ERASMUS SCHOOL OF ECONOMICS

Import of Horticulture Produce from Foreign Countries and Global Warming

A Comparison of Co2 Emissions of Kenyan, Dutch and Spanish Tomatoes

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Abstract

In light of current debates on global climate change, this paper investigates what is the best consumer choice of tomatoes in terms of Co2 emissions. This was done through a comparison of Co2 emissions caused by tomatoes sourced in the Netherlands, Spain and Kenya for consumption in the Dutch consumer market. The emissions caused by production and transport were estimated through existing estimates of energy use and emission factors. From the results obtained, some policy recommendations were given by the author.

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Chapter 1- Introduction

Every day, horticultural products travel great distances to supply consumers of developed nations with every kind of vegetable they desire all year round. As a consequence of the current debates on climate change, the desirability of these products is increasingly questioned. It is common belief that, as transportation is one of the main sources of Co2 emissions (Stern, 2006), it is more sustainable and thus more desirable to consume products that have been produced locally with minimal involvement of transport. This is plausible as a number of popular horticulture products are often transported over great distances by airplane as they are highly perishable. Airborne transport is the most polluting mode of transportation (Saunders and Hayes, 2007). Hence, the belief that these “flying” horticulture products cause more Co2 emissions than those produced locally might be justified. However, it is evident that the production of horticultural products in heated greenhouses causes significantly more emissions of Co2 than if these were produced in an environment where heating and other involvement of technology is unnecessary due to a more suitable climate. In the countries with colder climates in e.g. North Europe, a trade off can thus be seen between consuming local products produced with high energy use, or consuming non-local products which were produced with much less energy, but have been transported over great distances. Which of the two options is best in terms of global reduction of Co2 emissions is unclear. This paper thus aims to investigate whether the common belief discussed above is justified. This will be done by estimating the Co2 emissions caused by the production and transport of locally sourced horticultural products compared to those produced in foreign countries.

This paper will focus on tomatoes as a reference crop for Co2 emissions, as it is one of the more popular crops for consumption worldwide. Additionally, tomatoes are intensively grown in heated greenhouses as they originally grow in tropical climates (McCue, 1952). This paper will be based on The Netherlands as the consumer market for tomatoes, with Spain and Kenya as sources for import of tomatoes into the Netherlands. This is justified as follows. The Dutch horticulture sector is one of the most important producers of tomatoes in for the world market (FAOSTAT, 2007), meaning that Dutch consumers do have the possibility to consume locally produced tomatoes. Additionally, its production process is characterized by high energy use for heating and other technology (Van der Velden et al., 2004; LEI/Wageningen UR, 2009). The Spanish horticulture sector is one of the most important competitors to the Netherlands; both for consumption in the Netherlands and on the world market, and its production process employs much lower energy use. Spanish tomatoes are transported to the Netherlands by road, which might offset the low energy use for production. Finally, Kenya is one of the fastest growing horticulture exporters in sub-Saharan Africa where production is done in open soil with low technology use, thus employing very little energy (Minot and Ngigi, 2004; Otieno et al., 2009). On the downside, their tomatoes are transported by airplane and thus can be expected to be very energy intensive despite the primitive production processes. The three countries named above reflect the tradeoff between high Co2 emissions from production and high Co2 emissions from transport. By choosing to focus these three countries the scope of the results will be maximized. The two most important transport modes are included (airborne and road transport) as well as three different types of tomato production, namely high technology production in the Netherlands, relatively low technology production in Spain and primitive production in Kenya.

In chapter 2 of this paper, an overview of the current situation and opportunities of the horticulture industry in all three above mentioned nations will be provided. Chapter 3 will then explain the methodology employed for the calculation of Co2 emissions from, respectively, the transport and production of tomatoes after which the results from these calculations are given per country. Chapter 4 will discuss the results found as well as give some policy recommendations and discuss the limitations of this research, after which chapter 6 will give the conclusion.

Chapter 2- Sector profiles by country

This section aims to provide an overview of the horticulture sectors of the Netherlands, Spain and Kenya. It gives a short summary of how the each country's horticulture production developed through history along with a short overview of their export figures and production processes.

2.1- The Netherlands

From early Dutch history until 1947, data show that the Dutch greenhouse horticulture was characterized by production increase through expansion of the arable land area (Rijk and Bos, 2009). Existing, non-arable land above sea level was gradually developed to support agriculture. In more recent history, large portions of land were claimed from the sea, creating the typical Dutch polders. After 1948, the productivity of the greenhouse horticulture sector increased at a very fast rate due to strong specialization and mechanization. The total number of farms decreased significantly while the productivity per individual working in the sector had increased 3-fold in 2006 (Rijk and Bos, 2009). Additionally, due to increased demand for year-round supply of a large range of vegetables, the greenhouse horticultural sector grew rapidly to become one of the most important subsectors of the industry. (Rijk and Bos, 2009). The Dutch greenhouse horticulture sector is a very important on the world market, housing a quarter of all greenhouses in the world (Rijk and Bos, 2009). Many of the Dutch products are ranked number 1 in terms of world export, of which the most important are floriculture products (48% of total world trade) and tomatoes (23%) (Rijk and Bos, 2009). The largest portion of Dutch produce is exported to EU countries (LEI/Wageningen UR, 2009). Some reasons for the Dutch success will be given below.

To begin with, the Netherlands have one of the best developed ports in the world, ranking third in terms of cargo volume in 2008 (AAPA, 2008). The country has a very large hinterland, made accessible by a very well developed infrastructure in the form of river transport, road transport and train transport. In addition, the agriculture sector is well represented in political decision making with a delegation in the Social Economic Council (Sociaal-Economische Raad), which is the most important advisory organ for the Dutch government. Finally, the sector is supported by a very large knowledge base. There is thus a very good business climate for the Dutch horticultural sector to thrive (Rijk and Bos, 2009).

