MITIGATING CLIMATE CHANGE IN THE TEA SECTOR

TRADE IMPACT FOR GOOD

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MITIGATING CLIMATE CHANGE IN THE TEA SECTOR

In partnership with:

FLO-CERT

Rainforest Alliance

Ethical Tea Partnership

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The manual providing a set of tools and resources to support the tea sector, particularly tea factories and tea farmers, in addressing climate change mitigation and lowering their emissions, divided into four parts - part one focuses on mitigation options for tea factory emissions and is aimed at supporting factory management in addressing climate change mitigation; part two deals with mitigation options for farm emissions and provides descriptions of activities that can be implemented by tea farmers to address climate change mitigation at the farm level; parts three and four of the manual provide information and guidance on collecting data for emissions quantification and aim to support factory management to monitor and measure greenhouse gas emissions.

Descriptors: **Tea, Climate Change.**

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English

The International Trade Centre (ITC) is the joint agency of the World Trade Organization and the United Nations.

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Preface

Sub-Saharan Africa is home to almost 900 million people, 60% of whom are dependent on agriculture for their livelihood. Africa's farmers are among the most vulnerable to climate change, despite having the world's lowest rate of greenhouse gas emissions per person. Higher temperatures, variations in rainfall patterns and more frequently occurring extreme climate events are threatening food security. As a result, farmers are now finding themselves in a race to adapt to the changing climate.

In addition, exporters of agricultural products in Africa are increasingly subject to requirements set by buyers and retailers, to measure and reduce their carbon emissions. These requirements take the form of 'Product Carbon Footprinting' (PCFs). PCF standards offer opportunities for exporters to reduce production and processing costs, but they also create new non-tariff barriers, particularly for small and medium enterprises (SMEs). SMEs are in a disadvantaged position compared to larger exporters as they often lack in-house expertise to recognise and to comply with these private standards. An exporter may also have to comply with more than one standard, each of which uses a different methodology. SMEs are the growth and employment engines of the future with over 80% of employment generation in developing countries linked to SMEs. Hence, addressing non-tariff barriers through meeting these new private standards is an important contributor to reducing rural poverty and generating jobs.

The International Trade Centre (ITC) has prepared this guide to help SMEs navigate their way through the technical and managerial challenges for meeting these types of standards. ITC has a concrete mandate to help SMEs to internationalise and increase their competitiveness in regional and global markets and this is coupled with ITC's focus on ensuring sustainable production which minimises the negative impact on the environment.

This guide was produced as a key output from ITC's Trade and Environment Programme that has worked over the last three years in a Public Private Partnership with the Kenya Tea Development Agency (KTDA), the Ethical Tea Partnership (ETP) and two standard setting bodies: the Rainforest Alliance and FLOCERT. Forging innovative partnerships like these allows ITC to deliver Aid for Trade in an effective way and ensuring value for money and for investment.

The Kenya Tea Development Agency oversees tea production for more than 560,000 smallholder farmers in Kenya. The project piloted the climate change mitigation training at one of their factories in Chinga in the Central Province. Here, extension officers, factory management and KTDA staff were trained on mitigation strategies and energy-saving solutions using this training manual. The management has subsequently implemented the emissions reduction and climate adaptation strategy resulting in cost savings for the company.

ITC stands ready to provide further targeted support to SMEs and trade support institutions in farming communities in the African continent and beyond so that they can maintain their competitiveness in the face of the growing challenges that climate change presents.

Arancha Gonzalez

Executive Director, ITC

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Contents

Preface v
Acknowledgements vii
Acronyms xiii
Executive summary xv

PART 1: Mitigating climate change in the tea sector 1

1. Climate change in the tea sector 3

1.1. What is causing climate change? 3
1.2. The impacts of climate change 4
1.3. Climate change and tea 5
1.4. Responding to climate change: adaptation and mitigation 6

2. Mitigation in the tea sector 7

2.1. What are emission sources and sinks? 7
2.1.1. Emission sources 8
2.1.2. Emission sinks 8
2.2. Emissions mitigation in the tea sector 10
2.3. Benefits of emissions mitigation in the tea sector 11
2.3.1. Emissions mitigation and cost savings 11
2.3.2. Emissions mitigation and security of energy supply 11
2.3.3. Marketing of tea to international buyers 12
2.3.4. Adaptation benefits at the farm level 12
2.4. Emissions mitigation and the SAN climate module 12

PART 2: Management training – Mitigation options for tea factory emissions 17

3. Mitigation options for tea factory emissions 19

3.1. Reducing energy consumption: mitigation options 20
3.1.1. Reducing electricity consumption 21
3.1.2. Reducing fuel wood consumption 23
3.1.3. Reducing diesel consumption 26
3.2. Reducing the impact of energy consumption: mitigation options 27
3.2.1. Sustainable fuel wood sourcing 27
3.2.2. Alternative electricity sources 40
3.3. Improving waste water management: mitigation options 40
3.3.1. Good practice in waste water treatment 41

PART 3: Extension officer training – Mitigation options for farm emissions 49

4. Mitigation options at the farm level 51

4.1. Energy-saving stoves 52
4.1.1. Benefits of energy-saving stoves 53
4.1.2. Setting up an energy-saving stove project 54
4.1.3. Addressing farmers concerns 56
4.2. Indigenous tree planting 57
4.2.1. Development of a community tree nursery 57
4.2.2. Effective tree planting 58
4.3. Composting 59
4.3.1. What is compost? 60
4.3.2. Climate change mitigation and composting 61
4.3.3. Climate change adaptation and composting 61
4.3.4. Making compost 61
4.3.5. Using compost on a tea farm 64
4.4. Fertilizer application 65
4.4.1. Fertilizer efficiency of use 65
4.4.2. Reducing fertilizer requirements 65

PART 4: Measuring the carbon footprint of tea production emissions 69

5. Conducting carbon footprint assessment 71

5.1. Why quantify greenhouse gas emissions? 71
5.2. Quantifying greenhouse gas emissions - ‘carbon footprinting’ 73
5.2.1. Step 1: Scoping 73
5.2.2. Step 2: Data collection 76
5.2.3. Step 3: Carbon Footprint Calculation 78
5.2.4. Step 4: Reporting 79
5.3. Data collection at the factory level 80
5.4. Data gathering at the farm level 82
5.4.1. Sampling 82
5.4.2. Emissions associated with farm inputs 82
5.4.3. Data collection 84

Appendix I: Fertilizer use 87

Appendix II: Product carbon footprint assessment questionnaire 88

Table 1: Climate change problems and impacts for tea producers 5
Table 2: Carbon stores and when they become emissions sources and sinks 9
Table 3: Opportunities for climate change mitigation in the agriculture sector 10
Table 4: Co-benefits of greenhouse gas mitigation programmes 11
Table 5: SAN climate module and relevant manual chapters 13
Table 6: Emissions sources and potential mitigation activities at tea factories 19
Table 7: Cost-benefit analysis for fan upgrades at Iriaini tea factory 22
Table 8: Emissions targets for reducing fuel use 27
Table 9: Comparing vegetative and seed propagation 28
Table 10: Seed requirements for eucalyptus spp. growth 29
Table 11: Indicators of good or bad processes in waste water management: 46
Table 12: Climate change mitigation at the farm level 51
Table 13: Key participants in a stove project 55
Table 14: The 6 greenhouse gasses considered in the Kyoto protocol and their GWP 78
Table 15: Example results of a carbon footprint analysis 80
Table 16: Example of data collection table for a Kenyan tea factory 81
Table 17: Overview of emissions sources at farm level 84

Figure 1: The greenhouse effect 3
Figure 2: Global greenhouse gas emissions by gas and source 4
Figure 3: Climate change adaptation and mitigation 6
Figure 4: The carbon cycle 7
Figure 5: Kenyan tea factory energy use (% cost per energy source at an example factory) 20
Figure 6: Annual electricity use by tea production process (data from example tea factory) 21
Figure 7: Principles of good fuel wood storage - covering and drainage channels 24
Figure 8: Principles of good fuel wood storage – supported off the ground 24
Figure 9: Bad practice in fuel wood storage 25
Figure 10: Separating storm and waste water 41
Figure 11: Good practice in waste water treatment 41
Figure 12: Bad practice in waste water treatment 42
Figure 13: Water screening 43
Figure 14: Sedimentation tank 43
Figure 15: Organic waste management (bad practice) 44
Figure 16: Physical treatment 44
Figure 17: Gravel bed hydroponics 46
Figure 18: Surface cells 47
Figure 19: Layering for Compost 63
Figure 20: Fertilizer application: good and bad practice 66
Figure 21: The four steps in a carbon footprint assessment 73
Figure 22: Example process map for tea 76
Figure 23: Example carbon footprint results 79

Acronyms

The following abbreviations are used:

CFL	Compact Fluorescent Lamp
CO_2e	Carbon Dioxide Equivalent
CSR	Corporate Social Responsibility
CTC	Cutting, Tearing and Curling Process
ETP	Ethical Tea Partnership
FFS	Farmer Field Schools
FLO-Cert	Certification Body of the Fairtrade Label
FSC	Field Service Coordinator
GBH	Gravel Bed Hydrophonics
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GWP	Global Warming Potential
ISEAL	International Social and Environmental Accreditation and Labelling Alliance
ITC	International Trade Centre
KeFRI	Kenya Forestry Research Institute
KSH	Kenya Shilling
KTDA	Kenya Tea Development Agency
kW	Kilowatt
kWh	Kilowatt Hour
LED	Light-Emitting Diode
M&S	Marks and Spencer
PCF	Product Carbon Footprint
RA	Rainforest Alliance
SC	Surface Cells
SAN	Sustainable Agriculture Network
SME	Small and medium-sized enterprise
SPGS	SAWLOG Production Grant Scheme
SSP	Single Superphosphate
TESA	Tea Extension Service Assistant
TRFK	Tea Research Foundation of Kenya
UNCTAD	United Nations Conference on Trade and Development
UV	Ultraviolet
WTO	World Trade Organization

Executive summary

Sub-Saharan Africa is home to almost 900 million people, 60% of whom are dependent on agriculture for their livelihood. In Kenya, the tea sector employs more than 3 million people and smallholders account for 62% of total tea production in the country.

Climate change is expected to have a significant impact on global tea production. Because tea relies on well-distributed rainfall, increased temperatures and changes to rainfall patterns will influence both the quantity and quality of tea production, posing a threat especially to vulnerable smallholder tea farmers.

For instance, in Kenya, farmers are already reporting impacts on the quality and quantity of the tea they produce. As global temperatures rise further, it is predicted that these impacts will intensify as farmers experience more frequent droughts and pest infestations. Over time, these changes are expected to have implications on where tea can be planted, resulting in some traditional tea growing areas becoming unsuitable for tea growth (e.g. west of the Rift Valley in Kenya). Consequently, producers will have to make considerable adaptations to their existing practices to continue to meet global demand and quality requirements.

At the same time, a growing number of companies and consumers are interested in understanding the climate change impact of the goods they produce and consume. Many new market requirements, including product carbon footprinting standards, have started to emerge in developed countries and emerging economies. While these new market requirements can offer opportunities to increase efficiencies along the supply chain, for smallholders, including tea farmers, they can be costly and technically complex to comply with.

Dedicated resources on climate change mitigation in the tea sector are currently not available for tea farmers. ITC, ETP, Rainforest Alliance and FLO-CERT have partnered up to address this need and to ultimately make supply changes more robust to increasing environmental pressures and to support smallholder farmers to meet new and emerging market requirements around climate change.

This manual was created to provide a much needed set of tools and resources to support the tea sector - particularly tea factories and tea farmers - in addressing climate change mitigation and lowering their emissions. By bringing together different organizations, standards and certification schemes, the manual ensures a consistent and integrated approach to support small-scale producers address the challenges ahead.

Kenya Tea Development Agency (KTDA) is a farmer-owned organization currently managing 63 factories in Kenya. One of their factories in Chinga was used as a pilot to test the manual. Factory management and staff in Chinga were trained using the manual for factory management and an action plan was developed. Smallholder farmers supplying to Chinga were trained in the mitigation manual at the farm level. This publication has used Chinga as an example but it can be used in any tea factory.

This publication has been divided into three main manuals aimed at different actors in the tea sector. These are:

1. **Management training: Mitigation options for tea factory emissions**

This manual provides background information on climate change mitigation with a focus on emissions generated at tea factories. It is aimed at supporting factory management in addressing climate change mitigation. It details methods for achieving climate change mitigation and the benefits of doing so are given. The practices contained within this section provide additional benefits above and beyond climate change mitigation, itself typically in the form of cost savings or supporting the achievement of certification.

2. **Extension officer training: Mitigation options for farm emissions**

This manual provides descriptions of activities that can be implemented by tea farmers to address climate change mitigation at the farm level. It is intended that this information is used by extension officers so that they can provide training on these topics to smallholder tea farmers within the Farmer Field School (FFS) framework. The practices contained within this section provide additional benefits to the farmers, above and beyond climate change mitigation itself. This module builds on and expands the content of the climate change adaptation training manual developed in ETP's previous project and the two manuals should be used together by extension officers.

3. Measuring the carbon footprint of tea production emissions

This manual provides information and guidance on collecting data for emissions' quantification. Emissions' quantification provides a means for companies to monitor and report on the action they are taking to mitigate climate change. This manual has been produced to support factory management to monitor and measure greenhouse gas emissions. The manual is subdivided into four parts:

- **Section 1** provides background information on the global market developments related to climate change mitigation. These developments have resulted in an increased need for companies to quantify and communicate the greenhouse gas emissions associated with their operations or products.
- **Section 2** gives a detailed overview of the steps involved in quantifying greenhouse gas emissions, i.e. performing a 'carbon footprint' assessment.
- **Section 3** provides a detailed explanation of the data collection requirements at the factory level for undertaking a carbon footprint analysis.
- **Section 4** provides a detailed explanation of the data collection requirements at the farm level for undertaking a carbon footprint analysis.

This manual builds on a previous ETP project that developed training resources to support climate change adaptation and together the two sets of training resources provide a complete set of climate change resources for the Kenyan tea sector. The climate change adaptation manual can be accessed here on the Ethical Tea Partnership website (www.ethicalteapartnership.org).

PART 1:
Mitigating climate change in the tea sector

Chapter 1

1. Climate change in the tea sector

Climate change is an internationally recognised problem that is having impacts across the planet. Whilst the climate has always been changing naturally, the current impact of human activities is causing the climate to change in an unnatural way and at a faster pace than ever before. This unnatural and human induced climate change is problematic as it is causing shifts in the normal climatic conditions such as rainfall and temperature, which in turn is placing pressure on the planet's natural environment and having negative impacts on the planet's people. In particular climate change is having a significant impact on agriculture, especially those crops that are dependent on consistent climatic conditions.

Chapter overview

Section 1.1: What is causing climate change?

Section 1.2: What are the impacts of climate change?

Section 1.3: How is climate change affecting the quality and quantity of tea?

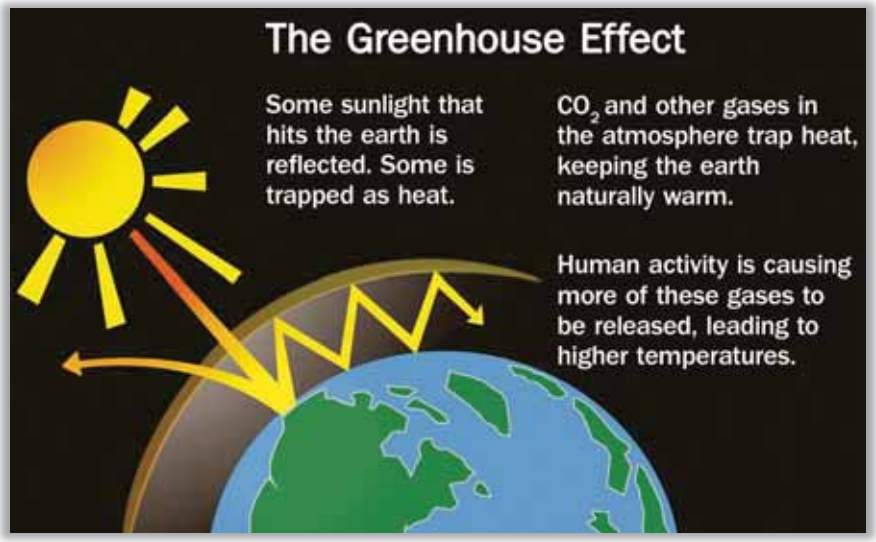
Section 1.4: How can we respond to climate change?

1.1. What is causing climate change?

Climate change is happening because humans are releasing and thus increasing the amount of heat-trapping gases in the earth's atmosphere called 'greenhouse gases'. Greenhouse gases occur naturally in the atmosphere and are important as they make the earth's temperature warm enough for life to exist. Without these heat trapping gases the planet would be far too cold making it uninhabitable. However, over time, humans have been increasing the concentration of these gases in our atmosphere, causing more and more heat to be trapped and which in turn is causing the climate to change.

Greenhouse gases act like the walls of a greenhouse. As warm energy released from the sun travels through the earth's atmosphere it heats the planet and provides us with a warm environment. Some of this warm energy is released back into space and some bounces back into the atmosphere when it hits the greenhouse gasses. This process whereby greenhouse gases trap the sun's heat is called the greenhouse effect.

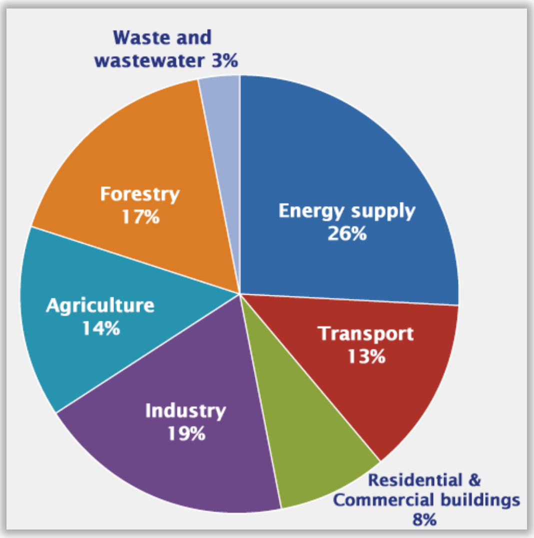
Figure 1: The greenhouse effect



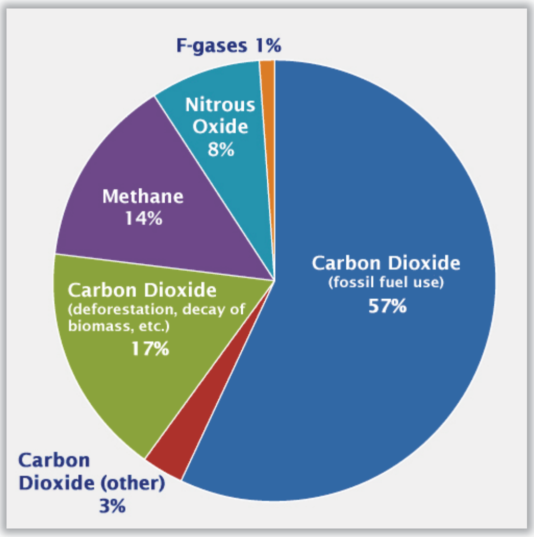
Natural greenhouse gases provide us with a warm and comfortable environment. However, as humans add more and more greenhouse gases into the atmosphere, more and more heat from the sun is captured making the planet hotter and hotter. This is what is causing a slow but steady temperature increase and eventually the climate to change.

Human activities release a range of greenhouse gases, however there are three gases that are causing the majority of climate change; carbon dioxide, methane and nitrous oxide. Carbon dioxide is the major global contributor to climate change and is released through the burning of fossil fuels (oil, coal and gas) and the removal of biomass, especially deforestation in the tropics. The second most important greenhouse gas is methane. Here the majority of emissions arise from agriculture and in particular from the management of manure and the decomposition of organic waste. The third key greenhouse gas is nitrous oxide, which is also released during agricultural activities such as the application of nitrogen fertilizers. The final category of greenhouse gases is fluorinated gases, these are emitted during industrial processes but have a minimal impact compared to the other gases.

Figure 2: Global greenhouse gas emissions by gas and source



Global emissions by source



Global emissions by gas

Source: (IPCC 2007[1])

In terms of emissions by source, the burning of coal, oil or gas for energy supply releases the most greenhouse gases globally (26%). After energy supply, the emissions released from industry are the next biggest contributor. Again this is primarily through the burning of fossil fuels to provide energy for processing and manufacturing. Next, deforestation and the clearing of land, primarily for agriculture, provide 17% of global emissions. Agriculture is responsible for 14% of global emissions with emissions arising from the management of soils, fertilizer application, livestock management and the burning of biomass.

