CRANFIELD UNIVERSITY

MICHAL ADAM KULAK

Use of Life Cycle Assessment to Estimate Reduction of Greenhouse Gas Emissions from Food through Community-supported Urban Agriculture

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Innovation and Design for Sustainability

MSc
Academic Year: 2009 - 2010

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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science

ABSTRACT

Currently, the production and supply of food is thought to account for as much as 20-30% of the greenhouse gas emissions in the UK. The government and environmentally-oriented Non-Governmental Organizations are seeking to reduce the environmental burden of food production. Local community farms in urban areas may provide one possible option.

This study used Life Cycle Assessment to estimate the potential savings of food-related greenhouse gas emissions that may be achieved with the implementation of an urban community farm and identified strategic elements of the local food production system that could be used to maximise reductions of greenhouse gas emissions. The results showed that the local food production and distribution scheme in the urban fringe could bring considerably diversified reductions depending on the crop. The greatest reduction was by crops providing the highest yields and supplied to shops throughout the year from energy-intensive production systems such as greenhouses. As monocultures on the community farm are not envisaged, mixed cropping scenarios were also examined as well as the possibility for the further development of the scheme over the local, derelict land. These showed that a pattern of land use that aimed to optimise greenhouse gas reductions within local market requirements resulted in a reduction of 85 t CO_2e ha^{-1} a^{-1}

The results envisaged that community farms can be used to help reduce the greenhouse gas burden associated with food production and supply in urban areas and that Life Cycle Assessment can be strategically used to examine the various available options.

Keywords: Life Cycle Assessment, local food production, urban agriculture, community farms, climate change, greenhouse gas

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1 INTRODUCTION

Since the 1970s, model predictions have highlighted the damaging consequences of the rapidly growing population (Meadows et. al. 1987) and there has been much debate over the direction that future development should take. Modern societies face many issues related to the overuse and degradation of natural resources, for example, water scarcity and contamination, eutrophication, acidification or extinction of species (Gardner et. al. 2008). One of the biggest challenges for the near future is seen to be climate change (IPCC 2007, Gardner et. al. 2008). It has been suggested that to reduce environmental degradation, there is a need for innovation that can bring rapid improvements in resource productivity (Reijnders 1998, Weizsacker et. al. 1998). Food production is a sensitive topic, since it has been argued that effective cuts of emissions cannot be easily achieved to reduce natural resource degradation as food is essential for human life (Steinfeld at. al. 2006).

Meeting food requirements for an increasing global population is considered to be one of the greatest threats to the state of global natural resources. Some of the significant negative impacts of modern agriculture are methane emissions from livestock breeding (Steinfeld et. al. 2006), nitrous oxide released as a result of fertilizer applications (Houghton et. al. 1997, Kroeze et. al. 1999), greenhouse gas (GHG) emissions from the energy-intensive production of fertilizers (Carlsson-Kanyama 1998), eutrophication due to the leakage of nutrients, acidification of soils and water (USEPA 1996, RIVM/UNEP 1997, Environment Agency 2000), and losses in biodiversity (Myers 1992, Wilson 1992). Agriculture forms only part of the food chain and there are many other environmental impacts associated with food production and consumption when a full life-cycle perspective is taken. As a result of globalization and free trade much of the food consumed in the western world is transported over long distances before reaching the end user. This has raised concerns over food transport-related emissions of GHG, which are described as "food-miles" (Paxton, 1994). Additionally, the food processing, packing, retailing, cooking and preparation, food waste disposal, digestion and wastewater treatment are all sources of negative environmental impacts related to food consumption. Studies taking into account product life cycles reveal that eating is responsible for as much as 20-30% for major categories of environmental burdens in Western Europe, including emissions of GHG (Tukker et. al. 2006). In the UK, the food chain's share (including primary production, processing, and the retailing of food) of the total national carbon footprint has been estimated by researchers to be between 18% (Garnett 2008) and 19% (Cabinet Office 2008). The expansion of agriculture to satisfy the dietary requirements of modern society results in extensive land use change. When the deforestation and soil carbon losses associated with this land use change are included, food consumption has been estimated to account for as much as 30% of the country's GHG emissions (Audsley et. al. 2009).

Public policy has attempted to tackle diet-related GHG emissions in many ways, for example, by enforcing legislation, funding advisory bodies such as the Rural Climate Change Forum (DEFRA 2010a), publishing roadmaps aimed at establishing more sustainable supply chains for certain food commodities (DSCF 2009), and through funding of the relevant research

(Cabinet Office 2008). There is also a group of initiatives besides these top-down governmental interventions, which include the projects and actions undertaken by local authorities, environmentally-oriented non-profit organizations, and other community groups that contribute to minimizing negative environmental consequences of food production and consumption and tackle climate change at a local level. Chapter 23 of the United Nation's Agenda 21 states that including individuals, groups, and organizations in decision-making that potentially affects those communities is one of the fundamental prerequisites for the achievement of sustainable development (UNCED 1992). Community supported urban food growing projects provide examples of initiatives that may have a significant impact on reducing the environmental burdens of food consumed by people living in the cities. Martin and Marsden's (1999) survey of all 409 local authorities in England and Wales revealed that 24.1% of respondents had considered establishing urban food production initiatives in their community and 7.5% of local authorities had already developed strategies for promoting urban food production. The most established initiative of this type is the urban fringe farm, which is generally located on local authority land on an urban fringe, and is used for farming by the community or leased out for this purpose.

The modern community farming and gardening movement in the UK emerged as a result of concerns over the state of natural resources in the 1960's and a growing environmental ethic (Viljoen et. al. 2005). This was probably inspired by the rapid development of community supported gardens in the US, where environmentally oriented groups supported by local authorities promoted the use of open urban space for food production as a part of a newly found alternative lifestyle and the notion of self-sufficiency. The first British urban community farm was established in 1971 in Kentish Town, North London and by the 1990s more than 60 such projects were to be found all over the country (Hough 1995). Originally, they were located in poorer areas and were intended to be used as environmentally friendly tools for social and economic urban regeneration. According to the federation of City Farms and Community Gardens (FCFCG 2010) there are currently more than 50 such sites in London alone. These vary in size, objective, and commodity production, and include school farms, community gardens, community managed allotments, and city farms.

In February 2010, the first community farm was launched in the London Borough of Sutton, providing 7 acres of land (2.83 hectares) for the local production of fruit and vegetables. The initiative was founded by two local charities, Bioregional and Ecolocal, as a part of their “One Planet Food” programme (BioRegional 2010). The goal of the programme is to develop solutions that would provide Sutton citizens with access to healthy, local food commodities, and create a replicable example of a sustainable food system (BioRegional and EcoLocal 2010). The Sutton community farm aims to produce a range of commodities with minimal environmental impacts, in order to bring the diet of Sutton citizens to a more sustainable level. The organizations involved in managing the project plan to provide the food to Sutton residents with the use of a mobile distribution stall called the “VegVan”.

Several authors have attempted to evaluate community supported urban agricultural projects in the UK. Researchers have highlighted the contribution of such schemes to economic development, creation of jobs, and helping vulnerable groups (Garnett 1997, Garnett 2000, Quayle 2008, Holland 2010). Studies reveal that community farms and gardens provide citizens with exercise, leisure and healthier diets (Garnett 1997, Quayle 2008, Holland 2010). These projects are also valued for their educational role and for helping to raise environmental awareness (Garnett 1997, Quayle 2008), but few researches have attempted to evaluate the direct and potential impact of community farms and gardens on the environment. Garnett (1997) has pointed out that sustainable urban agricultural schemes reduce losses in biodiversity associated with conventional production by cultivating rare varieties of fruits and vegetables and creating wildlife habitats. The contribution of community farms and gardens to reducing waste has also been highlighted. Limited packaging is used for commodities that are produced this way, household equipment is often re-used on such sites, and locally produced compost reduces the amount of food waste going to landfill. Garnett (1997) also assumes that local production of fruit and vegetables reduces the emissions associated with food transport, distribution, and shopping, although the size of this reduction is not calculated.

