Working Paper to support an Interactive Seminar on Environment & Sustainability in the High-Value Agriculture Sector in Africa

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1. Introduction

Exploring issues of environment and sustainability in high-value agriculture has to be seen in the wider context of humankind's use of the planet's resources and how this is linked to increasing population pressure and the perceived decline in natural resources:

> "Take one world already being exhausted by 6 billion people. Find the ingredients to feed another 2 billion people. Add demand for more food, more animal feed, and more fuel. Use only the same amount of water the planet has had since creation. And don't forget to restore the environment that sustains us. Stir very carefully." (Margaret Catley-Carlson; cited by Clothier *et al.*, 2010).

The threat to the environment from anthropogenic climate change has provoked a range of policy action at international and national level. Legislation is already in force in the UK to ensure that the net UK carbon account for the year 2050 is at least 80 per cent lower than the 1990 baseline year, with a reduction of at least 34 percent by 2020 to be achieved through action in the UK and abroad. For those in the high-value agriculture sector who predominantly access international markets there may be difficulties in maintaining export performance if countries adopt trade policies restricting the import of products which demonstrably impact negatively on the environment This will impact on all players in agricultural supply chains, from farmers through to consumers, particularly for the horticulture sector which is perceived by some to consume high levels of inputs, such as water, and to produce greenhouse gas emissions through year-round global supply chains.

Although, our understanding of the implications of climate change on agriculture is improving, there are still many uncertainties in the climate change science and the scale of impact, particularly at the local level. However, it is possible that in some situations even minor climatic changes will have a considerable impact on long-term agricultural productivity and food security. It is therefore imperative for all players associated with the high value agriculture sector to understand fully climate change and the challenges it presents in the short and long-term. Improved awareness of climate change challenges and opportunities is a first step in the process of finding appropriate responses and solutions.

2. Climate Change

How climate is changing in East Africa - understanding the current predictions at continental, regional, country and provincial levels – issues of uncertainty, timeframe, and how the climate will change

Examination of a range of coupled atmosphere-ocean circulation models predicts an increase in temperature in all seasons for east Africa that are larger than the global average response – with the average rise in temperature estimated to be up to 3.4 ^{o}C by 2080/99 (Doherty *et al.*, 2010). This is associated with a projected increase in average rainfall in the core of this region, east of the Great Lakes. In those areas with a wetter future climate, there is a potential for an increase in fresh water runoff and availability, which could have a positive impact on agriculture. However, there are some country variations in climate change predictions (Table 1), with a high level of uncertainty in predicting climate changes at the local level due to the localised and heterogeneous nature of the vegetation, topography and the impact of human activity.

Table 1. Climate trends to and beyond 2010

	Increase from 1960 to 2010			Increase to 2060	
Country	Mean Ann.Temp.	Hot days per year	Hot nights per year	Mean Ann.Temp.	Rainfall change
Kenya	+1.0^{o} C	57	113	+1.0 - 2.8^{o} C	-1 to +48%
Uganda	+1.3^{o} C	74	136	+1.0 - 3.1^{o} C	-8 to +46%
Tanzania	+1.0^{o} C	No trend	50	+1.0 - 2.7^{o} C	-4 to +30%
Mozambique	+0.6^{o} C	25	31	+1.0 - 2.8^{o} C	-15% to +34%
Madagascar*	0.2(south) to 0.6 ^{o} C (north)	N/A	N/A	+1.0 - 2.6^{o} C	+5 – 20% (wet season)

Source: UNDP Climate Change Country Profiles - http://country-profiles.geog.ox.ac.uk;
* Tadross *et al.* (2008) and Anon. (2008).

Whilst there may be less than full agreement about the medium to long-term trends in climate change, there is a recognition that changes are occurring in the number, frequency and nature of extreme weather events and in climate variability. For example, this variability can be seen by the recent series of droughts followed by flooding in Kenya. Observations suggest that such extreme events are on the increase. However, current modelling systems have been unable to predict with any certainty the future scale and frequency of extreme weather events and the resultant impact on agricultural activities. As discussed later, managing these extreme events is often of a greater and more immediate concern for farmers than adapting to more long-term changes, but some actors in the agricultural innovation system (e.g. policy makers, investors, strategic planners and plant breeders) need to take a longer-term view.

Issues:

Improving knowledge of the climate change processes and their complex interactions requires the collection of country-level weather data. The global network of World Watch Weather Stations, which provides real-time weather data, is very sparsely represented in Africa: there are only 1152 stations in Africa, a density of about 1 per 26,000 km^2, and eight times lower than the level recommended by the World Meteorological Organisation (Conway, 2009). This lack of data-collecting capacity makes it difficult to develop and validate climate models and hence predict with any degree of accuracy what will happen as a result of climate change at a country or local level. To resolve this requires:

- improved investment in co-ordinated national research capacity in meteorology and modelling (human, equipment and infrastructure) and regional networks of cooperation;
- development of seasonal forecast information systems to improve decision-making processes to assist policy makers, agriculture researchers, farmers, etc., in the development and adoption of adaptation strategies.

Adaptation - How will climate change impact on high-value agriculture in East Africa?

Climate adaptation will require the development of a range of activities (management, technological, institutional) designed to cope with changing weather patterns.

