Food Miles to Assess Sustainability: A Revision

Van Passel, S.*

*Hasselt University, Centre for Environmental Sciences, Belgium

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Abstract

Sustainability assessment is an essential part in our aim to reach a more sustainable production and consumption pattern. This research revise the food miles concept as guiding tool to assess sustainability. Food miles measure the distance that food travels from where it is grown or raised to where it is consumed. We describe three different concepts to assess sustainability: (i) food miles, (ii) enhanced food miles, (iii) food chain sustainability. Using an illustrative case study, we showed that there is a strong danger of oversimplification of using food miles as an assessment tool. Secondly, we showed that the food miles concept can be enhanced with all relevant transport externalities taking into account different transport modes and transport (in)efficiency. Thirdly, we propose to take into account all relevant economic, social and ecological aspects. Besides transport externalities, also externalities caused by food production, food packaging, food marketing, food consumption should be incorporated. Moreover, the trade-off with development goals cannot be neglected. As a consequence, there is a strong danger of incommensurability due to different sustainability model assumptions and unclear system boundaries. Nevertheless, sustainability assessment can enrich policy making and support tailored policy measures to improve food chain sustainability.

Key words: food miles, sustainability, sustainability assessment, sustainable development, externalities, food transport, food production

1. Introduction

It goes without saying that sustainability is at the forefront of the public debate. "Sustainable development can be described as a development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (WCED, 1987), with specific attention for the integration and synergy between the social, ecological and economic dimensions and where the realisation requires a transition where the use of all resources, the allocation of investments, the orientation of technological development and institutional changes are fine-tuned with both the future and present needs." Our concern for a sustainable development is obvious and justifiable, but sustainability proved a remarkably difficult concept to define and use precisely, because sustainable development is shaped by people's and organisations' different worldviews, which in turn influence how issues are formulated and actions proposed (Giddings et al., 2002).

Plenty methods and concepts are already developed and used to assess sustainability on different levels and systems. Several interesting examples exists for countries (e.g. Wackernagel and Rees, 1997), for urban sustainability (e.g. Bithas and Christofakis, 2006; Keirstead and Leach, 2008), for the construction industry (e.g. Sev, 2009), for agricultural production (e.g. Van Passel et al. 2007, Meul et al., 2008), for air transport (e.g. Daley, 2009; Walker and Cook, 2009), etc... The large amount of measurement systems and applications shows that indeed no single measurement system or

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management framework for sustainability exists (Köhn et al., 2001). Regardless of what indicators are devised, inherent deficiencies always exist (Mitchell, 1996) diminishing the policy guiding value of the applied indicator. Van Zeijl-Rozema et al. (2008) concludes that the debate on governance for sustainable development will be clarified if the perspective on sustainable development and the mode of governance for achieving it are made more explicit. Hence, the quest for the assessment of sustainability is critically important, and the need to analyse, refine and improve existing tools remains important.

Therefore, this research provides a profound analysis of the concept of food miles in assessing sustainability. Food miles are the distance food travels from where it is grown or raised to where it is consumed. The current food miles concept is used as an indicator of carbon costs of food transport. Furthermore, several authors (e.g. Saunders et al., 2006; Mila I Canals et al., 2007; Edwards-Jones et al., 2008; Coley et al., 2009) provide a more detailed analysis of the environmental costs of food transport also including food chain aspects. Despite the clear merits of these studies, they only focus on the environmental costs of food transport (and production). Consequently, there is a need for a conceptual discussion about the incorporation of economic and social costs to assess food sustainability.

The approach of this research is of a generic interest and the focus lies on discussing different conceptual aspects. In a following section we introduce the concept of food miles, the enhanced food miles concept and the food chain sustainability concept. In the next section, an illustrative example analysing apple transport and production, is used to clarify the different concepts. In a final section, several implications of assessing sustainability, using the different concepts, are discussed and some general conclusions and policy suggestions are made.

2. Assessing food sustainability: different concepts

Over the last five decades, the nature of our food production and consumption has undergone an enormous transformation. Our food production has more and more a global dimension. The trade of all kind of food products has increased during the last decades. Between 1968 and 1998, world food production increased by 84%, while food trade is increased by 184% (FAO, s.d.). Improving storage technology and transport infrastructure and increasing interest for foreign products partly explain the increase in food trade. As a consequence the average food mile per product has sharply increased. However, not only the rise in food trade explains the increase of food miles. The current organization of our food value chain (agricultural specialization, supermarkets, and large distribution centers) has also an important impact on the total distance that our food travels. The increased amount of food miles can result in a higher environmental pressure (e.g. air pollution, soil pollution, loss of biodiversity, noise pollution) and social pressure (e.g. road accidents, animal welfare). On the other hand, increasing food trade (and thus higher food miles) can have particular advantages such as higher food export of the poorest countries, higher food diversity, higher food availability, and cheaper food

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products. Moreover, a complex system of government interventions (e.g. import tariffs, quota and subsidies) exists with a major impact on our food price.

Mobility, food consumption and residential energy use appears to be responsible for the largest share of environmental impact of our consumption (Tukker et al., 2006). Reducing the environmental impact of food consumption is most likely possible due to the high degree of personal choice and a lack of long-term lock-in effects which limit consumers' day-to-day choices (Weber & Matthews, 2008). However, how to tackle the environmental impact of food consumption efficiently is not very clear. A straightforward strategy is to reduce the food miles. This research provides a conceptual discussion of the food mile concept as a guideline towards more sustainability.

A starting point of our conceptual discussion is the existence of externalities. Externalities can be described as third-party effects: a cost or benefit that arise from production and falls on someone other than the producer, or a cost or benefit that arises from consumption and falls on someone other than the consumer. Hence, when externalities are present, the price of a good does not reflect its social value. Theoretically, the fact that food externalities are not internalized can be sees as the reason of existence of the food miles debate. The food miles idea describes the concerns about the environmental impacts of transporting food long distances prior to its consumption.

To analyse the concept of food miles as an assessment tool for sustainability, we first describe three related concepts: (i) the food miles, (ii) the enhanced food miles and (iii) food chain sustainability. Note that we start with the food miles concept as a rough environmental indicator. Then, we incorporate relevant transport externalities to come to a enhanced food miles concept. Finally, we end with a food chain sustainability concept reflecting all relevant externalities. In this way, we reframe the food miles debate considering externalities to assess sustainability.