In order to assess the effectiveness of an alternative food supply system in reducing the negative impacts of food consumption, a holistic view on the food chain is needed. Life Cycle Assessment (LCA) is a technique that allows for the quantification of environmental impacts associated with a product, service or activity throughout all stages of its life cycle (Fava et. al. 1991, Lee et.

al. 1995). LCA is often used in industry as a tool for process selection, design, and optimisation, to minimize environmental burdens of industrial activity and estimate the potential for further improvement (Azapagic 1999). LCA can also be used to quantify the impact of various food production options and Williams et. al. (2006) have developed a model to determine the environmental burdens associated with the different production systems of major agricultural and horticultural commodities in England and Wales. The technique can also be applied to comparison of different supply chains, taking into account differences in burdens associated with particular stages of their life cycle (Williams et. al. 2009).

Urban community farms and gardens often form a part of the food supply network in modern cities. The development of such schemes can have an impact on the rate of food-related GHG emissions and act as an experimental facility for testing different types of systems. However, environmental impacts will differ according to the design and management of the production process. LCA can therefore be used to aid the development of the community farm, by helping to select solutions with the highest environmental benefit.

This paper attempts to estimate the potential saving of food related GHG emissions that can be achieved with the implementation of an urban community farm. The Sutton community farm and its distribution network are used as a case study for the analysis. LCA is used to compare the quantity of GHG emissions related to the delivery of fruit and vegetables from the community farm with the emissions that arise with the delivery of the same products from conventional supplies. The paper also attempts to identify strategic elements of the local food production system that can be used to reduce GHG emissions and different community farm designs are tested to find the best solution. The approach provides a method that can be used elsewhere to study sustainable food supply systems for cities and test their contribution to GHG reductions.

2 MATERIALS AND METHODS

2.1 Definition of the scope of the analysis

To estimate the reductions of food-related GHG emissions from the community farm, a comparative analysis of the two supply systems was performed. It was assumed that fruit and vegetables produced by the farm form an alternative to the same commodities available at supermarkets. Figure 1 illustrates stages of the food chain which are estimated to have negative impacts on the environment (Muñoz et. al. 2010). Elements of the food chain that differ between the conventional and alternative approach had to be considered to quantify differences in GHG emissions. An assumption was made that distance from home to the mobile distribution point – the “Vegvan” was the same as to the local supermarket. In this case, the implementation of an urban community farm scheme provided changes across two stages of the food chain - the production stage and the wholesale and retail stage. These phases were therefore the subject of detailed analytical investigation. It is worth noting that research has shown that the primary production phase of the food supply chain is the most significant source of GHG emissions (Williams et. al. 2009, Tukker et. al. 2006, Muñoz et. al. 2010).

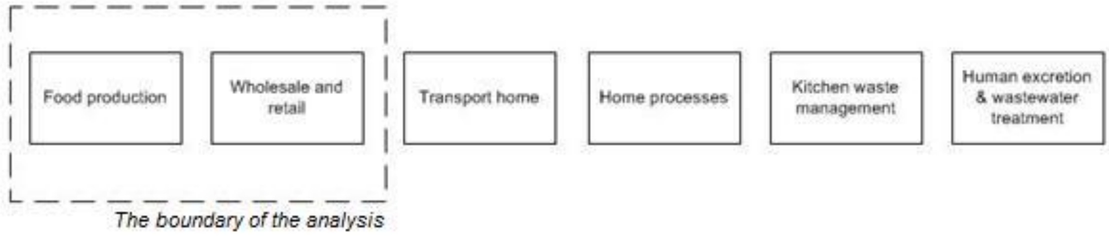

Figure 1 Stages of the food chain with negative impacts on the environment

2.2 System inventory

2.2.1 Field interview

A field research interview with the community farm manager was carried out to assist in building up an inventory of the system for analysis. The purpose of this research phase was to gather the quantitative data that could be used as an input for the LCA as well as obtain the broad spectrum of qualitative information to be used during the development and assessment of different scenarios. The field research interview technique was chosen for this purpose as it allows examination of the social meaning and understanding of multiple perspectives in the given social settings (Neuman 2003). Such an approach gives opportunity for better understanding of the decision-making context of the community farm design process. A semi-structured face-to-face interview approach was chosen for gathering the data (Robson 2002). Questions were pre-determined, but certain questions were omitted or modified during the process, if appropriate. Some explanation of the pre-determined questions was needed. Additional comments and suggestions by the interviewee were noted and taken into consideration.

The questionnaire schedule used during the interview includes an informed consent form signed by the participant prior to the interview (see Appendix A). Questions of a quantitative nature were designed to obtain the data on farming techniques, the use of raw materials and machinery, farm management and the product distribution processes that could be used for Life Cycle modelling. Qualitative questions were used to create deeper understanding of the determinants and implications of particular decisions over the community farm and food supply design process. This was crucial for developing scenarios and seeking solutions for further improvements.

2.2.2 Field observations

The additional data for the system inventory were gathered through direct informal observation. The technique was used for the inventory of the physical space needed for the technical farm infrastructure (roads, shed, warehouse). Community farms and gardens are projects of a multi-functional nature (Holland 2004). A participant observation technique was applied to understand the value of non-productive functions of the community farm that can have an influence on the design process. This was achieved by participation in the farm activities and interaction with volunteers.

2.2.3 Establishing the scope of comparative analysis

Based on the interview (see 2.1), observation (see 2.2), and literature review, a choice of 13 food commodities was made for which cultivation under the community farm conditions would be possible. Table 1 shows the variability of products and production systems that were considered for the community farm together with the estimated, achievable annual yields. As a result of the interview, only organic cultivation was considered as this was a stated objective for the community farm. Predicting yields is associated with uncertainty as yield levels depend on a wide range of conditions and variables. An extensive literature review was therefore carried out to select a set of conservative yield values. Table 1 includes the sources of data used for the estimation of yields.

Table 1 Commodities and projected annual yields for the organic cultivation in the UK

Commodity	Projected yield [t/ha]	Data sources
Organic potatoes	22.5	(Talbot 1984), (Lampkin et. al. 2002), (DEFRA 2008)
Tomatoes (polytunnel)	50	(Elbourne 2009)
Tomatoes (outdoor)	23	(Childers 2005), (Thomas et. al., 1977), (Elbourne 2009)
Lettuce	21	(Childers 2005), (Hospido et. al. 2009)
Peppers (outdoor)	20	(Childers 2005)
Apples	15	(Wiltshire et. al. 2009),
Carrots	36	(Lampkin et. al. 2002), (DEFRA 2008)
Onions	13	(Wiltshire et. al. 2009), (Lampkin et. al. 2002), (DEFRA 2008)
Cabbages	35	(Lampkin et. al. 2002), (DEFRA 2008)
Maize	10.1	(Talbot 1984)
Courgettes	60	(Childers 2005)
Beans	3.7	(Talbot 1984), (Childers 2005)
Pumpkins	10	(Childers 2005)
Spinach	0.5	(Childers 2005)

2.3 Inventory analysis and impact assessment

A comparative life cycle inventory was developed to estimate reductions of GHG emissions that could be achieved with the implementation of an urban community farm and its distribution network. The task was therefore divided into three stages: the community farm inventory analysis, the inventory of a conventional system and the calculation of potential reductions.

2.3.1 Community farm inventory analysis

Figure 2 presents stages of the alternative food supply system that has been developed with the establishment of the Sutton community farm.