1.2. The impacts of climate change

The release of greenhouse gas emissions is causing the Earth to get warmer. Warmer temperatures are causing other major changes around the world because temperature is interrelated to the Earth's global climatic systems. Impacts include a rise in weather related incidents such as floods, droughts, frosts, hailstones and destructive storms; the extinction of countless plant and animal species; the loss of agricultural harvests in vulnerable areas; the changing of growing seasons; the melting of glaciers; the disruption of water supplies; the expansion of infectious tropical diseases; the rising of sea levels and much more.

[1] Intergovernmental panel on climate change (IPCC), 2007, 'Climate change 2007: Synthesis report', http://www.ipcc.ch/publications_and_data/ar4/syr/en/spm.html

One of the sectors most affected by climate change is the agricultural sector as it is dependent on environmental stability in terms of water supply, atmospheric temperatures, soil fertility and the incidents of pests and disease. Furthermore, the most vulnerable to the expected impacts of climate change are developing countries and their citizens who have a lower resilience to climate change impacts due to limited financial and technical resources to support adaptation. Smallholder farmers in rural areas, such as the tea farmers in Kenya, will be especially hard hit unless action is taken now to ensure they are aware of the impacts of climate change and are supported to address these impacts using locally appropriate solutions.

1.3. Climate change and tea

The tea sector will be significantly impacted by climate change due to its dependence on stable temperatures and consistent rainfall patterns. Some of the specific climate change impacts and challenges for the tea sector are as follows:

Table 1: Climate change problems and impacts for tea producers

Climate Change Problem	Impact
Increased temperatures	Drying of the soils causing reduced water content in the tea, decreasing yields and negative impacts on quality
	Drying of the soils causing increased soil erosion
	Arrival of new pests and diseases not previously present
	Changes in the suitability of existing tea growing areas
	Sun scorch damage decreasing yields and lowering tea quality
	Biodiversity loss (including tree loss)
Reduced water content of tea crop	Decreases leaf quality
	Reduced resilience of tea crops
Changing rainfall patterns	Uncertainty in when to apply fertilizers
	Water scarcity and drought
	Extreme rainfall events
Increase in extreme weather events such as droughts, hail storms, floods, frosts and landslides	Crop damage and failure
	Increased financial vulnerability of tea farmers
	Soil fertility loss through erosion
	Frost damage
Reduced productivity of subsistence crops for tea farmers	Increased vulnerability of tea farmers through food insecurity

Furthermore, the combined impacts of climate change will likely reduce the tolerance of tea crops making them more susceptible to changing environmental conditions. These negative impacts on tea crops will have further negative impacts on smallholder tea farmers leading to issues of financial insecurity and the wider issues of poverty and food insecurity. For example, during times of drought the Tea Research Foundation of Kenya (TRFK) estimate that crop yields reduce by an average of 20 – 30% which reduces income and increases the vulnerability of small-scale farmers.

1.4. Responding to climate change: adaptation and mitigation

The content of this manual focuses on supporting tea factories and their farmers to address climate change mitigation, i.e. reducing the emissions of greenhouse gasses associated with operations. However, adaptation and mitigation are both ways to address climate change and it is important to understand the difference between the two. The examples used in this manual are from a tea factory in Kenya.

The term climate change adaptation is used to describe activities that help to manage the social, environmental and economic impacts of climate change. In essence adaptation activities reduce a population's vulnerability to climate change. Because tea farmers are already feeling the impacts of climate change, adaptation is already needed on the ground. However, because the climate will continue to change over coming decades, adaptation is not something that is implemented just once or that has only one solution. Instead, adaptation needs to be a process of change that is implemented in response to a continually changing environment. A training manual to support tea farmers implement climate change adaptation activities has been developed in a previous Ethical Tea Project with GIZ and can be accessed via the ETP website: http://www.ethicalteapartnership.org

Climate change mitigation is classed as any activity that reduces the concentration of greenhouse gases (the gases responsible for climate change) in the atmosphere. Through reducing emissions now, the future scale of climate change can be minimised. The main greenhouse gases are carbon dioxide, produced through the burning of fossil fuels and deforestation, and methane, produced during the decomposition of organic waste and from cattle. In the agriculture sector, the application of fertilizers also results in greenhouse gases in the form of nitrous oxide.

For smallholder tea farmers, climate change mitigation is not such an important issue as limited greenhouse gases are released as tea is grown with the majority being linked to the application and use of fertilizers. At the farm level mitigation activities should thus only be implemented where the farmer receives an additional benefit from the activity, which is often the case. Opportunities for farm level mitigation are included in Chapter 4 written for extension officers. At the factory level, mitigation becomes more important as this is where the majority of greenhouse gas emissions are produced and again, the reduction in emissions is often associated with additional benefits in the form of cost savings.

Figure 3: Climate change adaptation and mitigation

Adaptation

- Improve resilience of social and physical infrastructure
- Change of clones and agricultural practices
- Improve water and soil management
- Prepare for future pests and diseases
- Manage existing environmental threats

Mitigation

- Energy efficiency
- Low carbon energy source
- Change of agricultural practices e.g. judicious fertilizer use
- Change in consumer behaviour

Chapter 2

2. Mitigation in the tea sector

As stated in Chapter 1, climate change mitigation is the term used to describe any action that reduces the concentration of greenhouse gases in the earth's atmosphere. Through reducing greenhouse gas concentrations, the severity of future climate change impacts can be reduced.

There are two ways in which greenhouse gas concentrations can be reduced; through reducing emissions that are being released from emissions 'sources' or increasing the amount of emissions being absorbed by emissions 'sinks'.

Chapter overview

Section 2.1: What are the emission sources and sinks?

Section 2.2: Analysing emission mitigation in the tea sector.

Section 2.3: Benefits of mitigating emissions in the tea sector.

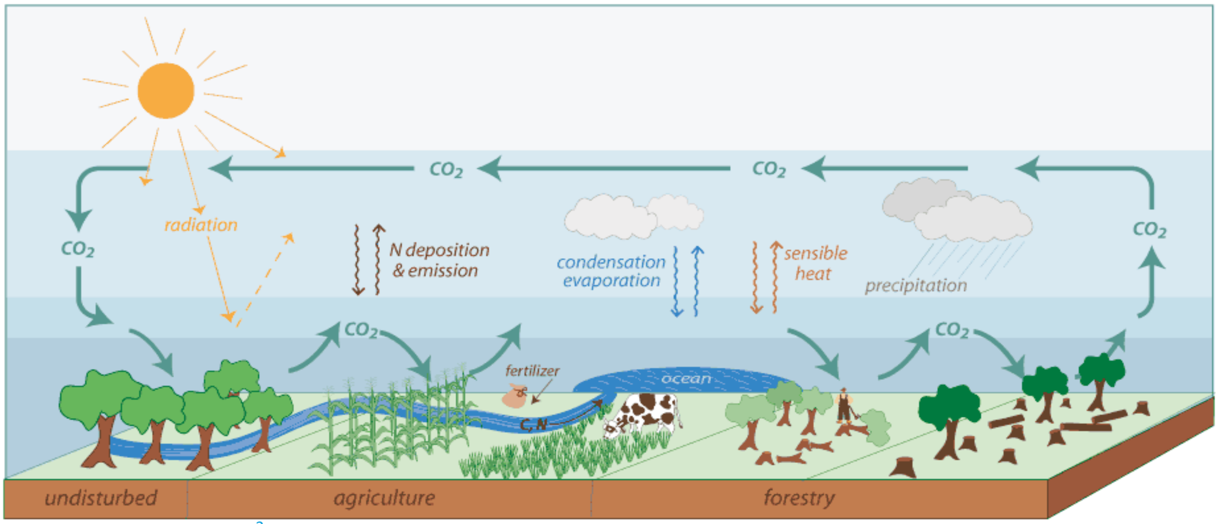
Section 2.4: Emission mitigation and the SAN climate module.

2.1. What are emission sources and sinks?

Forests, soils, oceans, vegetation, fossil fuels and the atmosphere all store carbon and can be called 'carbon stores'. The natural carbon cycle means that carbon is always moving between these carbon stores albeit at different rates. If a particular carbon store is absorbing more carbon than it gives off, it becomes a 'carbon sink', while a 'carbon source' will be emitting more carbon that it absorbs. The amount of carbon in the atmosphere at any one time depends on the balance that exists between these different carbon sinks and sources. This system of sinks and sources operates all over the planet and is known as the carbon cycle (Figure 4).

Key point: Emission sources release greenhouse gases into the atmosphere. Emission sinks absorb and store greenhouse gases from the atmosphere.

Figure 4: The carbon cycle



Source: (GFDL, 2013[2])

[2] Geophysical Fluid Dynamics Laboratory (GFDL) (2013) Accessed at http://www.gfdl.noaa.gov/land-model

Before the Industrial Revolution, the amount of carbon moving between the different carbon stores was relatively balanced and thus atmospheric greenhouse gas concentrations remained relatively stable. Today, however, human actions are causing a disruption in this natural balance. Through the burning of fossil fuels and the removal of vegetation (primarily deforestation and land use change), carbon is unlocked from natural carbon stores and is being released back into the atmosphere. This is causing atmospheric greenhouse gas concentrations to rise resulting in climate change.

2.1.1. Emission sources

Key emission sources

- Burning of fossil fuels (gas, coal, oil) for transportation and the production of electricity
- Deforestation and land use change
- Agriculture (exposed soils, animal husbandry, fertilizers, rice farming)
- Waste and waste water management

The most significant greenhouse gas emissions source produced by human activity is the burning of fossil fuels. Fossil fuels include coal, natural gas and oil. Fossil fuels were formed over hundreds of millions of years through the very slow decomposition and compression of organic matter. This organic matter eventually turns into fossil fuels which contain a high concentration of carbon. As fossil fuels burn, they release this stored carbon into the atmosphere. Fossil fuels are used the world over to power vehicles, operate machinery, produce products (especially plastics), generate electricity and provide heating.

Emissions are also released during the process of deforestation and other forms of ‘land use change’. Trees (and other vegetation) act as a carbon store. When trees are removed they are often burnt for fuel and if not, they eventually decompose. Both of these processes result in the stored carbon being released back into the atmosphere. Similarly, if land is cleared for agriculture, the emissions stored in the vegetation will be released back into the atmosphere when the vegetation is burnt or left to rot.

Agriculture also produces greenhouse gas emissions. These emissions can arise from the management of agricultural soils, livestock, rice production which uses methane producing microorganisms, biomass burning and the use of fertilizers and other agro-chemicals.

Waste and wastewater management also produces greenhouse gas emissions. Here, the largest source of greenhouse gas emissions is landfill methane, followed by wastewater methane and nitrous oxide. The burning of some waste products that were made with fossil fuels, such as plastics and synthetic textiles, also results in minor emissions of carbon dioxide.

2.1.2. Emission sinks

An emissions sink can be defined as anything that can increase the removal of greenhouse gasses from the atmosphere and store them for an identified period of time. The process of removing gases from the atmosphere is called ‘sequestration’. The main emissions sinks are oceans, which absorb carbon dioxide naturally though biological processes, vegetation (especially trees), which absorbs carbon dioxide through photosynthesis, and soils which absorb carbon through the accumulation of organic matter.

Key emissions sinks

- Forests or other vegetation increasing in size or density
- Soils which are accumulating organic matter
- Oceans

Forests and vegetation only become emissions ‘sinks’, or a climate change mitigation activity, when they are increasing in density or area. For example, if a forest stays at a constant size over time whereby tree growth is equal to decay, it is acting as a store for a constant amount of carbon. If the forest grows in size or density it must sequester (absorb) more carbon dioxide from the atmosphere to allow for this growth and is acting as a carbon sink. Thus, when a forest is increasing in size or tree density, or deforestation is being prevented, or a conversion is being made from unsustainable to sustainable forestry or new trees are being planted, it can be seen as a climate change mitigation activity. When deforestation or unsustainable forestry is occurring, the forest is decreasing in size and carbon is being removed from the forests carbon store and released back into the atmosphere. Under this situation, the forest is acting as a source of greenhouse gas emissions and contributing to climate change.

Soil is also an important emission sink as it stores more carbon than all vegetation and the atmosphere combined. Carbon accumulates in soils in the form of organic matter. This process happens as a result of the decomposition and breakdown of biomass (organic material) held in the soil e.g. dead vegetation and trees, leaves and animal wastes. However, poor and intensive farming practices the world over are causing much of this carbon to be released and preventing soil from being a useful emissions sink. Methods that enhance carbon sequestration in soil include no-till farming, residue mulching, cover cropping, and crop rotation, all of which are more widely used in organic farming than in conventional farming. Thus, as with forests and vegetation cover, soils can both be an emissions source and an emissions sink, depending on the prevailing management techniques.

Table 2: Carbon stores and when they become emissions sources and sinks

Carbon store	When it becomes an emissions source (i.e. causing climate change)	When it becomes an emissions sink (i.e. climate mitigation is happening)
Forests	Forest is reducing in area or density; • Deforestation • Forest burning • Unsustainable management	Forest is increasing in area or density; • Sustainable forest management • Tree planting • Avoiding or reducing deforestation
Vegetation	Vegetation is decreasing in density and cover; • Land use change from a higher density cover to a lower density cover e.g. land clearance for agriculture	Vegetation is increasing in density and cover; • Land use change from a low density cover to a higher density cover e.g. replanting bare soil with vegetation
Soil	When organic matter is being lost from the soil; • Unsustainable or intensive farming practices • Exposed soil leading to soil erosion	When organic matter is accumulating in the soil; • Good agricultural practices • Organic farming • Addition of composts, cover crops, mulching
Fossil fuels	The combustion of any fossil fuel (oil, gas and coal) is an emissions source	Natural emissions sink but only on a geological timescale
Oceans	When temperatures rise above a certain level	Natural emissions sink

2.2. Emissions mitigation in the tea sector

To look at opportunities for emissions mitigation in the tea sector it is useful to first think about potential emissions sources and sinks across the sector. These are detailed in Table 3 along with the associated mitigation activities. The remainder of this manual looks at these climate change mitigation activities in more detail focusing on those that can be implemented in tea factories. Mitigation activities that can be implemented at the farm level are included in Part 3 (Chapter 4) in the manual for extension officers. Some farm level mitigation activities also address climate change adaptation and training on these issues has been developed in a project with Ethical Tea Partnership and GIZ and included in a complementary climate change adaptation manual. Where appropriate this is hi-lighted in Table 3. The adaptation training manual is accessible at Ethical Tea Partnership Website www.ethicalteapartnership.org.

Table 3: Opportunities for climate change mitigation in the agriculture sector

Location	Agricultural emission sources	Climate change mitigation activities
Factory	Use of fossil fuels (gas, coal, oil) e.g. for tea transportation vehicles and boilers for drying the tea	• Reduce fossil fuel use (Chapter 3.2.2) • Switch to renewable or low carbon energy sources (Chapter 3.1.2, 3.1.3, 3.2.2)
Factory	Use of electricity e.g. for factory lighting and powering pumps and other electrical equipment	• Reduce electricity use (Chapter 3.1.1) • Switch to renewable or low carbon energy sources (Chapter 3.1.1)
Factory and Farm	Combustion of fuel wood	• Dry fuel wood to decrease use (Chapter 3.1.2) • Install energy-saving stoves (Chapter 4.1) • Install efficient boilers (Chapter 3.1.2) • Use fuel wood from sustainably managed forests that do not reduce in area or density (e.g. set up fuel wood plantations and manage in a sustainable manner) (Chapter 3.2.1, Chapter 4.2)
Factory and Farm	Removal of biomass Land clearing Tree cutting	• Reforestation (Chapter 4.2) • Agroforestry (Chapter 3.2.1) • Tree planting (Chapter 4.2) • Shade trees (ETP Climate change adaptation manual)
Farm	Fertilizer use	• Improving the efficiency of fertilizer use (Chapter 4. 4)
Farm	Burning of biomass	• Avoiding biomass burning useless for energy generating purposes (ETP Climate adaptation manual – Chapter 4)
Farm	Soils	• Composting, green manures, mulching and cover crops (Chapter 4.3) and climate change adaptation manual)
Farm	Manure and livestock cultivation	• Manure management into a soil enhancer (Chapter 4.3 and ETP climate change adaptation manual)
Factory	Waste water	• Low energy waste water management system (Chapter 3.3)
Farm	Vegetation cover	• Tree planting for shade trees and fuel wood, planting hedges for wind breaks and using cover crops (Chapter 4. 2 and ETP climate adaptation manual)
Farm	Soil	• Improved soil management through good agricultural practices (Chapter 4.3 and ETP climate change adaptation manual)
Factory	Forests	• Preventing deforestation through protecting forests, planting new forests or fuel wood plantations (Chapter 3.2.1)

2.3. Benefits of emissions mitigation in the tea sector

There are many benefits beyond pure greenhouse gas emissions mitigation to warrant investing in climate change mitigation. These ‘co-benefits’ can often provide strong rationales for investing in climate change mitigation activities. Typical co-benefits include reduced production costs through increased efficiency of equipment and processes, reduced waste (which in turn reduce environmental compliance and waste disposal costs), increased product quality, improved maintenance and operating costs, an improved working environment, decreased liability, improved public image and worker morale, and delaying or reducing capital expenditures. Table 4 provides an overview of the typical co-benefits associated with emissions mitigation in industry and following this are some specific details in relation to the tea sector (sections 2.3.1 to 2.3.3).

Table 4: Co-benefits of greenhouse gas mitigation programmes

Category of Co-benefit	Examples
Cost of operation	Reducing the use of energy through efficiency measures will require an initial investment but overall, operating costs will be reduced.
Health	Reduced medical/hospital visits, reduced lost working days, reduced acute and chronic respiratory symptoms, reduced asthma attacks, increased life expectancy.
Emissions	Reduction of dust, CO, CO2, NOx and SOx and reduced environmental compliance costs.
Waste	Reduced use of primary materials; reduction of waste water, hazardous waste, waste materials; reduced waste disposal costs; use of waste fuels, heat and gas.
Production	Increased yield; improved product quality or purity; improved equipment performance and capacity utilization; reduced process cycle times; increased production reliability; increased customer satisfaction.
Operation and maintenance	Reduced wear on equipment; increased facility reliability; reduced need for engineering controls; lower cooling requirements; lower labour requirements.
Working environment	Improved lighting, temperature control and air quality; reduced noise levels (e.g. more efficient machinery); reduced need for personal protective equipment; increased worker safety.
Marketability of products	Decreased liability; improved public image; increased demand for products produced in a sustainable manner; improved worker morale.

Source: (IPCC 2007)

2.3.1. Emissions mitigation and cost savings

One of the biggest benefits of addressing climate change mitigation is the huge potential for cost savings; this is particularly relevant at tea factories but also at the smallholder farm level. Currently a significant proportion of operating costs is dedicated to the purchase of electricity, fuel wood and fossil fuels to run the tea factories and operate transportation vehicles. There are many simple and cost effective ways in which this consumption can be reduced, both reducing operating costs and reducing the emission of greenhouse gases.

At the farm level, cost saving is also the biggest driver for climate change mitigation activities. Through installing energy-saving stoves and drying fuel wood, the costs of purchasing or the time taken to grow or collect fuel wood can be significantly reduced. Similarly, the appropriate and correct use of fertilizers, which can often result in reduced total usage, will not only reduce emissions but also reduce the amount of money farmers spend on this expensive input.

2.3.2. Emissions mitigation and security of energy supply

The security of energy supply is a second big co-benefit of a number of climate change mitigation activities. At the factory level, energy is required to produce tea. Electricity is required to operate the pumps, fans and lighting and fuel wood or fossil fuels to operate the boilers. Investing in a source of ‘on-site’ renewable electricity generation will help tea factories to ensure they have a secure and robust source of electricity during instances of power cuts and provide financial security in the face of future energy price increases. This can be achieved through investing in a local ‘on-site’ hydropower station as many tea factories are located near water sources due to their elevated positions. Options also include solar and wind energy. Each of there options needs to be considered on a site by site basis and using a 'cost-benefit' analysis (i.e. assessing the investment costs in comparison to the potential cost savings once implemented).

To power the boilers, security in energy supply can be achieved through investing in fuel wood plantations. When managed in a sustainable manner, these plantations can be seen as being carbon neutral, i.e. producing no greenhouse gas emissions. At the farm level, security of fuel wood supply for cooking is also a concern and provides a driver for tree planting amongst smallholder farmers.

2.3.3. Marketing of tea to international buyers

International markets, including the tea sector, are starting to recognise climate change as an issue that needs addressing within their supply chains. Front runners among private companies such as Unilever, Cafédirect, M&S, Bettys and Taylors and Twinings have started to estimate the emissions associated with their supply chains. Further information on the benefits of emissions quantification is provided in Part 4, Chapter 5 on emissions quantification.

Many companies are also developing environmental management strategies that seek to procure products that are produced in an environmentally friendly way. Setting targets to address climate change mitigation and monitoring and reporting on progress will thus be an additional marketing tool that tea producers can use to market their tea to packing companies who are looking to source environmentally aware products.

