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A PRELIMINARY ASSESSMENT OF GREENHOUSE GAS EMISSION TRENDS IN THE PRODUCTION AND CONSUMPTION OF FOOD IN MALAYSIA

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ABSTRACT
In the past decade, a small but growing body of research has drawn attention to the environmental concerns of rising greenhouse gas emissions associated with the consumption and production of food; this is an issue of increasing importance in Southeast Asia where rapid population growth is leading to year-on-year increases in food demand. To date, countries in Southeast Asia have shown little interest in addressing greenhouse gas emissions across the whole life cycle of food—production, processing, transportation, retailing, consumption, and final disposal—despite a growing awareness of climate change andits effects. This paper serves as a starting point to explore the relatively under-researched topic of greenhouse gas emission trends and the production and consumption of food in Southeast Asia, with particular focus on the Malaysian food sector. Previous research documenting greenhouse gas emissions from specific food products and components in the food supply chain has been used to determine the likely greenhouse gas 'hotspots' in Malaysia. The paper concludes by recommending the development of an overarching framework for Sustainable Food Systems in Malaysia and identifies specific areas of research to support this framework.

Keywords: Climate change; Consumption; Food systems; Production; Sustainability

1. INTRODUCTION
In recent years, it has been increasingly recognised that food, notably its production and consumption, is making a significant contribution to global greenhouse gas emissions (GHG). Recent studies have argued that the food and drink (F&D), transportation, and construction industry sectors are regarded as the most significant contributors to GHG emissions (European Commission, 2006; SEI et al., 2006; UNEP, 2008). In Asia, it is reported that these three sectors combined contribute between 70–80% of the continent's total GHG footprint (UNEP, 2008).

Global food production systems—particularly those feeding populations in the developed world—are far more complex and energy intensive than they were a century ago. As countries develop, there is a greater demand for processed and convenience food and greater expectations throughout the year for seasonal products, which are often imported over large distances. Significant changes in food production and increases in food transport have resulted. The production of food on farms has become increasingly mechanised, large-scale, and specialised; and food supplychains have become more complicated and transport-intensive (Roelich, 2008).

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Allowing for continued growth in the global population and the need for increased food production to avert the present day food crisis, it is highly likely that GHG emissions from food will remain constant or increase over the coming decades unless there is a move towards more sustainable food systems (Garnett, 2008). Addressing the requirement for an increase in the production and supply of food while tackling associated GHG impacts in the F&D sector is therefore, an issue of global concern.

The rise in funded research on this topic in the past decade, most notably in Europe and North America, demonstrates the importance of this issue. We believe that the focus of funded research should be widened to include food produced and consumed in Asia, one of the most rapidly growing regions of the world (UNEP, 2008) and the producer of a significant proportion of the world's food (Nellemann et al., 2009).

2. METHODOLOGY

To date, research examining GHG emission trends from the production and consumption of foodhave relied on a methodology known as life cycle assessment (LCA), a standardized method (e.g. ISO 14040, ISO 14044) for the evaluation of the environmental resources consumed during the life cycle of products, which includes the extraction of raw materials, manufacture of goods, their use by final consumers or in the provision of a service, recycling, energy recovery, and ultimate disposal (European Commission, 2007). This method allows for a detailed analysis of the GHG impact of food products, which has become an important factor in European policy development. In the UK, for example, Audsley et al. (2009) used LCA to investigate GHG emissions from the UK food systems. They examined detailed inventories of emissions from a wide range of foods and applied LCA methods to examine the effects of measures. As the authors clearly set out in the report's Foreword, the aim of the report findings was to influence UK policy makers to consider how to achieve more sustainable food systems.