The Dutch greenhouse horticultures sector is characterized by a very high energy use as well as a very intensive and large-scale production which. For reference, the energy use is 13 times larger than the energy use in Spain (Van der Velden et al., 2004). This is due to a high level of computerization, for climate control and irrigation combined with a high level of heating made necessary by the relatively cold climate in the Netherlands. The use of biological pesticides is widespread, practically ruling out the use of chemicals in the production process (Van der Velden et. al., 2004; Brouwer et al., 2004). Despite the fact that the energy per unit of produce in the Dutch greenhouse horticulture is still relatively high compared to other countries, it has been reduced by half since the 1980s (Brouwer et al., 2004). The sector is continuously striving to minimize the energy use and Co2 emissions from their activities through technological innovations (e.g. by channeling heat and Co2 from other nearby industrial activities to be re-used in greenhouses). Despite this, it will probably remain relatively energy intensive in comparison to competitors located in warmer climates (Van der Velden et al., 2004). Compared to the energy used by the production processes in Dutch horticulture, emissions from transport are practically insignificant, accounting for only 1% of total energy use in the sector.

2.2- Spain

The Spanish horticulture industry is an important player on the world market. It is the number 3 exporter of tomatoes in the world and thus an important competitor for the Netherlands. This is true not only for tomatoes but also for peppers, cucumbers and many other crops (FAOSTAT, 2007).

The importance of the Spanish horticulture sector originates in the mid-nineteenth century, when the international trade in fruits and vegetables surged due to the start of commodity market integration, defined as globalization (Pinilla and Ayuda, 2010). In the more temperate European countries, the Mediterranean horticulture produce was considered an exotic luxury good, and the development of better trade possibilities was a good opportunity for Spain and other Mediterranean countries to increase their production and export their produce to the rich countries in the North of Europe. This triggered the Spanish horticulture sector to improve the production facilities in the form of irrigation and fertilization so as to be efficient in their production. By the end of the 19th century, Spain was the world leader for Mediterranean horticultural produce, exceeding 30% of world market share throughout the first third of the 20th century (Pinilla and Ayuda, 2010). Initially, Spain specialized in the export of oranges, which still is one of the most important export products of the country, but gradually expanded its production towards other fruits and vegetables production, including tomatoes, thus achieving a market-dominating position. Given this, Pinilla and Ayuda (2010) especially attribute Spain's success to a long tradition of horticulture export, originating from relative geographical proximity to the richer European countries, good climate conditions and fast increase of supply.

The Spanish horticulture sector, unlike the Dutch, is characterized by low energy use, primitive technology, large but relatively non-intensive production areas and a high use of chemical pesticides. The production is mostly done in plastic greenhouses which lead to a relatively low yield due to limited heating possibilities, limited protection against pests and the fact that plastic is less transparent than glass and thus provides less light to the crops. In summer the greenhouses are not used due to the high temperatures and production is done in open soil. The summer period is the least productive due to the extremely low humidity.

During the last three decades, the Spanish production process did not develop much in terms of technology integration. Production increase was achieved by increasing the physical production area, with hardly any increase in productivity per square meter (Van der Velden et. al., 2004). The transport of Spanish vegetables accounts for 60% of the total energy use, while this is only 1% for e.g. the Dutch vegetables. From 2004 on, Spain has experienced increasing technology integration in the form of climate control, glass greenhouses, irrigation control and higher use of biological pesticides, but the country remains far behind on its Dutch competitors.

2.3- Kenya

Large scale production of horticultural products in Kenya started in World War II to supply food for the Allied Forces stationed in East Africa. In 1963, the year of their independence, horticulture only represented 0.3% of the total Kenyan export value. The industry grew steadily after this year, and by the year 1991, the export of horticulture products had grown 12-fold in terms of tons and 20-fold in terms of value and Kenya had become an important player in the world market (Jaffee 1995). The sector as a whole has grown continuously ever since and now accounts for 13% of the Kenyan economy (Otieno et. al., 2009), generating annual revenues of US$2 billion, from which the export market, accounting for just 10% of total volume, generates US$1 billion. There are 240 large-scale producers and roughly 150000 smallholder farmers while the sector supports about 4.5 million individuals (Gikunju Muuru, 2009).

Initially, the export of horticulture produce was dominated by a small number of Kenyan Asians with good connections to immigrants in Europe. Large exporters with financial and managerial background started entering the market in the 1980s and were mostly Kenyan Europeans and expatriates. Most of these exporters have contracts with large European retailers and have established processing factories near Nairobi where vegetables are sorted, washed, weighed, processed and packed. This group of exporting companies dominates the market and has competed away most of the Kenyan owned companies (McCulloch and Ota, 2002).

The production of vegetables for export was initially done by small scale farmers, who often cultivate a single plot of land (further to be mentioned as smallholders). However, in the late 1990s, tightened European regulations on pesticide use and quality had made it difficult for smallholders to produce for the export market as they did not have the means to satisfy these regulations. Combined with the high costs associated with collecting produce from many small farms, larger scale farms had started to take over and only 18 percent of exported produce originated from smallholders (McCulloch et. al. 2002). However, in 2009, Gikunju Muuru (2009) reports that the growing demand had forced exporters to resort to smallholders again so as to achieve a larger supply, increasing their share to 60%. The smallholder's produce is now collected and processed on larger scale commercial farms, from where it is further transported to the airport of Nairobi. Surprisingly, Gikunju Muuru (2009) also reports that the produce from small scale farms tends to have a better quality than when it is produced on larger scale farms, thus adding to the value of Kenyan produce.

Kenya's position on the equator provides year-round sunlight while the climate is temperate enough to allow continuous production. This might give Kenya and other African countries with the same conditions a competitive advantage for horticulture as, with some technological improvement, they could become much more efficient than the greenhouse producers in Europe (Gikunju Muuru, 2009). The production of crops in Kenya can be done without additional heating and in open soil. There are some signs of greenhouse technology being adopted in Kenya, but these are very simple constructions made of plastic with the only purpose of reducing crop losses due to pests thus reducing the needs for pesticides (USAID Kenya issue #19).