2.1. Concept 1: Food miles

Food miles or food kilometres measure the distance that food travels from farm gate to plate (consumption). The larger the distance, the larger the impact on our environment. Originally, the environmental impact of food miles was broadly conceptualised (SAFE Alliance, 1994; Subak, 1999). In that context, reducing food miles implies the need for food systems grounded in local ecologies (Murdoch et al., 2000). Local food systems are often described as systems that reduce food miles (Edwards-Jones et al., 2008, Coley et al., 2009). However, Edwards-Jones et al. (2008) explain that distance from source is not the only attribute that consumers associate with local food. Other relevant aspects are freshness, supporting local producers, environmental concerns and taste. Recently, food miles have been more linked to climate change (e.g. Smith et al. (2005)) shifting the food miles debate away from sustainable agriculture production systems per se to food

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distribution and retailing and in particular the use of carbon in transport (Coley et al. (2009)).

Using food miles to consider the use of carbon in transport, proponents state that food miles are an easy way to take environmental externalities into account, while opponents argue that the food miles concept is too simplistic ignoring several other relevant sustainability issues. Food miles can give a clear image of the globalization of the mainstream food system but only the energy consumption of the transport of food is taken straightforward into considerations. Food miles proponents urge a localization of the global food supply network, while opponents question the legitimacy because of different production practices in different regions or the increased storage needed to buy locally through all seasons (Sim et al., 2007; Weber & Matthews, 2008).

2.2. Concept 2: Enhanced Food miles

As mentioned, the current food miles concept translates the amount of miles (or kilometres) into an indication of environmental pressure. More specific, food miles cause the emission of greenhouse gases (mainly carbon dioxide). In fact, the emissions are by-products of our food consumption and production that harm our environment and well-being. Hence, the externality occurs because there is a direct (long-term) effect and there is no indirect effect trough changes in transport prices. If there was an optimal regulation of all externalities (by internalization), the (enhanced) food miles concept would be redundant. Moreover, the current food miles concept assumes only a simple straightforward relation with environmental transport externalities while there exist also social and economic transport externalities. Therefore, we define the enhanced food miles as the total external costs of food transports including environmental, social and economic external costs. In addition, the enhanced food miles should also relate to differences in transport mode and transport efficiency. There are major differences in external costs between different transport modes e.g. air transport has a very high environmental impact while the impact of sea transport is relatively low compared to road transport. Besides, there is a link between transport distance, vehicle size and transport efficiency. Moreover, transport distance can be lowered by improving transport efficiency through the supply chain. Analysing external costs should take into account efficiency differences if food systems differ in transport efficiency.

Summarizing, we could enlarge the original food miles concept with several externalities and refinements to an enhanced food miles concept. Note that the enhanced food miles concept only focus on food transport as depicted in Figure 1.

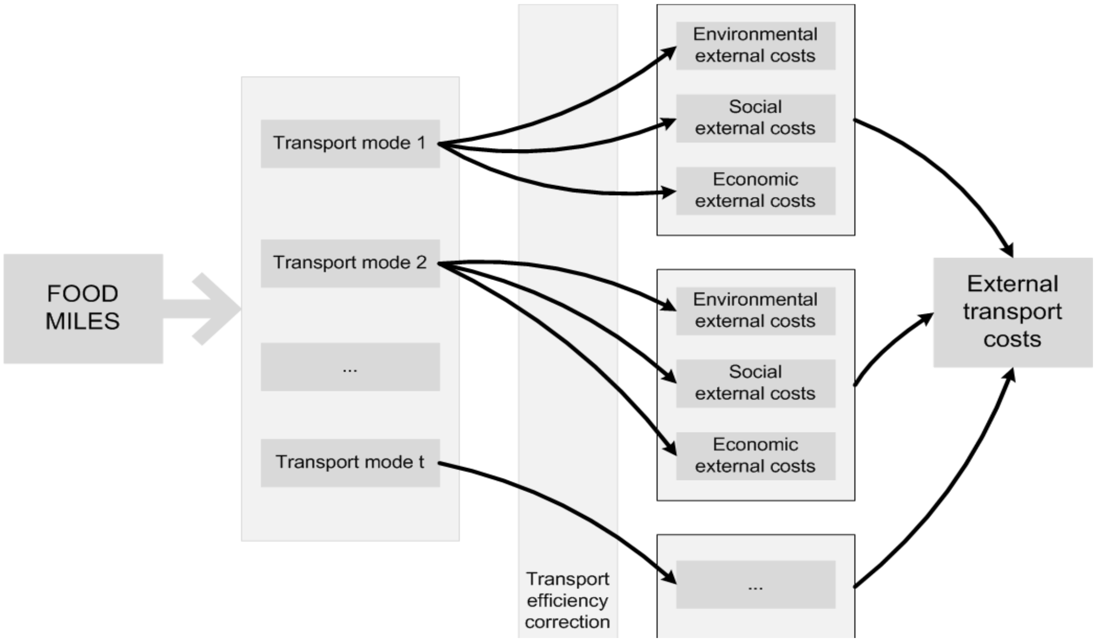

Figure 1: Enhanced Food miles concept

2.3. Concept 3: Food chain sustainability

Even if the original food miles concept is enhanced with all transport externalities, there are still shortcomings from a sustainability point of view. A major drawback of the (enhanced) food miles is the narrow focus on transport, ignoring for example production externalities.

A common methodology to assess an integral analysis of all relevant environmental impacts, is the life cycle assessment (LCA) methodology. Brentrup et al. (2001) shows that the LCA methodology is basically suitable to assess the environmental impact associated with agricultural production. However, application of LCA on practical firms requires in-depth research to understand underlying processes, and to predict or measure variation in emissions realized in practice (de Boer, 2003). Several applications using the LCA methodology exist, e.g. pesticides (Margni et al., 2002), crop production (Brentrup et al. 2004b), N fertilizer use in winter wheat production systems (Brentrup et al. 2004a), environmental impacts of apple production (Mila I Canals et al. (2006)). Note that the main focus of these applications lies on environmental aspects. However, there are also attempts to integrate social and economic impacts into LCA (Weidema, 2006, Hunkeler, 2006). Remark that the life cycle assessment approach can also be used on national level. An example of the assessment of the US food system using the LCA methodology can be found in Heller & Keoleian (2003). An interesting review of LCA can be found in Finnveden et al. (2009).