There are also strong movements to address mitigation at the international level. The FAO recently convened a meeting in Kenya to pull together stakeholders to discuss sector wide action that needs to be taken in the tea sector to address the challenges of climate change. The International Social and Environmental Accreditation and Labelling Alliance (ISEAL Alliance) is implementing a programme that supports its members (standard setting organizations) to upscale their efforts to mitigate climate change[3]. Individual voluntary standards active in the tea sector such as Rainforest Alliance are actively working on designing standards that can encourage and validate climate friendly tea farming[4] and which can be integrated into the existing SAN standard. This is explained in more detail in section 2.4.

2.3.4. Adaptation benefits at the farm level

At the farm level climate change mitigation activities have many co-benefits. As described above, there are cost and labour benefits associated with reduced fuel wood consumption. Also, many farm level mitigation activities help farmers to adapt to climate change. For example, emissions from soil can be prevented by implementing soil conservation measures and increasing the organic matter of soil. This has co-benefits of improving fertility of soils which will increase productivity and reduce crops vulnerability to extreme weather events such as heavy rainfall and droughts. Similarly, activities that increase vegetation and tree cover, such as planting shade trees to protect tea bushes, cover crops to protect soils and hedges to act as wind breaks and reduce soil erosion are all also forms of climate change mitigation.

2.4. Emissions mitigation and the SAN climate module

The Rainforest Alliance has developed and incorporated criteria that promote management practices with climate change mitigation and adaptation benefits into the existing voluntary sustainability standards of the Sustainable Agriculture Network (SAN) through its add-on Climate Module.

The SAN is a coalition of independent non-profit conservation organizations that promote the social and environmental sustainability of agricultural activities by developing standards. Certification Bodies certify farms or group administrators that comply with SAN's standards and policies. Certified farms or group administrators can apply for use of the Rainforest Alliance Certified™ trademark for products grown on certified farms.

Although the SAN's Sustainable Agriculture Standards promote numerous practices that lead to climate mitigation, additional criteria were needed for more explicit definition of practices, measures, and reporting needed to demonstrate verifiable climate-friendly activities. The SAN Climate Module continues on this path

[3] http://www.isealalliance.org/about-standards/sectors-covered/carbon-and-climate

[4] http://clima.sanstandards.org/

through a specific voluntary set of climate change adaptation and mitigation criteria which supplement the existing Sustainable Agriculture Standard.

The SAN Climate Module consists of 15 voluntary criteria that a climate-friendly farm must meet, in addition to the SAN certification criteria, if it chooses to become verified against the SAN Climate Module. Those producers that achieve compliance with the module will be able to assess the risks posed by climate change to their production systems and communities; analyse their practices to quantify and reduce the GHG emissions generated by growing, harvesting and processing activities; promote the identification and maintenance of existing carbon stocks; and increase the levels of carbon stored on their farms through the restoration of degraded lands, reforestation and improved soil conservation. In addition, these practices promote resilience in the face of altered growing seasons and other conditions.

Table 5 provides a summary table of the additional criteria of the SAN Climate Module and identifies which recommendations contained in this training manual cover those criteria. It is relevant to note that both farms and tea processing facilities can be certified under the SAN and therefore also the Climate Module. A full presentation of the SAN Climate Module is available in the documentation of the SAN Climate Module itself available at http://clima.sanstandards.org/ while the SAN Standard itself is available on the Internet at http://sanstandards.org.

Table 5: SAN climate module and relevant manual chapters

1. SOCIAL AND ENVIRONMENTAL MANAGEMENT SYSTEM	Relevant Mitigation Options
1.12. The farm's social and environmental management system must assess climate risks and vulnerabilities and include plans to adapt to and mitigate climate change. **Objective**: Management plans must be developed and contain an analysis of mitigation and adaptation opportunities along with the implementation plans necessary for undertaking appropriate and credible mitigation and adaptation responses.	The recommendations for mitigation that are formulated in this manual are based on an assessment of the principal opportunities for mitigation at tea factories. Additional mitigation opportunities are can be implemented at the smallholder farmer level. Please refer to Part 3-Chapter 4 on 'Extension Officer Training: Mitigation Options for Farm Emissions'
1.13 The farm must annually record data about its main GHG emissions sources related to, at minimum, nitrogen fertilizer input, pesticide input, fossil fuel use for machinery, methane generated in waste and wastewater treatment and animal husbandry. **Objective**: Related to 1.12 – data regarding principal GHG emissions sources must be kept and be available in order to demonstrate credible GHG mitigation benefits.	Please refer to the following training modules in this manual: • Chapter 3.1. 2: Reducing fuel wood consumption • Chapter 3.1.3: Reducing Diesel Consumption • Chapter 3.2.1: Sustainable Fuel Wood Sourcing • Chapter 4.1: Energy-savings (optional) • Chapter 4.4: Fertilizer Application Guidance on data collection at factory and farm level is provided in Chapter 5.
1.14 The farm must obtain available information on climate variability and its predicted impacts and adapt farm practices considering that information. **Objective**: Adaptive responses must be grounded in an analysis of and response to the best-available evidence of climate variability and its potential impacts.	This can be achieved through implementing the mitigation activities for extension officers on Chapter 4. Also the ETPs adaptation manual
1.15 The farm must map its land use and keep records of land use changes. **Objective**: Updated land use and land cover maps must be available and updated periodically to monitor land use changes to ensure valuable carbon stocks and habitats are protected.	This is partially addressed in Chapter 5 'Measuring the carbon footprint of Tea Production Emissions'

1.16 The farm's climate change adaptation and mitigation practices must be included in its training and education programs. **Objective**: Adaptation and mitigation plans must be communicated, understood, and applied by relevant actors as appropriate.	This can be achieved through implementing the mitigation activities for extension officers on Chapter 4. Also the ETPs adaptation manual
1.17 The farm must, to the extent possible, choose service providers that incorporate climate-friendly practices in their operations. **Objective**: Climate-friendly supply chains are encouraged whenever and wherever possible. Evidence should be available that service providers are demonstrably incorporating climate-friendly practices.	Not covered by exiting climate change training manuals.
2. ECOSYSTEM CONSERVATION	
2.10 The farm must reduce vulnerability, prevent land degradation or enhance ecological functions by planting native or adapted species or promoting natural regeneration. **Objective**: Where applicable, measures must be taken to protect and restore ecological functions to surrounding habitats.	Chapter 4.2: Indigenous Tree Planting See also 'Extension officer training manual – Adaption to climate change in the tea sector' available at www.ethicalteapartnership.org
2.11 The farm must maintain or increase its carbon stocks by planting or conserving trees or other woody biomass. The farm must conduct tree inventories every five years. **Objective**: The protection or enhancement of terrestrial carbon stocks must be demonstrated in a manner that is appropriate for the conditions and are applied in a credible and verifiable manner.	Please refer to the following training modules in this manual: • Chapter 3.2.1: Sustainable Fuel Wood Sourcing • Chapter 4.1: Energy-saving Stoves • Chapter 4.2: Indigenous Tree Planting See also 'Extension officer training manual – Adaption to climate change in the tea sector' available at www.ethicalteapartnership.org
4. WATER CONSERVATION	
4.10 The farm must analyse and implement wastewater treatment options that reduce methane emissions from wastewater treatment and recover the generated methane, to the extent possible. **Objective**: Waste water systems must be assessed for their ability to generate methane emissions, and where possible, measures taken that can credibly reduce this risk.	Information provided in this manual: • Chapter 3.3: Waste water management • Constructed Wetlands
4.11 The farm must adapt to water scarcity by practices such as harvesting and storing rainwater and selecting drought tolerant crop varieties. **Objective**: Risks of water availability must be addressed appropriate to the available evidence and activities should be supported by credible scenarios.	Information available in the climate adaptation training manual; 'Extension officer training manual – Adaption to climate change in the tea sector' available at www.ethicalteapartnership.org
6. OCCUPATIONAL HEALTH AND SAFETY	
6.21 The farm must implement an emergency preparedness and response plan for extreme weather events to prevent damage to people, animals and property. **Objective**: The preparedness of all relevant actors must be demonstrated for likely extreme weather events.	Not covered by exiting climate change training manuals.

7. COMMUNITY RELATIONS	
7.7 The farm must initiate or actively participate in community's climate change adaptation and mitigation efforts, including identification of relevant resources. **Objective**: Evidence of broader outreach related to climate change adaptation and mitigation to off-farm stakeholders is required.	This manual serves as the basis for factory level training on climate change mitigation, farm level mitigation and carbon emission quantifications. Additional training manuals on adaptation can be accessed at www.ethicalteapartnership.org
8. INTEGRATED CROP MANAGEMENT	
8.10 The farm must reduce nitrous oxide emissions through the efficient use of nitrogen fertilizers to minimize the loss to air and water. **Objective**: The GHG emissions potential of fertilizers must be assessed and data related to their usage and proper application should be available.	Information available in Chapter 4.4: Fertilizer Application and the supporting Appendix
9. SOIL MANAGEMENT AND CONSERVATION	
9.6 The farm must maintain or increase its soil carbon stocks by implementing management practices, such as crop residue recycling, permanent cover crops reducing tillage, and optimizing the soil's water retention and infiltration. **Objective**: Soil carbon stocks are in important sink and source of emissions, therefore the farm should utilize and maintain appropriate activities to maintain or improve soil carbon stocks .	Information available: • Chapter 4.2: Indigenous tree planting • Chapter 4.3: Composting Further training on soil conservation is provided in the climate change adaptation manual; 'Extension officer training manual – Adaption to climate change in the tea sector' available at www.ethicalteapartnership.org
10. INTEGRATED WASTE MANAGEMENT	
10.7 The farm must implement organic residue management practices that reduce GHG emissions, such as production of organic fertilizer or biomass energy generation. **Objective**: Organic residues generated by the farm should be re-utilized as farm inputs to the extent possible.	Information available in: • Chapter 4.3: Composting • Chapter 4.4: Fertilizer Application Further information on organic fertilizer production is provided in the complementary climate change adaptation manual; 'Extension officer training manual – Adaption to climate change in the tea sector' available at www.ethicalteapartnership.org

PART 2:
Management training – Mitigation options for tea factory emissions

Chapter 3

3. Mitigation options for tea factory emissions

The processing of green tea requires significant amounts of electrical and thermal energy, and thus at the factory level, the main source of GHG emissions is from energy consumption. Thermal energy is used in the withering and drying operations and is typically derived from fuel wood. If fuel wood is derived from a dedicated and sustainably managed plantation then it produces very few GHG emissions, however if sourced from unsustainable sources it can have a significant impact on climate change. In fuel wood deficient areas, factories often have to augment fuel wood supplies with fuel oil to fire boilers. This produces significant quantities of GHG emissions and can more than triple the cost of thermal energy.

Tea factories also require a significant quantity of electrical energy which is used for powering motors for the cutting, tearing and curling (CTC) process, running fans for the withering and drying and motors for vibrating, sorting and grading the tea. Electricity is also required for lighting the factories.

Table 6 lists the key emissions sources that are produced during the production of tea and associated options for emissions mitigation.

Table 6: Emissions sources and potential mitigation activities at tea factories

Emissions source	Mitigation activities (reducing emissions from the source)
Electricity consumption	• Reducing electricity consumption e.g. low energy lighting (see Section 3.1) • Converting to low carbon or renewable sources of electricity e.g. hydropower or solar (see Section 3.2.2)
Fuel wood consumption	• Reducing fuel wood consumption e.g. from drying fuel wood or improving boiler efficiency (see Section 3.1.2) • Sourcing fuel wood from sustainably managed plantations (see Section 3.2.1) • Setting up tree nurseries to support the distribution of native trees to smallholder farmers and to stock fuel wood plantations (see Section 3.2.1)
Truck fuel consumption	• Reducing diesel consumption e.g. through rerouting tea collection trucks (see Section 3.1.3)
Fossil fuel consumption in backup generators	• Provide an onsite renewable or low carbon source of electricity (see Section 3.2.2)
Fossil fuel consumption in boilers	• Improve boiler efficiency (see Section 3.1.2) • Increase security of fuel wood supply (see Section 3.1.2)
Waste water treatment	• Low energy and natural waste water treatment plant (see Section 3.3)

Reducing the total quantity of energy consumed is typically the first action taken to reduce emissions as it can provide a quick, easy and low cost solution to climate change mitigation. Reducing consumption can be achieved through turning off energy consuming machines when they are not in use or increasing the efficiency of energy use such as though installing low energy consuming products.

Once the consumption of energy has been reduced to a minimum, the next step in emissions reduction is to switch to using energy sources that release lower concentrations of greenhouse gas emissions or those which are emissions free such as wind and solar power.

Finally, other activities that directly cause the emission of greenhouse gases should be addressed. In a tea factory this will primarily be the management of waste water. If waste water is not treated, any organic matter contained in the water will decompose in ‘anaerobic’ conditions (i.e. in the absence of oxygen). When organic matter decomposes anaerobically it produces methane, a potent greenhouse gas. Thus, through proper waste water treatment, organic matter can be extracted and treated so that this is prevented.

Chapter overview

In this chapter, the following climate change mitigation activities are covered:

Section 3.1: Reducing factory energy consumption:

- 3.1.1: Mitigation Option 1: Reducing electricity consumption
- 3.1.2 Mitigation Option 2: Reducing fuel wood consumption
  - Drying wood
  - Improving boiler efficiency
- 3.1.3 Mitigation Option 3: Reducing diesel consumption

Section 3.2: Reducing the impact of factory energy consumption:

- 3.2.1 Mitigation Option 4: Sustainable fuel wood sourcing
- 3.2.2 Mitigation Option 5: Reducing the impact of electricity consumption

Section 3.3: Improving waste water management:

- 3.3.1 Mitigation Option 6: Ensure all waste water is properly treated

3.1. Reducing energy consumption: mitigation options

The easiest way to reduce emissions is to seek options to reduce energy consumption. A number of different energy sources are required by tea factories and these include; electricity for the powering of machinery (motors, fans etc.) and lighting; fuel wood for the running of boilers used in the tea drying process; diesel to operate tea collection vehicles; and oil to run back up generators or the boilers when fuel wood and electricity become unavailable. Figure 5 represents data on energy consumption from an example KTDA tea factory and is based on energy spend data. As can be seen, electricity comprises the biggest annual energy expenditure category followed by fuel wood for the boilers. However, in terms of energy use, it is the boilers that cost the most to run of all the processing processes. Electricity use is further broken down in Figure 6 which demonstrates that the withering process consumes approximately 40% of total electricity consumption and the CTC and drying of tea each consume approximately 20% of total annual electricity consumption.

Figure 5: Kenyan tea factory energy use (% cost per energy source at an example factory)

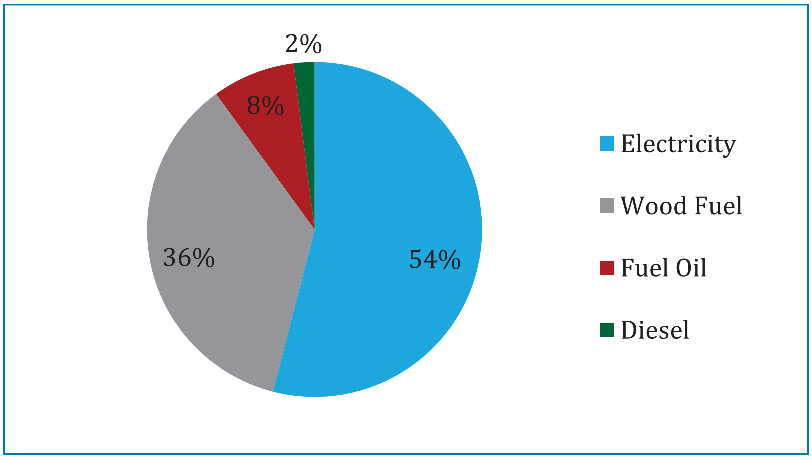
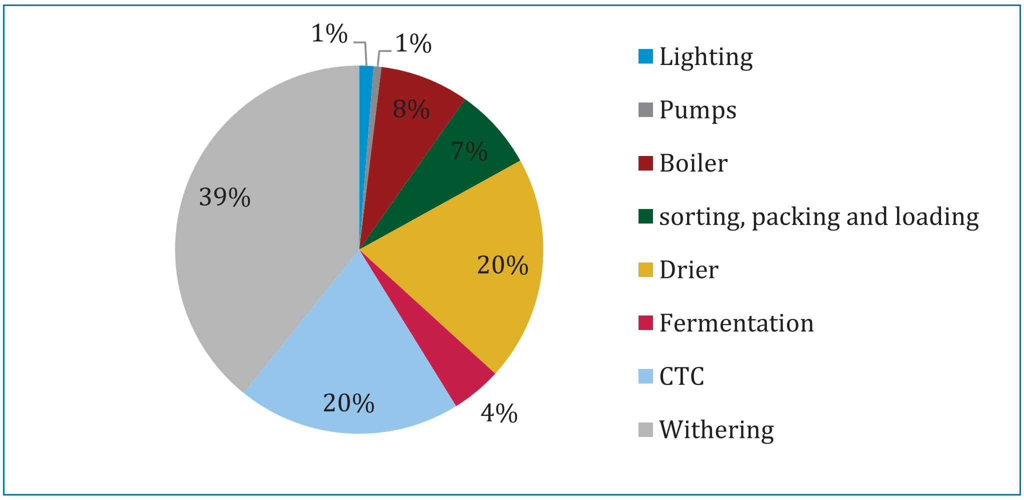


Figure 6: Annual electricity use by tea production process (data from example tea factory)



Whilst lighting consumes only 1% of electricity consumption, total annual expenditure on electricity at a KTDA factory is high and measured around 38M Kenyan shillings (US$440,000) at the factory under analysis and thus even 1% of total electricity consumption has a significant cost associated with it (in this example it is 380,000Ksh- US$ 4400).

Viable options can be sought to mitigate emission from all of these sources and these are outlined in the sections below as follows;

- Section 3.1.1 **Mitigation Option 1**: Reducing electricity consumption
- Section 3.1.2 **Mitigation Option 2**: Reducing fuel wood consumption
    - Drying wood
    - Improving boiler efficiency
- Section 3.1.3 **Mitigation Option 3**: Reducing diesel consumption

It is important to remember that a reduction in energy consumption has financial benefits beyond climate change mitigation which include the avoidance of unnecessary expenditure and increases in the profitability of tea production.

3.1.1. Reducing electricity consumption

Tea factories require a significant amount of electricity. Electrical energy is used for powering motors for the cutting, tearing and curling (CTC) process, running fans for the withering and drying of the tea and running motors for vibrating, sorting and grading the tea. Electricity is also required for lighting the factories. Finding ways in which the consumption of electricity can be reduced is a quick and easy way in which to mitigate climate change whilst at the same time reducing operating costs.

There are many ways in which electricity consumption can be reduced in tea processing and it is important that these are explored with factory staff. Some key options include:

- Upgrade fans used in the withering process
- Replace lighting with low energy alternative

Fans

Fans are used in tea factories to create airflow during the withering process to dry the tea. It is estimated that the fans consume around 40% of total electricity consumption (Figure 6). At KTDA factories, some of these fans are very old, having been installed when the factories were built, and have a large electricity requirement. It is possible to find fans on the market that produce the required airflow and which require up to 10% of the electricity requirement. Upgrading fans has the potential to provide both reductions in greenhouse gas emission and bring about financial savings through reduced electricity requirement.

Before making a decision to upgrade equipment, a simple cost-benefit analysis should be performed. This should take into account the electricity requirements of both the existing equipment and the new equipment and provide an estimation of energy requirements over a year period. For example, Table 7 provides a cost-benefit analysis of installing a new low energy fan based on the assumption that a fan runs on average for 8 hours a day and for 5 days a week that has been performed for Iriaini tea factory in Kenya. The original fan has a power consumption of 7.5kW per hour and the low energy fan of 1 kW per hour.

As can be seen, over a year period, a low energy fan would save the factory 123,520 kWh. This can be converted into a cost by using the average price of electricity at the specific factory. This example estimates that the cost saving for each new fan that is installed to be in the region of 162,240 Ksh per year (US$2000).

Table 7: Cost-benefit analysis for fan upgrades at Iriaini tea factory

Fan	Power intake (kW)	Runtime (h)	Operating days	Consumed electricity (kWh)	Cost (Kshs)
Conventional	7.5	8	260	15,600	187,200
New Fan	1	8	260	2080	24,960
			Savings	**13,520**	**162,240**

Lighting

Although lighting does not comprise a large proportion of total electricity use (around 1%), the cost associated with lighting can still be significant. Reducing energy from lighting is easy, it is as simple as turning off lights when they are not required and replacing high electricity consuming light bulbs with their low energy equivalents.