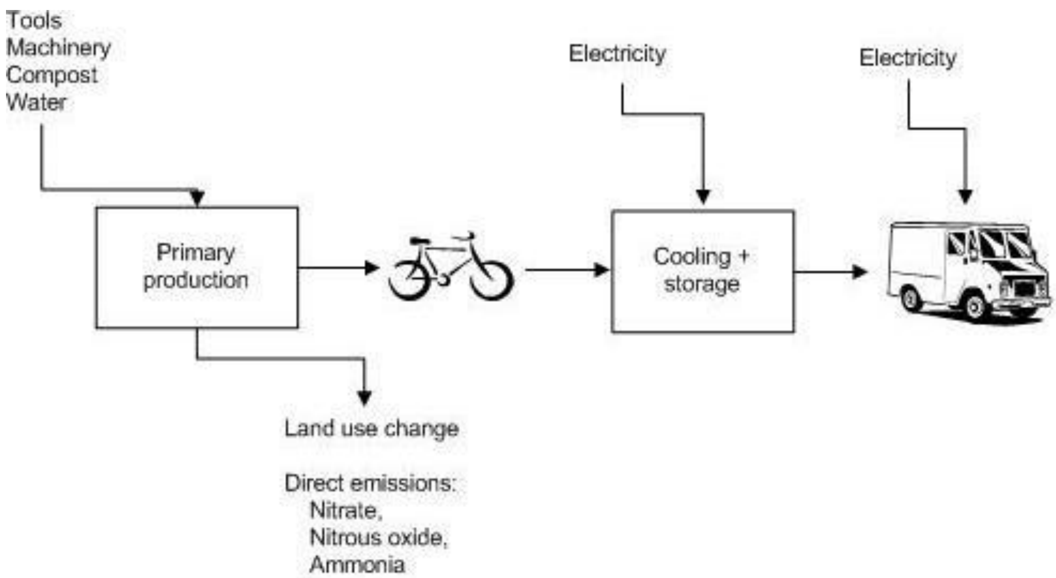

Figure 2 Alternative food supply system and analysed resource flows

2.3.1.1 Primary production

The values of global warming potential (GWP) from the primary production stage were modelled for the 14 commodity lines considered (see Table 1.). Values for potatoes, maize and beans were estimated using the software provided with the IS0205 model for LCA of major agricultural and horticultural commodities (Williams et. al. 2006). As the input data the information on cultivation techniques obtained during the interview at the farm was used. In the case of apples, the GWP values for organic cultivation were derived from the study by Williams et. al. (2009). Due to the lack of models for the outdoor cultivation of tomatoes in the UK the GWP from the primary production was conservatively assumed to be the same as Spanish and obtained from Williams et. al. (2009). The same as for Spanish tomatoes was assumed for courgettes, peppers and pumpkins as these commodities require a similar level of input. The GWP of the community farm-grown spinach and cabbage was assumed to be the same as for locally grown lettuce and obtained from Hospido et. al. (2009). Data on organic onions and carrots were derived from the study on applicability of the PAS 2050 standard for carbon foot-printing by Wiltshire et. al (2009). A detailed analysis of the energy and resource flows considered in all the LCA studies was performed in order to obtain the GWP values reflecting the farm conditions.

The environmental burdens related to the manufacturing and maintenance of polytunnels for tomatoes were taken into account. These values were calculated using the methodology of Warner et. al. (2010). The size of the polytunnel was assumed to be the same as that currently used at the community farm - 4.3 x 11 m. The size and thickness of the LDPE sheeting required for this polytunnel size was derived from information provided by the supplier- Highland Polytunnels Ltd (Highland Polytunnels 2010). The embodied GWP of the LDPE sheeting was estimated to be 2.34 t CO_2e t^{-1} of product, including manufacturing (Bousted 2003), landfill decomposition (Eggels et. al. 2001) and transportation. Transport distances for one-way journeys of goods were assumed to be 133 km. This is an average haulage distance in the UK for “miscellaneous manufactures” (National Statistics and DFT 2009). The use of a 38 tonne gross weight lorry was assumed for this purpose and DEFRA conversion factors were applied for the calculation of the GHG emissions from its use (DEFRA 2010b). The total embodied GHG emissions from the polytunnel sheeting were estimated to be 61 kg CO_2e. The embodied GHG emissions from the manufacturing of the 150kg galvanized, steel frame for the polytunnel (Berge 2009) and its transportation (DEFRA 2010b) were calculated to be 332 kg of CO_2e. The polytunnel sheeting was assumed to be changed every 5 years due to the mechanical damage, and the lifetime of the frame was assumed to be 10 years (after Warner et. al. 2010). As a result, the lifetime embodied GHG emissions from the application of the polytunnel at the community farm was estimated to be 45.4 kg CO_2e a^{-1}. As a polytunnel of this size provides approximately 40 square metres of growing space, the GHG emissions from its use was estimated to be 4.6 t CO_2e per one acre of land used by this type of cultivation over one year.

2.3.1.2 Refrigeration

During the interview, it was ascertained that all the harvested fruit and vegetables were transported from the community farm to the regional internal distribution centre in Wallington. Food commodities were then be chilled for approximately 12 hours prior to distribution. Refrigeration and storage processes cause indirect GHG emissions due to the consumption of electricity that is generated from fossil fuels. The energy consumption for the refrigerated storage of food commodities and the associated emissions of GHGes was calculated with the use of the data developed in Defra-funded project FO0405 (Tassou et. al. 2009) and the DEFRA GHG conversion factors (DEFRA 2010b). The cooling and storage of potatoes was included in the Cranfield Agri-LCI model (Williams et. al. 2006) so the refrigeration burden was not included for potatoes to avoid double-counting. The cooling of onions, maize and carrots was also omitted, as these vegetables were not chilled prior to distribution.

2.3.1.3 Distribution

The food commodities produced at the farm are distributed throughout the Sutton area with the use of an electric vehicle- the “Vegvan” which is a second-hand converted milk-float with a 60V battery. The vehicle travels approximately 15 miles a week and is charged from the regular grid electricity. Based on the data provided by the manufacturer of similar vehicles – Crompton Leyland Electricars Ltd (CLEL 1969), an energy use was calculated to be approximately 7kWh per week. The DEFRA GHG conversion factors (DEFRA

2010b) were applied to calculate the GHG emissions related to the vehicle's consumption of electricity.

2.3.2 The inventory for the conventional system.

To evaluate the environmental improvements from the alternative food supply system in Sutton, the emissions related to the consumption of the equivalent conventional food substituted by the community farm needed to be estimated. The conventional commodity (as opposed to the one supplied by the community farm) is assumed in the study to be an average of the same type procured for UK consumption and available in supermarkets throughout the year. This includes the average share of imported goods from the other European countries and the rest of the world, the share of organic and non-organic products as well as particular product varieties (such as classic loose and on-the-vine tomatoes). A study performed in 2006 by the National Consumer Council revealed that most British supermarkets provide imported fruits and vegetables during their UK growing season and in most cases no measures are implemented to promote the local product (NCC 2006). Figure 3 illustrates sources of GHG emissions from the conventional supply chain from primary production through to wholesale and retail.

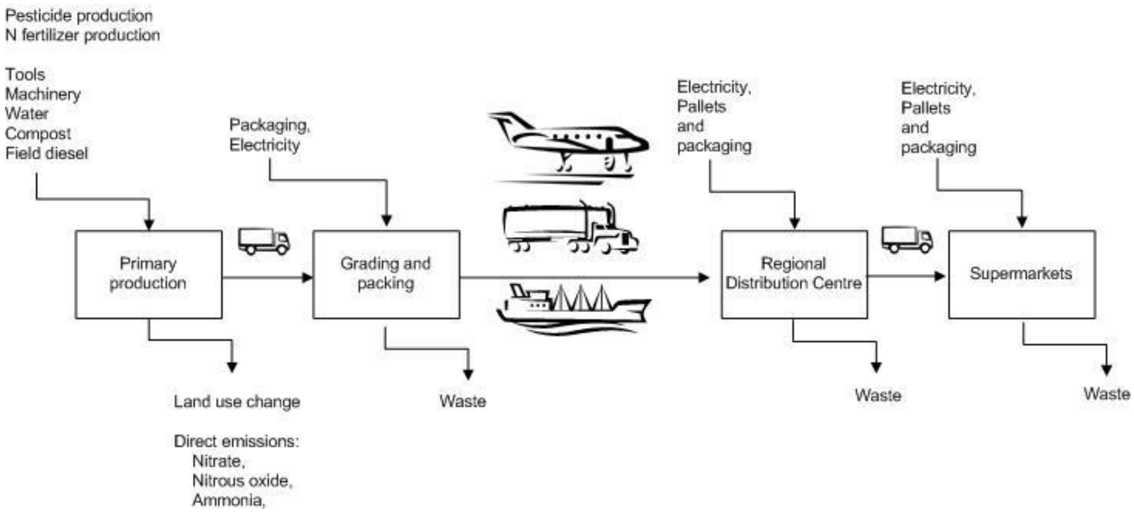

Figure 3 Emission sources in conventional supply chains for fruits and vegetables