Pretty et al. (2005) tried to estimate the real costs of the UK food basket and found that an increase of food price of 11.8% is necessary to take into account externalities. 28% of all externalities are caused by food production, 26% by domestic road transport, 32% by government subsidies and 14% by shopping transport. In other words, despite the high impact of several essential assumptions, Pretty et al. (2005) showed that considering only transport externalities will result in a too limited analysis.

Hence, food chain sustainability should be assessed by taken into consideration all relevant environmental, social and economic aspects. Besides transport externalities, also externalities caused by production, packaging, marketing, sale and consumption should be incorporated. As a consequence, sustainable supply chain management is an important element of integrating sustainability into the market (Seuring and Müller, 2008; Haake and Seuring, 2009).

Mila I Canals et al. (2006) underline the importance of connecting environmental impact results with socio-economic needs. In fact, we show that defining and describing different conceptual concepts can be used to illustrate the interrelated links between environmental, social and economic aspects.

An overview of the three different conceptual concepts and their interlinkages can be found in Figure 2.

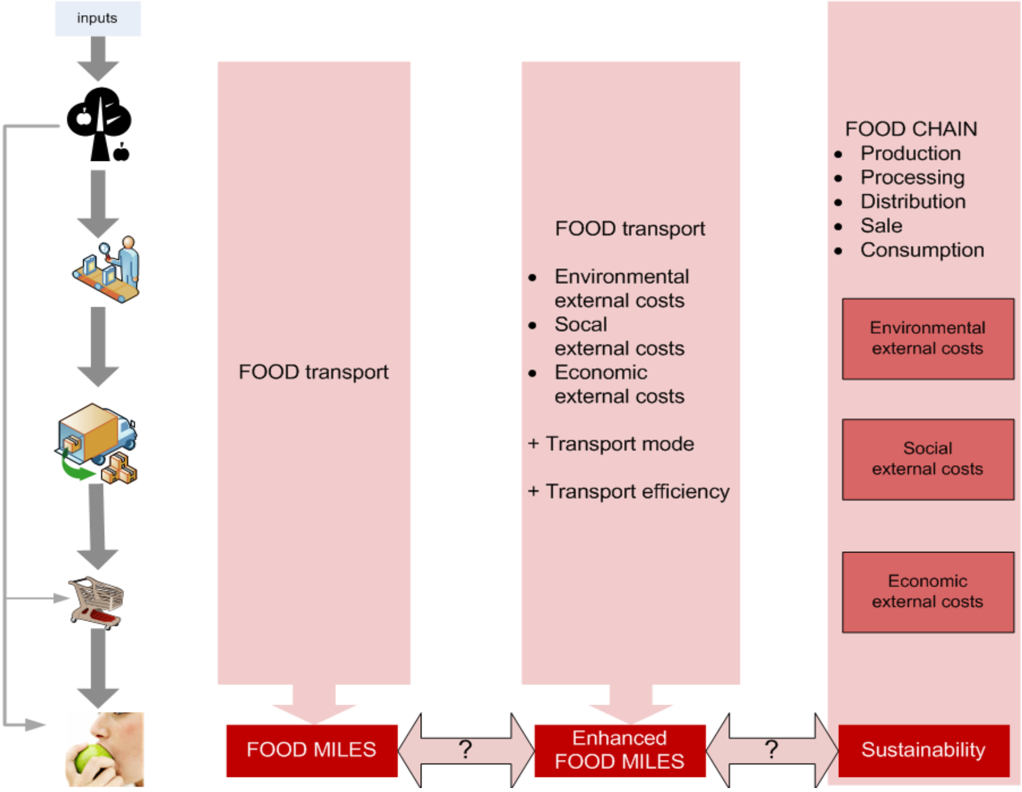

Figure 2: Conceptual framework from food miles to sustainability assessment

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3 Case study: Apple consumption

An illustrative case study will be used to discuss the three different concepts in detail. We opt for apple consumption in a small Western European country (Belgium). Moreover apples are cultivated in a wide range of countries over the world. Also, for a large majority of apples there is no need for a very complex process of processing, packaging and distribution. Finally, we choose apple consumption as our case study because apple consumption is often used as example in impact studies (e.g. Smith et al., 2005; Mathijs et al., 2006; Mila I Canals et al., 2006; Saunders et al., 2006; Mila I Canals et al., 2007). Note that our case study does not aim to give (again) a detailed (environmental) impact assessment, the simplified data is used to illustrate the (non)sense of using different sustainability concepts. For a more detailed impact assessment, we refer to the articles mentioned above.

In our illustrative case study, we assume only apple consumption and neglect the existence of composed food products (e.g. applesauce, apple juice) or meals. Although Belgium is a net exporter of apples, a significant amount of apples are imported from Southern countries (e.g. Spain) and even from the Southern hemisphere (e.g. New Zealand). We make no distinction between different apple varieties.

Note that we prefer to use ‘food mile’ and not ‘food kilometre’ although our case study uses kilometres instead of miles. This because the food miles concept is first introduced in Anglo-Saxon countries and the ‘food mile’ terminology is worldwide known and used.

3.1. Concept 1: Food miles

As mentioned in section 2.1, we define the original food miles concept as the distance from farm to plate. In our illustrative case, we compare the food miles of apples consumed in Belgium. In our comparison, we neglect the distance from supermarket to plate (assuming that the distance is the same for both an apple imported and a Belgian apple) and we use a simplified transport route (‘an average route’).

The Belgian consumer can for example choose between a New Zealand apple with a food transport distance of approximately 22 170 km, a Spanish apple with a food transport distance of approximately 2000 km and a locally grown apple with a food transport distance of approximately 80 km. More explanation about the distances can be found in footnote 4 of table 1.

The original food miles concept shows that locally grown apples are to be preferred. If you compare locally grown apples with apples cultivated at the other side of the globe, logically there is a major difference in food miles.

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Food miles concept: import versus locally grown

As shown by the illustrative case study, the original food miles concept has several shortcomings. The question arises if the original concept is totally meaningless. Using food miles as a single sustainability indicator is clearly wrong. Advising consumer to buy food with the lowest food miles is a bad advice because the (sustainability) focus is too narrow. You can argue that Belgian consumers should opt for locally grown apples (food mile ± 100 km) instead of choosing an apple of New Zealand (food mile ± 22 000 km). Note that food miles comparisons (using the distance in km) assume a certain fixed transport route while in reality this route can differ due to road repairs, weather influences (storms, floods,..), regulations (road and harbor taxes, no trucks allowed on Sunday,…), strikes (dockworkers, transport unions,…), road blocks,..