Traditionally, lighting has been provided by incandescent light bulbs. Whilst this form of light bulb may be cheap to purchase, they require a lot of electricity to run and are thus more expensive in the long term. New low energy alternatives that have revolutionised efficient lightly include CFL and LED lights. CFL lighting is estimated to require around 20% of the electricity of a traditional incandescent light bulb and is therefore five times cheaper to run. CFL light bulbs also last much longer meaning that they rarely need to be replaced. Whilst the CFL lighting costs more to purchase, this initial expense is readily recovered through the reduced cost of electricity consumption. LED lighting is better still, saving up to 90% of the energy from a traditional light bulb and lasting up to 10 times as long as CFL lighting. However, LED lighting can be expensive to install and therefore the payback times are significantly longer. Thus, before installing LED lighting it is recommended that a cost-benefit calculation is performed as demonstrated above.

3.1.2. Reducing fuel wood consumption

A significant amount of the energy used by factories is in the tea drying process. To dry the tea, wood powered boilers burn fuel wood to create heat which is then used in the drying process. If the wood used in this process is derived from a sustainable source, i.e. from a forest that is not reducing in terms of area or density, then this can be seen as a form of climate change mitigation as no net emission are being generated. However, this is often not the case.

Moreover, because of the large quantity of wood required to power the boilers, the purchase or growth and harvesting of fuel wood will be placing significant financial burdens on the operations of KTDA. For example, at the factory detailed in Figure 5, wood comprises over 35% of total annual spend on energy. The surrounding smallholder communities to each KTDA factory are also reliant on fuel wood, primarily for cooking, placing additional pressure on this valuable natural resources. Because of these reasons, there is a strong business case to reduce the amount of wood being used where possible, on top of its potential climate change mitigation benefits. There are a number of ways in which this can be achieved which include:

1. Drying fuel wood
2. Improving boiler efficiency
3. Using alternative fuels made from waste products e.g. briquettes

In addition to reducing wood consumption at the factory, farmers can reduce their wood consumption by installing energy-saving stoves. Information on this is provided in the complementary farmer based mitigation manual. The climate change impacts of wood consumption can also be reduced if the wood used is grown in a sustainable manner. More information on sustainable wood plots at the factory level is included in Section 3.2.1.

Drying fuel wood

Properly drying fuel wood before use is one of the easiest ways in which to reduce the amount of fuel wood required by a tea factory. Through drying, the moisture content of the wood is reduced and the calorific value increased. It is estimated that for the fuel wood to have an optimal calorific value, the moisture content should be less than 20%.

The drying process takes around 4 to 6 months but will be dependent on local conditions such as temperature, humidity and airflow. This means that factories will likely require a large storage area to ensure that their wood can be properly dried before use.

Key Point: The drier the wood, the more energy it produces. Wood should be completely dry before using it in a boiler.

The most effective way in which to dry fuel wood is to first split the wood and then stack it in piles. It is important to ensure that the wood is stacked in a way that leaves space for airflow and natural ventilation so that the wood can dry. It is also important to ensure that the fuel wood does not get wet or damp whilst it is being stored. If the wood gets wet, it will most likely cause rotting, evident through the growth of mould. This will lower the calorific value of the wood and the rotting process is a source of methane, one of the GHG's responsible for climate change. To prevent the wood from getting wet it should be placed on a surface above the ground, stacked under a cover and have effective drainage. If the wood gets wet during storage it is important to re-dry the wood before it is used in the boiler.

Principles of fuel wood storage

- The wood should be stored on a firm and flat surface, preferably murram.
- Split the wood before stacking to increase the speed of moisture loss.
- Stack the wood in a criss-cross manner to create space for aeration and thus increased drying.
- Arrange the stacks with respect to the direction of wind. This will allow wind to pass through the wood and increase drying.
- The wood stack must be covered to avoid rewetting. This can be achieved with polythene (well-constructed structure to withstand wind damage), tarpaulin or iron sheeting.
- Sit the wood stacks on ½ feet posts to avoid moisture uptake from the ground.
- Storm water drainage channels should be constructed around the storage perimeter to avoid rewetting of the wood.

Figure 7: Principles of good fuel wood storage - covering and drainage channels

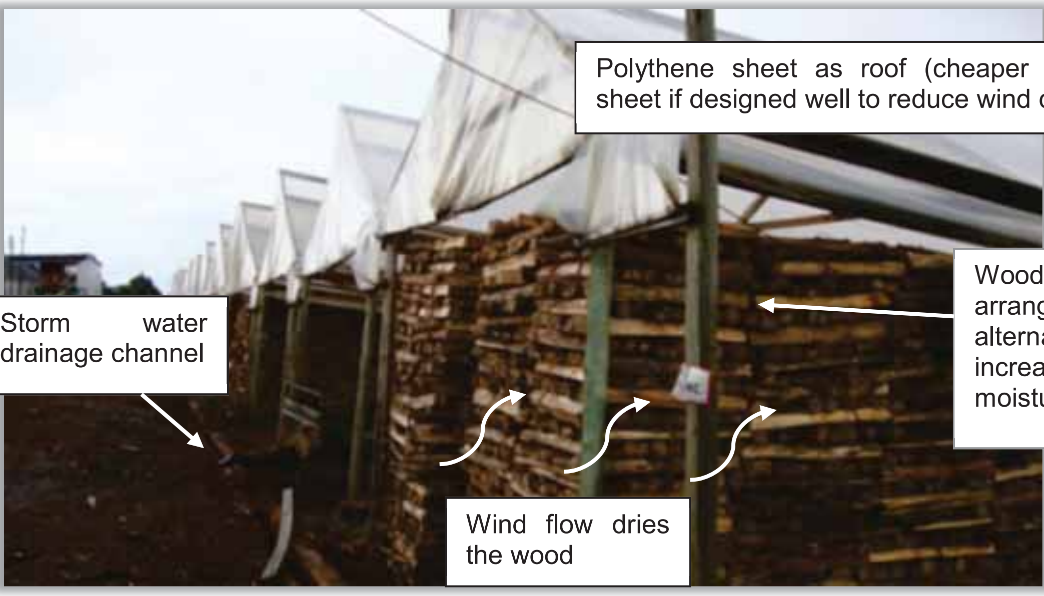


Figure 8: Principles of good fuel wood storage – supported off the ground

Figure 9: Bad practice in fuel wood storage

Improving boiler efficiency to reduce fuel wood use

The second way in which the quantity of fuel wood required by a tea factory can be reduced is to improve the efficiency of the boiler. This can be achieved in a number of ways. First it is important to ensure that there are no leaks in the system. The boiler and all associated piping should be checked on a regular basis for leaks and properly maintained. Second, it is important to ensure that the system is fully insulated. This will prevent any heat from being lost and reduce the amount of fuel wood required. Third, it is recommended that all boiler operators undergo training to ensure that there is a consistent level of understanding in how to operate the boilers in the most efficient way possible. For example, boiler operators should ensure that they are selecting fully dried wood for use in the boiler and ensure that the door to the boiler is kept shut as much as possible.

Factors affecting boiler efficiency

- Steam leaks
- Faulty steam traps
- Poor steam pipe insulation
- Poor condensate insulation
- Poor insulation to feed tank
- Poor insulation to hot air ducts
- Excessive blow down
- Blocked heat exchangers

Data for optimal boiler operation

- Stacked wood density: 550 to 650kg/m³
- Optimal fuel wood moisture content: 15 to 20%
- Pre-heated combustion air: 120 to 170°C
- Flue gas temperature: 120 to 160°C

Monitoring progress in the factory

If activities are being implemented to try and reduce the amount of fuel wood consumed it is recommended that a monitoring programme is implemented to track progress. To do this, the amount of wood (in cubic meters) that is required on a daily or weekly basis should be recoded along with the quantity of made tea produced by the factory. A calculation can then be made to determine the amount of wood required per kilogram of made tea. This can then act as a baseline against which the success of different activities can be measured.

3.1.3. Reducing diesel consumption

Tea factories often use trucks to transport tea from buying centres to the factory. These trucks run on diesel which is a fossil fuel and when burnt, produces greenhouse gas emissions that contribute to climate change. Whilst it will always be necessary to transport tea from the buying centres to the factory, there are ways in which the consumption of diesel can be reduced and money can be saved.

One option is to implement an economic driving programme. Depending on the way in which vehicles are driven, they use a different amount of fuel. For example, driving fast and regularly speeding up and then braking consumes a lot more fuel than driving at a steady and consistent speed. More examples are provided in the box below. To cut down on the fuel consumption, the driving habits of the drivers can be addressed with drivers being educated on how to implement economical driving practices.

Principles of economical driving

- Ensure tyres are fully pumped to the recommended level;
- Do not keep the engine running whilst the truck is left standing for long periods of time;
- Find routes that avoid steep and hilly terrain where possible;
- Reduce excessive gear changing;
- Keep the vehicle moving at a slow and steady rate rather than stopping and speeding or stopping and starting;
- Speeding uses more fuel: in large trucks a 22% reduction in fuel can be achieved by reducing speed from 56 to 50 mph;
- Using momentum instead of the accelerator when possible;
- Avoid unnecessary braking;
- Drive at a constant speed when possible.

Once the drivers have been educated, an incentive can be put in place to encourage drivers to implement efficient driving practices. Progress should also be monitored and this can be done easily by collecting data from each driver on the distance travelled and the diesel consumed. Through doing this, the average monthly fuel requirements per kilometre travelled can be recorded and a target set for a reduction in this target.

It is recommended that this is done on a group rather than an individual basis as different vehicles will have different efficiencies. An example of data that can be collected is provided in Table 8.

Table 8: Emissions targets for reducing fuel use

Target litres/100km	30

Week	Kilometers driven (Km)	Diesel Consumed (l)	Consumption litres/100km	Difference with target
1	2300	650	28.3	1.7
2	2000	640	32	-2
3	2100	625	29.8	0.2
4	2050	606	29.6	0.4

A second option is to analyse the routes the collection vans drive to ensure that the most economical route have been chosen.

Diesel will also be used by the trucks that transport fuel wood from tree plantations. Similarly a programme of fuel-efficient driving can be implemented. It is also important to consider how the wood at the fuel wood plantation is chopped to ensure that optimal wood loads can be stacked into the lorry. For example, a bigger load can be carried if logs are split rather than carried whole as they can be stacked more closely onto the lorry.

3.2. Reducing the impact of energy consumption: mitigation options

The production of tea requires energy. The impact that this energy use has on climate change will depend on the source of the energy. Low emission sources include wood from sustainably managed sources to power boilers and electricity generated from renewable sources such as hydropower or solar and using such energy sources can help to mitigate emissions. This section of the manual looks at ways in which tea factories can reduce the emissions associated with their energy use and includes the following:

Section 3.2.1 **Mitigation Option 4**: Sustainable fuel wood sourcing

Section 3.2.2 **Mitigation Option 5**: Reducing the impact of electricity consumption

3.2.1. Sustainable fuel wood sourcing

As stated above, the majority of the energy requirements at Kenyan tea factories are provided by wood fuel which powers the factories boilers. Wood has the potential to be a low carbon or an emissions free energy source if the forest from which the wood is derived is well managed. As concluded by the Intergovernmental Panel on Climate Change when discussing emissions mitigation from forests, 'a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber or energy from the forest, will generate the largest sustained mitigation benefit'[5]. A key emissions mitigation strategy for tea factories dependant on fuel wood is thus to ensure that the wood used to run their boilers is being supplied in a sustainable manner.

The easiest way in which this can be achieved is for tea factories to increase the size of fuel wood plantations so that they can fully supply each factory with its wood requirements and to manage these plantations in a sustainable manner. Increasing forest area and density through afforestation, reforestation and forest restoration results in increased absorption of carbon dioxide from the atmosphere, provided care is taken to avoid the felling of native forest in favour of managed wood plantations. Establishing wood plantations in areas that do not qualify as forest (fields, pastures) is preferred. Once the trees are harvested, new trees can grow in their place and continue to sequester carbon. This is a strong strategy for climate change mitigation.

[5] IPCC (2007) Fourth Assessment Report - Working group three: Climate change mitigation http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch9s9-es.html

However, it is unlikely that every tea factory will be able to provide all their fuel wood needs internally and therefore effort should also be placed in supporting local smallholder farmers to also develop woodlots in a sustainable manner and encourage smallholders to sell this wood to their local factory. Not only will this ensure that the factory has a secure wood supply, it will provide a source of additional income for local farmers. Information on indigenous tree planting for famers is provided in the farm level mitigation manual.

There are a number of steps involved in developing sustainable fuel wood plantations which include;

1. Developing efficient and large-scale tree nurseries
2. Planting tree seedlings in the plantation
3. Managing the plantation for optimal tree density
4. Harvesting the wood for use in a sustainable manner

Whilst this guide cannot be comprehensive on this topic, some key information and guidance has been provided.

The Kenyan Forestry Service recommends the use of Eucalyptus as a source of fuel wood. However, it should be recognised that Eucalyptus is a not an indigenous tree to Kenya and concerns have been raised over its water requirements. It is therefore important to ensure that when setting up a woodlot at the factory or the farm level that Eucalyptus is planted away from watercourses and in particular, Eucalyptus should not be planted along riparian strips.

Step 1: Developing tree nurseries

Tree nurseries are the first step in developing a sustainable fuel wood plantation. The ultimate goal of a tree nursery is to produce high quality planting material. New trees can be grown from one of two methods:

i) Grown from seeds

ii) Vegetative propagation of tree cuttings

Each of these two methods has its own advantages and disadvantages and these are outlined in Table 9 below. A description of the steps involved in developping a tree nursery using each of these methods follows:

Table 9: Comparing vegetative and seed propagation

Vegetative propagation	Seed propagation
Fast establishment in the nursery. Vegetative propagation seedlings are ready for field planting in average **60** days	Seed stock material is ready for field planting in **150 – 180** days
Trees of desirable traits are deployed in plantation for maximum profitability e.g. **high yield, higher calorific values & fast growth**	May have trees of undesirable traits
Uniformity in stands permits fairly *precise projections* to be made in *planning.*	Seedlings not uniform in stands hence not easy to precisely project activities during planning
There is an underlying risk of genetic uniformity. *The perceived risks are essentially related to a devastating new disease or pest being introduced*	Able to maintain genetic pool for future generation
Capital intensive – High cost	Labour intensive but lower cost
High level of technical skills required	Easier to deliver

When growing new trees quality control needs to be highly regarded to ensure that the resulting fuel wood plantation is of good quality and of a high density.

i) When growing trees from seeds

Step 1(i) a: Seed selection

It is important to ensure that only seeds of superior quality are used when growing trees. Use certified seeds from registered seed multipliers and outlets e.g the Kenya Forestry Research Institute (KeFRI) or seed collectors who have registered with KeFRI. If in doubt, always contact KeFRI for advice. Good quality seeds will have high viability and almost uniform characteristics. The seeds will also be labelled with the following details: the species, batch number, source of seeds, date collected, provenance, germination rate and weight.

Seeds should not be stored for more than a month and thus the correct number of seeds needs to be purchased and is dependent on the number of seedlings required. Table 10 details the number of seeds required to produce certain numbers of eucalyptus trees.

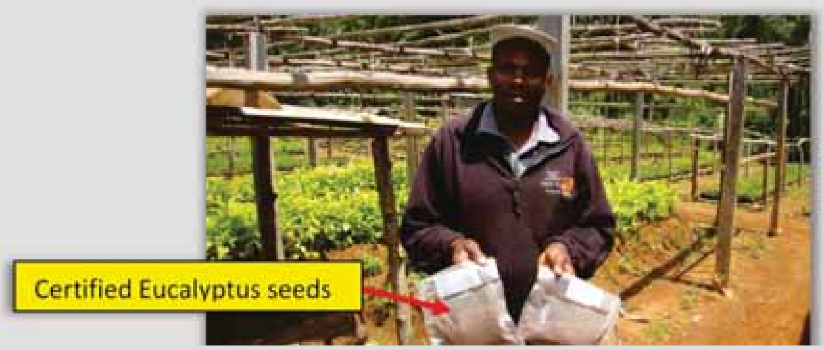
Table 10: Seed requirements for eucalyptus spp. growth

Species	Weight (kg)	Number of seeds	Expected number of seedlings
E. grandis	1.0	300,000	210,000
	0.5	150,000	105,000
	0.25	75,000	52,500
E. camandulensis	1	300,000	210,000
	0.5	150,000	105,000
	0.25	75,000	52,500
E. saligna	1.0	300,000	210,000
	0.5	150,000	105,000
	0.25	75,000	52,500
E. globulus	1.0	200,000	140,000
	0.5	100,000	70,000
	0.25	50,000	35,000
E. maculata	1.0	160,000	112,000
	0.5	80,000	56,000
	0.25	40,000	28,000

Source: KEFRI, Muguga

High quality seeds can be sourced from:

- **Kenyan Forestry Seed Centre** as part of the **Kenyan Forestry Research Institute** (www.kefri.org). Ensure that seed packets have the KEFRI label with the following details: the species, batch number, source of seeds, date collected, provenance, germination rate and weight.
- **Registered Seed Collectors**: Seeds can be sourced from trained seed collectors who are registered with KEFRI. The collectors should provide proof of registration with KEFRI.



Step 1(i) b: Seedbed preparation selection

Seeds purchased from a reputable source can be sown in a prepared seed bed at a tree nursery site. The key principles that should be followed when sowing tree seeds are as follows:

- Use soil free from weed, pests and diseases. Such soil can be obtained from woodlots or farm conservation areas.
- Soil should be collected at least three months before potting. The soil should be watered to allow weed seeds to germinate and be removed and ensure there is complete decomposition of organic matter. Regularly turn and mix the soil for complete germination of undesirable seeds.
- Mix the soil with sand – helps to loosen the soil hence reduced root damage of the tender seedling during transplanting allows good drainage and aeration.
- Secure the seedbed soil with a raised bed. This prevents contamination of the soil.
- Seedbed and nursery beds should be oriented east-west direction.
- Cover the shed against direct sunshine and rain – an iron or polythene sheet can be used to remove up to 25% of light.

Note: Every area of the bed should be accessible

- Water the surface of the bed.
- Seeds should be mixed with fine sand in equal ratio before they are sown.
- Place the seeds at 1 – 1.5 cm depth and cover with soil. The bed should never be dry but not soaked with water. To germinate the seeds require air (oxygen) and soaking may make the oxygen unavailable to the seed.
- The seeds will germinate after about 7- 14 days.
- Water the bed only early in the morning and late evening i.e. when the temperatures are low. Watering when it is too hot can cause cracking of the soil due to increased evaporation. The cracking will cut the tender roots of the seedlings causing death.

Nursery development

Step 1(i) c: Transplanting the seedlings into pots

Once the seedlings have three to four leaves, they should be transplanted into pots or potting sleeves. This activity must take place in the shade and the seedling must remain moist at all times to prevent damage to the rooting system. Once transplanted, the seedlings should be returned to the nursery and placed into beds for continued management. The nursery should provide shade and protection for the seedlings. The seedlings should be watered early in the morning and in the evening and follow a fertilisation regime as recommended for the species.

The following provides the key principles in transplanting seedlings once they have reached a suitable size:

- Transfer the potting soil three months before potting to the potting shed.
- Water the soil during this period. *This ensures that any weed present will germinate and can then be removed.*
- It is important for potting to take place in a potting shed as this provides shade and prevents the roots from being damaged.
- Potting should be done when the seedling has 3 - 4 leaves (usually 21 – 28 days after seed planting). A potting sleeve of 3'x6' is ideal. Large potting papers would be better for root establishment but will require a large field for equivalent number of seedlings.
- Water the soil in the potting sleeve before transplanting.
- The uprooted seedlings should remain in moist condition till transplanted in the sleeve.
- Use a dibble to make a hole at the centre of the soil in the sleeve.
- The depth of the dibble should be equivalent to the length of the roots of the seedling – *usually 3 cm. Roots that are too deep will create air pockets and cause the roots to rot. Too shallow will deform the roots hence poor establishment.*

Insert the seedling and gently press the soil around the seedling to help it remain upright (support) and remove air pockets around the roots.

Transplanting seedlings

Dibble making hole at the centre of the pot

Potting shed

Further information can be obtained from the Kenyan Forestry Research Institute (KEFRI) or any of the resources in the box below.

Additional sources of information on developing tree nurseries can be found at the following locations

- **Kenyan Forestry Research Institute** (www.kefri.org). They should be the first point of call for any questions
- A Guide to On-Farm Eucalyptus Growing in Kenya
  http://www.wrm.org.uy/countries/Kenya/Eucalyptus_guidelines.pdf
- Raising fuel wood and fodder trees in nurseries
  http://www.gardenorganic.org.uk/pdfs/international_programme/RaiseFire.pdf
- Tree planting manual – Seedling Nursery
  http://www.treeseedfa.org/doc/Manual_English/Chapter32SeedlingNursery.pdf
- Establishing a tree nursery
  http://www.anancy.net/documents/file_en/010_Establishing_a_Tree_Nursery_A4.pdf

When growing trees using vegetative propagation

Step 1(ii) a: Selecting the tea clone

It is also possible to grow trees from vegetative propagation. It should be recognised that this typically requires high levels of technical skills to manage and financial investment in the correct infrastructure.