2.3.2.1 Primary production and delivery to the Regional Distribution Centre (RDC).

The GWP from primary production and delivery to the regional distribution centre (RDC) of products equivalent to the goods produced at the community farm were derived from a comprehensive analysis of Audsley et. al. (2009). The boundaries and assumptions of the study were examined and cross-checked to ensure compatibility with the models used for the calculations of GHC emissions from the community farm (see 3.1.1.). The scope included emissions associated with all material inputs such as the production of fertilizers, pesticides or compost, the production and the use of the machinery, tools and buildings, as well as of different types of transportation for the delivery of commodities to the RDC. The share of goods being imported from other European countries and the rest of the world was extracted from Food and

Agricultural Organisation (FAO) trade statistics for 2005 (FAO 2009) to link to the GWP values of the selected commodities and to estimate their average UK consumption. There is an indirect impact of conventional agricultural and horticultural production that should be considered - the GHG emissions from changes in land use. Audsley et. al. (2009) estimated total observed land use change along commodity lines for UK consumption and the contribution to GWP. Those emissions were also taken into account in the inventory.

2.3.2.2 Emissions from the Regional Distribution Centre (RDC), wholesale and retail

This phase of the analysis involved the quantification of impacts from the RDC to the point where the product is ready to be picked up by the consumer in the local supermarket. This included the use of energy, fuel and refrigerants by the distribution centre, supermarkets, the use of pallets and packaging, transport emissions and the disposal of the food and other waste generated along the distribution chain. The embodied GWP values from this part of the food chain for the analysed food commodities were estimated with the use of a model developed by Tassou et. al. (2009). An assumption was made that the fruit and vegetables that are substituted by the equivalents from the community farm are sold and displayed at an ambient temperature. The breakdown of emissions associated with this stage of the food chain is presented in Table 2. The GWP of a gas is expressed as its impact on global warming over a set period of time in relation to that caused by carbon dioxide. The carbon dioxide by this definition has a GWP value of 1 (IPCC, 2007). The

GWP values of GHG's other than CO_2 in the present study are presented over a 100-year horizon.

Table 2 Estimates of GHG emissions from the RDC, wholesale and retail [kg CO_2e t^{-1} product].

Source of emissions.	GWP_{100}
Cooling [1]	0.1
Transport[2]	14.3
Retail Lighting	20.9
HVAC[3]	15.8
Plastic bags	8.3
Food waste (including transport)	9.8
TOTAL	**69**

[1] Refrigerated storage in the RDC.
[2] The use of 38 tonne Heavy Goods Vehicle. 190km total distance (see Tassou et. al 2009).
[3] Heating, ventilating and air conditioning.

2.3.3 Calculating the reductions

The reduction of GHG emissions from the delivery of a particular product by the alternative food scheme in Sutton (see Figure 2) was calculated at this stage of the study. This was achieved by estimating the difference between emissions of GHGs that are related to the delivery of a given quantity of product from both supply systems (see Figure 2 and Figure 3) up to the point of collection by the consumer. This was assumed to be the "Veg-van" for the alternative food supply system or the local supermarket for the conventional approach. The reduction in GHG emissions were linked to each stage of the supply chain to find out where the system could be optimized to provide the greatest benefits.

2.4 Improvement assessment through scenario assessment

As noted previously, the main aim of the study was to estimate the overall potential reduction of GHG emissions that could be achieved through a community supported local food production and distribution system. This was accomplished using different scenarios for the community farm land use. The process was divided into two stages: 1) the identification of strategic crop varieties, and 2) the modelling of GHG reduction for different scenarios.

2.4.1 The identification of strategic crop varieties

The goal for this stage of the research was to find crop varieties and cultivation techniques that had the biggest influence on the reduction of GHG emissions. This provided the foundation for designing the farm with the most efficient use of land in terms of GHG emissions. The research examined GHG reductions from the separate monoculture cultivation of 13 analysed commodities (see Table 1). As one acre out of the seven acres of the community farm was assumed to be necessary for farm infrastructure such as the tracks, paths, and equipment storage, six acres of land fully covered by cultivation were chosen as the total area for assessment.

2.4.2 The modelling of GHG reduction for different scenarios

Several approaches to the community farm land use were modelled to assess the potential reductions of GHG emissions. Five scenarios for the use of the 7 acres of land were generated to examine the variation in GHG reductions for the different scenarios. Scenario generation was based on crop diversification, ranging from monoculture cultivation of the most strategic commodities in terms of GHG emissions (Scenario 1) to the evenly diversified combination of all analysed crops (Scenario 5). As in Section 2.4.1 the cultivation was assumed to cover 6 acres of land with one acre left for the infrastructure.

2.5 Developing and testing the model for mass application

As the previous UK government has declared its support for initiatives related to sustainable food supply (HM Government 2010) it is likely that more community farms and gardens will be developed (Hough 1995, FCFCG 2010). According to the study by Sustain (Garnett 1999) there are at least 71 hectares of land in London that could be used for community farms and gardens in the near future and 1388 hectares of other vacant, derelict land. Appendix B presents results of the analysis on the use of open space performed on 8 selected Wards in the London Borough of Sutton. According to the study 26 ha of the land in the analysed area remains vacant. For this stage of the analysis, converting this total area to community farms was assumed. Assuming further development of community farms and local food distribution schemes could potentially result in overproduction for the local market. It was therefore necessary to assess seasonal consumer demand for fresh fruits and vegetables when considering the land use for the vacant land.

The population size of the analyzed area was estimated based on the most recent information provided by the Sutton council (Sutton Council 2010).

DEFRA Family Food Survey datasheets for the year 2008 (DEFRA 2010c) were used to quantify the consumption of particular fruits and vegetables by local citizens during the time of their practical availability from the community farm. The time of this availability was determined based on the duration of UK cropping seasons for analyzed food commodities, derived from studies on seasonal availability of UK-grown organic fruits and vegetables (Firth et. al. 2003, Firth et. al. 2005). An assumption was made, that courgettes produced at the local community farm can satisfy the demand for marrows, courgettes and aubergines from the local supermarket. Peppers, pumpkins, spinach and maize were not included as the demand for these crops is low- below 2 g per person per week (DEFRA 2010c).

Based on the results from the improvement assessment stage and the identification of strategic crop varieties (see Section 2.4.1.) the land use for the 26 hectares of vacant land was proposed focusing on the maximum reduction of GHG emissions without the overproduction of goods. This was done by maximising land use of the most strategic crops (i.e. those with the most potential to reduce GHG emission) till local and seasonal market demand was satisfied. One seventh of the total land area of 26 hectares was again assumed to be required for farm infrastructure.

3 RESULTS

3.1 Global Warming Potential

The estimates of GHG emissions related to the delivery of food commodities from both food supply chains is presented in Table 3. One kilogram of a ready-to-buy product at the point of collection by the consumer is used as the functional unit.

Table 3 Comparison of estimated GWP.

Commodity	GWP [kg CO_2e kg^{-1} product]	
	"Veg-van"	Local supermarket
Apples	0.11	0.71
Beans	0.54	6.17
Cabbage	0.21	0.39
Carrots	0.37	0.49
Courgettes	0.31	2.29
Lettuce	0.21	2.12
Maize	0.13	0.81
Onions	0.37	0.57
Potatoes	0.15	0.45
Peppers	0.31	4.67
Pumpkins	0.31	2.29
Spinach	0.21	2.29
Tomatoes (outdoor cultivation) [1]	0.31	1.57
Tomatoes (polytunnel)[1]	0.54	1.57

[1] The different assumed cultivation methods for tomatoes apply only to the community farm. GWP values for the conventional system are associated with the average quantity of different tomato varieties available for consumption in the UK (see Sub-section 2.3.2 The inventory for the conventional system).