The majority of LCA and food-related research to date has been largely concentrated in Europe, North America, and Australia, with very little taking place in Southeast Asia. While LCA was not under taken in this preliminary research, we adopted a life cycle perspective that considers the GHG impact of the Malaysian F&D sector in its entirety: from agriculture, manufacturing, transport, retailing, and consumption to final disposal of food waste. Previous research, industry reports, and publicly available reports have been used to identify the likely GHG emissions trends. Because there is limited LCA research taking place in the Malaysian F&D sector, certain assumptions have been made in this paper based on previous studies examining related or similar food products from different countries. Consequently, the trends identified in this section are not the only GHG trends in the food supply chain, but indicative of the likely GHG 'hot spots'. A summary of the main findings and priority areas can be found in Table 2 at the end of this section.

2.1. Agriculture

Within the F&D sector, agriculture is most notable for its GHG impact (Garnett, 2008), especially due to livestock rearing and crop production (IPCC, 2007). While difficult to measure and accurately quantify, especially when attempting to measure over large areas with varying soil compositions and different farming practices, it is estimated that approximately 10–12% of total anthropogenic emissions of GHGs are directly generated from agriculture (Garnett, 2008). If indirect emissions from the fertilizer industry and emissions from deforestation and land conversion are added, the total contribution of the agricultural sector could be as much as 26–35% (IPCC, 2007). The World Bank (2007) estimates that 80% of these emissions come from developing countries.

An abundance of space, consistently high humidity levels, and rich fertile soils have helped Malaysia's agricultural industry become one of the largest in Southeast Asia. In 2009, the country's agricultural industry contributed 9.5% to its total Gross Domestic Product (GDP) and provides employment for 16% of the country's workforce (Wong, 2007). Within the agricultural sector, palm oil, rice and meat production, particularly beef and poultry, are identified as the three largest contributors of GHG emissions.

2.1.1. Dairy and livestock

Rearing livestock for food production is one of the most significant contributors to global carbon emissions (IPCC, 2007), and cattle is the most GHG intensive of all livestock types (FAO, 2008). Methane generated as a by-product of the digestive processes of livestock is believed to be the most important source of anthropogenic methane internationally (Watson et al., 1992).

Whiledairy products tend to be less favoured by Malaysians, beefis one of the main meat staples in the national diet. Malaysia imports 80% of its beef requirements (Malaysian Industrial Development Authority, 2008), meaning the vast majority of GHG emissions associated with beef production are actually generated outside the country. Other than a small number of large-scale cattle farms, the majority of cattle, buffalo, sheep, and goats are farmed as a side activity of small holder farmers; it is therefore unlikely that these small farmers can take advantage of economies of scale to implement environmental practices. It is important to focus on consumption as well as production when exploring GHG emissions across the different components of the supply chain. Eighty-three percent of Malaysia's beef imports are from India (Business Monitor International, 2009), meaning that Malaysia contributes to India's GHG emissions. There are also GHGs associated with the transportation of the cattle to Malaysia, which should also be considered when assessing the full extent of GHG impact.

Malaysia is self-sufficient in the production of pork and eggs; it is the third largest producer of poultry meat in the Asia Pacific region. In 2007, 503 million broiler day-old-chicks were produced, with approximately 40 million birds exported to neighbouring Singapore (Business Monitor International, 2009). The sheer scale of Malaysia's poultry industry, especially when considering energy use and feedstock, implies a considerable GHG hot spot.

A further issue to consider is the anticipated growth of Malaysia's Halal market; the contribution of the Halal industry to Malaysia's GDP is expected to grow to 5.8% by 2020, from less than 2% currently (Malaysia Business News, 2011). Poultry is one of the principal meat types for Halal products and therefore any growth in the Halal market could result in an associated increase in the production of poultry in Malaysia.

2.1.2. Palm oil

Palm oil dominates the agricultural landscape in Malaysia and, as shown in Table 1 below, utilises just under two-thirds of total agricultural land use. Remaining agricultural land is divided up between rubber (17.1%), rice (6.5%), fruits (8%), vegetables (1.4%), cocoa (0.7%), and tobacco (0.1%).