The first step in vegetative propagation is to make a clonal garden of the desired tree varieties. This will provide the cuttings for vegetative propagation. The clonal garden can be raised from cuttings for the same tree variety in order to achieve similar growth rate in the clonal garden. The clonal tree is nipped 15 months or more after transplanting so that it can produce suckers which will be used as the cuttings. A Eucalyptus tree in a clonal garden can yield about 60 cuttings a year.

Step 1(ii) b: Greenhouse structure

The next step is to construct a greenhouse that can maintain the desired high temperature and humidity for establishment and faster growth of the cutting. Use a 1000 micron paper and line it with a black shade net on the side and at the ceiling. The shade net at the ceiling filters excessive hot air from reaching the seedlings.

Greenhouse construction – covered with shading and raised plant tables

Step 1(ii) c: Cutting establishment

When establishing cuttings it is important that the following key principles are followed:

- Use sterile soil for the vegetative propagation:
  - Root development is part of healing of a cutting. A nutrient rich soil sends signals to the plant that there is no need to develop roots as there is plenty food.
  - A sterile media causes the cutting to develop roots to go and look for food.
  - Sub soil is a good sterile media, easy to obtain and sustainable. If not available use commercial sterile media e.g. **vermiculite, sand soil** etc.
- Fill the mixture of sterile soil and stone chips in to a **root trainer.** *A root trainer has grooves that train the roots to grow down.*
- A paper pot causes root deformation (spiralling of roots); however it can be used if root trainers are too expensive.
- Water the soil in the groove and **do not** press down.

Once the root trainers have been prepared, a cutting can be taken:

- Using sterilized secateurs or a pair of scissors or sharp knife, get the cutting from the clonal garden and reduce its size to 8 cm from the bud.
- Trim the leaves – to reduce transpiration rate.
- Insert about 4 – 5 mm of the cut end in the soil (soil held by the root trainer). Do not press the soil.
- Arrange the root trainers in a rack and finally in a raised structure in the greenhouse.
- Seedling will remain for 21 days in the greenhouse before transferring to the hardening bed.

Using a root trainer


Grooves help to train the roots to grow down


8 cm and trimmed leaves cutting inserted into the root trainer


Taking a cutting from the clonal


Rack to hold the root trainers

Vegetative propagation

Propagation beds in the greenhouse

Hardening beds under shade

Raised beds in the greenhouse and hardening area

Established cutting 14 days after propagation

Step 2: Maintaining plant health

Whether tree plants are being grown from seed or via vegetative propagation it is important to maintain plant health whilst the tree is in the tree nursery. To support plant health the following principles should be followed:

- Keep the potted seedling under shade to reduce evapotranspiration and to protect them from rain storms.
- Water early in the morning (before 10 am) and in the evening (after 3 pm) - *to reduce evapotranspiration.*
- Avoid excessive watering. Keep the containers /pots moist but not waterlogged.
- Use recommended herbicides, fungicides and pesticides as advised by the forest field officers.
- Apply DAP (di-ammonium phosphate) fertilizer as a foliar 1 month after transplanting as this helps in root establishment (check quantities with KEFRI before application).
- Apply NPK or CAN fertilizer 2 – 3 months after transplanting (300g in 10 litres of water for 300 plants). – *this helps in foliage formation and the attaining the standard height required for planting, usually about 1 foot* (check quantities with KEFRI before application).
- Arrange the pots in beds of not more than 4 feet wide and paths between the beds for ease of management.

Step 3: Planting of seedlings in a plantation for fuel wood

When setting up a fuel wood plantation it is important to avoid planting eucalyptus trees directly on watercourses due to their high water requirements. Best practice is to plant indigenous trees alongside water courses to act as a 'buffer' at a width of approximately 50 meters.

To ensure that eucalyptus trees grow effectively in a fuel wood plantation it is important to practice the following principles:

- Thorough land preparation
- Pre-plant weed control
- Planting only good quality seedlings
- Planting early in the rains
- Blanking (infilling) no later than threeweeks after the initial planting
- Regular weeding in the first few months after planting.

Step 3a: Land preparation

The first step in planting new trees is to effectively prepare the land. This should be done in the following manner:

- Clear the area to be planted from weed at a minimum strip of 1.5 m along the planting lines.
- Mark the land and peg the planting point depending on the intended use of the wood.
- Wood fuel - 3 x 2 (1667) trees/ hectare.
- Timber – 3 x 3 (1111) trees per hectare.
- Make holes for the plants 30 cm wide x 60 cm deep:
  - These holes can be made a few hours before planting, or a day before planting if done by machine (drilling augur) and in an area relatively wet throughout during the rainy season. Machine is able to well mix the soil during digging.
  - If the wood lot is in a relatively dry area, the holes should be made several days before the rains, allowed to be drenched by rain to soften the walls and covered before planting. – *(this allows the soil to hold enough water to allow the seedling to establish before the rains go down).*

Marked and pegged field ready for planting

Step 3b: Planting of trees

First the sleeve needs to be removed:

- Drench the soil in the sleeve with water.
- Gently press the soil to compact it together.
- Hold the seedling upside down between two fingers near the soil as the fingers from the other hand gently slide the paper out.

Planting trees

Gently compacting the soil together with both hands

Removing the potting sleeve

Seedlings ready for planting

Once the sleeve has been removed the tree is ready for planting:

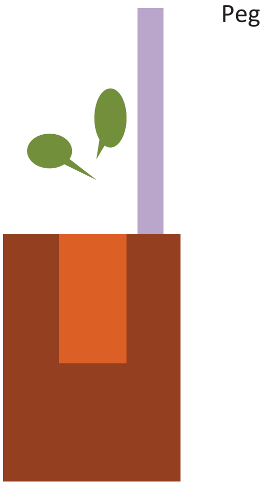
- Dig a hole deeper than the root length. For each hole mix fertilizer with the topsoil. The exact quantities and type should be checked with the Kenyan Forestry Research Institute (e.g. 50g TSP (triple super phosphate) and 30g rock phosphate fertilizers for eucalyptus).
- Without disturbing the soil around the roots cover the seedling to the level of the soil in the pot using the fertilizer-topsoil mixture.
- Gently press the soil to allow the tree to stand, but not too much to remove the air spaces.
- Allow the peg to remain until the tree outgrows it. If available, mulch the soil around the seedling (the mulch should not touch the wood of the tree – with a minimum of 10 cm radius away from the tree to avoid viral disease infections).

Adding Fertilizers

E. grandis, like many Eucalyptus species, often responds dramatically to fertilizer application. Fertilizing promotes fast early growth, which helps the crop to capture the site more quickly (reducing weeding costs). 30 grams of Single Superphosphate (SSP) can be added per tree at the time of planting. More information can be obtained from the KEFRI.

Key Point: If large areas are being planted soil tests and fertilizer trials should be carried out.

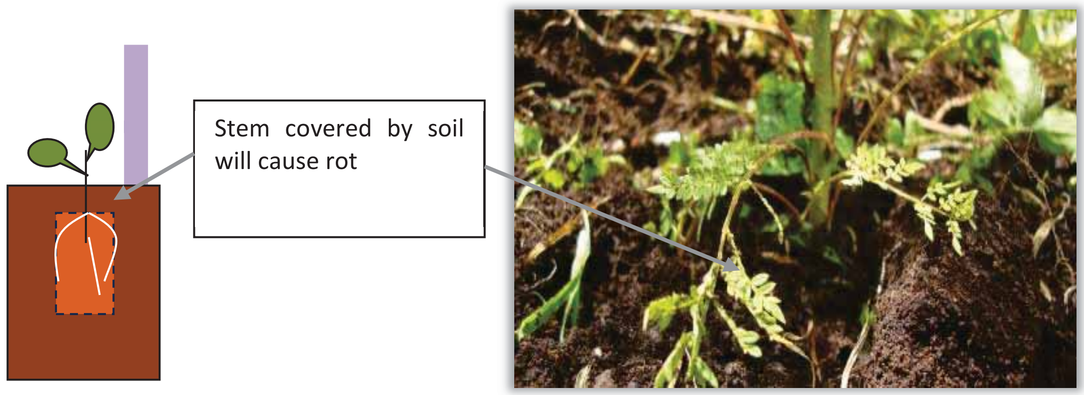
Good practice in tree planting



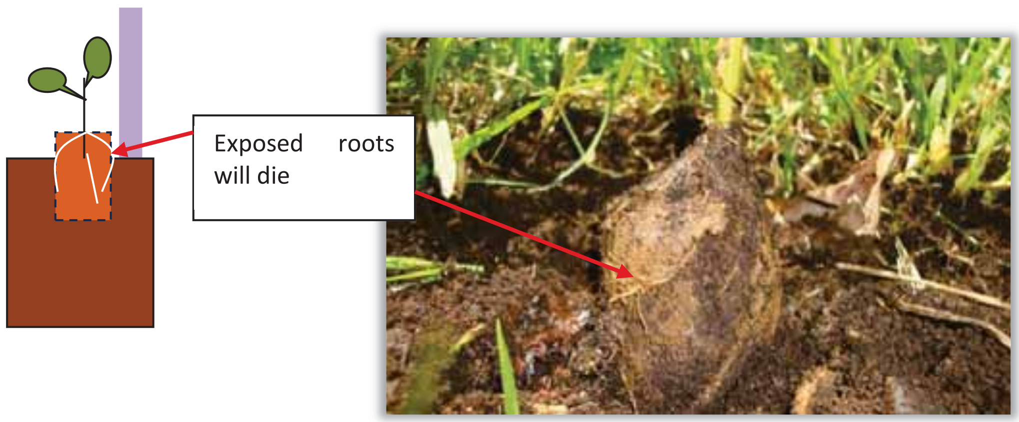
Bad practice in tree planting

The following planting practices should be avoided:

1. Covering the tree wood (stem) below the point initially covered by soil in the potting sleeve – *the soft tissues around the stem might rot causing the plant to die.*



2. Not covering the part of the soil initially in the pot. The exposed roots will die, which may cause the death of the entire tree or growth retardation.



3. Removing the peg (marker) besides the seedling.

   - May cause farm workers to step on the seedling hence damaging the plant;
   - Not easy to locate the position of the dead seedling requiring infilling.

Step 4: Fuel wood plantation maintenance

Poor weeding is the single biggest cause of poor growth in eucalyptus plantations. Weed little and often is recommended rather than waiting until the weeds are a real problem. Eucalyptus does not tolerate competition and they are particularly sensitive to grasses.

Key Point: Weeding is critical in eucalyptus plantations to ensure good growth.

It is recommended that the trees are kept free of weeds for the first two years or until they are about 1.5m high. For trees of 1.5m and above, spot weeding around the seedlings (one meter diameter) and slashing in between the seedlings should be done during the first year. There should be continuous monitoring of pests and diseases and if problems arise, advice should be sought from KEFRI. [6]

Step 5: Harvesting the fuel wood

Harvesting of eucalyptus grown for fuel wood takes place after 3-5 years if using KEFRI eucalyptus clones. The age of maximum volume returns is used to determine the coppicing cycle. The cycle is shorter in drier areas and longer in wetter areas. Advice can be sought from KEFRI on optimum coppicing cycles for specific varieties of eucalyptus.

The harvesting should be conducted in a manner that allows the wood to be ‘coppiced’. Coppicing is the process whereby the tree regrows from the ‘stump’ or ‘stool’ from which it has been cut and allows the grower to have multiple crops from the plantation without having to replant the trees.

Key principles that should be implemented to allow the wood to be ‘coppiced’ are as follows:

- Harvesting should be undertaken using saws and not axes and pangas because they damage the tree stump and affect its ability to be coppiced.
- The stump should be cut in a slanting way to ensure that water does not accumulate on the stump.
- Harvesting should be done during the rainy season.
- The stumps should not be less than 10cm height.
- Care should be taken not to damage the bark of the stump as this will prevent regrowth.
- The stump should not be left covered with slash as this will obstruct coppice shoots.

Key Point: Plantations that have been severely stressed will not coppice well and should be replanted after harvest.

If the above principles are followed, and once the initial crop has been harvested from the fuel wood plantation, the remaining ‘stumps’ or ‘stools’ will begin to grow new tree shoots. Because these new shoots all compete for light and water, it is important to implement a thinning process to ensure that a second good yield of fuel wood is provided. To do this, specific stems according to their size and position on the stool are chosen and the rest are removed. This allows the remaining shoots to grow well and with a good form, giving the best yield of fuel wood over time. This activity is undertaken in two stages so that the better shoots are selected and in the end the plantation provides a stocking (plant density) the same as the original plantation.

Further details of the coppicing process are provided by the SPGS in their ‘planting guidelines no 21[7].

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[6] SPGS Planting Guidelines no 9 and 10 ‘Growing Eucalypts for Timber, Poles & Fuelwood’
http://www.sawlog.ug/downloads/Guideline%20No.09&10%20-%20Growing%20Eucalypts.pdf

Kenyan Forestry Services (2009) ‘A Guide to On-Farm Eucalyptus Growing in Kenya’
http://www.kenyaforestservice.org/documents/Eucalyptus%20guidelines%20%20Final%202.pdf

[7] http://www.sawlog.ug/downloads/Guideline%20No.21-%20%20Coppice.pdf

3.2.2. Alternative electricity sources

Electricity consumption for the processing of tea leaf at tea factories provides a major financial burden. Section 3.1.1 of this training manual provides information on ways in which electricity consumption can be reduced.

This section of the manual looks at other ways in which electricity can be produced 'on-site' at the tea factory. This would provide multiple benefits which include:

- Reduced reliance on 'grid' electricity
- Reduced operational costs
- Emissions mitigation

There are a number of options for factories to produce electricity on site and these include:

- Small scale hydropower:

Hydropower is the term used to describe electricity that is generated by harnessing the power of moving water. Hydropower provides a carbon free source of electricity. The first KTDA small hydro pilot power project was at Imenti tea factory in Meru County with its 1 megawatt small hydro plant that was commissioned in 2009. The power plant has been able to reduce the factory electricity bill by almost 60 per cent. The factory consumes about half of the generated 0.4 to 0.5 megawatts and sells the surplus to the national grid. KTDA is now rolling out hydropower schemes to other factories.

- Wind energy:

It is also possible to create electricity from wind power through using wind turbines. KTDA is trialling this approach as well and it is reported that the electricity can be produced at a slightly lower cost in comparison to hydropower.

3.3. Improving waste water management: mitigation options

The waste water from tea factories contains cleaning chemicals and tea residues rinsed off from the tea production machinery. Waste water at tea factories is typically not treated and after screening is channelled back into local water systems. This has negative impacts in terms of climate change and the local environment. It is thus important to consider implementing a waste water management system.

Emissions from waste water occur when organic matter contained in the water decomposes. Because water prevents oxygen from reaching the organic material, the material decomposes in anaerobic conditions. This results in the release of Methane (CH_4) and Nitrous oxide (N_20) which are both greenhouse gases. If the water is treated it is possible to avoid these emissions. The appropriate type of waste water treatment system for use at a tea factory is location specific. It is therefore important for each factory to assess their own situation and identify methods of water treatment that make the most sense in terms of their own specific context.

Good waste water management process in a tea factory should:

Separate the solids from the waste water (screening and sedimentation);

Reduce the pathogens from the waste water to acceptable levels;

Reduce the dissolved chemical/ nutrients to acceptable levels;

Aerate the waste water to reduce the methane (CH_4) emissions.

3.3.1. Good practice in waste water treatment

Step 1: Do not mix waste water with storm water

The washing waster in the tea processing area should be directed into dedicated waste water collection channels. These channels should be separated from storm water channels. If the waste water and storm water mix together, then the water treatment system will have to deal with more water that it has been designed to manage and this can cause problems.

Figure 10: Separating storm and waste water

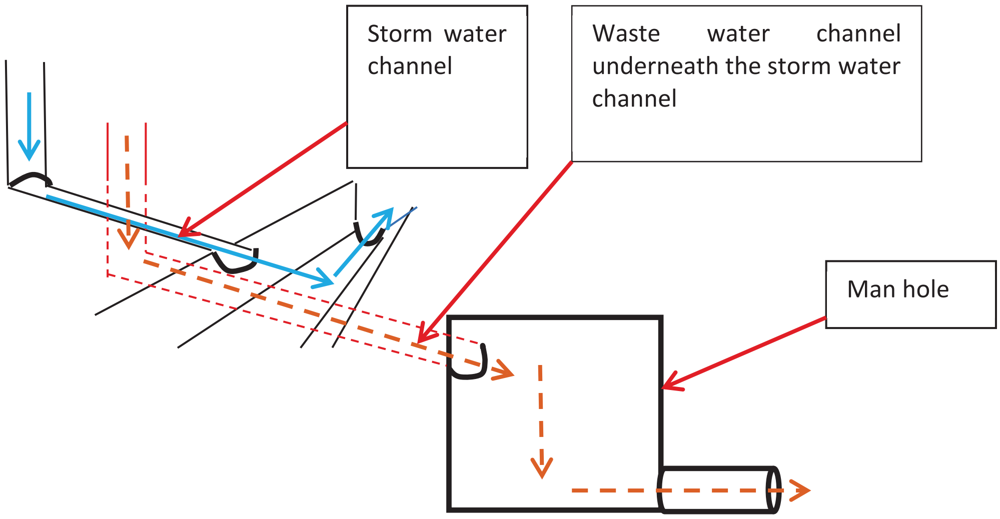


Figure 11: Good practice in waste water treatment

Figure 12: Bad practice in waste water treatment

Mixture of storm and waste water into the same channel (wrong practice)

Step 2: Organic matter removal and management

The next step in waste water management involves transporting the waste water from the tea factory down a delivery channel to the waste water treatment site.

Step 2a: Delivery channel design

It is important to design the delivery channels in a manner that prevents the large solid particles suspended in the water from settling at the bottom of the channel. If the sediment settles it will require labour to remove and it will start to decompose which will create greenhouse gas emissions. Preventing the solids from settling can be achieved through implementing the following design mechanisms:

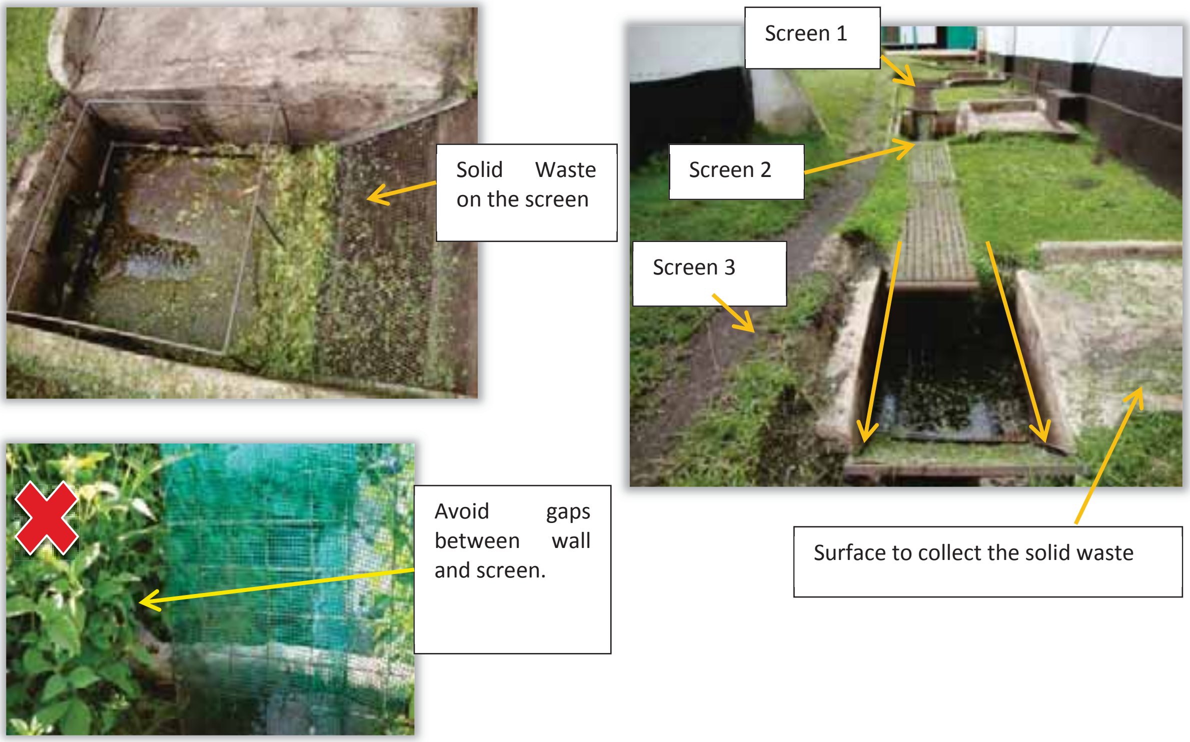
- Sloping the channel to allow for fast flowing water – solids will settle in slow moving water.
- Round bottomed channel - allows equal flow at all points, reduces side erosion of the channel, allows for a turbulent flow thus discouraging solids to settle on the base of the channel.
- Preventing vegetation growth on the channel walls or base – the manhole cover allows access to the channel to clean and remove material that has settled and preventing further sedimentation of the channel.