The community farm and local food distribution scheme produced lower emissions of GHG than the conventional approach for all the commodities. Values differed by a factor of 15 for peppers or 11 for spinach and beans. The largest benefit was calculated for beans (a reduction of 5.63kg CO_2e kg^{-1}) and peppers (a reduction of 4.36 kg CO_2e kg^{-1}). The lowest change in GWP was calculated for carrots and cabbages (0.12 kg CO_2e kg^{-1} and 0.18 kg CO2e kg^{-1} respectively).

3.2 Achievable savings of greenhouse gas emissions from the production of food commodities.

The reductions of GHG emissions that can be achieved with an organic monoculture cultivation of different crops on the community farm are presented in Figure 4. Each bar represents 6 acres of land covered by the crop, as 1 acre of land was assumed to be left for the farm infrastructure (see Section 2.4.1.).

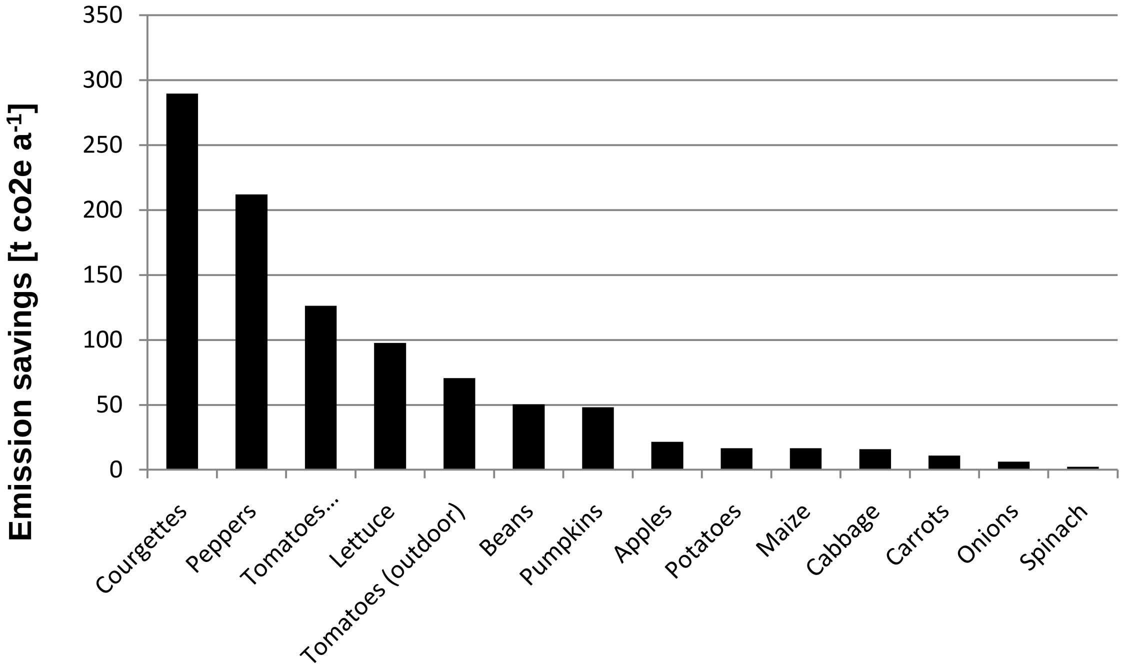

Figure 4 Emission savings from 6 acres of monoculture cultivation on the Sutton community farm

The results suggest that a monoculture of courgettes grown over the 6 acres of the community farm allows for the biggest carbon savings for the analyzed commodities – 290 t CO_2e a^{-1}. Significant reductions may also be achieved with the cultivation of peppers (211 t CO_2e a^{-1}) or by growing tomatoes in a polytunnel (126 t CO_2e a^{-1}). The lowest values were estimated for spinach (2 t CO_2e a^{-1}), onions (6 t CO_2e a^{-1}) and carrots (11 t CO_2e a^{-1}). There is a 145 fold variation in potential savings that can be achieved with the cultivation of courgettes and spinach and this demonstrates the potential importance of strategic selection of the crops that are to be grown on the community farm.

3.3 Reduction of greenhouse gas emissions from different scenarios

Figure 5 shows the food commodities and land use approaches chosen for each one of the modelled scenarios. Annual savings of GHG emissions that may be achieved with a particular farm solution are presented in Figure 6 with the contribution of particular crop varieties to the overall reduction.

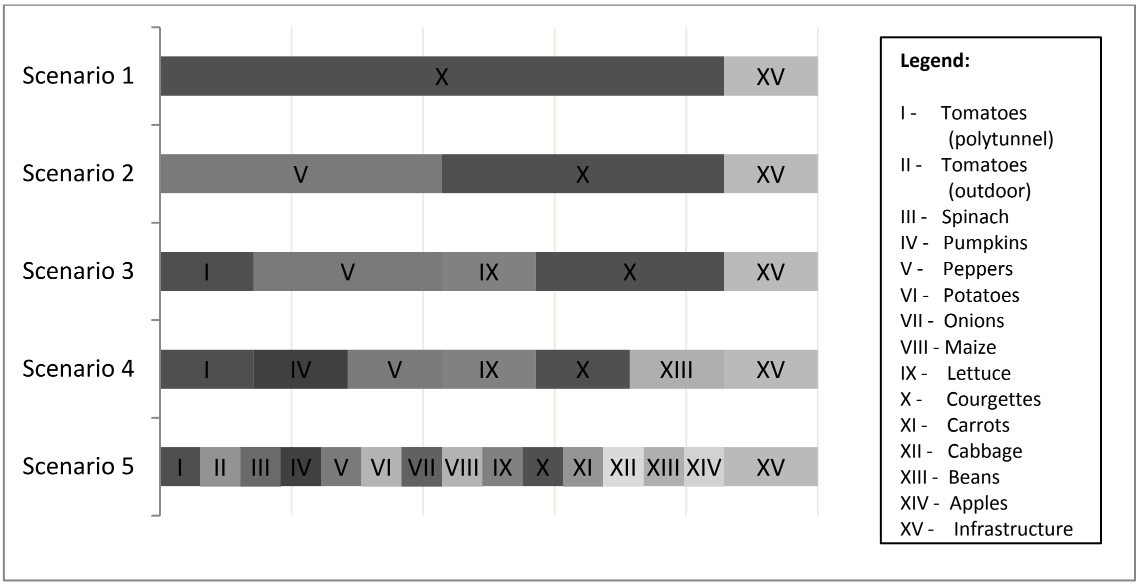

Figure 5 Proportion of land use for the different land use scenarios on the community farm

