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Measurement of Environmental Sustainability of Food Companies using a Life Cycle Approach

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1. Introduction

Today, sustainability is an important issue for many business companies. Addressing Corporate Responsibility (CR) and Sustainable Corporate Performance (SCP) is essential for their license to operate, and forms the basis for business principles and practices. In this way, companies meet social demand for responsible business behavior including accountability and transparency. In the last decades, this issue has become more important due to the increasing influence of multinational companies on societies all over the world (SER, 2001). Developments in this respect have been the foundation of the World business Council for Sustainable Development (1997), the Global Reporting Initiative (2000), and the development of standards for environmental management systems, such as the ISO and EMAS standards (OECD, 2001). Failure to meet societal demand for responsible business behavior raises three serious risks: (i) the threat of increased regulatory control by governments or international organizations; (ii) the threat of financial risks due to pollution and inefficient resource use; and (iii) damage to the corporate image (Rondinelli and Berry, 2000). The assessment of responsible business behavior, however, requires internationally accepted reporting standards on what, when, and where to report. So far, these general standards are lacking.

In the period 2000 - 2002, the Dutch University of Groningen cooperated with Royal Ahold company aiming at the design and development of a measuring tool for SCP. This multidisciplinary project designed a framework for SCP including an economic, social, and environmental dimension and selected indicators for its assessment. This practical measuring system should contribute to the increase of economic, social, and environmental values of corporate activities to society. These three added values terms form the components of the "sustainability value added" of a company. SCP develops activities that increase economic and social capital in society without affecting its natural capital. The general findings of the SCP project are reported in Steg et al. (2001).

This paper is part of the SCP project. It addresses the environmental aspects of SCP with a focus on the food production system. The aims of this paper are to:
- Identify and analyze existing methods for the assessment of sustainable business practices for food;
- Identify the key environmental issues for food production;
- Design and develop a measuring tool for environmental sustainability of food production systems.

The measuring method proposed here considers entire production systems rather then individual company performance and addresses global environmental issues. Although it calculates the use of resources for food, the method is applicable to other production systems as well.

2. System description

A large number of companies form a complex food production system that includes the agricultural and transportation sector, the food industry, trade, and retailing. This study distinguished three scale levels for the system: (i) the raw materials process level, where processes for the manufacture of raw materials take place; (ii) the raw material chain, made up of a series of processes in a vertical, linear chain that includes transportation from one chain link to another; and (iii) the food production web in which the output of raw material chains join and form an intricate horizontal web. Figure 1 shows a raw materials chain on level two and processes on level one.

Figure 1

Some companies are highly specialized performing only one process, while others control complete production webs. All processes in chain links and transportation between links in the production web of a certain food contribute to the overall environmental impact of that food, But, differences among impacts are large. Table 1 shows an example from energy studies (Kok et al., 2001) revealing the large differences in energy requirements between agricultural productions systems, among transportation modes, and emphasizing the necessity of a systems approach. If the aim is to reduce overall energy use, for example, the focus should not be on an individual company, but on the company in the chain or web where reduction strategies have the largest impact on final energy requirements. The consumer that has to make a choice between organically grown carrots form Africa

and locally produced carrots, for example, should realize that the African vegetable required 15 times as much energy for its total production than the local one.

Tabel 1

3. Methods

   Private business companies mainly address sustainability in relationship with individual company performance, while, on the other hand, scientific research focuses on general sustainability issues, often on a global level of scale. The study presented here made an analysis of existing methods to measure sustainability in food production and identified scientific global issues relevant for this production. It performed a literature search of scientific publications on sustainability issues for agriculture, transportation, manufacturing, and retailing, and obtained additional information from an OECD report on CR (OECD, 2001). Commonly used environmental sustainability indicators were clustered on three levels of scale: (i) the local level; (ii) the regional level; and (iii) the global level.
   To design and develop a system based measuring method for food production, the study combined results from bottom-up business approaches with the top-down scientific approach. Firstly, it selected a small set of environmental sustainability indicators addressing global issues relevant for food production. Secondly, it designed a method to measure these indicators in companies.