Whilst our understanding of long-term changes in climate is improving, there exists limited knowledge on how this will impact on agriculture and the options for adaptation. There is a perception that climatic change may have a considerable impact on the long-term agricultural productivity and food security, in some places there will be benefits for some crops, but in other situations even minor climate changes will have a considerable negative impact. Researchers are beginning to look at the predicted performance of selected crops based on a range of general climate models (e.g. warmer/wetter climate vs. warmer/drier, etc.) and differing carbon emission scenarios (low to high levels of atmospheric carbon dioxide). For example, simulation models have predicted that in East Africa, the yield of common bean (*Phaseolus vulgaris*) will decline by 2050 in all areas below 1000m in altitude and in many areas up to 1500 m (Thornton *et al.*, 2009). This is strongly related to exceeding the threshold temperature 20-22 ^{o}C for optimal seed growth, with water stress having little impact.

Horticulture crops, particularly fruit trees and crops of temperate origins, can be susceptible to high temperatures, causing flower and premature fruit abortion and reduced yield. For some crops such as tomato, eggplant and pepper the risk of adverse effects from exposure to heat stress will increase and this will have a negative impact on yields (Nelson *et al.*, 2010). In areas where there is a heavy reliance on supplementary irrigation greater variability in rainfall will affect production. For example, green beans grown in Kenya and Uganda require differing amounts of irrigation depending on the location and the rainfall pattern in a particular year. In some areas competing demands for water or the absence of an adequate water distribution system may make green bean production an increasingly marginal activity.

However, the ability to predict impact and resultant degree of yield and/or quality decline depends on the type of models, the scenarios used and access to fundamental knowledge of the crops and the farming systems. Research, at international, national and local levels, is required to develop new drought and heat tolerant germplasm, improved agronomic practices and management techniques that enhances the efficiency of input usage such as water and fertilizer, and soil management.

In addition to understanding the direct impacts of climate change on cropping systems, there is an urgent need to understand how climate change will impact upon the broader environment and the implications for smallholder and worker livelihoods. Better knowledge of the 'starting point' levels and determinants of producer vulnerability to all kinds of stresses and shocks is also relevant, in particular to long-term climate change and the variability in weather patterns, and the necessary adaptive capacity and adaptation strategies required to alleviate adverse impacts. Understanding vulnerability must be combined with knowledge of the climate-sensitivity of current agricultural systems and actors' adaptive capacity to respond to climate change. Agricultural innovations must be developed in a more decentralised and participatory system to allow for locally appropriate solutions to emerge and build adaptive capacity (e.g. the ability to participate in adaptation processes) along the way. Key concerns include:

- Are smallholder export-oriented horticulture farmers more exposed to climate stress because they cultivate one crop compared to farmers who supply national markets with a range of produce?
- What kinds of adaptive capacity do farmers have that will enable them to respond to pressures adequately?
- How resilient and robust are particular agricultural systems to climate change (and others pressures) in the short- and long-term?
- How will smallholder farmers selling to export markets fare compared to those selling to national markets, for example, when a drought hits or there is market volatility?
- Will exporting smallholders have greater adaptive capacity because they have earned more income and built up sufficient assets to provide a buffer to shocks or will they be less resilient because they have a less diverse base to their income sources? Therefore access to markets, the type of market and livelihood opportunities can be a key factor in determining adaptive response.

It is important to note that agricultural adaptation to climate change, whether in the high-value sector or elsewhere, will involve not only farm-level technological innovation, learning and knowledge transfer, but also institutional and policy adaptations. Regional information

sharing and technology transfer systems on adaptation must be encouraged between within the region.
In this respect, The Common Market for East and Southern Africa (COMESA) has put in place a comprehensive Climate Change Initiative 'to address climate change and its impacts in a manner that builds economic and social resilience for present and future generations' (Hichaambwa and Kabaghe, 2010).

Mitigation

Climate change mitigation aims to reduce the rate at which greenhouse gases (GHGs) are accumulating in the atmosphere, thereby minimising climate change and its effects.

It has been estimated that agriculture and associated land-use changes account for up to a third of the total emissions of human-produced greenhouse gases of which more than two thirds are estimated to come from low-income countries (Chambwera, 2010). However, there are a number of challenges in progressing climate change mitigation; not least is the development of an agreed standardized methodology for measuring and reporting carbon emissions. Many areas of this debate are still contested, with discussions on-going, for example, as to where emissions from food produced in East Africa and consumed in the UK should be allocated. However, the drivers for change in developed countries e.g. reduction in food miles and the use of carbon labelling, are real and could impact negatively or create opportunities for those high-value chains from East Africa accessing high-value markets. Smallholders supplying to international markets, in particular, may be disadvantaged by new requirements for carbon accounting, but opportunities may open up to secure funds from new climate finance schemes. But questions remain as to whether a high carbon price will be achieved, and also if retailers start demanding emissions reductions in the value chain who should pay for this.

Whilst there are some opportunities to improve agricultural practices and for mitigation purposes, there is a lack of certainty over the costs and benefits for resource-poor 'low carbon' developing countries. Southern stakeholders need a clearer voice in this discussion to identify where carbon emission savings can be made, and how best to create the incentives to lead to such changes in a way that does not negatively impact upon already disadvantaged groups and important export industries for East African nations. These aspects are looked at in more detail in Section 2 below.

In terms of the high-value agriculture there are a number of opportunities for mitigating greenhouse gas emissions.

Fertilizer application is a key source of atmospheric nitrous oxide (a potent greenhouse gas). Opportunities exist to reduce the emission of this greenhouse gas through practices that reduce nitrogen application such as improved field diagnostics, precision farming and fertilizer placement technologies, wider use of slow and controlled release fertilizers and of nitrification inhibitors.