The scale of palm oil production in Malaysia, and therefore, the corresponding GHG impact should not be underestimated. In 2009, Malaysia exported 15.8 million tonnes of palm oil, earning the country an estimated RM49.6 billion and employing approximately one million workers (MPOC, 2009). Major exporting countries and regions include China (25%), the EU (12%), Pakistan (11%), and India (8%). The climatic and soil conditions of Southeast Asia are well suited to supporting high yields; it is not surprising that Malaysia and neighbouring Indonesia produce 45% and 44%, respectively, of global palm oil needs (MPOC, 2009).

Table 1 Agricultural land uses in Malaysia, 2010 (Wong, 2007)

Crop type	Proportion of total (%)	Land (hectares)
Oil, Palm	66.1	4555
Rubber	17.1	1179
Rice	6.5	450
Fruits	8	555
Vegetables	1.4	100
Cocoa	0.7	45
Tobacco	0.1	7
Total	**100**	**6891**

The major sources of GHG emissions are associated with the growing and processing of palm oil, changes in carbon stock during development of new planting, and planting in peat soils (see Box 1). The GHG impact of changes in carbon stock and planting in peat soils have been the source of considerable debate in recent years. Supporters emphasize the efficiency and high yielding nature of the crop (Basiron, 2007; Lam et al., 2009); other commentators point towards the loss of important carbon sinks (primary and secondary forests, peatlands) and biodiversity as highly valued rain forests are cut down for planting purposes (Friends of the Earth, 2010). Furthermore, emissions associated with palm oil mill effluent (POME), particularly uncaptured methane from palm oil mills, is regarded as another major contributor of GHGs, especially since very few mills currently have the resources to successfully capture methane and turn it into a renewable energy source (Padfield & Hansen, 2010).

Box 1: Sources of GHG emissions in palm oil production

- GHG emissions arising from operations during palm oil growing and FFB processing, or more precisely:
    - Emissions related to the use of fossil fuels for plantation internal transport and machinery
    - Emissions related to the use of fertilisers
    - Emissions related to the use of fuels in the palm oil mill, and the use of palm oil mill by-products
    - Emissions from Palm Oil Mill Effluent (POME).
- GHG emissions arising from changes in carbon stock during the development of new plantings
- GHG emissions from peat (only when plantings are on peat).

Adapted from: Brinkmann Consultancy, 2009

Current debates are characterised by uncertainty over calculating GHG emissions associated with palm oil, especially with regard to indirect land use change. For example, recent research suggests that palm oil is environmentally preferable to other oils, assuming that new oil palm plantations are not replacing primary forest or peat land (Schmidt, 2010).

However, the conclusions can go both ways depending on assumptions and data sources. The point here is that scientifically and internationally recognised databases are needed to capture environmental palm oil data and obtain a satisfactory calculation for the GHG impact of palm oil. International initiatives, such as the Reducing Emissions from Deforestation and Forest

Degradation (REDD) project, are attempting to tackle some of the issues related to indirect land use change. REDD aims to create an incentive for developing countries to protect their forest resources in a process whereby developed countries pay developing countries 'carbon offsets' for their standing forests (United Nations, 2009). This initiative is especially pertinent for Malaysia, where there is mounting pressure for existing land, including areas of high ecological value, to be developed into palm oil plantations.

2.1.3. Rice

Studies examining the impact of agriculture on climate change have shown that the cultivation of rice is a major source of methane (CH_4) and nitrous oxide (N_2O) (Cai, et al., 1997). Methane and nitrous oxide are both important greenhouse gases; the latter is 300 times more potent than carbon dioxide, while the former is 21 times more potent than carbon dioxide (IPCC, 1995). The IPCC (1994) estimates global methane emission from rice fields as 37 Tg/year; total N_2O emissions from overall cultivated area is estimated at 1.8–5.3Tg tonnes/year.