Furthermore, suppose that a Belgian consumer has to choose between a Spanish apple (food mile ± 2000 km) and a New Zealand apple (food mile ± 22 000 km). Using the original food miles concept as guiding principle the Belgian consumer should opt for the Spanish apple with the lowest food mile. However, the Spanish apples are transported on European roads by trucks while the New Zealand apples are transported by the more environmental friendly cargo ships. In other words, the original food mile concept does not contain some essential information, for example it does not take the transport mode and transport efficiency into account. Moreover, if you use the food miles concept as a narrow guideline, you have to prefer for example apples of your own region in stead of apples of your neighboring region. What's more, you have to prefer apples of your own municipality or even better apples from your own trees. Hence, using the original food miles concept as a narrow instruction seems to be absurd. But that does not mean that the original concept is entirely meaningless. The original food miles concept can be useful if consumers can reduce the amount of food miles of their meals without increasing price and environmental and social burden (e.g. higher pesticide use). In this way, you can realize a contribution to sustainable consumption. In reality, this is mostly a matter of trade-offs. Therefore, more detailed information of all sustainability aspects is needed. A first step is to enhance the original food miles concept with other relevant external costs of transport.

3.2. Concept 2: Enhanced Food miles

To show the possibilities and limitations of the enhanced food miles concept (see section 2.2), the model can applied on our illustrative case study. In this case, the enhanced food miles of local and imported apples can be compared. Once again, we only focus on the distance from farm to store (and not from farm to plate), because we assume that the enhanced food miles (or external transport costs) will not differ between a Belgian consumer of Belgian apples and a Belgian consumer of imported apples. Remember that the enhanced food miles are calculated from the Belgian consumer point of view. In our example we take the environmental external costs of carbon dioxide of the different transport modes into account. As external social costs, the costs of accidents of food transport are incorporated. The costs of traffic jams are taken into account as economic external costs. We are aware that there exist several more important externalities related to food transport that should be taken into account. Examples are damage costs related to a unit of emission of particulate matter and costs due to noise (Bickel et al., 2005). However, it is our aim not to provide a complete picture of all external transport costs but to compare the enhanced food miles as a conceptual illustration.

Table 1 : CO_2-emission of apple transport of 1 ton apples consumed in Belgium

Transport mode	Distance	CO_2-emission (kg per ton-km)	CO_2-emission (kg per ton apples)
From New Zealand to Belgian supermarkets			
Truck	170 [4]	0.860 [1]	146.2
Ship	22 000	0.030 [1]	660.0
Initial cooling		3.6 kg CO_2-emission per ton [2]	3.6
Transport cooling		15% of transport emission [3]	121.0
		TOTAL CO_2-emission	930.8
		TOTAL carbon cost	18.6 Euro per ton apples
From Spain to Belgian supermarkets			
Truck	2000 [4]	0.860 [1]	1 720.0
Initial cooling		3.6 kg CO_2-emission per ton [2]	3.6
Transport cooling		15% of transport emission [3]	258.0
		TOTAL CO_2-emission	1 981.6
		TOTAL carbon cost	39.6 Euro per ton apples
Locally grown and consumed apples (in Belgium)			
Truck	80 [4]	0.860 [1]	68.8
Initial cooling		3.6 kg CO_2-emission per ton [2]	3.6
Transport cooling		15% of transport emission [3]	10.3
		TOTAL CO_2-emission	82.7
		TOTAL carbon cost	1.6 Euro per ton apples

[1] The CO_2-emission parameters are estimates based on several sources. We are aware that there exists a wide range of emission parameters for the different transport modes. In addition there exist very different trucks and ships with different emissions in different situations.

[2] The initial cooling uses 86.3 MJ per ton. Using a conversion factor of 0.0415 kg CO_2 per MJ, we find an emission parameter of 3.6 kg ton CO_2 (Saunders et al., 2006)

[3] Sainsbury Corporate Social Responsibility Report 2005

[4] We assume the following average distances: (i) orchard-port Nelson (20km); port Antwerp-wholesale (100km); wholesale-supermarket (50km); (ii) orchard-wholesale (1950km); wholesale-supermarket (50km); (iii) orchard-auction (10km); auction-wholesale (20km); wholesale-supermarket (50km);

Table 1 gives an overview of the CO_2-emission of apple transport of 1 ton apples in three different situations: (i) from apple producers in New-Zealand to Belgian supermarkets, (ii) from apple producers in Spain to Belgian supermarkets and (iii) from Belgian apple producers to Belgian supermarkets. If we assume a carbon costs of 20 Euro per ton CO_2 (Tol, 2008), the carbon costs of apple transport can be calculated. We find a total carbon cost of 18.6 Euro per ton New Zealand apples, 39.6 Euro per ton Spanish apples and 1.6 Euro per ton Belgian apples. The assumptions about distance and transport mode clearly influence the carbon cost. For example if Spanish apples are transported by ship (1830 km) and a smaller fraction by truck (170 km) the carbon cost will decrease to 4.7 Euro per ton apples. Table 1 shows that although the CO_2-emissions of ship transport are lower per ton km than the emissions of truck transport, the total share of CO_2-emission of ship emissions still counts for more than 80% (without cooling) in the case of New Zealand. Hence, considering transport mode is very important and improving transport efficiency and reducing transport emission is also essential.

An important and relevant issue is the consumption time. Belgium (and European) apples are harvested in September-October and can be stored (on or off farm) for several months in controlled atmosphere stores. On the other hand, New Zealand apples are harvested in March-April, cooled and shipped to the Northern hemisphere. In fact, we notice that in European markets, European apples are mainly consumed from September till March while from March till August imported apples from the Southern hemisphere play a significant role. Locally grown apples are available from the end of August and can be stored in cold storage rooms for several months till the following harvest. The timing issue is very relevant given the fact that the imported apples should be compared with locally grown apples that have been stored for 7-10 months if we focus on apple consumption between April and August. Hence, we have to include storage cooling in the calculation of CO_2-emission. If we assume 240 days of storage which is an average between April (180 days after harvest) and August (300 days after harvest), and if we assume an energy use of storage per day of 5.4 MJ/ton (Mila I Canals et al., 2007), then we find an extra CO2-emission of 53.7 kg per ton CO2 per ton apples. In other words, storage cooling will increase carbon costs in our example with 1.1 Euro per ton apples. Hence, if we focus on consumption during April-August the carbon costs of local produced apples will increase from 1.6 Euro to 2.7 Euro per ton apples due to storage cooling. Note that the timing issues is often neglected within the food miles debate and that assumptions (such as time of consumption) have an important impact on calculation results.