More efficient energy usage can be achieved at all stages of the value chain including land preparation, irrigation, product cooling, storage and transport which will have both environmental and financial significance. For long-distance transport, developing improved packaging systems employing controlled or modified atmospheres could reduce the need for refrigeration and conserve energy. A key message from approaches to reduce emissions in the UK is that" more efficient, more profitable farms are likely to have a lower carbon footprint than less efficient ones" (Evans, 2010).

Research and value chain financial investment will be needed to achieve technology development and uptake on these agricultural mitigation practices. It remains to be seen whether climate finance mechanisms will operate effectively in channelling international funds to this end and who will benefit. There are clearly equity issues and financing challenges on the horizon as agricultural industries seek to respond to climate change imperatives.

Supporting measures: Innovative insurance schemes

Can instruments such as crop insurance be developed to lessen the impact of extreme climate events and ensure that farmers can stay in business for more normal times?

Donors are beginning to look at insurance schemes to support developing country smallholders manage risks from the impact of adverse weather events. In Kenya, an innovative partnership between UAP Insurance, the Syngenta Foundation for Sustainable Agriculture and Safaricom, a mobile telephone company has produced an insurance scheme, Kilimo Salama (Swahili for 'safe harvesting'), for small-scale maize farmers. The scheme has the following key features:

- participating farmers pay an extra 5% on inputs such as seeds purchased from suppliers registered with the scheme which is the premium to ensure the resulting produce;
- the seed container has a bar code which is scanned and sent by the mobile telephone to the insurer;
- farmers are registered with one of 30 automatic weather stations;
- farmers receive an automated payment, via Safaricoms money transfer service, when the weather stations register rainfall levels outside an agreed threshold i.e. compensation is not related to yield losses.

The scheme has proved viable due to the fully automated financial and weather systems even though individual premiums are small (0.25 US $). Another insurance scheme is being tested in Ethiopia for teff farmers using satellite-generated data for monitoring rainfall. The continuing viability of such schemes will depend on scaling-up to achieve wider uptake. Can this approach be extended to high-value agriculture?

Recommendations:

- Resources are needed to support research in climate prediction and to understand crop responses to climate change trends. To-date most of the research on crop responses to changing weather patterns focused on cereal crops; more information is needed on a wider range of crops, including horticultural produce in different locations in Africa.

- Funds to support multidisciplinary research, knowledge transfer and action-learning processes are required to develop:
  - Adaptation technologies covering: land-use changes; breeding for water and temperature stress; introduction of new crops; improved cropping/farming systems; soil management; efficient use of inputs (e.g. fertilizer through micro-dosing, fertigation); anticipating and managing new pests and diseases; and improved water management usage/supply (e.g. drip irrigation, rainwater harvesting, improved on-farm water storage, and re-use of waste water). However, agriculture in general has suffered from years of underinvestment by governments and donors: targeted advocacy will be required to secure sufficient resources for climate change research and the development, sharing and scaling-up of technologies and institutional innovations and reforms for adaptation and mitigation. East African countries have limited resources and institutional capacity to deal with climate change and may want to focus more on adaptation rather than mitigation efforts
  - Financial innovations in climate finance: Lesson-learning on the functioning, effectiveness and impact of different financial innovations, such as climate index insurance schemes, is needed.
  - Policy and institutional reforms: Some agricultural adaptation and mitigation responses may require policy and institutional reforms. There is a need to understand the broader barriers (social, cultural, economic, environmental, political etc) to adaptation faced by farmers which constrains their adaptive capacity. Capacity strengthening e.g. for smallholders and larger producers, for agricultural research organisations, for extension agencies, for private sector researchers, for traders will be required at all levels. What type of information is required by different types of farmers? What approaches are there to support response farming by farmers through, for example, self-monitoring of local meteorological data? Who interprets forecast information and how is it taken up by users? How does the advice and information differ from farmers' own perceptions of changes in climate and adaptive practices they may already have in place? How will new adaptation technologies be developed by or reach farmers and how equitable will these processes be? What new kinds of producer organisation and learning are required to build adaptive capacity? What is the role and responsibility of all value chain actors to build their own adaptive capacity and to support that of others who may be already disadvantaged? This range of issues can only be addresses by multi-stakeholder national innovation systems.

- One of the key issues for discussion is determining government and private sector policy in support of all aspects of climate change research. Governments in East Africa may want to support more localised adaptive research rather than fund more strategic research on climate change and crop modelling which could be undertaken by other, more regional or international agencies. Equally some areas of adaptive research, e.g. in breeding, could be undertaken by international research programmes such as the The Challenge Program on Climate Change, Agriculture and Food Security, a new 10-year research initiative launched by the Consultative Group on International Agricultural Research. Securing funding through sources such as the Global Environment Facility must be a priority. However, there needs to be clear understanding of what research is required and what would be a public good and what should be undertaken by the private sector. Public/private sector partnerships may have to be developed to maximise resources and undertake adaptive research and to develop systems such as insurance schemes. Some of the issues that need addressing offer financial rewards (and the need for investment) for key players in the value chain, particularly when high-value markets are involved.