In Kenya tomatoes are mainly produced for the domestic market. It is only a minor export crop in Kenya (Mausch et. al., 2006) which is shown by the fact that it is only exported in April and even then in relatively low quantities (HCDA, 2009). One reason is the fact that it is a relatively heavy crop, making it more expensive for airborne transport. Indeed, the most important airborne transported export crops, green beans and mangetouts, are relatively light crops. Another reason might be the fierce competition from countries like the Netherlands and Spain, where tomatoes are produced year-round, in large quantities and are of high quality combined with lower transport costs (Van der Velden et. al., 2004). This competition is strengthened by the fact that tomatoes remain excluded from free entrance to the EU markets in the Cotonou agreement as of 1 January 2008 (EAC-EPA, 2008). Spreading the greenhouse production technique mentioned earlier could for example greatly improve Kenya's competitive position for tomatoes and increase the importance of this crop. Despite its relatively unstable government since independence (Collier, 2009), the country has managed to develop a decent transport infrastructure and has acquired a strong position in the world market for horticulture. This activity provides a very good basis for the countries' economy in general to develop further.

Chapter 3- Methodology and Results

This section will outline the data and methodology employed for this study, as well as the results obtained. Section 3.1 will focus on the emissions from transport of tomatoes per country, after which section 3.2 will deal with the emissions from the production of tomatoes per country. Finally, the results will be discussed in section 3.3.

3.1- Emissions from transport

In this section, I discuss the data, methodology and results for the emissions from transport of tomatoes for Kenya, Spain and the Netherlands. All calculations for this section will be done on basis of emission factors developed by the UK Department for Environment, Food and Rural Affairs (DEFRA 2008[a] and 2008[b]), which has done extensive research to develop emission factors for various types of transport to support their regulating activities. I use their most recent estimates, dating from 2008. The following paragraphs will outline the data and methodology used in this paper, starting with airborne transport and followed by road transport.

3.1.1- Methodology and data for airborne transport

Emission factors

DEFRA (2008[a] and 2008[b]) distinguishes between two types of airborne transport: transport by dedicated freight aircraft and transport in the belly of passenger aircraft. Data from the UK Civil Aviation Authority (CAA) show that passenger aircraft account for 70% of all long haul air freight transport. The importance of these freight movements by passenger aircraft creates significant complications in the calculation of emission factors. Consequently, the Co2 emissions from both types of airborne transport are calculated separately, after which the final emission factors are formed through a weighted average based on their respective proportion in total air freight transport.

For the calculation of emission factors of dedicated transport, specific fuel consumption/emission factors were used from AEIG (2006). Average freight capacities, load factors and proportions of ton.km for the different airlines and aircraft types have been calculated from CAA statistics for UK registered airlines for the year 2006. The basis of the calculation method for freight in passenger aircraft adopted by DEFRA is to take account for supplementary equipment like seating and galley in comparison to dedicated aircraft. The British Airways cargo configurations show that the load capacity for cargo in dedicated aircraft is generally estimated at 125 tons while only 20 tons is allocated to cargo in passenger aircraft. DEFRA concludes that the difference equal to a 100 tons is attributable to the space lost to passengers, their luggage, seating, galley and other attributes necessary for passenger service. Assuming an aircraft that can carry 350 passengers, this means that the weight per seat is equal to 300kg, which is about three times larger than the average weight of 100kg per passenger and their luggage. This factor three difference is used to upscale the CAA passenger ton.km data, increasing its share in the total ton.km of passenger aircraft. A 10% uplift factor to correct for underestimations of emissions by the AEIG (2006) methodology compared to real-world fuel consumption is directly included in the emission factors. The emission factors obtained by this methodology are then multiplied by an additional uplift factor of 9% following IPCC (1999, Ch. 8.2.2.3), so as to scale up Great Circle Distances to take into account indirect flight paths, delays and circling. It is stressed that this uplift factor is applied separately from the first uplift factor of 10% discussed above. Table 1 below shows the emission factors for air freight transport discussed above.

Table 1: Air Freight Transport Conversion Factors (DEFRA 2008)

Length of flight	**Kg Co2 per ton.km**	**Km uplift factor**
Domestic	1.898	109%
Short-haul international	1.316	109%
Long-haul international	0.606	109%

Distance traveled

To determine the flight distance between Kenya and the Netherlands, the flight distance calculator from the Great Circle Mapper (2010) will be used. The distance is given as 6222 kilometers from Jomo Kenyatta Airport near Nairobi, Kenya to Schiphol Airport near Amsterdam, the Netherlands.

3.1.2- Methodology and data for transport by road

Emissions factors

The DEFRA emission factors for road transport are based on 2006 road freight statistics from the UK Department for Transport (DfT) based on a survey on the average miles per gallon and average loading factor for different sizes of Heavy Goods Vehicles (HGV), combined with test data from the European ARTEMIS project showing how fuel efficiency, and hence Co2 emission, varies with vehicle load (DEFRA 2008[b]). Using the standard fuel conversion factors given in DEFRA (2008[b]), miles per gallon are converted to kilograms Co2 per kilometer while taking into account the percentage loading per truck on weight basis derived from the Dft statistics mentioned earlier.