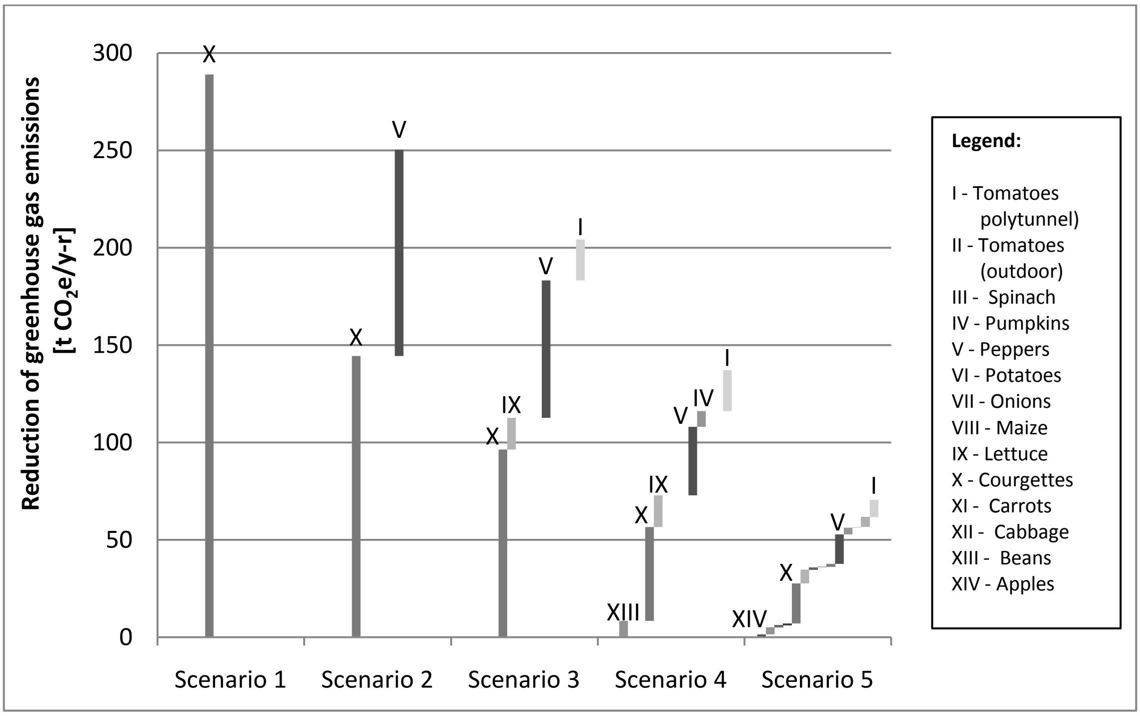

Figure 6 Emission savings from the five land use scenarios on the community farm

Annual emission savings from the different scenarios differ by a factor of four. The reduction ranges from 70 t CO_2e a^{-1} for the even distribution of all commodities across the land (Scenario 5) to 289 t CO_2e a^{-1} for the monoculture of courgettes (Scenario 1).

3.4 System expansion

Table 4 presents the proposed model for the use of the vacant land in the analyzed 9 wards of the London Borough of Sutton (see Section 2.5 and Appendix B).

Table 4 The proposed use of the vacant land in the London Borough of Sutton.

Land cover	Production season [weeks] [1]	The local, seasonal demand [tonnes][2]	Land cover [ha]
Courgettes	12	57	0.95
Tomatoes (polytunnel)	16	116	2.33
Lettuce	16	48	2.30
Beans	16	26	7.06
Apples	12	159	4.18
Carrots	32	282	5.48
Infrastructure	-	-	3.7

[1]UK cropping season for the organic cultivation (Firth et. al. 2003, Firth et. al. 2005)

[2] Data derived from the DEFRA Family Food Datasets (DEFRA 2010c)

Covering all the derelict land area with crops such as courgettes and peppers, that bring the biggest GHG reduction, would result in their over-production. The population of the 9 wards is estimated to be 81,677 inhabitants (Sutton Council 2010). The quantity of courgettes fully satisfying the demand of this population during the 12 week period of potential local production and distribution can be grown on as little as 0.95 ha. The local demand for tomatoes, lettuce, beans and apples during the time of their potential local production can also be fully satisfied with the use of the vacant land. In addition, 5.48 hectare was allocated to carrots, satisfying 70% of the consumer demand.

The analysis shows that converting 26 hectares of vacant land to community farms would allow 594 tonnes CO_2e to be saved each year, that would otherwise be emitted to the atmosphere, resulting in a saving of 85 t CO_2e ha^{-1} a^{-1}.

4 DISCUSSION

4.1 Environmental improvements

There are various reasons for the differences in GWP for both food supply systems (Table 3) that depend on commodity analysed. In practical terms, one of the main advantages of the community farm food production system over the conventional approach is in the different socio-economic conditions behind the decision-making process. The conventional supply chain is managed by private companies and the rules of the market. The fundamental responsibility of every business organization is to make a profit for shareholders and decisions are therefore made with this principal goal in mind (Friedman 1962). The community farm is managed by an externally- funded Non Governmental Organization and supported by the work of volunteers and community workers. This makes it independent of conventional economic conditions and allows for decision-making that is more environmentally than financially oriented, for example, when choosing crop varieties and methods of cultivation.

One of the main reasons for the difference in the GWP observed for both systems results from the energy-intensive production of some fruit and vegetables in the conventional system. All fully commercial UK tomato production occurs in heated glasshouses using significant amounts of energy and gas (Williams 2006, Williams 2009). Heat is required throughout the year to preserve the optimal growing conditions and almost all of the conventional production is based on hydroponic systems, requiring synthetic material inputs (Williams 2009). The same applies to the relatively high values of GWP for peppers. Although UK-grown outdoor lettuce is available during the season, a large share of the produce comes from domestic heated greenhouses operating all year round (Hospido et. al. 2009).

The second factor that significantly affects the carbon footprint of some horticultural commodities is transportation. As a result of globalised trade, a large share of fresh fruits and vegetables in British supermarkets come from distant locations on heavy good vehicles, ships, and planes. The conventional system also involves travel between distribution centres and the transportation of additional waste created in the supply chain (Figure 3). Although travel distance alone is not a sufficient basis for comparing the environmental burdens of products (Williams 2007, Edwards-Jones et. al. 2008), the analysis has shown that for certain items, transport has a crucial role to play. Almost 50% of green beans are shipped to UK from abroad, including air freight transport from Kenya (FAO 2009), and this is the biggest reason for the difference observed with the community farm supply (Table 3). A large proportion of apples are also shipped or air-freighted to the UK in-season and off-season. In the case of maize, courgettes, pumpkins, and spinach, almost 100% of the goods available in retail stores come to UK supermarkets from other European countries.

4.2 Strategic crop varieties and community farm design process

Considering GWP alone can be insufficient when selecting crop varieties and planning the land use for an urban community farming project. To maximise the reduction of GHG emissions it is necessary to choose the crop varieties and cultivation techniques that not only bring significant differences in

GWP but also provide the greatest outputs for those emissions. For example, courgettes were identified as a crop with the biggest potential to reduce carbon emissions (Figure 4) due to the relatively high yield that can be achieved on the community farm. For tomatoes, the calculations suggested that using polytunnels was preferable to outdoor cultivation, since the benefit from the increase in yields outweighed the emissions associated with polytunnel production and disposal.

If the reduction in carbon emissions were the only factor that influenced the community farm design process, the most beneficial solution would be to grow a monoculture of courgettes. However, community farms and gardens are projects of multifunctional nature, providing recreational and educational value for the local community (Garnett 1997, Quayle 2008). Maintaining this function is therefore important from a social perspective. By cultivating different crops, volunteers are able to learn skills that can be applied on their allotments or gardens. The monotony of tasks related to the cultivation of a monoculture could increase the risk of disinterest among volunteers and the loss of willingness to participate. Whilst crop diversification might have a negative impact on the quantity of emissions reduced (Figure 6), it is nevertheless important and possible to maintain balance and fulfil the multiple functions of the community farm. This can be achieved by strategic diversification – using multiple crops but choosing varieties that bring the biggest improvements per unit of land.

4.3 The development of the local food production and distribution schemes

Numerous research has suggested that community farms and other forms of agriculture may become an integral part of the urban landscape, as a sustainable food source for cities (Garnett 2000, Martin and Marsden 1999, Viljoen et. al. 2005). If community farms are to satisfy a large share of the needs for fresh fruits and vegetables during the season, product types and quantities need to reflect consumer demand. Such an approach limits the scope for management of carbon reduction with the choice of strategic crop varieties, since focusing only on carbon reduction, may result in local oversupply. Nevertheless, even when bearing in mind the local demand for farm products, it is still possible to use vacant suburban land for organic production of food crops, and reduce the GHG emissions by up to 85 t CO_2e ha^{-1} a^{-1}.

It is worth mentioning that Dewar and Cannel (1992) estimated the average carbon sequestration rate for young British forest plantations as 2-5 t C ha^{-1} a^{-1}. These estimates mean that approximately 7.3 – 18.3 tonnes of CO_2 are absorbed annually by one hectare of land. Given this, it is clear that a reduction of up to 85 t CO_2e ha^{-1} a^{-1} that could be achieved with local community farms in London is of significant value, exceeding the rate of carbon sequestration by covering the land with forests. The reduction of carbon emissions is therefore worth keeping in mind while communicating the benefits of urban community farms to the local planning authorities.