3. Issues of carbon emissions, food miles and carbon footprints

Introduction: African agri-food responding to climate change mitigation

Greater awareness of the challenges posed by climate change for humankind has made it imperative that not only governments and civil society but also the private sector take action. Progress in the international climate negotiations has been painfully slow, but there is a growing international public debate on what sustainable food systems might look like in a carbon constrained world. Mitigation of climate change involves reducing all greenhouse gases so that all nations shift to low-carbon development pathways, but achieving this is fraught with difficulty because of the costs involved and also because of the issues relating to 'climate justice': developed countries have emitted most of the greenhouse gases to the atmosphere that are causing global warming, and have benefited from industrialisation. As developing countries also industrialize and seek to reduce poverty amongst their populations, the levels of greenhouse gases they emit will grow, leading to demands that they shift to 'low carbon' pathways. However, developing countries argue that it is their right to pursue economic development and that they should not have to pay the costs of employing cleaner technologies which are more expensive, because they have not contributed nearly as much to global warming as the developed countries.

It is within this broader context that governments, the private sector and civil society are seeking to respond to widespread public concern about climate change. Various mechanisms are emerging, such as the creation of mandatory and voluntary carbon markets, and private sector carbon standards and labelling[1]. The future policy landscape is likely to be a mosaic of carbon taxation, regulation, as well as carbon accounting (measurement) and labelling, but only the latter is beginning to be implemented as yet. High-value agriculture in East Africa is already in the international spotlight because of labour rights, food safety and pesticide use and water extraction issues. More recently, attention has turned to issues relating to carbon footprints and focus on water footprints. The focus on carbon emissions in high-value agriculture in East Africa has been driven by a number of factors:

[1] The word carbon is often used as shorthand for all greenhouse gas emissions. Similarly, 'carbon emissions' is often used in the same way not only to describe carbon dioxide emissions, but including other greenhouse gases such as methane and nitrous oxide.

- many of the early carbon standards and labels emerged in the UK, as a result of retailer innovation;
- fresh produce is regularly consumed and the UK market imports large quantities of fresh horticultural produce from East Africa, which means it has a relatively visible profile amongst consumers;
- the carbon footprint of single ingredient products are easier to measure than those in more complex, often processed, products;
- the history of social and environmental private standards in African export agribusiness.

Carbon emission and transport: Food Mile Myths

Export horticulture from East Africa has been under scrutiny through the lens of the concept of 'food miles': the distance travelled by food from the site of production to where it is consumed. The concept rapidly gained currency because it draws upon an intuitive notion that flying fruit and vegetables to the UK is not environmentally sustainable, particularly in the wider context of climate change. Several retailers, (e.g. Tesco, M&S and Wal-Mart) have taken up the idea of food miles to manage risk to their reputations and gain positive publicity, especially those that have innovated first. It was also seen as a way of identifying and making supply chain efficiencies. There is debate about where to attribute carbon emissions from flights with both passengers and freight on board and what the calculation should be (by relative weights in tonnes), the relative prices paid or the relative space taken up (Brenton *et al.*, 2009).

However, the idea of 'food miles' has largely been discredited, because it is only a partial assessment of the carbon emissions embedded in a product. Whilst a more robust evidence base is needed, early studies indicate that favourable cultivation conditions can more than offset the emissions incurred by long-distance transportation (Brenton *et al.*, 2009). Transportation is but one factor amongst many in determining carbon emissions and is not necessarily the most important. A more accurate and rigorous approach to carbon accounting is Life Cycle Analysis which when focused on greenhouse gas emissions measures these from the production end of the chain through to the end use of products and waste disposal arrangements. However, Life Cycle Analysis is itself not without challenges - in fact it is extremely complex, with a number of contested elements.

Carbon emission complexity

Despite the enthusiasm of many retailers and some governments for carbon labelling, it has become clear that carbon emission patterns are in reality extremely complex. There are a number of determining factors shaping the levels of carbon emissions along the supply chain, including: the favourability of the climate in the location of production and seasonality; the scale and carbon efficiency of production; the source of inputs (types used and transportation); the types of energy used (e.g. fossil fuels vs. renewable sources); the intensity of farming (degree of mechanisation); the level of scale economies achieved; and certain characteristics of the commodity. Each of these elements is explained in more detail in Appendix 1.

Energy source and usage is one of the key elements in cultivation and post-harvest handling. Protected production (under glass or in polytunnels in the case of horticulture) tends to be more energy intensive than non-protected production because of a) the use of heat and light; b) the use of steel, plastics and glass in construction in greenhouses. This provides many developing countries, which have relatively favourable climates, with a possible opportunity (Brenton *et al.*, 2009). Some cut flower production in Kenya is using thermal energy which enables it to lower its emissions despite the air-freighting of produce. In 2007, an initiative was launched in Kenya called 'Grown under the Sun', which aims to educate UK consumers and supply chain actors on the development and climate change benefits of importing cut flowers from Kenya, rather than Holland: *'emissions produced by growing flowers in Kenya and flying them to the UK can be less than a fifth of those grown in heated and lighted greenhouses in Holland. Why? Because Kenya is warm and sunny, and heating greenhouses in Holland uses enormous amounts of energy'.* Greater use of renewable energy technologies, e.g. thermal energy in Kenya, can have a positive impact on reducing carbon emissions and improve consumer perception and market access.

However, the use of renewable resources and increasing competitiveness is also being introduced in UK and Europe (Box 1), although vegetables grown in non-protected environments in East Africa may retain the advantage of clement climates in out-of-season comparisons with northern Europe.