For road transport of Spanish and Dutch tomatoes, it can be safely assumed that the relevant DEFRA emission factors, being based on transport in the UK, can be generalized. The quality of the roads and the trucks is thus assumed to be comparable. For road transport within Kenya, i.e. from the production location to Nairobi airport, this is slightly more difficult. The roads are known to be of bad quality and the Kenyan government agencies do not maintain databases on the composition of the fleet, the capacity energy use etc. (World Bank, 2005). What is known is that the transport of produce destined for international trade is generally done by large firms, who sporadically buy new trucks but generally buy second hand, three year old trucks from Europe that are at the end of their leasing period (World Bank, 2005). This means that the fleet used for the road transport of produce meant for international trade is relatively modern. As this is the only clue available about the type of trucks used, it will be assumed that the emission factors for freight transport set up by DEFRA (2008[a] and 2008[b]) are applicable. Additionally, to be able to compare the results better, the best practice is to use the DEFRA emission factors for all transport modes. Another complication arises as precise information on the average size of the trucks in use is not available. The most reliable figure that can be found is from GlobalHort et. al. (2010), stating that the 10 largest transport companies together own 125 trucks with the capacity to transport 719 tons of horticultural products a day. Assuming that each truck can make one trip a day from the production location to the airport of Nairobi, it can be concluded that the average capacity per truck is equal to 5.75 tons. For the sake of comparability, mentioned truck weight of 5.75 tons will be assumed for Dutch and Spanish road transport. To assure that the results specifically reflect emissions attributable to tomato transport, we finally assume that trucks are loaded with tomatoes at 100% on the way to delivery, but go back to the point of departure laden at 0%. The relevant emission factors for road transport computed by DEFRA are shown in table 2 below.

Table 2: Emission Factors of Road Freight Transport (DEFRA 2008)

Gross vehicle weight (tons)	% weight laden	Kg Co2 per ton.km
>3.5-7.5	0%	0.525
	50%	0.571
	100%	0.617
	41% (UK average)	0.563
>7.5-17	0%	0.672
	50%	0.768
	100%	0.864
	41% (UK average)	0.747
>17	0%	0.778
	50%	0.949
	100%	1.119
	41% (UK average)	0.969

Distances traveled

The average distance traveled by tomatoes has been calculated per producing country. Please refer to Appendix 1, 2 and 3 for the detailed tables on the distances per country. In Kenya, the complicating factor was that there is little information available that can be used to determine which production areas produce tomatoes for the export market as tomatoes are only a minor export crop (Maush et al., 2006). PKF Consulting and International Research Network (2005) have prepared an overview of the production areas of vegetables and fruits in Kenya. In their paper they do not count tomatoes as an export crop, probably due to its minor importance relative to e.g. French beans. Their research does show that tomatoes are produced in a large portion of the Kenyan rural areas, most of which do not produce anything for the export market. Only a few major areas in Kenya produce for the export market. Thus, assuming that production for the export market is restricted to these areas, I chose to define the relevant production areas for Kenyan export tomatoes as those areas that, according to previously mentioned paper, produce tomatoes for the domestic market as well as other crops for the export market. Consequently, the distance between each relevant production area and Nairobi airport was determined so as to obtain an average distance. This approach is not optimal but seems to be the only option given the available data.

For the calculation of the distances traveled by Spanish tomatoes to the Netherlands and Dutch and Kenyan tomatoes within the Netherlands, the location of the Dutch consumer markets had to be defined. For this, I assumed that that all Dutch consumer markets are located in the 20 largest cities of the country. Consequently, I collected data on the distance from Schiphol Airport to these cities. Finally, I computed a weighted average of the distances based on the number of inhabitants per city compared to the total inhabitants of the 20 cities. This was done under the assumption that the more inhabitants it has, the larger a city's need for tomatoes and thus the larger the percentage of tomatoes transported to this location. The points of departure are straightforward: Kenyan air freighted tomatoes arrive at Schiphol Airport, and are further transported by road to the Dutch consumer markets. The Spanish tomatoes are transported from Almeria and Murcia. We computed an average distance from these two production locations to the Dutch consumer markets as defined above. Finally, the Westland has been chosen as the reference for the origin of Dutch tomatoes as it is by far the most important area for productionn of tomatoes in the Netherlands.

3.1.2- Results obtained

Results for airborne transport

Following the data and methodology discussed above, I will now show the calculations and results for the Co2 emissions from transport of tomatoes derived from the methodology discussed above. Concerning the emission factors for air freight, there is no globally agreed upon definition for long-haul and short-haul international flights, but the flight distance between Kenya and the Netherlands can be safely defined as long-haul. Thus this is the emission factor that is relevant for our calculations. From the DEFRA conversion factors for air freight transport presented in table 1, the following equation for long-haul transport can be derived:

$$y = d \times 0.606 \times 1.09$$

Where y is the kg Co2 emitted per kg of tomatoes produced and d is the total distance travelled in kilometers per ton tomatoes.

Results for transport by road

From table 2, the relevant emission factors for road transport are 0.617 kilogram Co2 per ton.km on the way to delivery and 0.525 kilogram Co2 per ton.km on the way back. These factors are derived according to the assumptions made in the previous section on truck weight and percentage load. The following equation can thus be derived for the calculation of emissions from tomato transport by road:

$$y = \frac{0.617d + 0.525d}{5.75}$$

$$y = \frac{1.142d}{5.75}$$

Where y is the kg CO_2 emitted per kg of tomatoes produced and d is the total distance travelled in kilometers per ton tomatoes. Following the two equations for air and road freight discussed above, we now present all results from the calculation of the emission of Co2 from transport of tomatoes in table 3:

Table 3: Emissions from transport (in kg. Co2 per ton tomatoes)

	Average distance	**Kg. Co2 per ton tomatoes (rounded figures)**
Kenya		
Air freight from Kenya to the Netherlands	6662	4400
Road transport within Kenya	605.8	60
Road transport between Schiphol Airport and Dutch consumers (back and forth)	157.3	15
Total emission		4475
Netherlands		
Road transport between Westland and Dutch consumers (back and forth)	175.4	100
Spain		
Road transport between Almeria/Murcia and Dutch consumers (back and forth)	4442.4	441

3.2- Emissions from production

In this section I discuss the emissions caused by the production of tomatoes in the Netherlands, Spain and Kenya. In section 3.2.1, I provide an outline of the methodology used for the calculations, after which section 3.2.2 will show the results.