4.4 Future research and the way forward

There are several areas where future research is needed improve the methodological framework used here. First of all, the issue of seasonal variation in the conventional food chain needs to be examined. The calculation of GWP from the conventional supply chain is based on the FAO data on imports and exports of goods that are available for UK consumers throughout the whole year (FAO 2009). The community farm however supplies only seasonal fruit and vegetables. The availability of food of different origins in supermarkets differs according to the time of the year, and this is what influences their embodied GWP. In this analysis, this is important for lettuce, as there is clear variation in its GWP throughout the year (Hospido et. al. 2009). There is limited data on the share of organic fruits and vegetables that are being imported to UK throughout seasons (Firth et. al. 2003, Firth et. al. 2005). However, a study by the National Consumer Council revealed that imported goods were still available in British supermarkets during their UK growing seasons and in most cases domestic products are not especially promoted during this time (NCC 2006). Numerous studies reveal that domestic products do not necessarily have lower GWP than imported ones (Williams et. al. 2007, Audsley et. al. 2009). The actual life cycle quantity of GHG emitted as a result of the delivery of a food commodity differs depending on the applied cultivation methods (Warner et. al. 2010). Detailed analysis of sources of the food stock in British supermarkets over seasons would therefore need to be performed looking at the applied methods of cultivation rather than just the country of origin.

The life cycle embodied GHG emissions from the manufacturing and maintenance of the "Veg-Van" were beyond the scope of the analysis. Only the vehicle energy use was considered. Although the impact of the distribution phase of the product life cycle was estimated to be low in comparison with the primary production phase, LCA of the electric vehicle is nevertheless important in order to determine if this results in an environmental benefit over the use of a typical diesel van.

The results obtained from the Life Cycle inventories have an element of uncertainty to them. This is due to a multitude of factors. There are still limited background data for life cycle inventories of food commodities in the UK as the research is time-consuming and costly. Some assumptions were made where data gaps existed in relation to the food commodities grown on the farm (see Section 2.3.2). Assumptions have also been made by researchers analysing the conventional food supply system (see Audsley et. al. 2009), for example, very high uncertainty is associated with emissions estimates for land use change (Audsley et. al. 2009). More research is needed to fill these data gaps. There are also some uncertainties associated with other stages of the study methodology. The GWP conversion factors for different gasses have been revised three times since the IPCC First Assessment Report and these are still being investigated (IPCC 2007). Results of the study should therefore be treated with a degree of care, although the estimated values of the GWP and reductions in GHG emissions can still be used as an indicator of environmental impact and used for planning and decision-making.

The study approach may underestimate the potential of community-supported urban food-growing projects in the UK. The applied methodology covers only two stages of the food chain that were assumed to be influenced by the introduction of the community farm (see Figure 1). In fact, community farms and gardens have a role in raising environmental awareness and inducing behavioural changes (Garnett 1997, Quayle 2008). This may bring further reductions of GHG emissions through change in diets or other kinds of environmental commitment. The study scope is also limited to the GHG emissions. However, community farms have a role to play in increasing biodiversity in the urban environment through cultivation of rare crops and habitat creation for wildlife (Garnett 1997).

The improvement phase of the project was limited to the exploration of land use scenarios with organic cultivation of 14 selected commodities. However, the use of methods such as inter-cropping, polycultures, or multiple-cropping can bring substantial increase in yields (Vandermeer 1990, Piper 1998, Rosset 2000) and should be examined. There are also other ways to increase the community farm food production. If polytunnels are used, the growing area within them could be increased using hanging shelves and boxes for the cultivation of soft-fruit and lettuce. Some authors suggest the use of hydroponics is an efficient technique for urban farming (Garnett 1999), but a LCA of the resulting products should be undertaken as the technique requires high levels of inputs. An effort will be made in the community farm design to increase productivity per unit area and to further reduce GHG emissions, and some of the options noted above may be appropriate and should be examined.

Community-supported urban farms can produce a greater range of food commodities than those analyzed in the study but the effectiveness of these crops could not be examined due to limited data. Some of these commodities could be more effective than those identified here for their effectiveness (Figure 4.) A recent study by Warner et. al. (2010) showed that the GWP of UK-grown strawberries at the farm gate can vary from 0.13 to 1.14 t CO_2e t^{-1} depending on the cultivation method used. Such values could make strawberries a strategic crop for community farms, as it is possible to use low energy cultivation techniques with them. There are also examples of urban food production initiatives extending beyond seasonal cultivation of popular fruit and vegetables. For example, eggs, honey, and meat production may typically be produced on community urban farms (Garnett 1997) and in the USA, a Milwaukee community urban farm is producing fish and watercress in aerated tanks in greenhouses, as well as ducks, goats, and chickens (Buttery et. al. 2008).

5 CONCLUSIONS AND RECOMMENDATIONS

Life Cycle Assessment can be applied for measuring and managing potential savings of GHG emissions from community-supported urban agriculture. This analysis for a community farm in Sutton in South London has shown that urban agricultural schemes can bring considerable reductions in GHG emissions. However there is potentially large variation in this reduction depending on decisions made at different points in the food chain.

The biggest savings in greenhouse gas emissions from the implementation of a community farm can be achieved with appropriate management of limited growing space. This involves choosing the right crop varieties and cultivation techniques. From a carbon reduction perspective, the most effective crops for substitution provide high yields when grown locally, but are normally produced in energy-intensive sheltered crop systems and transported in from distant locations. The availability of volunteer labour at the community farm and external funding makes sustainable cultivation of such crops feasible.

Community-supported food growing projects could become an integral part of the urban landscape. The analysis here suggest that there is sufficient derelict and unused land that if used for cultivation of food in urban fringes, could satisfy a large proportion of the consumer demand for seasonal fruit and vegetables, and bring substantial reductions in diet-related greenhouse gas emissions. However, care needs to be taken during the planning process to select the most strategic crop varieties and cultivation techniques whilst avoiding overproduction of the crop beyond the capacity of the local market.

In the course of the analysis opportunities for further research and crucial information gaps have been identified. Due to the availability of volunteer labour and external funding, there are specific economic conditions on the community farm that could allow alternative cultivation techniques such as intercropping to be used. An analysis of the yields achievable at community farm level under these specific conditions could be undertaken in order to fully assess the potential of community farms to provide seasonal food and reduce GHG emissions. This needs to be accompanied with a better assessment of food stocked in British supermarkets throughout the year, which takes into account the different production methods and supply chains used. Such research will further advance understanding of how local and conventional food supply systems compare.

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APPENDICES

Appendix A Interview form

A.1 Informed consent form

Cranfield thesis project questionnaire

SECTION 2. INFORMED CONSENT (please read and sign)

I have been briefed about the purpose and principles of the research project entitled "Environmental burdens and diet in the sub-urban community- A life cycle approach to the food consumption patterns in the London Borough of Sutton."

I understand that the information provided will not be used for any other purpose than this study. If not otherwise stated, information remains strictly confidential and no personal data are going to be revealed during the execution of the research. In such case the information will not be stored or used in a way that allows for anyone to determine the identity of the interviewee.

I am aware of the fact that I can withdraw the consent at any time prior to the submission of the research paper (16th August 2010). In this case, all data and personal information will be destroyed.

Knowing that, I voluntarily agree to allow the data collected from me to be used for the purpose of the research "Environmental burdens and diet in the sub-urban community- A life cycle approach to the food consumption patterns in the London Borough of Sutton".

I give permission to cite information given (please tick) ☑

I give permission to reveal my identity in the final research paper (please tick) ☑

Date: 3-7-10.

Signature of the participant:

A.2 Predetermined questions for the semi-structured open interview with the community farm manager

<u>What is the exact area covered by the community farm?</u>

a) What is the soil composition? Clay/Loam /Sand [%]

b) Are there any plans to expand the area in the near future?