4. Results

4.1 Existing measuring methods for environmental sustainability.

   The literature search revealed an enormous number of scientific publications on the topic of CR and SCP. Companies, especially large multinationals, try to find ways to enhance their contributions to society. Originally, the focus was mainly on social issues, but gradually included environmental and economically responsible performance as well (WBCSD, 1997). In this way, they react on the societal concern caused by their increasing economic, social, and environmental impacts. Many companies have developed tools to address responsible performance, such as codes of conduct (OECD, 2001). The study identified three important steps companies have made in the 20th century towards better SCP: the formulation of business principles, practices, and outcomes. In the 1970s, companies issued principles, i.e. policy statements on business ethics and legal compliance, resulting in actual codes of conduct. The principles have formed the basis for practices, i.e. action strategies and programs, resulting in management systems. More recently, business has formulated the outcomes, i.e. standards for business reporting and non-financial performance.
   Today, the number of companies that publishes on environmental impacts of activities is still increasing (Rondinelli and Vastag, 2000). However, companies differ considerably in the scope and depth of reporting, because internationally accepted reporting standards are absent (OECD, 2001). As a result, reports range from rudimentary to more full scale. The OECD study showed that in Europe high environmental impact companies, for example companies in the chemical industry, report better on SCP than companies in general. If companies report on this performance, however, 62% provide some quantitative data, while only 15% report on all key environmental issues.
   With respect to consumer demand, the study found that consumer pressure focuses on recognizable goods, often associated with large multinationals (Hall, 2000). As a result, companies in supply chains far from final consumers, and small-scale companies find themselves under little environmental pressure. MacDonalds, a large multinational, therefore, will have to earn its license to operate, while a local butcher is not under significant pressure.
   The literature search on indicators for the assessment of environmental sustainability in food production showed that companies focus on issues on a local level and pay less attention to global issues. In the first chain link, agriculture, individual company performance receives most attention, while further down the chain attention shifts towards preceding links. Retailing, in the last chain link, is mainly concerned with effects of upstream activities rather than own company performance. The search also showed that the indicator set is extensive and not uniform among or within sectors. A detailed presentation of results can be obtained from Gerbens-Leenes et al. (2003).

4.2 Research issues for environmental sustainability

   From a scientific point of view, research recognizes the importance of a systems approach for sustainability issues. It developed, for example, Life Cycle Assessment (LCA) as a tool to assess

potential environmental impacts related to manufacture throughout the complete lifecycle of a product (e.g. Heijungs et al., 1992; Weidema, 1999; Weidema and Meeusen, 2000). To evaluate impacts due to production of a consumer good, it addresses all chain links and transportation between. For food production, many studies have recognized the importance of energy use (e.g. Wilting, 1996; Wilting et al., 1999; Kok et al., 2001; Carlsson-Kanyama and Faist, 2000), land use ((Van Vuuren and Smeets, 2000; Gerbens-Leenes et al., 2002; Wackernagel et al., 1997), water use ((Falkenmark, 1989; Rosegrant and Ringler, 1998; Rockstrom, 1999), and nutrients (Andersson (2000).

5. Measurement of environmental sustainability of food companies

5.1 Indicators for environmental sustainability of food companies

For the measurement of environmental sustainability of food companies, this study proposes a systems approach that addresses overall environmental effects of all contributions to the production of a final food. It firstly integrated company measurements and scientific approaches; secondly, it selected a small set of indicators; and thirdly it made a model for actual measurements.