3.2.1- Data and methodology

In a comparison of the Spanish and Dutch horticulture industry, Van der Velden et. al. (2004) thoroughly analyzed the energy use of the sector for the two main horticulture centers in Spain, Almeria and Murcia, and in the Netherlands. They base their estimates on a literature review, information obtained from relevant websites and organizations operating in the sector and interviews with sector experts. From the data obtained through their research, Van der Velden et. al. (2004) have converted the energy use into natural gas equivalents. These are shown in table 4 below. As the authors consider heating for the production of tomatoes in Spain as being near-inexistent, energy use for heating has not been included in their calculations for the Spanish horticulture. It has to be noted that the figures for Spain are based on best scientific guess, as obtaining objective quantitative data appears to be difficult in Spain (Van der Velden et. al., 2004).

Table 4: Energy use in natural gas equivalents of Spanish and Dutch tomato production (Van der Velden et al., 2004)

Production area	Physical production (kg/m^2)	Energy for cultivation (m^3 g.e./m^2)
Almeria (Spain)	9	0.3
Murcia (Spain)	8	0.3
Netherlands	50	57.1

g.e. stands for natural gas equivalent

Concerning production of tomatoes in Kenya, it is difficult to find reliable information on the production process, the energy use or Co2 emissions from growing fruits and vegetables in Kenya, let alone for tomatoes specifically. Some clues can be derived from Gikunju Muuru

(2009), who states that 60% of all fruits and vegetables exported to the EU originate from smallholder farms. Most, if not all, energy used in their production process can be expected to be human energy, and thus not significant causes of Co2 emissions. Some sources suggest modest starts in the use of greenhouse horticulture, but the goal of these greenhouses is only to reduce crop losses due to pests and there is no heating (USAID Kenya issue #19). As even the large commercial farms are very labor intensive (Gikunju Muuru, 2009), it is assumed that for the purpose of this paper that the Co2 emitted due to production of tomatoes in Kenya are negligible enough to be equalized to 0.

3.2.2- Results

For the purposes of this paper, the energy use in m^3 natural gas equivalents per m^2 of production area has been converted to kilograms Co2 per ton of tomatoes produced. Marland and Turhollow (1991) take the net CO2 emissions attributable to natural gas as being equal to 13.78 kg Co2/GJ (Co2 per GigaJoule). Now following the common conversion guidelines for converting GJ to cubic meters of natural gas, 1 cubic meter of natural gas is taken to be the equivalent of 0.038 GJ (Natural Resources Canada, 2006). This leads to the following equation:

$$z = 13.78 \times 0.038 = 0.52364$$

Where z is the Co2 emitted by 1 m^3 of production area. Following equation will then be used to determine the Co2 emissions in kilograms per ton of tomatoes, defined as y.

$$y = \frac{z \times m}{q} \times 1000$$

Where m is the energy use in natural gas equivalents per m^2 and q is the physical production per m^2, both derived from table 4. This fraction is multiplied by 1000 to obtain the results per ton tomatoes.

Table 5: Co2 emissions of tomatoes produced in Spain and the Netherlands

Production area	Kg. Co2 per ton from production
Almeria (Spain)	17.50
Murcia (Spain)	19.60
Spain average	18.55
Netherlands	598.00
Kenya	0

As mentioned before, the Co2 emission from production in Kenya is assumed to be zero

3.3- Summary of the results obtained

My findings, summarized in table 6, suggest that tomatoes currently imported from Kenya indeed cause significantly larger emissions of Co2 than if they were sourced locally in the Netherlands. Tomatoes produced in Spain for the Dutch consumer market have the best environmental performance in terms of Co2 emissions. Dutch tomatoes cause slightly less than 1.5 times the Co2 emitted by the Spanish tomatoes while this is more than a factor 9 for the Kenyan tomatoes. If this study would limit itself to the results obtained so far, the conclusion would be clear cut: In light of reducing global Co2 emissions, it is a better choice for Dutch consumers not to consume tomatoes sourced in Kenya. Tomatoes sourced in the Netherlands are not the best option either, due to the high emissions from production in greenhouses because of the relatively cold climate. The best choice is thus to consume tomatoes sourced in Spain.

Table 6 summary on findings Co2 emissions

Country	Kg. Co2 per ton from production	Kg. Co2 per ton from transport	Total
The Netherlands	598	17	615
Spain	37 *(17.50 + 19.60)*	441	478
Kenya	0	4476 *(75.38 +4400.52)*	4476

Chapter 4- Discussion

In this section, I discuss the implications of the results found. Additionally, I propose a way to induce Kenya to reduce the disproportionately high emissions from its tomato export.

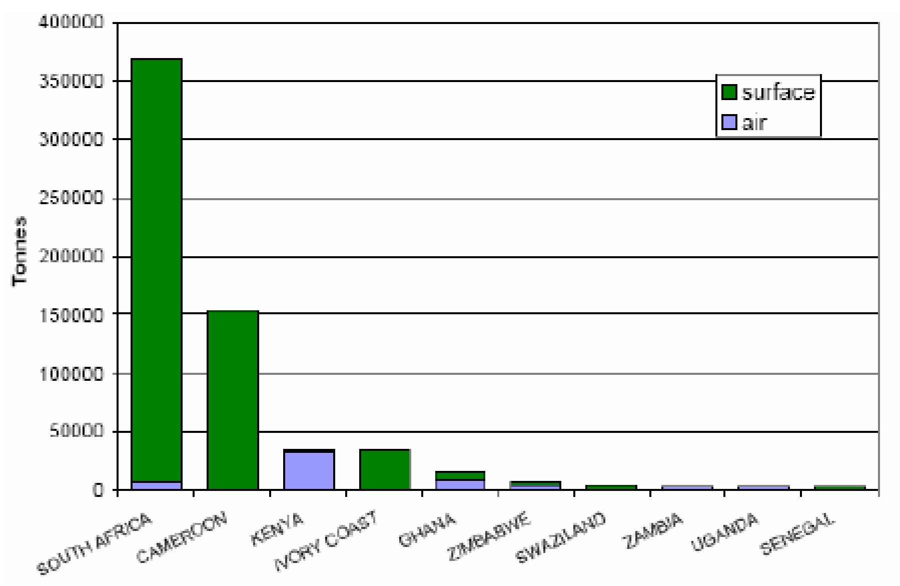
4.1- The development benefits of Kenya's tomato export