Step 2b: Screen out solid matter from the waste water

Solids must be separated from the waste water. This can be achieved through passing waste water first through a screen to remove large matter and then though a sedimentation tank to remove smaller suspended particles.

It is recommended that the waste water passes through a series of 3 screens placed at between 4 - 6m intervals depending on space. The screen mesh should be of different sizes and reduce in size from one to the next i.e. 1cm, 0.5cm and 0.25 cm diameter. The screens should fit the size of the channel to avoid any solid escaping through the sides. The screened solid waste should be collected on a flat surface that allows the surface water to drain back to the waste water channel. Any metals and plastics should be separated from the organic waste.

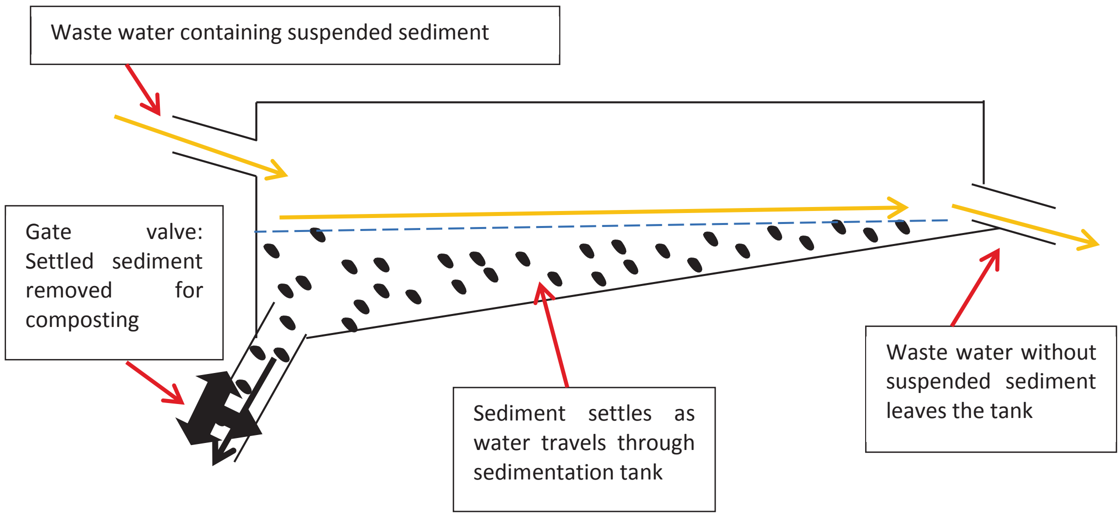
Figure 13: Water screening



Step 2c: Use a sedimentation tank to remove organic matter

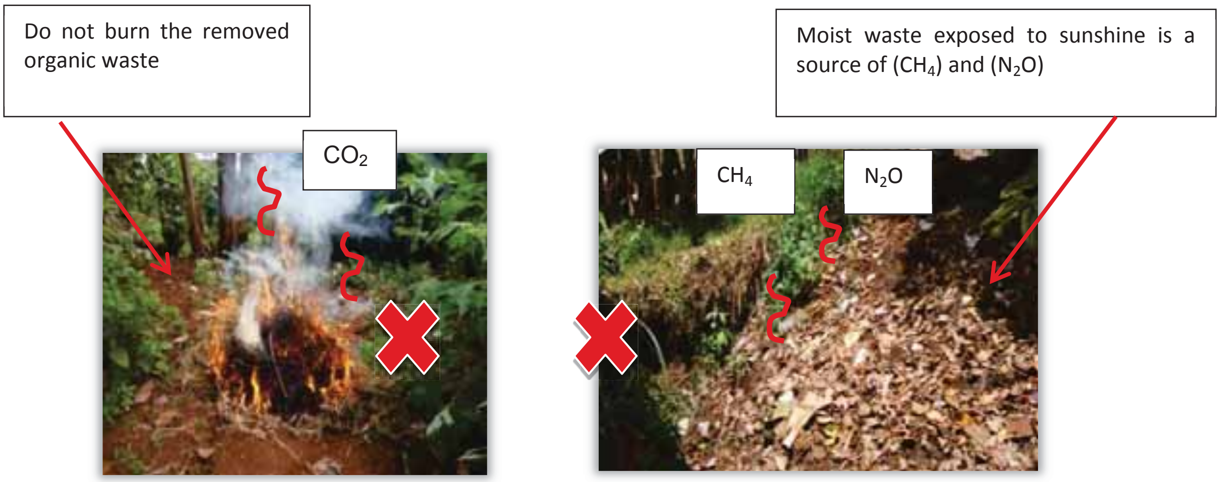
Once the water has passed through the screens, only very small organic particles that remain suspended in the water will still be present. These should be removed using a sedimentation tank. Sedimentation tanks are tanks that water moves slowly through to allow any suspended particles to separate and sink. A sedimentation tank will be deeper at the waste water entry point as this is where the majority of sediments will settle. The deep end has a gate valve to release the sediment for composting. Sediment will need to be removed via the gate valve on a regular basis.

Figure 14: Sedimentation tank



Once the organic solid waste has been separated from the waste water it should be composted or fed into a digester. This will ensure that greenhouse gas emissions are avoided.

Figure 15: Organic waste management (bad practice)



Step 3: Treating the remaining water in a constructed wetland system

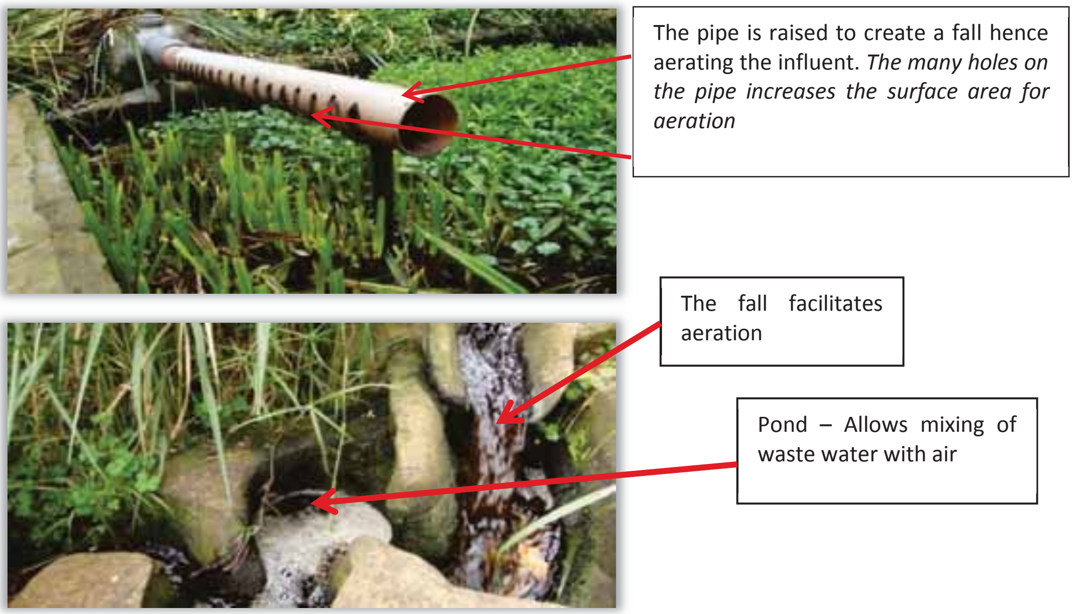
Once the organic matter has been removed from the waste water it can then enter into the final stage of treatment. This typically involves a constructed wetland treatment system. Wetland treatment systems provide a common and affordable method that combines both physical and biological methods of treatment.

When it is not possible to implement a constructed wetland treatment system, it may be preferable to install an effluent treatment system. Such systems are expensive to install and require significant energy and chemical inputs to run and therefore are not seen as a climate change mitigation strategy.

Step 3 a: Constructed wetlands - physical treatment

This is the first step in a constructed wetland treatment system and involves aerating and agitating the waste water. This is achieved by creating falls and shallow ponds along the channel in which the waste water is flowing. The purpose of this is to support the further breakdown and decomposition of any remaining particles and pollution that have not been removed by the screens or sedimentation tank. Aeration of the water also reduces the chance of methane generation as any remaining organic matter decomposes in the presence of oxygen. Because methane is a strong greenhouse gas, this is a form of climate change mitigation.

Figure 16: Physical treatment



Step 3b: Constructed wetlands - biological treatment

The second step in a constructed wetland system is biological treatment. The purpose of biological treatment is to remove any remaining pollution from the water using natural biological processes. In this wetland environment, aquatic plants and microorganisms are used to naturally breakdown and remove pollution.

In constructed wetlands, pollution becomes the nutrients of micro-organisms and is passed on along the food chain until they are removed out of the system. Other pollution removal pathways in constructed wetland systems include:

- Chemical and biological breakdown and transformation processes, whose by-products diversify with rising levels of oxygen;
- Bacterial predation;
- Uptake by plants;
- Absorption of substances (including heavy metals) on to base sediments or submerged parts of plants;
- UV radiation (sunlight).

Constructing a wetland system for biological treatment requires the construction of a series of ponds. These ponds serve different purposes. The two types of ponds required are;

1. Gravel bed hydroponics (GBH);
2. Surface cells.

In each of these pond systems, aquatic plants and microorganisms are used to naturally break down and remove any final contaminants and pollution in the water.

Biological treatment - gravel bed hydroponics (GBH)

Gravel bed hydroponics (GBH) is the first stage in the biological treatment process. As the water travels through the GBH system, the majority of pollutants are removed which prevent the surface cells from becoming overloaded with pollution. Hydroponics is the process of growing plants in water or sand rather than in soil and thus a GBH is a single pond filled with water plants. Water takes around seven days to pass through a GBH pond.

The way in which GBH ponds work is as follows. The GBH pond is filled with graded crushed aggregate. Bacteria grow on this aggregate and as water passes through they act as a filtering system, breaking down the pollution. Whilst the establishment of the bacteria on the gravel is a natural process, bacterial growth can be boosted by adding bio-augmentation products e.g. EM (effective micro-organisms).

Pollution-resistant aquatic plants are grown in the GBH ponds. These plants feed hydroponically on the waste water, absorbing around 15% of the pollutants as nutrients (*a list of pollution tolerant plants are provided on page 44).* The plants also create an underwater environment allowing more bacteria to thrive. This further improves the system's ability to break down pollution.

Figure 17: Gravel bed hydroponics

Biological treatment – surface cells (SC's)

Once the water has fed through the GBH system, it enters a series of three small ponds called surface cells. The dimensions of surface cells, which are typically soil based, are determined by the daily volume of throughput and should be designed to retain water for about seven days.

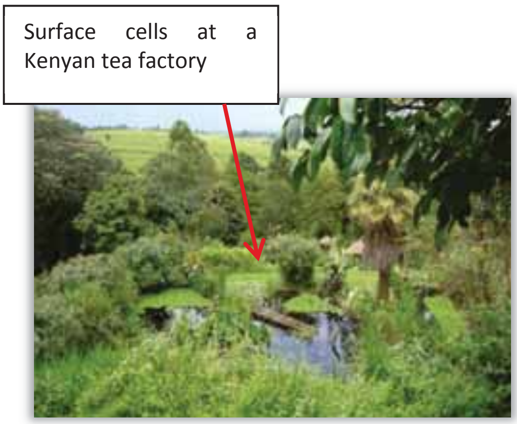
The surface cell ponds are used to filter out any remaining pollutants and to kill pathogens that are present in the water. The ponds are specifically designed to moderate the flow of water and to expose the water to air and sunlight. As before, air supports the breakdown of particles in aerobic conditions preventing the production methane. Exposure of the water to sunlight assists in killing pathogens so it is important that some of the water is exposed to sunlight i.e. not all of the ponds are shaded by vegetation. Again, a diversity of aquatic plants is planted to encourage the absorption of nutrients and particles.

Algal growth is common in the first surface cell and this is a positive sign – these microscopic plants are unable to survive in heavily polluted waters and the oxygen they produce during daylight hours kick-starts the further breakdown of pollutants.

Table 11: Indicators of good or bad processes in waste water management:

Good process	Bad process
Diffused green algae in SC1 and 2 – cannot survive in severely polluted water.	Algae in SC3 – indicates a block in nutrient removal chains.
Less vigorous plants in SC3. Shows high removal of nutrients in earlier stages.	Vigorous plant growth in SC3 – this means fewer nutrients are removed in early stages.
Presence of small and large animals in SC3– shows that the food chain is not broken and pollutants reduced.	Lack of animal(s) – pollution is high.

Figure 18: Surface cells



Routine practices for maintaining gravel bed hydroponics and surface cells

1. Net out any large (usually brownish) algal growths and the highly prolific green lemna plant to allow some of the surface area to be exposure to sunshine. It can be spread out thinly on grass as fertilizer.
2. Maintain plant diversity for optimal performance. Reduce population of the most vigorous plant species.
3. Prune and remove old and dying plant parts to avoid re-polluting the water.
4. Introduce indigenous fish (omnivores) in surface cells 2 and 3 after the vegetation has established e.g. Nile tilapia (*Oerochromis niloticus)*.
5. Contoured surface cells offer a broad choice of habitat for all forms of life, small microbes to large wading birds.

Aquatic plants that can be used in constructed wetlands

1. Umbrella flatsedge (*Cyperus involucratus*

2. Water lettuce (*Pistia stratiotes)*

3. Elephant ear (*Xanthosoma violaceum)*

4. Sphaeranthus spp

5. Hydrocotyle ranunculoides

6. Lemna Plant

PART 3:
Extension officer training – Mitigation options for farm emissions

Chapter 4

4. Mitigation options at the farm level

Smallholder tea farmers can play a role in climate change mitigation by selecting agricultural practices that reduce greenhouse gas emissions or which store carbon. It has been estimated that mitigation efforts in agriculture, such as enhancing soil carbon, could potentially offset up to 80% of current global agricultural emissions demonstrating huge potential within the sector. There is a large gap, however, between what is technically feasible and what farmers are willing or able to do.

For many rural farmers, the main aim of agriculture is to secure their livelihoods. Climate change mitigation practices will not be activities that are consciously undertaken and no mitigation activity will or should be implemented if there are trade-offs against farm productivity or food security. Thus, climate change mitigation at the farm level should be seen within the context of farmer decision making.

To encourage farmers to use climate change mitigation practices, the focus should not be on mitigation itself, but instead on the financial, social and environmental co-benefits of implementing that practice. Encouragingly, many mitigation practices have such co-benefits in the form of improved income, increased yields and reduced risk through improved ecosystem and livelihood resilience.

There are two general approaches to mitigating emissions in the agriculture sector; reducing or avoiding the release of emissions or creating sinks to remove emissions. Table 12 sets out key emissions reduction strategies that can take place at the farm level based on these two approaches.

Table 12: Climate change mitigation at the farm level

Emissions source	Mitigation activities (reducing emissions from the source)
Fertilizer use	• Appropriate application and dosage (Section 4.4)
Fuel wood use	• Reducing fuel wood consumption from unsustainable sources e.g. through using energy-saving stoves (Section 4.1)
Soil	• Sustainable soil management practices (included in ETP adaptation manual)
Pesticide use	• Appropriate application and dosage
Livestock	• Manure management
Emissions stock	• Mitigation activities (increasing the store of carbon in the emissions stock)
Vegetation	• Cover crops (included in ETP adaptation manual)
Trees	• Preventing deforestation • Indigenous tree planting (Section 4.2) • Use of shade trees (included in the adaptation manual)
Soil	• Composting and adding compost to the soil (Section 4.3) • Green manures (included in adaptation manual) • Ensuring all farm residues are reincorporated back into the soil

There are a number of different strategies that can be implemented to mitigate emissions at the farm level. Strategies that reduce emissions include the judicious use of fertilizers i.e. ensuring that they are being applied in an appropriate manner and at an appropriate dosage. The main source of fuel used by rural Kenyan tea farmers is fuel wood which is often derived from unsustainable sources. Fuel efficient stoves, the proper drying of fuel wood and tree planting are good solutions to assist in reducing emissions from this source. Soil provides another key emissions source if not well managed, and to prevent this, effort need to be placed into good agriculture practices that prevent soils from degrading or eroding.

Agricultural emissions can also be prevented through enlarging emissions sinks. This can be achieved in a number of ways. First, biomass can be increased through incorporating trees and bushes into the farming system. For example, the use of shade trees (a key climate change adaptation technique) also doubles as a mitigation activity. The same can be said for planting trees on the farm that can be used as a sustainable source of fuel wood. Great potential also lies in increasing the carbon content of soils. Through the restoration of degraded soils, the soil carbon sequestration rate can be improved. Further, significant mitigation benefits can be seen through increasing the organic matter content of soils and in particular through adding compost. Again, compost addition has multiple benefits beyond mitigation such as increasing the water retaining capacity of soil thus improving the ability of crops to be grown in times of water stress. These co-benefits that arise from the uptake of mitigation activities at the farm level should be used as the rationale to support uptake of the practices by farmers.

In this chapter, a number of climate change mitigation activities that can be implemented at the farm level are discussed in detail. Because many climate change mitigation activities also help farmers adapt to climate change, a number of mitigation activities have already been covered in the climate change adaptation manual that was produced in 2012 by the Ethical Tea Partnership[8] and this manual should be referred to for more details on these topics. The only topic that is included in both manuals is composting due to it being a critical strategy for both mitigation and adaptation.

Chapter overview

In this chapter, the following climate change mitigation activities are covered:

- Mitigation Option 1: Energy saving stoves to reduce fuel wood use
- Mitigation Option 2: Tree planting to absorb more carbon and ensure fuel wood consumption is sustainable
- Mitigation Option 3: Composting to ensure no methane and carbon returned to soil
- Mitigation Option 4: Proper application of fertilizers

4.1. Energy-saving stoves

Biomass provides 90% of rural energy requirements in Kenya with the primary source being from fuel wood. With cooking accounting for nearly all household energy requirements, cooking by fuel wood is the most significant energy consuming activity of Kenya's rural population.

However, in many locations the rate of fuel wood consumption is unsustainable and having negative impacts on the local environment. Through overuse, the availability of fuel wood is decreasing, and causing an increase in the amount or time families have to give to its collection or money to its purchase, placing extra burdens on rural families.

This chapter introduces energy-saving cooking stoves as a key method for reducing fuel wood consumption and provides guidance on how extension officers can develop a stove programme within their catchments. Such programmes have significant social and environmental benefits as well as providing a method to both mitigate and adapt to the impacts of climate change. The first section of the manual discusses the benefits of implementing an energy-saving stove project, the second section provides guidance on implementing a stove project with farmers and the third section provides some background information that can be used to help answer questions raised by farmers during stove sensitisation sessions.

Facilitating with farmers: how much wood is consumed?

Farmers will likely perceive that the tea factory uses far more wood than they do. It is therefore useful to demonstrate to farmers the total quantity of wood that they consume on a yearly basis and compare this to the factories wood consumption. This will help to demonstrate the role that farmers can play in reducing local fuel wood consumption.

It is estimated that on average a person living in a tea growing area uses 1.5kg of wood per day for cooking purposes. It is also estimated that the average farming family consists of 5 people.

[Wood consumption] x [family size] x [number of farming families] = daily wood consumption

[1.5 kg/ppd] x [5] x [10,000] = 75,000 kg wood per day

75,000 (kg wood per day) x 365 (days per year) = 27,375 tonnes/year

This value can then be compared to the factories annual wood consumption. Quite often, farmer wood consumption will be significantly higher to that used by the factory.

[8] 'Extension officer training manual – Adaption to climate change in the tea sector' available at www.ethicalteapartnership.org

4.1.1. Benefits of energy-saving stoves

Energy-savings stoves are highly beneficial due to their ability to reduce fuel wood consumption. Not only does this result in emissions reductions, playing an important role in climate change mitigation, but it provides other environmental and economic co-benefits. The following section outlines the benefits of energy-saving stoves in more detail and can be used as the basis of discussions held with farmers.

Climate change mitigation (reduced greenhouse gas emission)

Under the right conditions, fuel wood can be seen as a renewable energy source. Renewable sources of energy are those that do not contribute to climate change. For this to be the case, the amount of fuel wood that is used must be the same as the amount that is grown on a year by year basis. This means that for no climate change impact to take place, the total amount of trees must either stay constant over time or increase. The use of energy-saving stoves play an important role in this through reducing domestic wood requirements, making it easier for stocks to replenish and in doing so reducing the impact fuel wood use has on climate change. It is important to recognise that for fuel wood to be used in a completely sustainable and 'renewable' manner there will typically be a need for a complementary tree-planting programme to be in place (see section 4.2 of this manual). That being said, any activity that reduces the rate at which tree stocks are being depleted is a form of climate change mitigation as it will reduce the speed at which carbon dioxide is entering into the atmosphere.