Table 2: Accident costs of transport in Belgium (48 567 million ton-km[1])

Casualty type	Unit costs (Euro)[2]	Amount (2007)	Costs (million Euro)
Fatal	2 355 763	1071	2523
Serious injury	850 033	6997	5947
Slight injury	34 943	58 847	2056
TOTAL (million Euro)			10 526
TOTAL (Euro per ton-km)			0.22

[1] Source: FPS Economy Belgium (year 2007) including domestic transport, import, export and transit
[2] Source: Marginal unit value of preventing a road casualty (De Brabander & Vereeck, 2007)

Besides environmental external transport costs, there are also other relevant external transport costs such as congestion costs, accident costs, noise costs, air pollution costs (e.g. particulate matter), etc. To illustrate the possible impact of other environmental transport we will discuss accident costs and congestion costs.

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Table 2 shows that the social external transport costs of road accidents in Belgium can be estimated on 0.22 Euro per ton-km. Transport by ship is much safer than truck transport. Smith et al. (2005) assume that the accident costs on sea equals 213 Euro per million ton-km.

If we assume a similar external cost of road accidents in European countries and New Zealand, we can easily calculate the external cost of apple transport: (i) 42.1 Euro per ton apples imported from New Zealand (170 km by road transport and 22 000 by ship transport); (ii) 440.0 Euro per ton apples imported from Spain (2000 km by road transport); and (iii) 17.6 Euro per ton apples locally produced (80 km by road transport). Once again, external costs estimations are enormously influenced by the assumption. For example, if we opt for a combination of road transport and sea transport to transport Spanish apples to Belgium, the external cost of road accidents decrease to 37.8 Euro per ton apples (170 km by road transport and 1830 km by ship transport). Or if we assume other casualty unit costs, the impact of accident external costs will logically differ. Note that accident costs also differ between urban transport and interurban transport which we did not take into account in our illustrative example. Furthermore, in reality external costs of road accidents differ between regions and countries (and change through time), due to differences in geography, infrastructure, policy, behavior, etc… These differences should be taken into account and a changing transport route will cause a change in external costs of transport accidents.

An example of economic external costs of transport are congestion costs. In Belgium, there are on average yearly 527 500 hours of truck transport lost due to congestion (Vanhove, 2008). De Ceuster and De Schrijver (2002) value one hour of truck transport 45.95 Euro. Using this data, we find an external congestion cost of 0.0005 Euro per ton-km. Theoretically, the congestion costs should differ considering urban versus interurban traffic and peak versus off-peak traffic. In our illustrative example, the external congestion costs are ≤ 1 Euro per ton apples, considering the different scenarios. Note that the estimated congestions costs are rather low, while congestions cost calculated for the UK-generated food transport by Smith et al. (2005) are high and dominate (> 50%) the direct environmental, social and economic external costs. This indicates once again the major impact of model assumptions and system boundaries.

Table 3: Overview of external transport costs (in Euro per ton apples)

	From New Zealand to Belgian supermarkets	From Spain to Belgian supermarkets	Locally grown and consumed apples
Carbon costs	18.6	4.7 - 39.6	1.6
Carbon costs including storage cooling[1]	18.6	5.8 – 40.7	2.7
Accident costs	42.1	37.8 – 440	17.6
Congestion costs	≤ 0.1	≤ 1	≤ 0.1

[1] Consumption during April-August

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Table 3 summarizes the external costs of three different scenarios considered. It is important to note that it is not our intention to suggest the correct measure of external costs. In fact, Table 3 shows already the impact of certain assumptions and system boundaries. Moreover, our case study illustrates the different sustainability concepts and in this way, we try to tackle existing shortcomings as discussed in the following section (3.2.3).

3.2.3. Enhanced food miles concept: import versus locally grown

As explained, the enhanced food miles concept sketch a picture of the external costs of food transport. As illustrated in our example, there are several different relevant external costs of food transport. A first finding is that calculating all external costs requires a lot of data, assumptions and time. In practice, it is impossible to calculate all relevant external costs in detail but it is possible to compare food transport externalities in a decent way. Nevertheless, using average values (for transport routes, transport technologies,…), including certain externality costs, excluding certain externality costs, assuming certain transport modes and efficiencies severely influence results (and comparisons). Secondly, the enhanced food miles concept does take into account the characteristics of different transport modes as illustrated in our example. Moreover, it should be also possible to correct the calculations for transport inefficiencies (e.g. half-empty trucks). However, in our illustration we assumed full transport efficiency. Thirdly, the enhanced food miles concept enriches the straightforward original concept and provides more detailed insights. In fact, considering carbon costs is important but it neglects other essential transport externalities such as accident costs, congestion costs, noise, particulate matter,… Our illustration for example shows that the impact of accident costs can play an important role to compare different transport routes. This is already illustrated by for example Pretty et al. (1995). In other words, it is important to incorporate not only environmental transport externalities but also economic and social transport externalities. Fourthly, the seasonal aspects are important. In our example, we see that apples imported from New Zealand should be compared with locally produced apples stored for an average of 8 months. The question arises if fresh products are to be offered to consumers all year round. It is relevant to look for environmental friendly technologies to store fresh products and maintain sufficient quality. In our illustrative example, we therefore compared locally grown and stored apples with imported apples. If storage is not possible, imported food products are sometimes the only solution if fresh products are to be offered to consumers. Another possibility is to create an artificial environment to replicate summer growing conditions. In that case, the environmental and social impact should be compared with the impact of similar imported food products.

3.3. Concept 3: Food chain sustainability

As mentioned in section 2.3, food chain sustainability assessment incorporates all relevant environmental, social and economic aspects. Hence, not only transport externalities but also externalities caused by production, processing, marketing, sale and consumption should be taken into account. In practice, assessing food chain sustainability requires a large amount of data assuming that all aspects can be quantified.

