to national	Production phase, historical	LC perspective
Carbon reduction label	International	Product type	Specific to product, historical	LCA
MK	South Africa/EU	National scale, specific to company and product type	Production phase, historical	LC perspective
EPD	International	Same as LCA	Same as LCA, historical	LCA

The life cycle thinking labels (KRAV and MK), do not use LCA but should covers all aspects of production from raw material extraction to production, distribution, use phase and disposal. Spatial and temporal considerations are not clearly stated other than to specify location of production for food categories. MK relies on national data, but for KRAV spatial scale depends on product category. The temporal scale in KRAV and MK only considers the growth stage of products and is historical. Farm ICT and IoT has the potential to improve the information conveyed by the Carbon Reduction label by providing time and location specific data for modelling and labelling. Similar possibilities arise for KRAV and MK. Real time data from sensing, ICT and IoT can be specific to an item within a product class or can be temporally current for classes of product, thus bringing better information to the consumer.

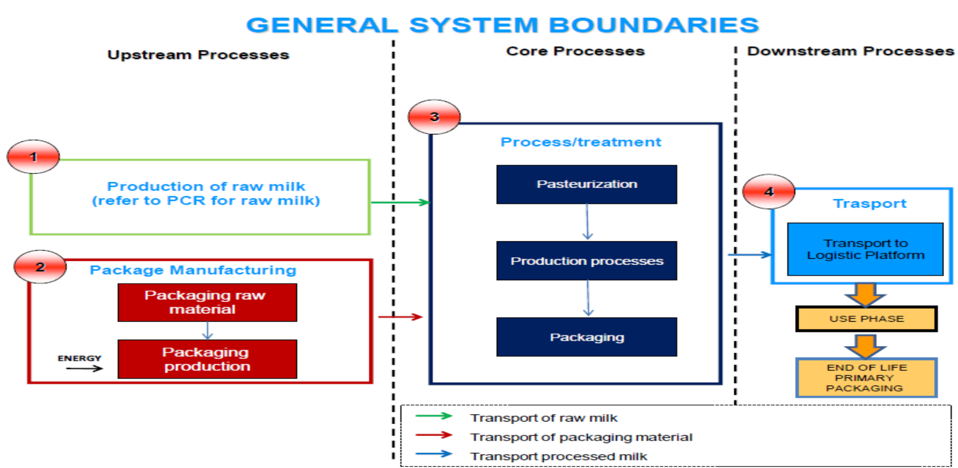

Figure 1. System boundary for Product category rules (PCR) of processed liquid milk and cream

Taking diary products as an example of an EPD, the life cycle has two distinct stages, cradle-to-farm-gate and farm-gate-to-consumer (EPD 2014) (Figure 1). As for many food products, the raw product (in this case milk) production is the main contributor to environmental impacts. The spatial specificity will be limited to the contributing farms, or a sample of the types of farms, while the temporal specificity will be historical, but the sampling period can be of various. A label derived from this system boundary will be spatially specific and historical for packaging and processing, but only the most general information can be included in the downstream processes because a label cannot reflect specific consumer behaviours. It should be made clear however what population the downstream data are derived from as shopping behaviour, transport distances and usage patterns will influence the outcome for this stage.

3.3. Farm system example

The avarage Irish milk production system from "gradle to farm gate" (Figure 2) describes a low-cost, grass-based, rotational dairy system (Casey and Holden, 2005). This system is assumed to be composed of five units: (i) concentrate feed, (ii) fertiliser, (iii) livestock, (iv) manure management and (v) energy. There are different spatial scales using in each part of the system diagram.