As discussed in the summary of the previous section, Kenyan tomatoes are currently the worst consumer choice in terms of Co2 emissions, while Spanish tomatoes are the best choice. This is true for the current situation, without taking into account the development benefits for Kenya. Presently, the export of vegetables to developed countries is an important source of income and economic development for developing countries (Minot and Ngigi, 2004; McCulloch and Ota, 2002; Otieno et. al. 2009). Horticulture is seen as one of the best opportunities for these countries to reduce poverty, which is proven in the case of Kenya as horticulture export accounts for about 23% of the country's earnings (KCBS, 2006). McCulloch et al. (2002) find that Kenyan households involved in export horticulture are significantly better off than those that are not. The Kenyan horticulture export can thus be seen as a very strong alternative for the large amounts of money that are donated to developing countries like Kenya every year. Besides the fact that it reduces the need for money donations, development of a country's own business activity is a much more effective and durable way to develop its economy, as it provides jobs and triggers investment. Additionally, it creates incentives for educated individuals to work in their home country instead of migrating to developed countries (Collier, 2009). Finally, the economic development of Kenya might increase its ability to deal with the problems caused by climate change. These costs are often gauged to be much higher for developing countries as they lack the means to properly prepare for all possible damages that might arise due to climate change (Stern, 2006).

4.2- Reducing Co2 emissions from Kenyan tomatoes

Ruling out the import of tomatoes or other horticultural products from Kenya would be the easiest way to reduce Co2 emissions of tomatoes consumed in the Netherlands, but, as was discussed above, it is not socially optimal. It would be better to find a way to reduce Co2 emissions from Kenyan tomatoes without damaging the country's economy. Consider figure 1 below, which shows that Kenya is the only one of the major fresh fruits and vegetables exporters in Sub Saharan Africa that still transports practically everything by air freight (Saunders and Hayes, 2007).The other major exporters of fresh fruits and vegetables, e.g. South Africa, Cameroon and Ivory coast, transport (practically) all of their produce by sea. This is made possible by controlled atmosphere techniques, allowing for perishable goods to be transported over long distances. I expect maritime transport to cause significantly smaller Co2 emissions and as Kenya does possess a seaport, which is located in the city of Mombasa, this option should be investigated. Hence, the following paragraphs will provide an estimate of the total Co2 emissions per ton tomatoes in the hypothetical case that Kenya would switch entirely towards maritime transport for its tomatoes.

Figure 1: Top 10 Sub Saharan Africa fresh fruit and vegetable exporters to the EU by mode of transport.



(Source: Wangler, 2006)

4.2.1- Co2 emissions of Kenyan tomatoes in case of a hypothetical switch to maritime transport

In table 7, the DEFRA emission factors for maritime shipping are shown. These are based on fuel consumption rates for engine power and speed associated with different vessels.

Table 7: DEFRA 2008 conversion factors for maritime transport:

Type of vessel	Vessel deadweight, tons	Kg. Co2 per ton.km.
Small tanker	844	0.020
Large tanker	18371	0.005
Very large tanker	100000	0.004
Small bulk carrier	1720	0.011
Large bulk carrier	14201	0.007
Very large bulk carrier	70000	0.006
Small container vessel	2500	0.015
Large container vessel	20000	0.013

The Co2 emissions from cooling tomatoes during transport deserve some attention. Until 2002, HCFCs (HydroChoroFuoroCarbons) were commonly used to refrigerate containers on ships carrying perishable produce. These gases contribute both to ozone layer depletion and global warming when released in the atmosphere and installations using this gas were thus prohibited on newly built ships by EU regulation as of 2005. Distribution of this gas was entirely prohibited as of 31 December 2009. By then, an innovation on HCFC, HFC (HydroFuoroCarbon) had already been widely adopted. Due to the elimination of Chlorine, HFCs did not contribute to the depletion of the ozone layer, but still had significant influence on global warming (Faber et. al., 2009). HFCs are now widely used as a refrigerator on sea vessels, but as of 2011, EU regulation will impose the installation of refrigerating devices using natural refrigerants. These cause negligible greenhouse gas emissions as they use gases that are already present in the atmosphere. An example of a natural refrigerant is Co2, which is tapped off as a byproduct from the ship's combustion engines and is thus completely neutral in terms of Co2 emissions (Visser, 2002; Faber et. al., 2009). Hence, the expectation is that, by 2020, emissions from cooling in maritime transport will be negligible despite the fact that the greenhouse gas emitting HFCs are currently still widely used.

I did not find satisfactory data as a basis for calculating the greenhouse gas emissions in Co2 equivalents from cooling in maritime transport per ton tomatoes. As this paper focuses solely on Co2 as a greenhouse gas, I will bear in mind the fact that cooling causes some emission of greenhouse gases. In the meanwhile, it appears from the above information that the future prospects are very promising in this field as greenhouse gas emissions from cooling are expected to be near inexistent by 2020.

The transport of tomatoes would be done on reefer ships in containers equipped with modified atmosphere technology. As DEFRA does not provide emission factors for reefer ships specifically, I will base my calculations on container vessels, specifically large container vessels, as the most common ships that call at small to medium-sized ports like Mombasa have deadweight of about 20000 tons (UNCTAD, 2000). From the itinerary calculator of Portworld (2010), it is known that the nautical distance between Mombasa port and Rotterdam port is equal to 11508 km. From table 7, we then derive the equation below, where d is the total distance traveled and γ represents the Co2 emissions in kilograms per ton tomatoes.

$$\gamma = 0.013d$$

To provide a complete image of the changes in Co2 emissions from this change in transport mode, I calculated the emissions caused by the road transport from the production location to Mombasa and from the point of arrival in the Netherlands, this time the Port of Rotterdam, to the retailers in the Netherlands. For the distance travelled in the Netherlands I followed the same reasoning as I did in the previous sections. The workings for the calculation of the distances between Kenyan producers and Mombasa Seaport and Rotterdam Seaport and the Dutch consumers can be found in appendix 4.