In our case study, we will only add certain production externalities in addition to transport externalities. Hence, we will focus on differences of indirect energy use, more specific on the externalities of pesticide use and fertilizer use. Moreover, we only focus on the CO_2-emission of producing and transporting pesticides and fertilizers and do not take other externalities such as soil and water contamination into account. We will not analyze the impact of the use of direct energy inputs (e.g. electricity, fuel) and machinery. In this context, Saunders et al. (2006) found a much higher CO_2 emission per ton apples in the UK compared to New Zealand. Several other production externalities (e.g. labor, landscape) and other chain externalities (e.g. packaging, sale) are not considered in our illustrative case study.

Table 4: Energy use and CO_2-emission of pesticides and fertilizer nutrients

	Energy use (MJ/kg)	CO_2-emission (kg CO_2/MJ)	CO_2-emission (kg CO_2/kg pesticide)
Herbicides	276[1]	0.06[3]	16.6
Insecticides	278[1]	0.06[3]	16.7
Fungicides	214[1]	0.06[3]	12.84
Mineral oils	120[2]	0.06[3]	7.2
Plant growth regulator	175[2]	0.06[3]	10.5
Nitrogen	65[4]	0.05[4]	3.25
Phosphorus	15[4]	0.06[4]	0.90
Potassium	10[4]	0.06[4]	0.60

[1] Source: Meul et al. (2007) [2] Source: Barber (2004) [3] Source: Barber (2004) [4] Source: Wells (2001)

Table 5 shows the CO_2-emission of producing and transporting pesticides used to produce apples in New Zealand and in Belgium. We observe high differences in herbicides, fungicides, mineral oil and plant growth regulator use between New Zealand and Belgium horticulture. In general, we see a higher CO_2-emission average per ton apple production in Belgium (8.96 kg/ton) compared to New Zealand (7.3 kg/ton). Furthermore, in Table 5 we find the CO_2-emission of different nutrients used as fertilizer in apple production in both New Zealand and Belgium. In general, we do not observe large differences between Belgium and New Zealand with regard to CO_2-emissions of fertilizer use in apple production.

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Table 5: CO_2-emission of pesticides and fertilizer use of apple production

	Use (kg / ton apples)	CO_2-emission (kg CO_2/kg pesticide)	CO_2-emission (kg/ton apples)
	New Zealand		
Herbicides	0.021 [1]	16.6	0.35
Insecticides	0.037 [1]	16.7	0.62
Fungicides	0.115 [1]	12.84	1.48
Mineral oils	0.502 [1]	7.2	3.61
Plant growth regulator	0.092 [1]	10.5	0.97
Total pesticide use			**7.3**
Nitrogen	1.60 [2]	3.25	5.20
Phosphorus	0.15 [2]	0.90	0.14
Potassium	1.16 [2]	0.60	0.70
Total fertilizer use			**6.04**
	Belgium		
Herbicides	0.091 [3]	16.6	1.51
Insecticides	0.031 [3]	16.7	0.52
Fungicides	0.516 [3]	12.84	6.63
Mineral oils	0.040 [3]	7.2	0.29
Plant growth regulator	0.001 [3]	10.5	0.01
Total pesticide use			**8.96**
Nitrogen	1.56 [4]	3.25	5.07
Phosphorus	0.22 [4]	0.90	0.20
Potassium	1.10 [4]	0.60	0.66
Total fertilizer use			**5.93**

[1] Source: Manktelow et al. (2005): data from 2003 (production level: 570 000 ton apples)
[2] Source: Saunders et al. (2006) (production level: 550 000 ton apples)
[3] Source: Van den Bossche and Van Lierde (2003): data from 2001 (production level: 335 000 ton apples)
[4] Source: Lenders et al. (2008) (production level: 415 000 ton apples)

If we assume a carbon costs of 20 Euro per ton CO_2 (Tol, 2008), the carbon costs of apple production (only pesticides and fertilizers use) can be calculated. In our illustrative example we find 0.27 Euro carbon costs per ton apples in New Zealand and 0.30 Euro carbon costs per ton in Belgium.

3.3.3. Food Chain sustainability concept: import versus locally grown

In our illustrative example we only calculate the environmental external costs of pesticide and fertilizer use. The pesticide use of New Zealand and Belgian apple production is very different. New Zealand apple producers use many plant growth regulators and mineral oils while the Belgian apple producers use many fertilizer products. The fertilizer use (and also the environmental impact) is very analogous. In our illustrative example, the calculated production externalities are only a small fraction of the total externalities calculated (transport and production externalities). Nevertheless, note that we only calculated carbon costs of pesticide and fertilizer use as illustration. Evaluating energy consumption of a New Zealand orchard in detail, Mila I Canals et al. (2006) found that the production of pesticides and agricultural machinery was found to be significant in the overall energy consumption of the orchard. Note that Mila I Canals et al. (2006) and several other interesting papers (e.g. Edwards-Jones et al. (2008); Weber and Matthews (2008)) only focus (in a detailed way) on the environmental impacts of apple production. Using life cycle analysis (LCA) they provide a comprehensive view of environmental impacts. However, not all types of impacts are equally well covered in a typical LCA (Finnveden et al., 2009).

Table 4 shows the energy use and CO_2-emission of five different pesticides groups and three different nutrients used as fertilizer in apple production.

Other possible external costs and benefits to consider of farm production are for example soil erosion, losses of biodiversity, health effects from pesticides, farm subsidies, landscape aspects, deforestation and fair trade aspects. Quantification of these externalities will significantly increase the amount of production externalities compared to the transport externalities. Unfortunately, no single study can incorporate all relevant production externalities. As a result, very different outcomes can be observed (Edwards-Jones et al. 2008). Nevertheless, studies such as Pretty et al. (2005), Saunders et al. (2006), Mila I Canals et al. (2007) are very informative and useful. Only, generalizations should be avoided and model assumptions and limitations should be taken into account.

As already mentioned in section 3.2.3, impact assessment studies use average values. In reality, there exist large differences between farmers, processors, distributors and consumers. They often use different technologies and products resulting in different impacts. Instead of comparing products produced (and transported and consumed) in different countries, it seems more relevant to compare products between different producers (and all other market players of the value chain) between and within countries. Individual producers/processors/distributors/consumer have greater potential to influence sustainability impacts than they are aware of.

Hence, not only transport externalities are important to compare different food systems, but also all other relevant externalities resulting from the farm input use, food production food processing (including packaging), food distribution, food sale and food consumption.