Like most countries in Southeast Asia, Malaysia relies on rice as adietary staple and produces approximately 72% of the rice it needs, with the remaining amount imported from around the region. The government intends to increase production in order to be entirely self-sufficient by 2015 (Bernama, 2011). As shown in Table 1, Malaysia has approximately 450,000 hectares of land used for rice cultivation, making upapproximately 6% of total agricultural land. FAO (2010) noted that rice production in Malaysia rose slightly over the past thirty years with 2.3 million metric tons (MT) produced in 2009, compared with 1.9 million MT in 1990. Considering the importance of methane and nitrous oxide to global climate change and the expected rise in rice cultivation to meet future demand in the country, the GHG impact from rice in Malaysia will continue to remain an important GHG hot spot in the F&D sector.

2.2. Food manufacturing and retail

Various studies have identified energy usage and CFCs from food refrigeration as the major GHG emission hot spots in the manufacturing of food (Garnett, 2008). Malaysia has a large and growing food-manufacturing sector; in 2008, food manufacturing contributed approximately 10% to Malaysia's total manufacturing output (MIDA, 2008). Local food analysts also report that Malaysia's cold chain sector is expected to experience growth in the next decade with the increase in consumption of frozen-refrigerated food (Food Business Directory Malaysia, 2010). Considering the scale and expected growth in the cold chain sector and a tropical climate conducive to rapid spoiling of food without adequate refrigeration, it can be assumed that this component of the supply chain deserves further evaluation to better understand GHG intensities and sources. Energy usage from refrigeration and CFC emissions is likely to be high, especially since current interest in environmental management systems (EMS) in the food manufacturing and retail sector is low. Minimal adoption of measures to curb GHG emissions is anticipated (personal communication, 2011).

As in the manufacturing sector, the principal GHG sources for the retail and catering sector are associated with the refrigeration of foods. In Malaysia, the rise of supermarkets and out-of-town shopping complexes, as well as the growing demand for domestic refrigerators (Wong, 2007), are regarded as GHG hotspots. Coupled with annual increases in food consumption, refrigerator use in supermarkets and the home are likely to be important GHG sources for years to come. Supermarkets use considerable amounts of energy to maintain comfortable ambient temperatures; this is especially critical in the tropical climate of Malaysia where air-conditioned stores are increasingly favoured by shoppers. Unless there is widespread adoption of energy abatement measures, continued growth in supermarket retail will lead to increasing energy consumption and rising levels of GHG emissions.

2.3. Transportation

Transportation of food is a significant and growing source of GHGs (Garnett, 2008). Factors such as the globalisation of the F&D industry, a demand for seasonal goods all year round, and concentration of sales in supermarkets have contributed towards increasing food miles. In Malaysia, road freight is likely to be the most common form of food transportation because of heavy government fuel subsidies and Malaysia's extensive road network. Compared with more sustainable transportation modes such as electric trains or shipping, motor vehicles are generally regarded as major pollutants (CER, 2010). Various reports have drawn attention to the rising contribution of motor vehicle emissions to Malaysia's urban air pollution (Awang et al., 2000).

In addition, the low cost of fuel is less likely to encourage efficient loading of vehicles or efficient travel routes, especially for shorter journeys. GHG emissions associated with the transportation of imported and exported foods are additional factors to consider when analysing total emissions from Malaysia's food sector. In 2008, Malaysia was a net importer of food products, with annual imports in excess of US$4.6 billion. The main importing countries were India, China, Australia, Thailand, and Singapore (BMI, 2009). The scale of food consumed from overseas sources indicates that Malaysia's food sector continues to depend on the transportation of foods produced outside its borders.

Total export of food products from Malaysia was US$3.1 billion in 2007; the country doubled its export of processed food to more than 80 countries in the last decade (BMI, 2009). Two-thirds of exported food (or US$1 billion) comes from processed food (i.e. halal products, fish, vegetable and snack products, oil-based foods), and the main export markets are Singapore, United States, Indonesia, Japan, the Netherlands, and Thailand (BMI, 2009). It is assumed that air and shipping will be the dominant transport modes for imported and exported food, in addition to overland transfer to neighbouring countries. As Garnett (2008) proposes, it would be interesting to examine what contribution a country makes to another country'sfood GHG emissions, especially considering the scale of Malaysia's food exports.