This research has shown that SCP focuses on local issues rather than global ones using large indicator sets. Differences among sectors are large, while for individual companies their contribution to the environmental impact of a food is not clear. Environmental research has identified the most important issues and has provided the LCA tool. Related to food production, however, trade-offs among resource uses are still poorly addressed, while LCA assumes a linear relationship between the amount of a product manufactured and its environmental impact. For food, however, the upscaling of production often leads to shifts in a production system and goes along with shifts in environmental impacts. Livestock production, for example, firstly applies waste streams from sugar or oil production to feed animals (Nonhebel, 2004), but when these streams are depleted, it applies crops wich have different environmental impacts than wastes.

This study integrates company measurements and scientific approaches by adopting the LCA approach that addresses all steps in the lifecycle of production and by using its allocation methodology, while, on the other hand, the study recognizes that similar measurements are needed in individual companies. For the assessment of environmental sustainability, the study selected a core set of indicators that (i) provide relevant information; (ii) are reliable and measurable; (iii) are based on available data; and (iv) provide information that can influence management choices and optimize production. For the identification of relevant information, it used a key concept in ecological economics, the concept of natural capital, firstly developed by Costanza and Daily (1992). This concept recognizes four types of natural capital: land, water, air, and habitats (Ekins and Simon, 2003) performing four key functions for society. These are the "Source function", the "Sink function"(Daly, 1990), the "Life support function" (Van Dieren, 1995; Ekins and Simon, 2003), and the "Human Health and Welfare function" (Ekins and Simon, 2003). The "Source function" refers to the delivery of natural resources to the economy, such as energy carriers, agricultural land, or biological resources, the "Sink function" to the possibility to dispose of waste, the "Life support function" to a set of functions performed by land, water, and air essential to sustain life, and the "Human health and Welfare function" to services which maintain health and contribute to human well-being. According to Daly (1990), the sustainable use of natural resources has three implications: (i) renewable resources should not be exploited at a greater rate than their regeneration level, (ii) non-renewable resources should not be depleted at a greater rate than the development rate of renewable substitutes, and (iii) the absorption and regeneration capacity of the natural environment should not be exceeded. All types of natural capital are essential for food production; all functions are important for food production and consumption.

For the selection of indicators, the study addressed three important requirements for food production: agricultural land, fresh water, and energy input. For land and water input, the human use of these resources is mainly dominated by food production; for energy input, the use for food production is substantial. Globally, 38% of the total land area is used for food (FAO, 2002). Moreover, arable land becomes scarce (Oldeman et al., 1991) because land is needed for other purposes, such as the generation of renewable energy. The study proposes the quantity of land use as an indicator for the use of scarce natural resources of the "Source function", as an indicator for the "Life support function", and as an indicator for the potential competition among agricultural interests, energy production capacity, and the requirement of natural areas for biodiversity.

The second essential requirement for food production is the availability of sufficient fresh water of adequate quality. Nowadays agriculture already requires 70% of total human fresh water use (Falkenmark, 1989; Rosegrant and Ringler, 1998; Rockstrom, 1999) . Moreover, especially in

developing countries, industrial and household activities will claim growing quantities of water. When competition sharpens, irrigated agriculture might be the losing sector, since it cannot bear a water price as high as can the urban and industrial sectors {Falkenmark, 1998} . In some parts of the world, irrigation water is already scarce, for example, in Eastern Asia and the former USSR (Penning de Vries et al., 1995). This study therefore proposes the quantity of fresh water use as an indicator for the use of scarce, high quality, fresh water resources of the "Source function" and of the "Life support function".

The third essential requirement for food production is energy, generated either by fossil energy carriers or by renewables, such as biomass. The consumption of food has a considerable impact on household energy use (Kramer, 2000). An average EU household, for example, requires 19% of its energy use for food (Nonhebel and Moll, 2001). This study therefore proposes the quantity of fossil energy use as an indicator for the depletion of non-renewable resources of the "Source function" (IPCC, 1996), and for possibilities of the "Sink function" to neutralize climate change and acidification. The quantity of renewable energy use is also an indicator for the "Life support function", and for the potential competition among agricultural interests, energy production capacity, and the requirement of natural areas for biodiversity.