Box 1: Thanet Earth – UK protected production of fresh produce using combined heat and power stations

A huge development of glasshouses on the Isle of Thanet, Kent is expected to produce 2.5 million tomatoes each week, with 700,000 peppers and 560,000 cucumbers each week between February and October. The large-scale greenhouse hydroponic complex covers 92 hectares. Fresca Group (Britain's largest importer and distributor of fresh produce) is the parent company behind the £80m development, with three Dutch companies. It is expected to supply 15 % of the UK's home-grown crop of salad vegetables. Although this kind of production is new to the UK, it has been common in the Netherlands and Spain for many years, but Thanet Earth has made strides in energy use, relying on its own combined heat and power stations. Each greenhouse has its own power station, using natural gas to power a turbine that produces electricity. Electricity will power the site, and provide for 50% of the needs of the Thanet area, plus sell to the National Grid. The heat and CO_2 produced will be used to control the climate in the glasshouses, which means that Thanet Earth will be a net producer of energy with its CO_2 emissions largely absorbed by the plants. The Thanet Earth example is not thought by its manager to be widely replicable in the UK due to limited winter light, lack of appropriate land areas for sale with transport links etc., but other parts of Europe may seek to develop renewable energy sources for protected production.

Crowded fields: An overview of the current carbon labelling landscape

In the last few years, retailers in Europe, often with significant government support, have begun initiatives to address mitigation of emissions through product carbon labelling. However, the development of approaches to reduce greenhouse gas emissions has proved to be a complex process due to:

- lack of co-ordination as first movers seek to obtain market advantage, in the absence of a clear public policy framework; trade distortion and consumer confusion are possible risks (Brenton *et al.*, 2009) from this fragmented, but not uncommon approach;[2]

- the need to have a widely-accepted standard method to estimate embedded 'carbon';

- uncertainty over the level of consumer understanding and demand - although it is often said that consumer demand is increasing for low-carbon products[3], this does not necessarily mean a) that there is a demand specifically for carbon labels, b) that there is a willingness to pay a premium to cover the costs of a low-carbon product;

- too many different initiatives and labels may confuse consumers, which would effectively reduce their impact on purchasing decisions and represents a challenge for suppliers in developing countries if different retailers ask them to comply with different standards and labels (with each having differing methodologies), examples include:
  - a stringent label, ClimaTop, aiming to drive up standards (and lower carbon emissions) by identifying 'carbon champions' – i.e. products with significantly (20%+) lower embedded emissions compared to other products;
  - Tesco has a long-term plan to carbon-label all its products (70,000+) and 20 products have been in store since 2008;
  - The French supermarket Casino has developed a labelling scheme focusing on climate change and waste management, based largely on the flawed food miles concept and using traffic light system to indicate environmental friendliness - the French government have asked all French retailers to consider a similar system;
  - A number of US retailers and brand-name manufacturers are also developing similar schemes;
  - From January 2009 air-freighted organic food in the UK will have to meet Soil Association Ethical Trade Standards or FLO standards, as well as an additional commitment and plan to reduce dependence on air-freight;
  - In Sweden, KRAV is developing a carbon labelling scheme for both organic and conventional products;
  - Similar initiatives for organic food are being established in Switzerland;
  - FLO is seeking to develop more cost-effective systems of Producer Carbon Footprinting (PCF) that will also unlock access to climate mitigation finance.

All European countries are preparing (or have established) legislation to move towards a low-carbon economy. The EU has an action plan on sustainable consumption, production and industry. The need for greater clarity may encourage national governments and the EU to step in and create greater standardization and to prevent abuses, which could be termed

[2] In the UK a Publicly Available Specification (PAS 2050) was developed in response to broad community and industry desire for a consistent method for assessing the life cycle GHG emissions of goods and services.

[3] For example, the Fairtrade Labelling Organisation (FLO) states that 'Consumer and Retail behaviour is changing: the demand for low-carbon products is increasing' (Louw, 2010).

'carbonwash'. It is possible that carbon legislation and taxes will in future be established, but if retailers were to require actual carbon reductions from their suppliers, then this would be the biggest driver for action on emissions reductions. However, this would require a carbon price in global supply chains and a universally accepted methodology (Macgregor, 2010). There is also the possibility that carbon could be employed as a trade tool, with tariffs set on imported products that produce more emissions than those produced internally: this situation should be monitored closely (Macgregor, 2010)[4].

Ecological space and equitable emissions – strengths and weaknesses

Ecological space refers to the concept of the balance between the amount of available global energy, water, and other natural resources and their use by the total population and the capacity of the earth to absorb all forms of pollution, e.g. GHG emissions, without infringing on the rights of future generations to use earth's resources. It suggests that there is an environmental capacity to the earth's resources, and it can then be calculated what each individual person would be allowed if a sustainable amount of the planet's resources were distributed equally. The concept thus introduces the idea of inter-generational equity as well as focusing on equity in the present day. The concept is said to be useful because it sets out a universal guiding principle offering an alternative pathway to excessive consumption of the richer nations and provides a foundation for a global standard of justice that incorporates notions of north-south equity and inter-generational equity. Compared to industrialized countries, developing countries have 'ecological space' credit, because of lower emissions past and present, and a greater capacity for absorbing emissions. African countries account for less than 5% of global emissions, which can be used for economic development through activities such as high-value agricultural exports (Macgregor and Chambwera, 2007).

However, for this concept to be used in practice requires an enabling framework and new mechanisms that change behaviour and practice e.g. socially differentiated tax system on aviation that produces environmental benefits, allocation of carbon emissions from fresh produce export to the country of production rather than the country of consumption (Macgregor and Chambwera, 2007).