In table 8 I now present the Co2 emissions in the hypothetical case that all Kenyan tomatoes were transported by sea. It is again assumed that the trucks are laden at full capacity on the way to deliver the tomatoes and 0% laden on the way back.

Table 8: Total Co2 emissions when all produce is transported by sea

Itinerary	Average distance	Kg. Co2 per ton tomatoes
Between production location to Mombasa Port (back and forth)	1568.66	155.8
From Mombasa Port to Rotterdam Port	11508	149.6
Between Rotterdam Port and Retailers (back and forth)	109.11	21.7
Total kg. Co2/ton		327

4.2.2- Stimulating the switch to maritime transport of Kenyan tomatoes

Interestingly, it follows from the calculations above that, if the exporters would manage to switch entirely towards maritime transport, Kenyan tomatoes would become the best option in terms of global Co2 emissions reduction as a source for fresh tomatoes to be consumed in the Netherlands. In this scenario, the emissions per ton of Kenyan tomatoes are only 2/3 of the current emissions per ton of Spanish tomatoes, which are currently the best option. Based on the future scenarios for energy use of the Spanish and Dutch tomato production developed by van der Velden et. al. (2004), I expect the difference with Spain to increase significantly. The authors expect large scale introduction of heating in Spain to increase its productivity in the colder months of the year. As a consequence, the total energy use in the production process is expected to increase to an average of more than 18 m^3 natural gas equivalents per m^2 production area. For reference, I based my calculations of current emissions on a figure of 0.3 m^3. Concerning the Netherlands, Van der Velden et. al. (2009) expect reduction of the energy use through new technologies and more use of sustainable energy. However, this expected reduction is not large enough to compete with the low emission from Kenyan tomatoes transported by sea. In addition to being more sustainable, maritime transport would be less costly (Wangler, 2006). The competitiveness of Kenyan tomatoes on the world market would thus be improved market both in terms of minimizing Co2 emissions and in terms of transport costs.

MacGregor and Vorley (2006) report that certain industry participants are considering investing in technology to enable maritime transport, but achieving change in a relatively unstable, corrupt and underdeveloped country like Kenya is not an easy task (Collier, 2009). The developing countries in the world, Kenya included, claim to have the right to emit so as to achieve growth. This "need for equity and non-restrictive economic development for developing countries" is recognized by the Kyoto protocol of the UNFCCC. For this reason, the Kenyan government might not feel the need to induce change so as to reduce the country's global Co2 emissions. Consequently, I argue that outside intervention is necessary in the form of a tax on air freighted Kenyan tomatoes imported to the EU, which will be abolished for any tomatoes imported by maritime transport. The previous should be introduced as a condition for free entry of tomatoes to EU markets in the continuous Economic Partnership Agreement (EPA) negotiations between the EU and Kenya. The most recent EPA between Kenya and the EU has been signed in 2008 as part of the Cotonou agreement, and still imposes a 25% tax on tomatoes and other Kenyan horticulture products like green beans and mangetout (EAC-EPA, 2008). The current argument in favor of this tax employed by the EU is that the EU producers of these goods still need protection from outside competition. But if the policy proposed by this paper is successful, I argue that the outcome would lead to greater efficiency in global tomato production as the import from Kenya would be cheaper and would benefit global Co2 reduction. It has to be noted that, for the proposed policy to be successful, the level of the current import tax of tomatoes might have to be altered. The reason for this is that it will not be optimal for Kenyan exporters to change transport modes if the costs of this change are higher than if they would keep doing business as usual. Further research should thus determine the appropriate level of the proposed tax.

There is an ethical argument involved with the idea proposed above, i.e. imposing a tax to induce change in another country affects the country's sovereignty. This might be true, but imposing this kind of change on Kenya would benefit the country in many ways. Firstly, maritime transport is a cheaper transport mode than airborne transport, and thus would improve the competitiveness of Kenyan horticultural produce on the world market. This argument is especially valid for tomatoes, as one of the reasons that it is not a major export crop is that it relatively heavy and thus more costly to transport by airplane than e.g. green beans (PKF Consulting and International Research Network, 2005). Secondly, Kenya would get a chance to contour European protectionism and thus enjoy fair competition against EU producers. Thirdly, Collier (2009), in his ground breaking book on African economies and their pitfalls, argues that outside intervention is sometimes the only way to help a country develop. The proposed policy thus seems justified, but I recommend further research aimed at investigating the feasibility of such a policy as well as the details on how to implement it.

4.3-Limitations

This study is not exhaustive due to certain limitations. The most important one is the lack of data availability on the Kenyan production processes and the technologies employed in the road transport sector (cooling facilities, type of trucks, and quality of the roads). There probably are some Co2 emissions involved in the Kenyan production process, though it can indeed be expected to be very low relative to heated greenhouses. The use of the DEFRA emission factors for road transport in Kenya probably leads to underestimation of the actual Co2 emissions, as the relatively bad quality of the Kenyan roads, compared to those in the UK on which DEFRA bases its calculations, might lead to higher actual emissions.

This study focuses solely on Co2 emissions. While Co2 is the most important greenhouse gas, other greenhouse gases might be involved in the production and transport of tomatoes. Additionally, the use of pesticides in the production of tomatoes has not been considered. From the sector overviews given in chapter 2 of this paper, it is known that a large amount of chemical pesticides are used in the Spanish production processes. Although no clear documentation of pesticide use in Kenya has been found, it can be expected that the low technology integration necessitates the use of chemical pesticides as well. In the

Netherlands, on the contrary, biological pesticides such as beneficial insects have almost entirely ruled out the use of chemicals. If pesticides had been included in our research, the environmental performance Dutch tomatoes might thus have been positively influenced relative to those produced in Kenya and Spain.