Commodities being currently produced at the farm.

Please fill up the available data for the basic commodities that are being currently produced at the farm. The most important ones are the average expected annual yields.

1) Potatoes – Main Crop. ☐

a) What is the expected annual yield [kg]? ________________________

b) Please mark the applied cultivation method: Plough based/ Reduced tillage/ direct drilling

c) Is there any mineral fertilizer applied? If so, what is the average rate? ____ [kg/ha] Is there any use of urea? If so, what is the proportion? ____ [%]

d) Is there any organic fertilization applied? If so, how much compost is imported to the site____ [t/ha], manure____ [kg/ha], sewage sludge___ [kg/ha].

e) Is the field irrigated? YES / NO

f) What is the area of land covered by the cultivation? ________________

2) Potatoes – 1st earlies. ☐

a) What is the expected annual yield [kg]? ________________________

b) Please mark the applied cultivation method: Plough based/ Reduced tillage/ direct drilling

c) Is there any mineral fertilizer applied? If so, what is the average rate? ____ [kg/ha] Is there any use of urea? If so, what is the proportion? ____ [%]

d) Is there any organic fertilization applied? If so, how much compost is imported to the site____ [t/ha], manure____ [kg/ha], sewage sludge___ [kg/ha].

e) Is the field irrigated? YES / NO

f) What is the area of land covered by the cultivation? ________________

3) Potatoes – 2nd earlies. ☐

a) What is the expected annual yield [kg]? ________________________

b) Please mark the applied cultivation method: Plough based/ Reduced tillage/ direct drilling

c) Is there any mineral fertilizer applied? If so, what is the average rate? ____ [kg/ha] Is there any use of urea? If so, what is the proportion? ____ [%]

d) Is there any organic fertilization applied? If so, how much compost is imported to the site____ [t/ha], manure____ [kg/ha], sewage sludge___ [kg/ha].

e) Is the field irrigated? YES / NO

f) What is the area of land covered by the cultivation? ________________

4) Beans. ☐

a) What is the expected annual yield [kg]? ________________________

b) Please mark the applied cultivation method: Plough based/ Reduced tillage/ direct drilling

c) Is there any mineral fertilizer applied? If so, what is the average rate? ____ [kg/ha] Is there any use of urea? If so, what is the proportion? ____ [%]

d) Is there any organic fertilization applied? If so, how much compost is imported to the site____ [t/ha], manure____ [kg/ha], sewage sludge___ [kg/ha].

e) Is the field irrigated? YES / NO

f) What is the area of land covered by the cultivation? ________________

5) **Maize** ☐

a) What is the expected annual yield [kg]? ________________________

b) Please mark the applied cultivation method: Plough based/ Reduced tillage/ direct drilling.

c) Is there any mineral fertilizer applied? If so, what is the average rate? ____ [kg/ha] Is there any use of urea? If so, what is the proportion? ____ [%]

d) Is there any organic fertilization applied? If so, how much compost is imported to the site____ [t/ha], manure____ [kg/ha], sewage sludge___ [kg/ha].

e) Is the field irrigated? YES / NO

f) What is the area of land covered by the cultivation? ________________

6) **Eggs** – organic/free range/other ☐

a) What is an average annual egg production? [pcs] ___________
b) What is the chickens breed? ________________
c) What is the number of layers _______, pullets________, layer breeders_________?
d) What is an average egg weight? [g] _____________
e) What is an average number of eggs / layer? ________
f) What is an average layer feed? [g/week] ___________

7) **Tomatoes (please mark)-** Classic loose/specialist loose/classic vine/specialist vine, organic/non-organic (Nutrient Film Technique)/non-organic (rockwool as a growing medium) ☐

a) What is an average annual production? [kg] _________
b) Tomatoes are being grown in greenhouse/polytunnel (please mark).
c) What is the area of land covered by the cultivation? ________________

8) **Strawberries –** outdoor/polytunnel ☐

a) What is an average annual production? [kg] _________
b) What is the area of land covered by the cultivation? _______________

9) Chillies and peppers ☐

a) What is an average annual production? [kg] _________
b) Greenhouse/polytunnel (please mark).
c) What is the area of land covered by the cultivation? _______________

10) Cucumbers – outdoor / polytunnel ☐

d) What is an average annual production? [kg] _________
e) What is the area of land covered by the cultivation? _______________

11) Cauliflowers and broccoli ☐

a) What is an average annual production? [kg] _________
b) What is the area of land covered by the cultivation? _______________

12) Garden peas ☐

c) What is an average annual production? [kg] _________
d) What is the area of land covered by the cultivation? _______________

13) Apples ☐

a) What is an average annual production? [kg] _________

b) What are the cultivated varieties and their proportion? [kg] _________

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c) Is there any mineral fertilizer applied? If so, what is the average rate? ____ [kg/ha] Is there any use of urea? If so, what is the proportion? ____ [%]

d) Is there any organic fertilization applied? If so, how much compost is imported to the site____ [t/ha], manure____ [kg/ha], sewage sludge___ [kg/ha].

e) Is there any use of synthetic pesticides and insecticides? Please list types and quantities:

____
____
____

f) How are the trees irrigated?
____
g) What is an average water use? _______ [l/year]
h) Is there a use of chemical thinning agents (carbaryl, 1-naphthlyacetic acid)? YES/NO. If so, please list the type and quantities used.__________________________________
i) What is the area of land covered by the cultivation? ________________

14) Lettuce and chicory ☐

a) What is an average annual production? [kg] _________
b) What is the cultivation method? Please mark: Open outdoor/polytunnel/heated greenhouse.
c) What is the area of land covered by the cultivation? ________________

15) Onions and shallots ☐

d) What is an average annual production? [kg] _________
e) What is the area of land covered by the cultivation? ________________

16) Carrots and turnips ☐

f) What is an average annual production? [kg] _________
g) What is the area of land covered by the cultivation? ________________

17) Pears and quinces ☐

j) What is an average annual production? [kg] _________

k) What are the cultivated varieties and their proportion? [kg] _________

l) Is there any mineral fertilizer applied? If so, what is the average rate? ____ [kg/ha]   Is there any use of urea? If so, what is the proportion? ____ [%]

m) Is there any organic fertilization applied? If so, how much compost is imported to the site____ [t/ha], manure____ [kg/ha], sewage sludge___ [kg/ha].

n) Is there any use of synthetic pesticides and insecticides? Please list types and quantities:

____
____
____

o) How are the trees irrigated?

____

p) What is an average water use? _______ [l/year]

q) Is there a use of chemical thinning agents (carbaryl, 1-naphthlyacetic acid)? YES/NO. If so, please list the type and quantities used.________________________________

r) What is the area of land covered by the cultivation? _______________

18) Other commodities ☐

Please list all other commodities being produced at the community farm. If possible, please indicate an average expected annual production quantities and an area that is being taken due to the production of the item.

Commodity	Av. Annual production [kg]	Area

Buildings.

a) Is the farm supplied with a greenhouse? YES/ NO. If yes:
    a. What is the area? [m^2]
    b. What is the heating source: CHP/ electricity /other ____________
b) Is the farm supplied with a polytunnel? Yes/No. If yes:
    a. What is the area? [m^2]
c) Is there a machinery store? YES/NO. If yes:
    a. What is the area? [m^2]
    b. What is it made of?

    ____

Other buildings and structures (please list):

Building type	Area	Materials	Energy source

Machinery.

a) What is the brand________, type________ and year of production _______of a tractor?
b) What is an average annual mileage?

Please list any other machinery used for the crop cultivation at the farm:

____

____

____

____

____

____

Food distribution

a) Are the vegetables being washed, chilled, processed or stored in special conditions prior to the distribution? YES/NO If yes, please provide some details:

b) How is the food being distributed? What proportion is being sold in the Veg Van?

c) How many people from Wallington/Carshalton/Sutton / outside the Borough may have an access to the goods from the farm?

1. Any other observations/suggestions.

Appendix B Results of the study on the use of open space in the London Borough of Sutton