In terms of transport associated with the consumption of food, the increasing use of private vehicles coincides with the growth in supermarkets. Wong (2007) attributes this growth to continued urbanization, rising disposable income, increasing ownership of refrigerators and a relatively young population willing to pay for trace ability, food safety, and branding. Combined with a reliance on private vehicles, there is likely to be a rise in emissions from people shopping for food at supermarkets.

2.4. Food waste

There are two principle GHG effects arising from food waste. First, food waste generates GHGs when disposed in landfills. Degradation of all biodegradable wastes in landfills produces a potent GHG, methane; if not managed appropriately, it can escape from a landfill either directly to the atmosphere or by diffusion through the cover soil. Second, and far more significant from a climate change perspective, are embedded GHG emissions associated with food waste. For example, it is estimated that householders in the UK waste 30% of the food they buy; of this, approximately 60% is edible, or would have been were it eaten by its sell-by date (WRAP, 2008).

In Malaysia, the rising level of food waste is quickly becoming a major environmental problem. According to government sources, 17,000 tonnes of municipal solid waste (MSW) are produced every day, of which food waste comprises 45–50% (Ministry of Local Government and Housing Department, 2005). To date, weak enforcement of legislation and limited stakeholder coordination have hindered the adoption of sustainable waste management practices (Manaf et

al., 2007). Furthermore, economic drivers tend to force food processors to eliminate waste in their operations; however, the low cost of food as a consequence of a heavy government subsidy strategy has fostered profligate attitudes towards food, especially by consumers and within the food service sector (Papargyropoulou, 2010).

In terms of waste disposal, there are currently few alternatives to landfills. According to government data, 95–97% of all generated wastes are disposed of in landfills and illegal dumpsites, and the remaining fraction is recovered through recycling (Ministry of Local Government and Housing Department, 2005). Most of the 112 landfills on Peninsula Malaysia are at full capacity, with the vast majority operating under old standards; as a result, most of the landfills are dumpsites that present serious environmental and social threats (Yunus & Kadir, 2003). While food waste rates remain high and alternatives to landfill do not materialise, the problem of rising GHG emissions from the decomposition of waste from landfills will continue to have an impact on the overall carbon footprint from the food sector.

2.5. Summary of GHG emission trends

Table 2 summarizes trends with corresponding priorities areas (high, medium, low). The priority areas were designated based upon a comparative analysis between the identified hot spots and current GHG trends, which are expected to be applicable in the future.

Table 2 Summary of GHG Emission Trends

Component of Supply Chain	GHG HotSpot	Priority (High, Medium, Low)	Justification
Agriculture	Palm Oil production	High	Various studies underline the high GHG impact from palm oil production. Principle GHG sources are from changes in carbon stock, planting on peatlands, and operations. Malaysia is 2nd largest producer of palm oil in world. Growth in biofuels markets is also expected.
Agriculture	Livestock & Dairy	High	Rearing of livestock is largest contributor of GHG in global food production. Malaysia is self-sufficient in pork and eggs and is 3rd largest producer of poultry in Asia. Despite importing 80% of beef requirements, rearing of cattle is expected to be a significant source of GHG.
Agriculture	Rice production	Medium	Rice production is a significant source of nitrous oxide, an important GHG. Malaysia aims to become self-sufficient in rice production in next 10 years.
Transportation	Road freight	Medium	Motor vehicles are dominant, with large food manufacturing base; therefore, GHG impact is expected from transportation of food.
Transportation	Imported and exported foods	Low	Regional trading of food is increasing and therefore GHG impact from transportation is expected to rise.
Manufacturing, Retail & Catering	Refrigeration	Medium	Research in the UK demonstrates that refrigeration is one of highest GHG contributors in F&D sector. Malaysia has a strong food manufacturing base, in addition to a growing retail and catering sector. Uncertainty surrounds the performance of refrigeration units; high levels of CFCs emissions are expected.
Waste	Food waste	High	Minimal programmes are in place to limit food waste. Since there are currently no alternatives to landfill, GHG impact from food waste is expected to be considerable.