Efficiency resulting in time and cost savings (reduced fuel wood requirements)

Energy-saving stoves have the benefit of being very efficient in comparison to the traditional '3 stone fireplace'. Depending on the type of stove installed, fuel wood for cooking can be reduced by 40 – 60%. The benefits of this to a farming family are numerous. If the family collects wood for cooking, then time is saved in undertaking this activity and there will be more time to tend to their tea farms or to engage in other activities. If the family has to purchase fuel wood then there will be significant cost savings.

Health benefits (reduced smoke emissions)

The stoves are also beneficial to health as they are designed to significantly reduce the amount of smoke in the kitchen. Many traditional stoves release the smoke from the fire into the cooking space. Because people are cooking in enclosed indoor spaces, this provides a major health issue for all family members. The World Health Organization cited that traditional stove use in Africa results in '1.5 million deaths a year – mostly of young children and their mothers'. Also that 'living in a house with such a fire is the equivalent of smoking 2 packets of cigarettes per day'[9], which is obviously not a good thing for anyone, especially the women and children who are more at risk from this form of exposure.

Through installing an energy-saving stove, smoke is reduced to an absolute minimum resulting in healthy farmers, less hospital visits and less medical bills which all have an impact on farmers' social and economic well-being.

Environmental benefits and climate change adaptation

Through reducing fuel wood consumption it is possible to conserve more trees in the local environment. Trees are important for a number of reasons and support farmers in both mitigating and adapting to climate change. Tree cover assists in protecting land from periods of extreme rainfall as they act as a soil stabiliser. They also provide shade to the soil reducing evapotranspiration (shade trees). Some tree species can be used as fodder for animals or input for compost, providing multiple benefits to the farmers.

Stove programmes can bring local employment

A well implemented energy-saving stove project builds stove building capacity within the local population amongst entrepreneurs. This creates a form of local employment and capacity within the local community to install and maintain the stoves. The trained stove builders will then market their stoves to the local population. Within the context of KTDA, it would be advisable to invite local stove builders to farmer field schools or to invite the farmers to the stove builder's house to see one of the efficient stoves in action.

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[9] http://www.who.int/indoorair/publications/fuelforlife.pdf

Facilitating with farmers

Discussion: Discuss with the farmers the importance of fuel wood in their daily lives:

- How much time do you spend collecting fuel wood?
- What are the problems with tree removal?
- Discuss the advantages of energy efficient stoves.
- Explore the amount of fuel wood used by local tea farming families and compare this to the tea factories annual use of fuel wood (see above example).

Activity: Invite the local GIZ stove project implementer to present the stove programme to farmers during a Farmer Field School event to explore setting up a project in the locality. If a project exists, invite a local stove builder to present to the farmers or facilitate a field trip to see a stove in action. Stoves can also be promoted at FFS graduation events.

4.1.2. Setting up an energy-saving stove project

In 2006 GIZ started a programme of distributing energy-saving stoves to households across Kenya. At the start of the programme, approximately 15,000 improved stoves were sold on an annual basis. Today, due to the huge success of the programme, this has grown to around 200,000 per year. It is estimate that each stove saves 1.09 tonnes of fuel wood per year.

When setting up a local stove project, GIZ work within the local community to identify individuals who can be trained to become stove builders and installers. These individuals then receive training to provide them with the technical and entrepreneurial skills necessary to take on this role. Once trained, the stove installers go out into the communities and enter into informal contracts with interested households for installing the stoves. Once both parties have agreed, the stoves are installed in the kitchen according to the households needs. GIZ play a role in monitoring the quality of the work delivered by the stove builder to ensure that the stoves are functioning well.

At the same time, GIZ take on the role of delivering a local sensitisation campaign aimed at key stakeholders in the area to ensure that the local community is informed about the project and know how they can participate.

It is recommended that tea extension officers work with the GIZ stove project implementation team to integrate the programme into their catchment areas. The first step in doing this is to set up an initial meeting with the local stove project officer or to get in touch with the ‘Improved Stove Association of Kenya’. This initial meeting should involve all extension officers from the locality to ensure that all staff are sensitised on the importance and benefits of energy-saving stoves.

Contact details:

GIZ PSDA Stoves Promotion:

- Address: PO Box 41607 00100 Nairobi, Kenya
- Telephone (20) 273 1826
- Email stoves@psda.co.ke

Improved stove Association of Kenya:

- Address: PO Box 41607, 00100, Nairobi, Kenya
- Telephone (mobile) 0725478802
- Email: kenaisa@yahoo.com; jeffaphan@yahoo.com

The local stove project officer will advise on the best way forward. For example, they will advise if there are already trained stove builders within the extension officer’s catchment area or if new stove builders will need to be trained. If existing stove builders are present it is recommended that the stove builders are invited to present to farmers during either farmer field schools or other community meetings. Another idea would be to hold a demonstration event whereby the local stove builder takes the farmers to a household where they have installed an efficient stove or to install one at a farmer's house who is part of the farmer field school programme. Similarly, energy-saving stove demonstrations at farmer field school graduation events have proved successful.

If a stove programme is not already in place then it is recommended that the regional GIZ stove building project representative is consulted to determine how best to proceed with setting up the programme in the locality. This will involve identifying local people who can become trained stove builders and exploring the availability of local materials.

Experience from many stove projects has shown that successful information campaigns to raise public awareness and interest in improved household technologies are a precondition for successful stove introduction and dissemination. Without campaigns highlighting the many problems associated with traditional cooking, and describing affordable solutions, the dissemination of energy-efficient household technologies is likely to fail. It is thus the responsibility of the extension officers to ensure that the farmers within their catchment have access to this information and that it is disseminated in an appropriate manner such as through the farmer field schools.

The roles of project participants are detailed in the Table 13.

Table 13: Key participants in a stove project

GIZ staff	FSC	TESAs
Introduce the concept to extension staff at a specific factory	Contact regional GIZ stove project representative and organise initial sensitisation meeting with extension officers	Sensitise farmers on the concept at FFSs and farmer training events
Train stove builders and provide technical assistance	Identify potential implementation areas	Promote the energy-saving stove concept in their catchment
Monitor stove builders	Monitor work of the TESAs	Identify and mobilise stove builders and users
Introduce concept to lead farmers or FFSs on a needs basis	Coordinate the identification and training of stove builders	Monitor the use of the stoves
Support in the promotion of the concept at community events/trainings		Facilitate contact between stove builders and interested households

Other points to consider:

Credit

It may be necessary to think about ways to provide credit for stove installation to farmers. This could be channelled through existing credit options available to farmers e.g. those that are promoted by KTDA.

Communicating with the community

Many energy-efficient stoves require a change in behaviour for communities who have been using a three-stone fire for many generations. This adaptation takes time. Cooking is a personal activity and has been learned from an early age. Stove users will only change their customs if they experience many advantages of the new technology over a period of time so it is important to provide a means for communities to discuss the use of the stoves on a regular basis.

Fuel wood drying

Fuel wood is often collected on a daily basis and has no time to dry before use. This makes the use less efficient as heat is wasted to drive the moisture out of the wood. Moist wood also produces more smoke. Properly drying fuel wood before use is another easy way for to reduce the amount of fuel wood they require on a day to day basis. Through drying wood, the moisture content is reduced and the calorific value increased. The drying process can take up to 4 to 6 months but will be dependent on local conditions such as temperature, humidity and airflow.

Key Point: The drier the wood, the more energy (heat) it produces and the less smoke. Wood should be completely dry before use.

Principles of fuel wood storage

- The wood should be stored on a firm and flat surface.
- Split the wood before stacking to increase the speed of moisture loss.
- Stack the wood in a criss-cross manner to create space for aeration and thus increased drying.
- Arrange the stacks with respect to the direction of wind. This will allow wind to pass through the wood and increase drying.
- The wood stack must be covered to avoid rewetting. This can be achieved with polythene, tarpaulin or iron sheeting.
- Sit the wood stacks on ½ foot posts to avoid moisture uptake from the ground.
- Storm water drainage channels should be constructed around the storage perimeter to avoid rewetting of the wood.

Farmers should be taught about how they can store and dry firewood before use. The most effective way in which to dry fuel wood is to first split the wood and then stack it in piles. It is important to ensure that the wood is stacked in a way that leaves space for airflow and natural ventilation so that the wood can dry. It is also important to ensure that the fuel wood does not get wet or damp whilst it is being stored. If the wood gets wet, it will most likely rot, evident through the growth of mould. To prevent the wood from getting wet it should be placed on a surface above the ground, stacked under a cover and have effective drainage. If the wood gets wet during storage, it is important to re-dry the wood before use.

Facilitating with farmers:

- Explore the benefits of drying fuel wood
- Ask if any of the farmers dry their fire wood
- Explore challenges and barriers to drying wood and how they can overcome these challenges

4.1.3. Addressing farmers concerns

If the farmers raise concerns over the use of energy-saving stoves during discussion the following provides some useful information:

The stove produces no light and heat: This is partly true and often a reason why efficient stoves are not immediately accepted. Only after the women have been convinced that the advantages outweigh the disadvantages, stoves will be accepted and regularly used. There are better ways to provide heat and light. Insulating houses is useful, and saves fuel. There are well-designed lamps that run on a variety of fuels. Where it is usually cold, some stoves that are made of metal give out a lot of heat – but they tend to use quite a lot of fuel, and give out heat even when it is not needed. Additional metal stoves just for heating are used in some regions.

Smoke and mosquitoes: There is no scientific evidence that smoke drives away mosquitos from homes. However, if people are convinced that smoke helps to reduce unwanted insects and other pests they can still use an improved stove to smoke the kitchen area once a day. During this time they should leave the kitchen to protect themselves from indoor air pollution. There is no need to produce smoke during cooking when people have to be present in the kitchen.

4.2. Indigenous tree planting

Trees help to mitigate climate change by storing carbon as they take up carbon dioxide during the process of photosynthesis, protecting soils through reducing land degradation, providing fuel to substitute fossil fuels and fixing nitrogen to reduce the use of fertilizers. Trees in agricultural landscapes represent a globally important carbon stock: almost half of the world's agricultural land has at least 10 percent tree cover[10]. Maintaining and increasing the quantity of trees in agricultural landscapes is therefore a very important climate change mitigation strategy.

Trees also play an important role in climate change adaptation in a farming landscape. Some trees produce fodder or products that can help to diversify land use practices and thus have positive impacts in terms of livelihoods and sources of income. Trees can also help to buffer against weather-related production losses and thus enhance resilience to climate impacts in the farming system. For example, in the tea sector, shade trees have been seen to reduce the impacts of frost through creating localised micro-climates. Trees are also beneficial in times of heavy rainfall or extreme temperatures, protecting the soil and crops from erosion and evapotranspiration.

Because of these combined mitigation and adaptation benefits, supporting smallholders to plant indigenous trees on their farms is a highly beneficial activity. Extension officers can either work will smallholders to support them setting up their own tree nurseries in the community (e.g. on farms, at schools, churches or other local institutions) or use a dedicated factory tree nursery to grow trees which are then distributed to the smallholders.

Facilitating with farmers

Classroom: Ask the farmers about the trees they have on their farm? How many trees do they have? What benefits do these trees provide? Explore the climate change benefits trees can provide in terms of frost and sun protection.

Information on setting up a tree nursery for a fuel wood plantation is provided in Chapter 3. This information is included under mitigation option 4 and can be found in section 3.2.1 with supporting information provided in the Appendix's. Information on shade trees is provided the climate change adaptation manual (available at www.ethicalteapartnership.org). This manual discusses appropriate tree species for planting and their benefits. The remainder of this section thus focuses on key points that need to be considered in supporting the development of community tree nurseries. It is intended to provide a starting point rather then a fully comprehensive set of guidelines. Links to additional resources and information are provided at the end of the chapter.

4.2.1. Development of a community tree nursery

There are a number of key points that need to be considered when setting up a community tree nursery. These include:

Reliable and nearby water supply: Water is vital to maintaining the health of tree seedlings and daily watering will be necessary. It is therefore vital that a community nursery is located near a reliable water source that is easily accessible.

Source of soil: The soil needs to be highly fertility and free from weeds and disease. A good mix of soil could include three parts of soil collected from under vegetation cover, such as under large trees, two parts of clay soil and one part sand. To check that the soil is of the correct composition farmers can roll a damp sample in their hand; a good mixture should roll and hold its shape but break if the roll is bent. If it does not break, then it has too much clay. If it crumbles before you can roll it, then it has too much sand and the soil mix should be adjusted accordingly. To ensure mixed soil has adequate fertility, one part of well rotted and sieved manure or compost can be added to every four parts of the soil mixture.

Shading: A tree nursery needs shading. Ideally this should be natural shade such as tree cover but if this is not possible then some form of shading will need to be constructed to protect the seedlings from strong

[10] www.fao.org/docrep/013/i1757e/i1757e02.pdf

midday sunshine. If shade is being constructed then it should be constructed in an east to west direction to protect seedlings from hot sun. The shade will also protect seedlings from strong winds and heavy rain.

Seeds: It is important that the species of trees that are planted are appropriate for the location. Advice can be sought from the Kenyan Forestry Research Institute (KEFRI) and a list of KEFRI recommended trees is provided at the link in the additional sources of information box at the end of this chapter. Seeds should also be sought from a verified source to ensure that they meet quality standards and will thus grow well. Again advice can be sought from KEFRI.

Protection: The nursery should be in a location where it is protected from weather and from animals. For example, the nursery should be located on a gentle slope and on well drained soil. This will minimise the risk of the nursery flooding during times of heavy rainfall. The nursery should also be located in a sheltered spot to protect it from heavy winds. A barrier between the nursery and any animals and chickens must be provided to prevent damage to the seedlings.

Nursery management: There are a number of important actives that need to be considered when managing a community nursery and these include:

- Ensure the seedlings are not overcrowded to minimise competition for nutrients and water.
- If it is very hot and dry, water twice a day to protect the seedlings from wilting. Never water in full sunshine as this will damage the seedlings.
- Weed regularly to prevent weeds from competing with the seedlings.
- Harden-off seedlings by gradually reducing the shade and frequency of watering. This allows them to get used to field conditions before transplanting. Most seedlings will be ready to plant out between two and six months, depending on the type of trees.

4.2.2. Effective tree planting

Healthy tree seedlings cannot grow and survive if they are not properly planted. The following provides some important steps that need to be taken when planting trees. It should be noted that some trees may require specific planting techniques such as the addition of specific fertilizers and advice should be sought from KEFRI.

Before planting the young trees

The key points to remember before planting young trees are as follows:

- Ensure that seedlings to be planted are big enough (at least 1.5 ft high).
- Plant the seedling as soon as they have been taken from the nursery.
- Do not plant trees too close to buildings and installations such as power (electricity) lines, water pipes or telephone posts.
- Water the seedlings just before transporting from the nursery to the planting site; this water is to protect the seedlings from drying during transportation.
- It is better to plant the seedlings when it has rained for at least two weeks or when the soil is well soaked with water.
- Dig holes. Planting holes can be dug before the rainy season if possible as water will collect in the hole and help the tree to grow. The planting hole will depend on the size of the tree but should be about 30 – 60 cm in width and depth.

Planting the trees

Spacing: It is important that the correct spacing is used when planting the trees. The spacing will be dependent on the tree species and its use. Advice can be sought from KEFRI.

Planting process: Refill ¼ of the hole with wet topsoil. Remove the seedling from its pot carefully so as not to damage the roots. Place the seedling in the hole and cover with the remaining topsoil then the subsoil. Where possible this soil should be combined with compost and well rotted manure to provide the tree with extra nutrients. Press down the soil and firm with a hand or foot. If the soil is pushed down slightly lower than the soil level, rain water will collect in the dip and water the tree.

Key Point: The seedling should sit in the ground at the same level as it sat in the container in the nursery.

Caring for the trees

Watering: If the tree is planted in the dry season or if it is not raining enough, water the tree twice weekly in the morning or evening. Never water in full sunlight as this may damage the tree.

Protect the tree: If animals or chickens are present the tree should be protected. This can be achieved by building a fence of sticks or thorns around the tree.

Support: Some tree species will need support. If a tree seems weak or not very straight, place a strong stick in the ground close to the seedling and tie a piece of plastic wrapper (sisal string can damage the seedling) between the stick and the seedling.

Mulching: Once planted, the soil around the tree should be covered with organic material such as grass or straw. This helps to retain water in the soil through preventing evaporation.

Additional sources of information

- Detailed guide on good practices in a community nursery (World Agroforestry Centre) http://www.worldagroforestry.org/downloads/publications/PDFs/MN15937.PDF
- A basic guide for setting up a community nursery (Centre for Agriculture and Rural Cooperation) http://www.anancy.net/documents/file_en/010_Establishing_a_Tree_Nursery_A4.pdf
- A list of trees suitable at specific altitudes and rainfall levels compiled by the Kenyan Forestry Research Institute http://www.infonet-biovision.org/default/ct/634/agroforestry

4.3. Composting

Chemical fertilizers (agrochemicals) derived from fossil fuels are commonly used to replace lost nutrients in soils. However, with the increasing costs of fossil fuels and the advent of climate change, this is becoming a problematic solution. An alternative to chemical fertilizer is compost, an organic material that can be added to the land to create biomass-rich soils that in turn create productive and healthy agro-ecosystems.

Compost is a freely available resource that is created by combining organic materials at specific ratios. Over time, and with some management, these ingredients will breakdown to form dark brown soil with a high nutrient and humus content. The resulting compost can then be dug into soils to provide both improved soil structure and improved growing conditions for crops.

Key Point: Compost is the most reliable method of converting the nutrients held in organic waste materials into a useful resource.

This section of the training manual provides details of how smallholder tea farmers can produce compost for use on their farms.

Benefits of compost

- Free to produce
- Provides a slow long term release of nutrients to plants
- Supports soil organisms
- Improves soil structure
- Improves soil aeration
- Humus in soil significantly increases the amount of water the soil can hold
- Improves the value of manure

Problems with chemical fertilizers

- Costly
- Supply nutrients to the plants for a short period only
- Can cause river and ecosystem pollution
- Does not improve soil organic matter, soil structure or water retaining abilities of the soil

Problems with compost

- Labour intensive: Takes time to gather the materials and build the heap
- Materials may not always be available

Benefits of chemical fertilizers

- Not labour intensive
- Can be crop specific by replacing specific nutrients
- High crop yields in the first year of use

4.3.1. What is compost?

Composting is used to describe the controlled decomposition of plant and animal materials (mainly animal manure) into a form that can be easily applied to the soil and where the nutrients can easily be used by plants. Compared to the uncontrolled decomposition of organic waste, composting occurs at a faster rate, reaches higher temperatures and results in a product of higher quality.

Composting is important because it helps to improve long-term soil fertility, especially for smallholder farmers with limited access to manures and fertilizers. However, compost is more than a fertilizer as it provides long term improvements to soil structure including its capacity to hold and provide both nutrients and water to plants. When added to the soil, compost has also been demonstrated to enhance the drought resistance of crops. However, it should be remembered that producing compost can be a time consuming and laborious operation.

Key Point: Compost helps maintain long-term soil fertility and can be made for free.

Facilitating with farmers: compost

Discussion: Find out what the farmers know about compost and how they value it compared to mineral fertilzsers

- Have the farmers heard of composting?
- Do farmers practise any variance of composting like heaping crop residue under a tree and waiting for it to decompose then applying onto crops?
- Do they think it is worthwhile to invest in compost?
- Do they know the benefits of compost?
- How much do they spend on fertilizers?

Find a local farmer who regularly uses compost and discuss the benefits that he sees from using compost.

4.3.2. Climate change mitigation and composting

Composting helps to reduce greenhouse gas emissions and is thus a method of climate change mitigation. The process of composting locks organic carbon matter into the soil, preventing it from being released back into the atmosphere. Once compost has been added to the soil it promotes plant growth. As plants grow they take in carbon dioxide from the atmosphere (one of the main greenhouse gas responsible for climate change) and through the process of photosynthesis convert it into energy.

The use of compost also reduces the need to use man-made fertilizers, which also has climate change mitigation benefits. The production of the majority of mineral fertilizers requires a lot of energy and thus the release of many greenhouse gas emissions. Compost provides an alternative source of plant nutrition and thus negates the requirement for mineral fertilizers and in turn leads to emissions reductions and climate change mitigation.