An important criterion for the selection of the indicators land, energy, and water is the interaction among these indicators. For example, "high external input" farming requires large energy input in the form of fertilizer and pesticides to reach its high production levels. As a result, land use is relatively low. On the one hand, irrigation in agriculture results in higher yields and thus lower land use, but, on the other hand, in larger energy and water requirements. The use of the three indicators proposed in this study, therefore, also address interactions among aspects of environmental sustainability.

5.2 Measurement of environmental sustainability

Measurement of environmental sustainability requires the assessment of energy, water, material flows, and land use of companies. This is done in three steps in which the output of one step forms the input of the next one.

Step one

Step one calculates annual company energy, water, and land use. It converts energy use into primary energy use, or in the case of renewable energy, such as energy derived from biomass, into land and water use. Economic company data provide information on the direct use of basic materials, land, energy, and water.

Step two

Step two calculates direct *and* indirect annual company land, energy, and water use. It combines direct resource use from step one with resource use of suppliers in preceding chain links. Companies must obtain required information from their suppliers.

Step three

Step three calculates total resource use per unit of food. It uses the output of step two and adopts an allocation method from LCA in which resource use is allocated over end products according to their economic value. Company economic information can provide the required data. The final outcome of the three steps is the specific resource use per unit of food.

Table 2 shows an application of the measuring method for the energy use of chicory grown in two different agricultural systems at two different distances from final retail.

Table 2.

Although the output is exactly the same, one kg of the vegetable chicory, Table 2 shows that differences in energy use in chain links have important impacts on the final energy use of a specific food. This is also the case for the other resources, land and water. The use of these resources, however, mainly depends on the agricultural system applied, while energy use takes place in the whole production chain.

6. Discussion

Today, most companies include sustainability issues into their business behavior but an overall accepted measuring and reporting system is lacking. The large indicator sets applied differ among business sectors and even among companies in the same sector. Moreover, the sets do not always address interaction among indicators. The information generated in this way provides time trends per company or sector and forms a basis for regulatory compliance but is unsuitable to evaluate the sustainability of a production system.

The measuring method proposed here has been designed to assess sustainability from a systems perspective and addresses all processes that contribute to the production of a final food. In this way, SCP is extended towards other companies in a chain or web leading to the concept of *Shared Responsibility*, a corporate responsibility extended towards SCP in a production web. SCP, on the one hand, focuses on the relationship between a company and its direct stakeholders. These stakeholders are well known, while issues, often on a local level, can be negotiated among identifiable partners. Shared responsibility, on the other hand, addresses systems as a whole and global issues for which there are few stakeholders.

Although it is designed as simple as possible, for companies, the proposed method requires new efforts. It provides a tool to evaluate time trends and targets, to benchmark a company, but also to address the company contribution to the environmental impact of a food. The systems approach provides a tool to find the weakest links in a production web, and contributes to the development of more sustainable and efficient production.

7. Conclusions

SCP often addresses environmental issues on a local level using large indicator sets. Information generated in this way is incompatible and does not provide general knowledge on production systems. The measuring method proposed here addresses systems as a whole rather than company performance, and issues on a global level for which there are few identifiable stakeholders. The approach leads to the concept of Shared Responsibility for chain-related environmental issues. The

method proposes only three indicators, the use of land, energy, and water that give information on the use of natural capital and its possibility to provide products and perform functions essential for human existence. Actual measurements take place on a company level but results are passed on along production chains. Although the method has been designed for the food system, it has a wide applicability, and makes global sustainability measurable for many companies.