Our illustration compares the sustainability between locally grown apples and imported apples from farm to store. In fact, we assumed no differences in the route between store and consumption. This does not mean that the impact from store to plate is not important. Moreover, the environmental impact of the consumer collecting his food can be higher than the total environmental impact from farm to store (Coley et al., 2009).

Furthermore, our illustrative example assumes similar apple quality. However, in reality there are differences in nutrients, appearance, texture, consistency, freshness, etc. Taking differences in product quality into account is certainly not straightforward, given the fact that the food price does not always represent quality differences, also marketing aspects matter. The average consumer price of New Zealand apples in Belgium is 2 Euro per kg while similar locally grown apples have an average price of 1.5 Euro per kg. Probably, consumers are willing to pay more for imported apples due to differences in quality. However, smart marketing can also have a significant impact, given the fact that marketing campaigns can persuade consumers to buy imported products. Note that the also seasonal aspects (linked with product quality) have an impact on the consumer price.

Besides differences in consumer price, there are also differences in cost structure. The transport costs of imported apples (from New Zealand) are significantly higher (even without taken externalities into account) and the producer price of New Zealand apples is lower. This can indicate a lower profit margin. Another possible explanation of the lower production costs of New Zealand apples are lower labor costs. The food miles concept or the enhanced food miles concept only focus on environmental externalities and do not take economic aspects into account such as differences in cost structure. One can argue that for example labor cost differences represent differences in comparative advantages. However, several tax systems and subsidy programs interfere the well functioning of labor markets. In fact, sustainability assessment should also take into account these differences.

The environmental and socio-economic impacts of changes in international trade patterns are complex and controversial (May and Bonilla, 1997). We already discussed direct impacts such as higher energy consumption and emission of pollutants. But higher international trade can also result in long term impacts such as deforestation (Barbier and Burgess, 1997). The impact of international trade on the degradation of the natural resources is case dependent: for example a negative impact in Ghana (Lopez, 1997) and a positive impact in Ivory Coast (Lopez, 2000). Also, the socio-economic impact of trade needs consideration. In certain cases, the impact of exporting food products can have significant impacts. In other words, environmental aspects should also be weighted against development gains. The main argument in favor of trade liberalization and globalization is that in the long run economic efficiency will grow (Würtenberger et al., 2006). For example in several African countries trade benefits those living in poverty. However, economic growth itself does not have the expected effect of decreasing the gap between the rich and the poor. Poverty in certain rural areas is still much deeper than poverty in urban areas (Binder and Lopez, 2000; Murray, 2001). Furthermore, fair trade organizations, guaranteeing fair prices, have been developed to support producers of poor areas (Renard, 2003). Young and Utting (2005) concludes that fair trade schemes do work in practical terms and in helping marginalized producers. There are also possible schemes where fair trade can provide for example gender equality (Rice, 2009).

To estimate both environmental and socio-economic impacts of agricultural trade, Würtenberger et al., (2006) developed the concept of virtual land. Virtual land can be defined as the productive areas hidden in imported and exported agricultural goods. Würtenberger et al., (2006) found that only 40% of total arable land needed to supply the Swiss demand for agricultural products is provided by the country itself. Furthermore, Würtenberger et al., (2006) constructs both environmental and socio-economic utility per hectare of wheat cultivation. Using a multi-criteria assessment of different impacts, several socio-economic impacts such as farm income, stability and justice are used to construct the socio-economic utility of land use. They found a clear difference of socio-economic utility per hectare between Argentina and European countries (e.g. France and Switzerland), underlining the importance of taking into account a wide range of trade impacts. However, Würtenberger et al., (2006) report several difficulties regarding data availability.

4. Discussion and conclusion

4.1 From simplicity to complexity

The current food miles concept has several shortcomings. As illustrated, using food miles as a narrow guideline of sustainability is clearly wrong. The fact that you only focus on transport in a straightforward way can lead to wrong conclusions with regard to sustainability. Note that already several authors (e.g. Mila I Canals, 2007; Edwards-Jones et al., 2008; Coley et al., 2009) point on the weakness of food miles and incorporate also environmental costs of production besides environmental costs of transport. However, social and economic costs are neglected to a larger extent and conceptual framing is needed. Therefore, we proposed to enhance the original food miles concept with relevant transport externalities of different transport modes (described as enhanced food miles). In this way, a more balanced analysis of food transport can be made. In fact, not only transport externalities but all relevant external costs and benefits of producing, packaging, selling and consuming food should take into account to assess food chain sustainability.

However, the original concept is not entirely meaningless. It seems advisable to minimize the distance between production and consumption. Nevertheless, caution is needed. Minimizing food miles while increasing certain environmental and social external costs is not always the way to go. In that case, a sound trade off analysis is needed to compare different food systems.

Unfortunately, comparing food systems is not straightforward and in most cases a complete comparison of different food systems incorporating all relevant aspects is not attainable in practice. Calculating all externalities is time and data consuming and thus costly. As a result, lack of data restricts the conclusions that can be drawn from specific case studies. Moreover, not all externalities are measurable. However, measuring certain externalities (e.g. production externalities) can enrich the sustainability debate. Rather than developing a data decision tool, the empirical results can be used as a supporting element in assessing sustainability. In fact, the major aim of measuring sustainability is to detect windows of opportunity to improve sustainability. Comparing the sustainability of food chains can be useful to identify superior strategies and technologies from a sustainability point of view. In other words, empirical applications are still needed, not to obtain a magical number but to identify paths of improvement. The main driver of comparing food systems should be to identify successful strategies to reduce environmental and social pressure.

4.2 Assumptions and system boundaries

An important aspect of the evaluation of sustainability impacts of food production is the definition of the system boundaries and model assumptions. Analysing different life-cycle-analysis studies considering the energy use of local and imported food, Edwards-Jones et al. (2008) found contradictory results. They argue for the use of similar system boundaries and methodologies when making comparisons between different food systems. It is only if the system boundary of the sustainability analysis of the food system includes all phases of the food chain that accurate impact estimates can be obtained.