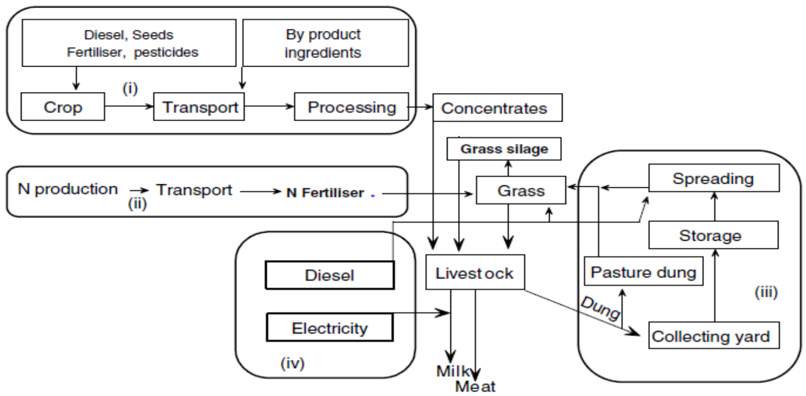

Figure 2. A flowchart of the ''cradle to farm-gate'' milk production system representing the processes included for describing a typical Irish dairy unit. Where (i) is concentrate feed related, (ii) is fertiliser related, (iii) is manure management related and (iv) relates to electricity and diesel usage (Casey and Holden, 2005).

For concentrate feed, the data will generally be global, using national yield data and management data, and the detail is completely different from that applied in the livestock unit and manure management units. Despite 60% of concentrate feed used in Ireland being imported these data are considered background, yet it is clear that differences in concentrate use will be reposnsible for significant differences between farms. The production of ingredients for concentrated feed accounts for nearly 12% of GWP in this milk production system, and for grass-based systems is likely to be decreased by reducing concentrate feed. Month-by-month, and season-by-season the management of concentrate feed can vary between unprocessed rotations of locally-sourced products to purchased mixes of imported feed. This information cannot currently be conveyed on eco-labels but with modern precision feeding systems it should be possible to collate data at least at farm scale to label milk products. For example, farm ICT can sense the health status of cows for precision feeding to decide the quatity and quantity of supplementary feed. In the context of labels based on EPD (Figure 1), it should be possible to weight contributions from suppliers to dairy processors to link the farm phase to the final product rather than relying on arbitrary historical data.

For the feritiliser unit the impact comes from the decision about which fertiliser to use, when to spread it and how much is used. Fertiliser production accounts for a significant part of the carbon footprint of a farm (14% from prodcution and transportation, 8% from application) therefore tactical and operational management decisions have the potential to siginficantly change the environmental footprint of livestock products. Efficient N management can not only reduce the GWP, but also some local impact categories, like acidification and eutrophication. Modern farm management software and regulatory requirements for N management reporting in Europe (and elsewhere) suggest that more temporally specific data could be associated with products at the farm gate, and then integrated at the processing stage. Modern farm manegement sofatware can use forecasts of polluting losses to support decisions about the best time to carry out slurry application therefore eco-labels should reflect the quality of these decisions in the information they carry.

For the livestock unit, the most important contributor to carbon footprint is CH_4 from enternic fermentation. According to Casey and Holden (2005), a 10% reduction in enteric fermentation from all stock would cause a 5% reduction in kg CO_2 eq $_{ECM}$ (energy collected milk) at the farm gate. It is possible to use known animal attributes collated in livestock registers and known milk production to estimate livestock emissions at the farm scale. As a farmer manages the herd to optimise production this could be reflected in an eco-label because the necessary data are already collected, but are not tagged to the physical product as it goes for processing. At present spatial averages are used on a regional or national scale rather that spatially and temporally specific data.

Farm ICT can identify the breed and age of animals and link to related databases to get the unique animal attributes for estimating the CH_4 emission.

The manure management unit is perhaps less important as its contribution to carbon footprint was estimated at around 7%, thus small changes in management will have relatively little impact, but contribution to acidification and eutrophication is unclear. There is relatively little currently available technology to monitor organic nutrient resources so these are less likely to be considered in the first instance, but as they are the subject of wide ranging regulation this situation might change. It is possible to apply ICT systems on farm for monitoring the emission from manure management (especially storage) and thus real time data collected by ICT could improve the spatial and temporal resolution of the data about manure management phase greatly.

The energy unit includes diesel and electricity consumption. Spatial and temporal specificity could be achieved by using modern farm accounting software to identify consumption from costs, or by using monitoring systems. As this is a relatively small contributor it is less likely to be an immediate focus. The electricity generation for farm can affect its environmental performance in an insignificant way, unless a more energy efficient means of milk preservation is introduced.

4. Discussion

Spatial scale of LCA can be very important for environmental impact assessment. According to (Hauschild 2006), there are three levels of spatial differentiation in LCA, but these tend to relate more to the assumed impact than the detail of the system being modelled.