Acknowledgements

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Figure 1
The food system containing production, consumption, and waste handling, and the system boundary of this study. The study distinguished three system levels: the process level (level one), the chain level (level two), and the web level (level three). Production processes take place in several business sectors that find themselves in the boxes. A series of processes that produces a raw material forms a production chain. The third system level, the web level, consists of several chains. The arrows represent transportation of physical streams between chain links. Closed arrows represent transportation in one direction on level 2, open arrows represent physical streams in the opposite direction on level 3 (Source: Gerbens-Leenes et al., 2003).
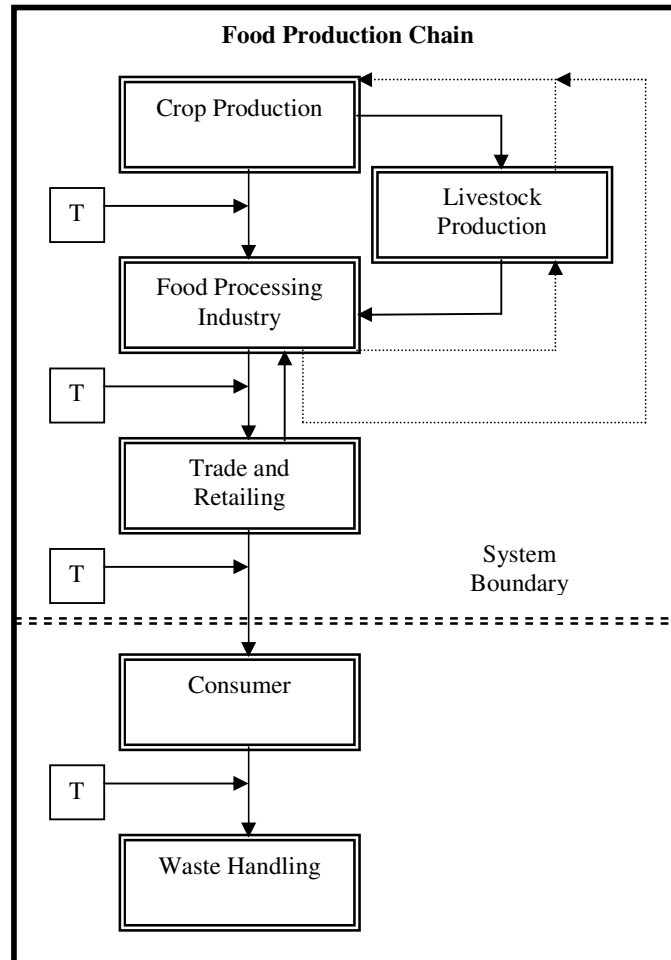
Tabel 1
Overview of energy requirements in production chains of vegetables available in the Netherlands (Source: Kramer and Moll, 1995; Kok et al., 2001)

process	energy requirement (MJ per kg vegetables)
agriculture	
open air production	0.7
greenhouse production	26.2
food industry	
production of frozen vegetables	6.0
production of conserved vegetables	8.0
production of one way glass jars	8.0
production of jars	3.0
transportation	energy requirement (MJ per 1000 kg per km)
ship (sea, bulk)	0.1
ship (inland shipping)	0.6
train	0.6
lorry	1.7
airplane	9.0

Table 2.
Application of the measuring method for the energy use of chicory grown in two different agricultural systems, open air and greenhouse horticulture, at two different distances from final retail, a short distance of 100 km and a long distance of 2000 km (Source: Gerbens-Leenes, 2000; Gerbens-Leenes et al., 2003)

	energy use chicory, open air, short distance (MJ per kg)	energy use chicory, greenhouse, short distance (MJ per kg)	energy use chicory, open air, long distance (MJ per kg)
agriculture			
growth chicory pens	1.00	26.00	1.00
growth chicory	6.90	6.90	6.90
transportation			
agriculture to market	0.30	0.30	18.00
market to retail 1	0.06	0.06	0.06
retail 1 to retail 2	0.50	0.50	0.50
trade			
retail 1	0.52	0.52	0.52
retail 2	2.63	2.63	2.63
total	*11.95*	*36.95*	*29.65*