As a final remark, one should be careful when generalizing the results and policy recommendations to the entire horticulture sector. The energy necessary for production, and thus the Co2 emitted, strongly varies per crop (Van der Velden et al. 2004). As a consequence, the results of a similar study focused on another crop than tomatoes might lead to entirely different conclusions.

Chapter 6- Conclusion

This paper has determined the Co2 emissions from production and transport of tomatoes sourced in the Netherlands, Spain and Kenya for consumption in the Netherlands. In the current situation, Kenyan tomatoes cause by far the largest amount of Co2 emissions due to their use of airborne transport. Spanish tomatoes appear to cause the smallest amount of Co2 emissions as its producers employ little heating relative to the Netherlands and road transport is employed instead of the airborne transport employed by Kenyan exporters. In the current situation, the best option for consumers in terms of Co2 emissions is thus to choose to buy Spanish tomatoes. However, it might not be socially optimal to stop consuming Kenyan tomatoes. The export of tomatoes and other horticulture products is a significant opportunity for a developing country like Kenya to achieve economic growth. The horticulture export accounts for 23% of the country's earnings and is still growing steadily. Avoiding to cut spending on Kenyan tomatoes and other horticulture produce thus reduces their dependence on donations from developed nations, thus benefiting these developed nations too. Additionally, the ratios for Co2 emissions discussed above are expected to change according the future scenarios discussed in this paper. Spain will see its energy use increase significantly in an effort to improve its productivity per square meter while the Netherlands will struggle to reduce their emissions through new technologies and the use of more sustainable energy. Kenya, on the contrary, has the potential to decrease its Co2 emissions to such a level that its tomatoes would become the most competitive of the three countries in terms of minimizing Co2 emission, while reducing transport costs.

The improvement of the environmental performance of Kenyan tomatoes can be achieved by redirecting Kenya's transport network in such a way that all tomatoes can be transported by sea. However, as is stated by the award winning development economist Collier (2009), it might be difficult to achieve such drastic change in developing countries like Kenya. Consequently, I propose a tax on air freighted tomatoes imported into the EU, to be abolished for any Kenyan tomatoes imported by maritime transport. This should be included as a condition in the ongoing negotiations for free access of, specifically, Kenyan tomatoes to EU markets. With some caution due to possibly different outcome for other crops, this statement could be generalized to other horticultural products. If the policy proposed in this paper is successful, the benefits will be two-sided: Global Co2 emissions from tomatoes will decrease drastically and Kenya's economy will flourish as a consequence of increased competitiveness of their tomatoes on the world market.

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Appendix

Appendix 1- Weighted average distance from Spanish producers to Dutch consumers

Cities	Number of inhabitants	Distance from Almeria	Distance from Murcia
Amsterdam	752120,00	2357,00	2158,00
Rotterdam	537990,00	2297,00	2085,00
The Hague	481860,00	2324,00	2111,00
Utrecht	260810,00	2325,00	2112,00
Eindhoven	212270,00	2251,00	2039,00
Almere	185750,00	2361,00	2149,00
Tilburg	184470,00	2271,00	2059,00
Groningen	181150,00	2497,00	2285,00
Nijmegen	150630,00	2304,00	2091,00
Haarlem	148190,00	2371,00	2158,00
Arnhem	143770,00	2230,00	2117,00
Breda	141750,00	2257,00	2044,00
Apeldoorn	139740,00	2362,00	2150,00
Enschede	134100,00	2337,00	2165,00
Amersfoort	130410,00	2343,00	2131,00
Zoetermeer	120880,00	2320,00	2107,00
Dordrecht	118410,00	2279,00	2066,00
Leiden	116790,00	2336,00	2123,00
Maastricht	115500,00	2170,00	1957,00
Zwolle	115310,00	2396,00	2183,00
Total	4371900,00		
Weighted average		2324,02	2118,33
Spain average			2221.175

Distances obtained from maps.google.com

Appendix 2- Weighted average distances of transport within the Netherlands

Cities	Number of inhabitants	Distance from Schiphol Airport (arrival location air freighted Kenyan tomatoes)	Distance from Westland (Dutch producers)	Distance from Rotterdam Seaport (arrival of maritime freighted Kenyan tomatoes)
Amsterdam	752120,00	17,80	69,50	103
Rotterdam	537990,00	60,30	26,20	35,7
The Hague	481860,00	45,30	12,40	54,8
Utrecht	260810,00	50,40	77,80	101
Eindhoven	212270,00	127,00	140,00	137
Almere	185750,00	42,40	94,10	138
Tilburg	184470,00	118,00	107,00	105
Groningen	181150,00	192,00	243,00	280
Nijmegen	150630,00	162,00	138,00	136
Haarlem	148190,00	21,60	68,80	102
Arnhem	143770,00	108,00	129,00	140
Breda	141750,00	112,00	75,20	72,9
Apeldoorn	139740,00	101,00	140,00	160
Enschede	134100,00	174,00	220,00	237
Amersfoort	130410,00	64,00	100,00	120
Zoetermeer	120880,00	39,40	25,10	58,7
Dordrecht	118410,00	85,60	49,20	46,9
Leiden	116790,00	32,00	33,00	66,6
Maastricht	115500,00	219,00	226,00	224
Zwolle	115310,00	124,00	163,00	183
Total	4371900,00			
Weighted average		**76,67**	**87,72**	**109,22**

Distances obtained from maps.google.com

Appendix 3- Average distances of transport within Kenya

Production area	Distance to Nairobi Airport (back and forth)	Distance to Mombasa Seaport (back and forth)
Embu	326	1324
Meru	520	1436
Nyeri	354	1326
Murang'a	218	1136
Busia	914	1886
Siaya	824	1798
Kakamega	790	1762
Bungoma	814	1786
Kisimi	692	1664
Average	605.8	1568.7

Distances obtained from maps.google.com