Recommendations:

In relation to impact on different types of producers and other value chain actors in East Africa export horticulture there are a number of issues:

- There needs to be a recognition that it is not only farmers that need to respond to climate change, but that all value chain actors have a role to play. Retailers, value chain intermediaries, producers, NGOs and governments need to work together to find ways of reducing greenhouse gas emissions in agriculture which also serve adaptation ends. Reducing GHGs can mean efficiency savings (possibly after an

[4] The US Clean Energy and Security Act passed by the US House of Representatives states that the president could set carbon tariffs on imported products after 2012 if industrial carbon emissions from the country are higher than those in the US (Macgregor, 2010).

upfront investment) and may unlock access to climate mitigation financing if these emissions are measured and implemented.

- The concepts of food miles and carbon labels may not achieve emissions reductions. Therefore other strategies need to be found that can achieve this end, but southern stakeholders need a voice in finding these strategies, and the cost and burden of implementing these strategies should not be confined to actors in the global south.
- There is a need for greater co-ordination, transparency, and clarity for all stakeholders from farmers through to consumers, and agreed standards and methodologies for carbon accounting for use in all emissions reductions-related schemes. Greater understanding and awareness-raising is needed to show the pros and cons of different approaches and methods, for smaller and larger producers, for developing versus developed countries, and for different supply chains and commodities.
- Where private standards and labels are being developed, retailers and value chain actors should share in the costs of certification, implementation, and capacity building, rather than placing yet another burden on suppliers and smallholders. Southern value chain actors should have a say in how they are developed, their content and monitoring/verification processes. As well as producers and trade associations, other groups should be part of these discussions, not least national governments, environmental and development NGOs, etc.
- Attention needs to be paid to how carbon standards and labels will affect different parts of the industry, with a particular focus on smallholders (especially those not linked to larger producers in outgrower schemes) as these schemes may represent another hurdle to participation in export markets.
- Greater public dialogue and understanding is necessary to address the various issues of contestation that currently exist, such as where should responsibility for product emissions be attributed? Given that they are consumed in the UK and Europe should they be attributed there or to the exporting country (Macgregor, 2010)? Some argue that if the emissions should be attributed to the exporters in Africa because they have more ecological space which allows them room for expansion and would prevent the UK importers from moving away from East African exports. However, this area is still unclear and the development implications require exploration.
- Need for more scientific studies on low-income country supply chains and capacity strengthening to measure and verify life cycle analysis - can existing certification and verification systems such as GlobalGap, organic certification, and fair-trade certification be further developed?
- The cost and complexity of measuring carbon emissions is significant, particularly for low-income country value chain actors, and may be prohibitive for smallholders - however, there may be opportunities for larger and smaller producers to tap into climate mitigation finance once they have managed to measure their carbon footprints.
- There is a need to develop multi-stakeholder initiatives and a greater voice for developing country stakeholder participation in framing the sustainability issues and responses in agricultural development and in agricultural landscapes. It is important that the different environmental and development challenges are not treated separately, but in a more holistic manner. If standards are developed (either public or

private standards) then it is important that spaces for participation are created that enable key stakeholders to have a say in code content, and auditing. Existing multi-stakeholder initiatives have not yet been particularly successful in East African horticulture, because broader value chain power relations and contexts have not been conducive. This means that efforts should be redoubled for extensive participation of southern voices (farmers, workers, NGOs, trade unions, trade associations, governmental bodies, as well as retailers and value chain intermediaries) in the debate on sustainability in agriculture, including the role of high-value agriculture and the most appropriate responses, but changes may be required in governance of the value chain for these approaches to ultimately succeed.

4. Water resources

The Comprehensive Assessment of Water Management in Agriculture panel concluded that the world has sufficient land and water resources to feed the projected population in 2050, provided that policy makers and practitioners make wise decisions regarding the allocation and management of water in agriculture and other sectors (Clothier *et al.*, 2010). The globalisation of fresh water externalises the indirect effects of consumption to other countries. Economic gains in the short term should not be made at the expense of long-term environmental benefits. If, for example, freshwater resources in Africa are depleted by horticulture exports, short-term economic benefits could soon dissipate (Orr and Chapagain, 2006).

Global population growth and rise of living standards increase the demand for food, both in quantity and quality

The two major factors contributing to increased food demand, and thus to increased water use for food production, are population growth and changes in diets as living standards improve (Molden, 2007). People, particularly in urban areas, are consuming more water-intensive food items such as meat, fruit, vegetables, wheat and rice. Whilst this offers market opportunities, the sustainable increase in food production requires institutional innovations for water management, particularly in those areas of the world where demand for water for various uses exceeds supply. Economic development is also driving an increase in water use for domestic and industrial purposes, competing with water use for agriculture. Cities are rapidly increasing their claim on water at the expense of rural uses such as farming, and often represent a source of pollution impacting downstream irrigation and aquatic ecosystems (Molden, 2007).

Despite increases in large-scale irrigation infrastructure over the past half century, the bulk of the world's agricultural production is coming from rainfed lands (Molden, 2007). Even where water shortages are not endemic, there is a pending crisis of water supply in much of the world not because of a shortage of water but because of lack of management of water resources. Countries in East Africa face economic water scarcity as investments in infrastructure to increase water supply are lagging behind the growth in water demand.

Climate change alters the distribution (in time and space) and availability of fresh water

People will feel the impact of climate change most strongly through changes in the distribution of water around the world and its seasonal and annual variability. Globally, around 70% of all fresh water is used for food production. Although climate change may have little impact on the total volume of global water supply, it will alter the patterns of water availability by intensifying the water cycle. Droughts and floods are predicted to become more severe in many areas. Differences in water availability between regions are expected to become increasingly pronounced as well as seasonal and year-to-year variability in water availability. As the water cycle intensifies, billions of people will lose or gain water and with growing populations and competing demands from other sectors, food must be produced using less water.