As learned from our illustrative case-study, the relative benefits and costs vary with the seasons. The question arises if fresh products are to be offered to consumers all year round. Anyway, the different off-season options should be compared with the same weapons including all relevant externalities. Secondly, the impact of scale differences of production on different levels (local and global) should also be handled with care. Thirdly, technology differences (in all stages of the food chain) should be considered. Fourthly, to assess the sustainability of food systems, similar food quality is mostly assumed. However, in reality there are always differences for example in size, shape, freshness, nutrients, firmness, cleanliness, lack of damage, freedom of disease, color, appearance, etc. Food miles can have an impact on quality but food quality will rather depend on time since harvest and the type of processing. Fifthly, not only differences in quality matter also differences in tax and subsidy systems, marketing and cost differences through the whole food chain. Sixthly, there is no detailed insight of the origin and production aspects of some food components of composed food products (e.g. prepared meals). This makes the estimation of (enhanced) food miles nearly impossible, and the estimation of food chain sustainability not feasible. Seventhly, the (enhanced) food miles concept is blind to the possible benefits associated with food trade from developing countries. Moreover, the environmental impact of food transport should be put into the context of the total current use of natural resources and the total environmental harm. For example, it makes no sense to disfavor food products from developing countries with (historically) very low carbon emissions and choose for locally produced food in developed countries with high carbon emissions.

As already mentioned, different assumptions (of key variables) result in a wide range of outcomes and even in contradictory results (Edwards-Jones et al. 2008). But even more important and relevant with regard to sustainability are variations within food systems

(Mathijs et al., 2006). For example there are large variations in the distance farmers/processors travel to deposit their products. Moreover, there are large variations in essential aspects such as the load factor of the transport, the used transport mode, combustion process and the efficiency of the storage facilities (Mathijs et al., 2006). Hence, instead of comparing different food systems with average values, it seems useful to improve food chain sustainability within a food system. Moreover, best practices can be found within the food system and in different food systems. In this way, enhanced food miles calculations and sustainability assessment of different food systems incorporating variation within and between systems can contribute to improve sustainability.

4.3 Policy implications

Theoretically, economic values must be assigned to the relevant externalities. If these externalities related to food production, processing, storage and transportation are accounted for in the food's price, then the food price reflects the true value of food incorporating sustainability concerns. In other words, if all externalities were internalized, the (enhanced) food miles concept would be redundant. Hence, a first policy recommendation is to internalize externalities as far as possible. In this way, real transport and production costs will result in (more) sustainable food production and consumption. In reality, this is not the case and sustainability measures are needed. Therefore, we recommend applying integrated sustainability indicators more often as policy guiding tools. Estimations of enhanced food miles and food chain sustainability can support policy makers. However, as already mentioned, caution is needed using food miles as a policy guiding tool. We showed that there is a strong danger of oversimplification of using food miles. Nevertheless single issue labels (e.g. food miles or energy rating labels) can help consumers concentrate their limited efforts (Young et al., 2010). In fact, complex sustainability analysis (including several relevant assumptions) are not able to give simple messages to consumers who are seeking to make informed but uncomplicated purchasing decisions (Edwards-Jones et al., 2008). To avoid improper use, food miles should only be used as a signal that reducing food transport is advisable if it does not result in a major increase of other relevant sustainability impacts.

Reducing food miles without increasing environmental and social pressure can decrease or increase costs. If it reduces costs, this indicates resource misallocation and thus economic inefficiency. Theoretically, economic agents will exploit these win-win opportunities. If reducing food miles without increasing other environmental and social pressure increases costs, then government can provide support or companies can try to create a niche market with higher prices. Local producers and food brokers can use food miles as a straightforward marketing signal to explain several benefits associated with local food systems. In this way, they use food miles in their market message to explain how their products differ from those in the conventional system. However, local producers should be careful with unjustified sustainability claims and with incomplete confusing product information. Besides, retailers can play a significant role by incorporate sustainability issues (such as food miles) in their decisions to construct a product portfolio, but also in their choice to locate supermarkets and distribution centers. Business agents trough the whole food value chain can develop corporate sustainability strategies. We refer to Baumgartner and Ebner (2010) for some specific aspect profiles for sustainability strategies.

The interaction of economic, ecological and social aspects highlights the inherent interdisciplinarity of food chain analysis. Sustainability assessment is needed to understand the advantages and disadvantages of different food supply chains. However, it seems impossible to make a complete comparison of food systems. Numerous assumptions and clear system boundaries are needed to construct empirical models. As a consequence, there is a strong danger of incommensurability. Nevertheless, qualitative analysis extends our knowledge of different food systems and enrich sustainability assessment.

Bagheri and Hjorth (2007) argue that triggering a social learning process with full involvement of all stakeholders and planners in the process would be the most suitable strategy for sustainable development. An opportunity of government agencies is to launch sensitization campaigns to increase the consciousness of consumers with regard to food consumption. The government can give balanced information of the impact of food transport. Weber & Matthews (2008) suggest focusing on a dietary shift instead on decreasing food miles to reduce the average household’s food-related climate footprint. For example, government can teach consumers what foods are in season in their area, what foods have a lower footprint and try to build a diet around them. Moreover, policy makers can help to reduce the environmental impact from store to plate by promoting efficient food collection, food storage and meal preparation. Furthermore, the government can stimulate the food industry to reduce the overall environmental and social impact of food production, transport, marketing and sale. Different options are possible such as sectoral letters of intent, charters or binding agreements. Government agencies can also stimulate the development of new sustainable food technologies and support valorization and applications of sustainable innovations in food production, processing, transport and consumption. Further, companies can be stimulated to increase transparency of the different food components of composed food products. This can result in a decrease of avoidable transport. Besides, policy makers can introduce or strengthen sustainable production preconditions before subsidizing certain agricultural activities. For example, the European common agricultural policy already introduced some environmental requirements for farmers to maintain subsidy payments. On the other hand, we believe that information and sensitization campaigns are to be preferred above subsidy programs given the fact that subsidy programs result in higher market distortions.

Reconciling food miles with fair miles is not an easy job and requires smart politics both in developing and developed countries. In this context, it seems fruitful to stimulate in a balanced way the production of high value exotic food products in developing countries increasing product diversity in developed countries. In this way, poor countries exploit their comparative advantages and still earn the necessary income without avoidable environmental harm of food transport.

Note that the existence of different food systems can have a positive impact with regard to sustainability. In fact, food system diversity can reduce risk aspects. If you assess the sustainability of several different food systems and you opt for only one system, the question arise what if your comparison turns out to be wrong. Therefore, it seems more rational to improve the sustainability of different food systems instead of choosing the apparently most sustainable system.

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