3. THE NEXT STEP: A FRAMEWORK FOR SUSTAINABLE FOOD SYSTEMS IN MALAYSIA

Addressing each of the stated GHG emissions hot spots is no easy task; indeed, there is no single solution to bring about positive change. An appropriate way forward for the Malaysian F&D sector is to learn from countries attempting to address similar food-related environmental issues. One approach currently being adopted is the development of nation-wide and cross sector sustainability frameworks. This approach is not limited to countries with high income economies; developing countries such as Ethiopia, Jamaica, and Thailand have all made ambitious commitments to address sustainable development through holistic framework development, which support goals of appropriate policy making and target setting (UNEP, 2008).

Furthermore, since the early 2000s, the United Nations Environment Programme (UNEP) have hosted world and regional forums and provided publicly available guidelines advocating practices of Sustainable Consumption and Production (SCP) – a concept that rests on the notion of reducing resource use, degradation, and pollution while improving quality of life. Developing national and sector-specific frameworksand setting measurable targets to measure progress are the pillars of this approach (UNEP, 2008).

Developing a framework for sustainable food systems in Malaysia is one way of addressing GHG emission trends. Currently, Malaysia has in place a National Food Security Policy and National Agricultural Policy, but no overarching framework that considers the sustainable consumption and production of food systems. Such a framework could integrate similar recommendations and approaches taken by countries tackling this particular issue. For example, the UK's National Food Strategy addresses sustainable development through its stated priorities of increasing food production through sustainable means and reducing the food system's greenhouse gas emissions (Defra, 2010).

As part of a framework for sustainable food systems in Malaysia, it is necessary to establish a quantitative baseline of GHG impact. Since there is limited available LCA research in this field, recommendations for priority LCA studies to support the baseline are suggested below:

- Livestock, with emphasis on poultry and cattle
- Agriculture, with emphasis on rice and palm oil
- Food miles of food imports and exports
- Refrigeration of food and emission of CFCs from refrigeration
- Waste generation fromhouseholds and catering/retail sectors

Other suggestions for non-LCA studies include research of indirect land use change (iLUC) because of food production and consumption. As Malaysia moves towards developed country status, it is likely that people's attitudes, preferences, and behaviours may change with regard to food. Understanding these changes in behaviour will help in achieving more sustainable consumptive patterns.

Scientifically and internationally recognized data bases for environmental palm oil data are needed for satisfactory calculations regarding the GHG impact of palm oil. There is still a considerable amount of uncertainty regarding the climate change impact of palm oil due, in large part, to a lack of agreed methodology; this issue remains a high priority for research and extends to understanding the impact of palm oil on biodiversity.

4. CONCLUSION

This paper has examined the relatively under-researched topic of GHG trends and the production and consumption of food, focusing specifically on the Malaysian F&D sector. Across the different components of the supply chain, the likely GHG emission hot spots have

been identified, with production of palm oil and rice, and livestock rearing singled out. Development of a Sustainable Food Systems framework for Malaysia is recommended to establish a baseline to monitor progress.

The overall aim of this paper is to serve as a platform for further research, with the intention of stimulating interest in this particular topic amongst researchers and policymakers in Malaysia. Drawing attention to the impact of GHG emissions will hopefully focus efforts towards creating a more sustainable food system in Malaysia.

Finally, it is important not to neglect the full environmental impact of the production and consumption of food. In particular, loss of biodiversity and water scarcity issues are persistently associated with unsustainable food production. Additionally, as we consider how to reduce GHG emissions from the food sector, we should recognize that acute climate changes (drought conditions, extreme weather events, less predictable weather patterns) will create challenges for food production. An improved understanding of the relationship between food and climate change supported by sector frameworks and structured research programmes will enhance the profile of this issue amongst governments across Southeast Asia.

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