International trade of food commodities results in international movement of virtual water and nutrients

Export of food commodities from East Africa to Europe extracts water and nutrients from the production area. Water used in production processes of commodities is called 'virtual water' contained in the commodity. International trade of food commodities produces international flows of virtual water. It has been estimated that during the period 1995 to 1999 at least 13% of the water used for crop production in the world is used for export rather than domestic consumption. The staple crops wheat, soybean and rice were responsible for 63% of the exported virtual water (Hoekstra and Hung, 2005).

> Kenya's cut-flower constitutes 7% of the Kenyan export value over the period 1996-2005. 95% of Kenya's exported cut-flowers comes from the area around Lake Naivasha. The total virtual water export related to the export of cut flowers from the Lake Naivasha Basin was 16Mm^3 yr^{-1}. About half (7.6 Mm^3 yr^{-1}) of the water use is abstracted from the lake. The virtual water export related to vegetables from the Lake Naivasha Basin is estimated at 8.5Mm^3 yr^{-1} of which 3.7Mm^3 yr^{-1} is abstracted from the Lake. The total volume of water abstracted from Lake Naivasha is estimated at 45.6Mm^3 yr^{-1} for agricultural purposes. Thus, water abstraction for the export of agricultural produce has a 25% share in the total volume of water abstraction from Lake Naivasha. According to Mekonnen and Hoekstra (2010), the cut-flower and vegetables export contributes to the decline in the lake levels, but does not have sole responsibility as water is abstracted for other purposes as well (e.g. drinking water). However, a declining lake level means that less water is available for all users and thus abstraction licences may need to be revised for all water users in the Basin.

The concept of virtual water is closely linked to the water footprint which is the total volume of fresh water used to produce a product taking the entire supply chain into account. The impact of a country's (or individual's) water footprint depends on where and when water is extracted. Water use in a water-abundant area is unlikely to have an adverse effect on society or the environment, whereas in a water-scarce area the same level of water use could result in the drying up of rivers and the destruction of ecosystems. Externalizing the water footprint (that is, having a net import of virtual water) can be an effective strategy for a country experiencing internal water shortages but it also means externalizing environmental impacts. The virtual water trade is influenced by global commodity markets and agricultural policies which generally overlook the possible environmental, economic and social costs to exporting countries (Hails, 2008).

> It is estimated that every year the UK uses 155Mm^3 of sub-Saharan African virtual water as a result of the import of green beans (Orr and Chapagain, 2006).

Urbanisation results in an increasing movement of virtual water and nutrients from rural areas to urban centres

By moving food commodities from rural areas to the growing urban centres, nutrients and virtual water are also moved out of the rural areas. As a result, urban centres are not only nutrient sinks, they also have a strong 'urban water footprint', considering not only domestic water demand but also the water required to produce the food that is consumed. Rapid urbanization raises the spatial challenges on how to make sufficient food available for a locally agglomerating population, and how to manage the related waste flows (Drechsel *et al.*, 2007; de Fraiture *et al.*, 2010).

Horticulture in Sub-Saharan Africa typically takes place near urban and urban centres contributing to contamination and health hazards

While the majority of calorie-rich food is derived from rural areas, urban and peri-urban farms provide significant shares of certain, usually more perishable, commodities (i.e. horticultural crops). A particular 'urban' challenge is the consideration of water quality in both the virtual water and urban water footprint concepts. Although water recycling (domestic return flow into the natural system) reduces the urban water footprint, this amount remains marginal compared to the additional environmental water requirements to dilute its contamination load where wastewater treatment is poorly developed (Drechsel *et al.*, 2007). Using untreated waste water for horticulture in urban areas has the undesirable side-effect of inducing health risks to consumers and producers (Bahri *et al.*, 2008).

Recommendations

Effective management of water resources is intimately linked to sustainable land management

Improving water management in agriculture and the livelihoods of the poor in East Africa requires the mitigation or prevention of land degradation. Smallholder farming is an important intervention point for measures aimed at conserving soil and water and increasing agricultural productivity by making more efficient use of water and nutrients available (Bossio and Geheb, 2008). Water resources can furthermore be used more effectively by investing in infrastructure for the treatment, recycling and storage of fresh water.

Global water use efficiency through international trade

Some regions are water scarce and other regions are water abundant. There is a low demand for water in some regions and a high demand in other regions, but there is not necessarily a correlation between water demand and availability. Hoekstra and Hung (2005) suggest that a water-scarce country may aim at importing food commodities that are water intensive and export products that require less water for their production. But there are other limiting factors, such as population density, agricultural productivity and agro-climatic conditions that determine whether a country is a net importer or exporter of virtual water. Mapping the flows of virtual water between and within countries provides essential information for optimal water management practices by informing production and trade decisions (Aldayo *et al.*, 2010).

International protocol for full-cost water pricing

Water is generally seen as a common good but as it becomes increasingly scarce, water also becomes an economic good. Water is a major input to agricultural but typically underpriced resulting in its inefficient use (Hoekstra, 2010). It is assumed that full-cost water pricing will result in an efficient allocation of water to where it has high returns. However, farmers will protest against this measure fearing their competitiveness is put at risk (Mekonnen and Hoekstra, 2010). Establishing an international water pricing protocol would need to take into account the full cost of water use including investment costs, operational and maintenance costs, a water scarcity rent and the cost of negative externalities of water use. Without an international treaty on proper water pricing it is unlikely that a globally efficient pattern of water use will ever be achieved (Hoekstra, 2010). However, resistance from producers and consumers alike is to be expected.