Site-generic modelling takes all sources considered to contribute to the same generic receiving environment. In this case, we do not have to consider spatial differentiation between sources and subsequent receiving environments. From the analysis of label types, example labels and the example dairy system is it clear that there is the possibility of an over-emphasis on site-generic activity data for food products for pragmatic reasons. While precision may be lost, accuracy may be assured. IoT has the potential to permit eco-labelling systems to move from a reliance on site-generic activity data as it becomes more common in food production systems.

Site-dependent modelling considered some spatial differentiation to distinguish between classes of sources to determine the receiving environment. Source categories are typically defined at the level of countries or regions within countries (scale 50–500 km). The receiving environment is typically defined at high spatial resolution (scale at maximum 150 km, but often down to a few kilometres). With respect to activity data for eco-labelling, some specificity is typical, such as inventory of data for specific suppliers or types of supplier. Again, IoT has the potential to radically enhance the information conveyed on eco-labels so that the data are more focused on the actual suppliers at a specific time.

Site-specific modelling requires large volumes of data to build models for specific locations to evaluate the environmental impacts that are very close to the source. This typically involves local knowledge about the conditions of specific ecosystems that are exposed to the emitted pollutants. This level of spatial differentiation modelling is rare for more than a few processes in a product system. The development of IoT on farms will permit eco-labelling to migrate towards site-specific data and more sophisticated modelling.

Agricultural production systems have different resource consumption (energy, water, natural resource) and emission characteristics depending on the local natural resources, specific management decisions and weather. When compared between different regions or countries eco-labels should reflect these differences, but to date there has been little focus differences between farms and years. A label with site-generic spatial information cannot reflect the true impact of a food product. Farm ICT and sensing has the potential to permit eco-label awarding organizations to demand site-specific data in the near future. Taking dairy farming as an example, the calculation of CH_4 emission from livestock, feed management and fertilizer management should all be possible to ensure products are labelled with information that is specific to the mass flow of product and no more than 12 months old. This improvement of data capture will greatly increase the reliability of information conveyed on eco-labels.

Temporal scale also plays a significant role in the accuracy of LCA, which is generally poor at accounting for time and temporal information (ISO 2006a). The temporal specificity of impact is limited for two reasons. Firstly in the LCI phase aggregated emission data from all the unit processes dispersed through space and time, are typically used (Finnveden et al. 2009, Heijungs & Suh 2002), and secondly during the LCIA phase the potential impacts of the aggregated emissions are assessed using characterization factors based on a fixed time horizon (de

Haes et al. 2002). The temporal specificity of activity data is critical because of internal annual variation in management and changes in technology during the life of the product. For example, the timing of slurry application is very important for GHG emission. N_2O emissions from early time (April) spreading may be 10 times greater than later time (July) spreading (Chadwick et al. 2000), but prolonged storage over the summer period would offset any advantage from late spreading. In addition, the method of application can have a great impact on volatilization losses (Søgaard et al. 2002). When farm ICT can record the time and amount of slurry application the related emissions can be calculated more accurately.

5. Conclusion

This study investigated how spatial and temporal scale is considered by current Eco-label schemes and evaluated whether integrating the ICT systems and life cycle assessment at farm level may have implications for future eco-labels. Considering the extent of application of life cycle assessment to eco-labels for food and agricultural products, it may be premature to talk about consumer attitude towards spatial and temporal scale in eco-labels, but based on the result of this analysis, it will be technically feasibly in the near future to address this matter. If consumers pay more attention to the environmental impacts of their choices they are likely to become more aware of the importance of spatial and temporal scale. The increased popularity of 'local food' suggests that a consumer understanding of scale is now emerging. A label with better-specified spatial and temporal information might be more transparent, thus improving credibility.

Life cycle assessment is a useful tool for assessing the environmental performance of a product or service. In term of accuracy, spatial and temporal scale is important for deriving activity data and for many impact categories in life cycle assessment. It is clear that scale issues are not the focus of labelling, but that technologically it should be possible to forge a closer link between the item labelled and the information on the label. For food products this is particularly important because we know that specific management choices will influence the magnitude of the impacts calculated. Data are increasingly being collected for management, regulation, national statistics and economic reporting, and these will also allow improved calculations for eco-labels if the data are linked to product mass flow. As this is possible for food safety it should be possible for eco-labelling. IoT on farm should in time provide even better information that can be used for eco-labelling.

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