Water sustainability premium or certification

As an alternative to full-cost water pricing, or an international water-pricing protocol, a water sustainability premium has been recommended by some. Such a premium involves a water-sustainability agreement between major agents along the supply chain and includes a premium to the final product at the retailer end. A 'water sustainability premium' will raise awareness among consumers and encourage producers to use water in a sustainable manner. The collected premiums generate a fund that can be used for financing measures to reduce the water footprint and to improve watershed management. The sustainability premium also reduces the risk of producers losing their competitiveness (Mekonnen and Hoekstra, 2010). However, it is unknown whether consumers would be willing to pay for such a water sustainability premium, and too many certification schemes may become confusing to consumers.

More efficient use of water and better water management in high-value agriculture requires technical development and political and institutional reforms:

Relative to other crops, particularly staples, high-value agriculture makes use of irrigation to produce high quality and continuous volumes to fulfil market demand. However, as highlighted above, this can lead to conflicts with other users of water, particularly in times of drought or with other pressures such as population increases or changing population patterns/migrations, increase in other domestic and industrial demands. As the need for irrigation becomes more important in managing uncertainties in rainfall, is there the necessary policies, regulatory and infrastructure to provide water allocation on a rational and equitable basis for all end-users? Molden (2007) suggests the following policy actions:

1. Encourage a more integrated way of thinking about water and agriculture, addressing policy issues of water availability, allocation and cost.
2. Increase the productivity of water: however, will farmers invest in irrigation equipment without clear policy directives and market opportunities?
3. Upgrade rain-fed systems by improving water conservation and possibly supplemental irrigation.
4. Technological and managerial upgrading of existing irrigation systems. Technologies to improve water use efficiency e.g. precision irrigation can also improve efficiency of fertilizer application through fertigation.

5. A wider policy and investment arena needs to be opened by breaking down the divides between rainfed and irrigated agriculture and by better linking fishery and livestock practices to water management.
6. Deal with tradeoffs and make difficult choices; reconciling competing demands on water requires transparent sharing of information.

There is a need to begin to map and understand the water resources in the agro-climatic zones in each country and how these could change under various climate change scenarios. This will increase the understanding of the potential impacts on high-value agricultural production and aid decision making. For example, there is a need for research in improved water use efficiency e.g. improved irrigation equipment and application, good scheduling (optimising the volume and frequency of irrigation) and efficiency, use more drought tolerant or low water use cultivars, shorter growing cycles, improved soil structure and fertilizer use. Who will provide the resources for this research: could there be a role for public–private partnerships?

Crucially, sustainable water management options need to developed and understood as part of the stewardship of shared water resources. This will require improved management at the watershed level which addresses equity of access, recognizing multiple users and their interdependence in the face of limited water supplies. Only by using water much more efficiently, and considering other users in the chain, can impacts be reduced and conflict be avoided in the future.

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Appendix 1. Life Cycle Analysis

Table 1: Supply chain and commodity specificities shaping emissions patterns	
Factor	**Example LCA analysis**
Climate conditions at site of production.	A clement climate in Brazil contributes to small differences in emissions of domestically produced and consumed chicken cf. chickens produced in Brazil and shipped to Sweden for eating (Fogelberg and Carlsson-Kanyama, 2006).
Seasonality: carbon emission balances changes with season: in-season domestic production and consumption may be most carbon efficient, but in out-of-season periods, long-distance travel may be more efficient	Apples produced in the Southern hemisphere are as energy efficient as EU apples during the Spring and Summer of the Northern hemisphere, because energy used for storage (refrigeration) in EU locations can outweigh emissions created in shipping of imported apples (Mila i Canals, et al, 2007).
Source of inputs: Importation of inputs affects carbon emissions of a product	Use of domestically sourced feed means only small differences in emissions between chickens produced in Brazil and shipped to Sweden for eating, and chickens both produced and consumed in Sweden where feed is imported, sometimes from Brazil (Fogelberg and Carlsson-Kanyama, 2006).
Type of energy (renewable or fossil-fuel) used in production	The emissions from the production (using geo-thermal energy) and transportation of Kenyan roses to the UK market were significantly less than those produced in the Netherlands, in which fossil-fuel energy is used to power the greenhouses[5] (Williams, 2007)
Intensity of farming: types of technologies (e.g. degree of mechanisation) & use of primary fossil fuels	No substantive differences found in carbon emissions in a comparison of frozen broccoli transported from South and Central America to Sweden, with high transportation-related emissions but low levels of mechanisation and primary fossil fuel consumption, compared to fresh Swedish broccoli consumed in Sweden involving high use of diesel (Fogelberg and Carlsson-Kanyama (2006)
Extent of exploitation of scale economies	In comparisons of German, Brazilian and New Zealand fruit juices and lamb consumed in Germany, large global companies were found to be exploiting opportunities to reduce energy inputs due to greater scale and outweighing transportation-related emissions (Schlich & Fleissner (2005).
Characteristics of a product (e.g. perishability).	Beans transported from Kenya to UK by ship would use 56MJ/kg less than airfreight, but this does not take into account the need for chilling the beans on a 11 to 12 day journey (Jones, 2006)
Geographical location & mode of transport	Mode of transport (e.g. short or long haul, type of aircraft, combined freight and passenger service Shipping is less carbon intensive than airfreight, but slower journeys often involve refrigeration