Mitigation benefits of compost

- Locks carbon in the soil
- Reduces the need to use fertilizers which release greenhouse gases in their use and production
- Reduces soil erosion, a GHG emissions source

Adaptation benefits of compost

- Reduces vulnerability to wind and water erosion caused by climate change
- Reduces the impacts of drought
- Improves crop productivity

4.3.3. Climate change adaptation and composting

In terms of climate change adaptation, composting also provides numerous benefits. First adding compost to soil improves soil structure, texture and aeration, which means better moisture-holding capacity, nutrient retention and, ultimately, reduced vulnerability to water and wind erosion. For example, in clay and compacted soils, compost will work as an aerator and loosen soils to enhance root growth and help roots access nutrients and water. In sandy soils, compost acts as a water retainer due to the increased organic matter added to the soil. It is estimated that 1kg of humus (a component of compost) can hold up to 6 litres of water. In terms of water retention, the addition of compost has multiple benefits. As well as allowing more water to be held in the soil, it also allows water to be held for longer. For example, research from Ethiopia has shown that, in dry periods, crops grown on soils with high compost can go on growing for two weeks longer after the rains have stopped than crops grown on soil given chemical fertilizer (FAO 2011[11]). Furthermore, when it rains, the addition of compost helps water to infiltrate into the soil rather than running off the surface. This has the multiple benefits of reducing the likelihood of flooding, reducing the likelihood of springs drying up in the dry season and reducing soil erosion. The addition of compost also protects against wind erosion as the humus in the compost helps to bind the soil together.

The soil's improved capacity to retain nutrients and water through the addition of compost has a direct effect on crops by increasing yields and the health of the plants. Specifically, compost is a good source of Nitrogen, Phosphorus and Potassium as well as trace elements and micro-nutrients which all support plant growth throughout the growing season. As such, compost helps to increase both income and food security for farmers. Organic matter in the compost provides food for microorganisms, which keeps the soil in a healthy, balanced condition. In addition, the coverage offered by healthy vegetation can help to reduce wind erosion of the soil.

4.3.4. Making compost

There are many different ways in which compost can be made. This manual describes one method but descriptions of other methods are available as detailed in the box below.

1. **Selecting a location:** Key to all methods of compost making is choosing an appropriate location. The composting process should be conducted in a place that is easy to access for easy transport of materials to the composting site and close to the fields where the compost is to be used after production. The compost should also be close to a water source as it must remain damp and requires

[11] FAO 2011 Climate change and food systems resilience in sub-Saharan Africa http://www.fao.org/docrep/014/i2230e/i2230e00.htm

regular watering. Dampness is vital for the decomposition of the waste. If no water source is available then the compost should be made during the rainy season.

A well drained and levelled ground is important too. Natural shade such as a tree or a purpose built shade structure will help to reduce evaporation. The compost site should also be an appropriate distance from short term crops such as vegetables to avoid the risk of contamination, especially if animal waste is used.

2. **Collection of materials:** Compost requires a mixture of materials. Fresh green materials should comprise about 75% of the compost mix and dry materials the other 25%. A good balance between wet and dry materials is important because if too much fresh wet material is used there will not be enough air available for the microorganisms to break down the waste and nitrogen will be lost. This will result in a pungent compost heap. Similarly, if there is not enough fresh material the microorganisms will not have enough food and again the waste will not be broken down into compost.

   Good sources of fresh material include weeds (but not persistent perennial weeds), grasses and any other plant materials cut from inside and around fields, in clearing paths and in weeding. Crop residues are another good source of fresh green materials, especially after harvest. Dry materials can take the form of dry grass, hay and straw left over from feeding and bedding animals. Animal bedding is very useful because it has been mixed with the urine and droppings of the animals. Dropped leaves and pruning from almost any tree and bush except those which are especially tough also provide a good source of dry material. Only 10% of the total material should be ‘woody’ as this is difficult for the microorganisms to break down. Woody materials should be chopped into pieces 5–10 cm in length before use.

   Whenever possible animal manure should also be added to compost as it accelerates the composting process and results in a compost of higher nutritional benefit. Ash can also be spread in thin layers between the other materials. Soil or old compost should be mixed into compost because soil contains a ready source of microorganisms which are vital to the composting process.

Key points: materials for composting

- A mix of fresh green and dry brown materials
- Manure should be added when possible
- The addition of soil or compost provides the microorganisms that break down the organic materials
- The compost must be wet and hot to aid decomposition of the organic materials

Materials not to use for composting

- Materials from diseased or pest infested plants
- Plants that have been sprayed with pesticides or herbicides
- Materials with hard prickles or thorns or large amounts of woody materials
- Persistent perennial weeds

3. **Digging a base for the compost heap:** The compost heap can be started in a shallow of around 2 feet deep. This ensures that the compost heap is steady and will not fall over. It also helps to keep the moisture in the compost heap. The diameters of the pit will determine the size of the compost heap and it should be 1.5 meters wide and as long as is needed based on the amount of material available for composting. The soil at the bottom of the pit should be loosened to increase microbial action.

Key Point: The soil extracted from the pit should be saved for use in the compost layering.

Layering the compost: once a pit has been dug, the compost heap should be built up in layers:

Layer 1: The first layer should comprise of 30 cm of prunings from a tree or bush or maize stalks. This is to ensure that drainage of the compost heap can happen. This initial layer should be watered well.

Layer 2: 3 - 5 cm of soil (pesticide free)- This provides the microorganisms.

Layer 3: 3 - 5 cm of manure (optional)

Layer 4: 20 - 30 cm of chopped fresh green material

Layer 5: Sprinkling of ash (optional)

Layer 6: Sprinkling of water

This layering should be repeated until the compost heap is around 1 – 1.5m high and finished with a layer of green material. Make sure to water each new layer well to create humid conditions. As for composting, aerated conditions are needed, the compost heap should not be stamped. A well-made heap has almost vertical sides and a flat top.

Figure 19: Layering for Compost

4. **Covering the compost**: The final compost heap should be covered with a 10cm layer of soil, to prevent gases from escaping from the compost pile. Lastly, cover the whole pile with dry vegetation or banana leaves to prevent loss of moisture through evaporation.

5. **Inserting a compost temperature checking stick**: Take a long, sharp, pointed stick and drive it into the pile at an angle. The stick helps to check the condition of the pile from time to time. After one week, pull the stick out and place it on the back of the hand. If the stick is warm then decomposition has started and is normal. If the stick feels cool or cold the temperature is too low. This may also be demonstrated by white mould growing on the stick. A low temperature usually means that the materials are too dry, and some water should be added. Lift the top layers of the compost and add water. Replace material in layers of 25cm adding water along the way until the heap has been replaced.

   If the stick is warm and wet and there is a very bad smell like ammonia, this indicates that there is too little air and too much water in the compost. The materials will be rotting and not making good compost. Lift the top half of the compost and add dry material to the bottom portion of the compost. Observe the top materials, if they are wet and decaying, put in alternate layers of new dry plant materials with the wet materials. If the top materials are moist and brown showing compost making has started, put them back as they are.

   Testing for heat and moisture should be done every week to 10 days until mature compost is made.

6. **Keeping the heap moist**: If the compost heap is made during the dry season then it should be watered every three days to ensure that moisture is present. This is necessary to help the microbes break down the organic materials into compost. Constructing the compost heap in the shade and

keeping it covered with soil and dry materials will also help to keep the moisture in the compost heap during the dry season.

7. **Turning the compost**: The compost heap can be turned after 21 days (3 weeks). Before the heap is turned, a new hole of the same proportions should be dug next to the original hole. Remove the soil and dry material covering the heap and put to one side for later use.

   Pull the top and side layers of the compost pile into the bottom of the new hole so that they form the middle of the new compost pile. This ensures that all materials in the compost pile go through the proper composting process. Do not add any extra materials to the compost pile. Recover the compost with the soil and dry material and leave for a further 21 days when the process is repeated a second time.

   The final compost will be ready after the third turning, about 60 days.

Facilitating with farmers

It is recommended that extension officers take the farmers to a demonstration farm in the community and demonstrate the construction of a compost heap. The demonstration should be used to discuss the importance of the different input materials and go through the important steps in compost development including how to identify if compost needs more water or more dry materials.

4.3.5. Using compost on a tea farm

Mature compost will be black-brown in colour and have a pleasant small. Once ready it can be used immediately or stored until it is needed. If storing, the compost should be kept moist and covered with a layer of dry material such as banana leaves or topsoil.

There is no such thing as adding too much compost to the soil. Instead, because there is a limit to the amount of compost a farmer can make, it is important to apply compost so that it has the biggest benefit to the crops as possible. Compost should thus be added to the soil so that it can be used as a source of nutrition and moisture by the intended plant.

It is likely that farmers will decide to apply compost to the crops in their kitchen gardens rather than their tea fields however compost can be beneficial to tea plants as it will increase the water holding capacity of the soils and thus increase productivity in the dry season. Compost will also provide nutrients to the tea bushes. If farmers decide to add compost to their tea fields the best times to do this is after pruning when space is available. The compost should be lightly dug into the soil. Compost can also be added to the soil when infilling gaps on the far with new tea bushes.

Compost is typically added to vegetable fields. Where crops are being planted, it is best to mix compost with topsoil and apply it into the planting holes. Compost should be applied first to plants with high nutritional demand such as tomatoes. If seeds are being sown, compost can be mixed into the topsoil prior to planting. For perennial tree crops, compost should be applied along the drip irrigation line of the trees and not at the foot or the trunk. Compost is beneficial in seed beds but it must be well composted before being applied. Compost can also be hoed into the topsoil as a top dressing.

For further guidance on compost making please consult one of the following documents

- FAO ‘How to make and use compost’ http://www.fao.org/docrep/014/i2230e/i2230e14.pdf
- FAO ‘On farm composting methods’ ftp://ftp.fao.org/agl/agll/docs/lwdp2_e.pdf

4.4. Fertilizer application

The use of fertilizers results in greenhouse gas emissions and for many smallholder farmers fertilizer use will be the main source of emissions on their farm. Thus, increasing the efficiency at which fertilizers are used is a key strategy for climate change mitigation. Not only that, efficient fertilizer use has the potential to generate cost savings for farmers, creating real incentives for reducing consumption.

Fertilizers generate emissions in two ways; when they are applied in the field (direct emissions) and when they are produced in a factory (indirect emissions). To reduce emissions it is therefore important to both apply fertilizers in the correct way and to reduce the total amount used where possible.

Key Point: When exploring fertilizer use with farmers, discussions should be framed in terms of the amount of money farmers spend on fertilizers rather than climate change mitigation, as this will be the driving force behind behaviour change.

4.4.1. Fertilizer efficiency of use

It is important to train farmers on best management practices associated with fertilizer application. Key to this is that fertilizers come from the right source, are used at the right rate, at the right time of year, under the right conditions and in the right place. If best management practices are used then this can reduce both the amount of fertilizer required by the crops as well as the amount of greenhouse gas emissions associated with their application.

Principles of good fertilizer application

- Store in a dry covered place away from direct sunshine
- Do not apply fertilizer during drought or on hot days
- Apply fertilizer directly on the soil and under the tea bush (do not broadcast over the leaves)
- Apply fertilizer when the soil is moist to aid absorption
- Do not apply fertilzser during periods of heavy rain as they will wash away
- Do not remove tea prunings from the tea plot *(the prunings will shield fertilizers from direct sunshine)*
- Apply fertilizer at the recommended rate
- Use compost and composted manure to help reduce the fertilizer requirements of the crops

The first step in fertilizer application is to ensure that they are applied under the best conditions. For tea, this should be at the end of the heavy rain season or during periods of moderate to low rainfall when the soil is moist. Periods of heavy rainfall should be avoided as heavy rain will wash away the fertilizer before the nutrients reach the tea bush. Hot and dry weather should also be avoided as this will prevent the fertilizer from entering the soil rendering it unavailable to the plants.

Fertilizers should also be applied using the most efficient and practical method. For tea, this involves the use of a measuring cup. This allows the correct amount of fertilizer to be applied to each tea bush and ensures that each tea bush receives the same amount of nutrients for optimal growth. Finally, the addition of mulching material, such as tea bush prunings, protects the soil and thus helps prevent fertilizers from being washed away and protects the fertilizes from direct sunlight.

4.4.2. Reducing fertilizer requirements

In addition to increasing the efficiency of fertilizer application, the better integration of organic resources into the soil can improve soil fertility and reduce fertilizer requirements and thus helping to mitigate the indirect emissions associated with fertilizer production. Organic residues that improve soil fertility include animal waste, crop residues, compost, mulch and green manures. It is therefore important to optimise the use of these inputs to boost crop yields and reduce the need for inorganic fertilizers. Additional information on improving soil fertility is included in the climate change adaptation training manual available at www.ethicalteapartnership.org.

Figure 20: Fertilizer application: good and bad practice

1. Use recommended dosage rates

Good practice: Using a specific measure per bush

Bad Practice: Scattering the fertilizer in unmeasured quantities

Good practice: Apply fertilizer under the bush to reduce or reduce nitrous oxide emissions (a key GHG)

2. Apply fertilizer under the bushes

Good practice: Apply fertilizer under the bush to reduce or reduce nitrous oxide emissions (a key GHG)

Bad practice: Fertilizers on the leaves will release more GHG emissions that those under the bushes

3. Leave prunings in situ

Good practice: Prunings cover fertilizer from sunshine, thus reducing emissions

Bad practice: Removing prunings exposes soils and fertilizers to erosion and sunlight

Facilitating with farmers

In class: Ask the farmers about how often they apply fertiliszer and how they apply them? Do they stick to the recommended doses or do they apply more or less? How much do they spend on fertilizers? Is this expenditure a concern to them?

Assessing farmer fertilizer application data: It is likely that some farmers will be overdosing with fertilizers, assuming that this will help them to grow more tea. Instead this will be costing them more and generating more GHG emissions with very little additional benefit in terms of productivity. One of the best ways to investigate this issue and teach farmers on the most appropriate levels of fertilizer use is to collect data from the farmers on how much fertilizer they are using and tea bush productivity. Farmer field books can be used for this purpose. Thus, at a farmer field school, request farmers to record data on the amount of fertilizer applied and the volume of tea harvested over a year period. At the end of the year pull the data together and see what it shows and present it back to the farmers.

Date of application	Area of field/ number of bushes	Type of fertilizer	Rate of application

Do those farmers applying the most fertilizer per hectare produce the most tea?

Additional Information

- More information on fertilizer use and climate change can be found at the following sources:
- http://www.sustainablecropnutrition.info/ifa/HomePage/SUSTAINABILITY/Climate-change
- http://www.fertiliser.org/ifa/HomePage/SUSTAINABILITY/Fertiliser-Best-Management-Practices

PART 4:
Measuring the carbon footprint of tea production emissions

Chapter 5

5. Conducting carbon footprint assessment

This chapter provides information on how to collect data for a carbon footprint assessment in the tea sector.

Chapter overview

Section 5.1: Background information on the benefits of performing a carbon footprint

Section 5.2: How to collect data for carbon footprint

Section 5.3: How to collect data for carbon footprint analysis at tea farm level

Section 5.4: How to collect data for carbon footprint analysis at tea factory level

5.1. Why quantify greenhouse gas emissions?

With growing awareness of the impacts of climate change, consumers and governments are requesting businesses to monitor, manage and reduce the greenhouse gas emissions associated with their daily operations and the products that they produce. As such businesses are coming under increasing pressure to understand and monitor the emissions in their supply chains. This involves looking at the emissions that the businesses produce themselves as well as those being produced by their suppliers.

In some countries the international agreements about reducing greenhouse gas emissions (i.e. the Kyoto protocol) has translated into regulations for some business sectors that place limits on their emissions, but in most of the world companies manage and report their emissions on a voluntarily basis.

There are many reasons why companies decide to measure their greenhouse gas emissions and these include the following:

1) Corporate social responsibility (CSR)

More and more companies are being required by their clients to show what they are doing to reduce their climate change impact. For big international companies and brands, reporting on their environmental and social performance has become an essential part of their business and marketing strategy. Furthermore, the demand for action and transparency is no longer limited to a specific company or brand itself but to the whole product supply chain. This means that companies have to look at their full supply chain, i.e. to their suppliers and their suppliers suppliers, to understand the full climate impacts of the products or services that they provide. For this reason, commitments to quantify greenhouse emissions often appear in companies CSR strategies.

Because of this increased requirement for international companies to monitor their full supply chain impact, issues around CSR and the reporting of environmental impacts, including climate change is becoming of increased importance to producers supplying international markets. For example, in the tea sector, tea sold on the international market will often be purchased by large International tea brands who will have climate related CSR objectives in their corporate strategies. Supporting the objectives of the tea buyers by monitoring and measuring the climate change impacts of tea production can help tea producers to improve the marketability of their tea.

Carbon credits and the voluntary carbon market

A common way for companies to offset emissions is to purchase '**carbon credits**' on the **Voluntary Carbon Market**. A carbon credits represents 1 tonne of greenhouse gas emissions that have been prevented from entering the atmosphere or which have been removed from the atmosphere through sequestration (e.g. through extra tree planting). Carbon credits are created by carbon credit projects such as wind energy, solar energy or reforestation projects. The emissions reductions associated with these projects are then certified and sold on the carbon market. For example, if a company wanted to sell a carbon neutral tea product and their tea supply chain had a carbon footprint of 2,000 tonnes of greenhouse gas emissions per year, they would have to buy 2,000 carbon credits per year to promote their tea as carbon neutral.

Recognized terminology related to greenhouse gas emission quantifications:

- **Carbon Footprint:** the carbon footprint is a calculation of the total greenhouse gas emissions in CO_2e associated with a product, organization, process or event. For example, the carbon footprint of a 250g box of tea would include all the emissions associated with the growth of the tea, processing the tea, packaging the tea and transporting the tea

- **Carbon Label:** A carbon label can be presented on a product to communicate the carbon footprint of the product. The carbon label means that the carbon footprint has been calculated using an internationally accepted methodology and that a commitment has been made to reduce emissions. With the label consumers can choose products with a low impact on climate change.

- **Carbon neutrality:** This means that a product or business has a net carbon footprint of zero. To achieve this, the actual emissions of the product or business will have been 'offset' through investing in emissions reduction activities inside or outside of the supply chain and/or buying carbon credits (see next text box) from projects that avoid emissions.

- **Carbon offsets:** A carbon offset is a reduction in emissions of greenhouse gases that is made to compensate for emissions made elsewhere. If these offset emissions are certified then they can be sold on the carbon market as carbon credits.

2) To support emissions reductions

The quantification of carbon emissions supports organizations to understand both their environmental impact and opportunities to reduce this impact. A carbon footprint assessment will identify where in the production of a product or the operation of a business the most impact takes place i.e. it will assist in the identification of carbon 'hotspots'. With this information, a company can make informed decisions about how best to manage its carbon impact and where the biggest return on investment in carbon mitigating activities can be achieved.

3) Reducing costs

The majority of carbon emissions come from the consumption of energy, the use of physical input materials or the generation of emissions in processing. Reducing the carbon footprint can therefore be achieved through reducing energy consumption, reducing material inputs or consumption and improving the efficiency of processes. All of these initiatives will have knock on benefits in terms of cost savings and thus a real incentive to monitor and measure emissions generation is to support the implementation of cost saving initiatives.

5.2. Quantifying greenhouse gas emissions - 'carbon footprinting'

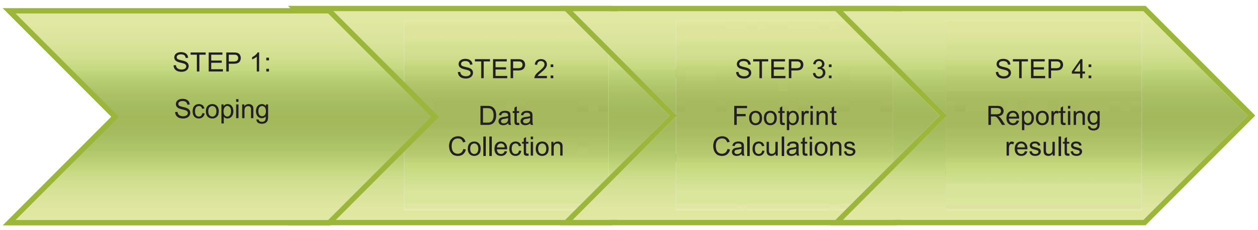
This chapter has been written to support the tea sector in collecting and managing carbon footprinting data.

A carbon footprint is the internationally used approach to quantify the greenhouse gas emissions associated with a company, a product or a process. For example, a carbon footprint can be calculated for a company such as KTDA and will include all the emissions associated with KTDA's operations including the fuel to transport tea from the field, the energy required for tea processing and the energy required in running the regional and head offices. A carbon footprint can also be calculated for a product such as a kilogram of tea or a box of 100 tea bags. Here, the emissions will include those generated in the full tea production lifecycle, such as the fertilizers used by the farmer, tea processing emissions at the factory, the transportation of the tea to auction and the emissions released in the production of the tea packaging. A product carbon footprint will exclude any emissions not directly related to tea production e.g. head office emissions (more details are provided in the text box on carbon footprinting).

Following clearly defined and transparent steps is essential when calculating an accurate carbon footprint. The content of this chapter provides an overview of the steps involved in a carbon footprint assessment, based on the guidelines of the PAS 2050:2011, a publically available and commonly used methodology for carbon footprinting[12].

Generally speaking a carbon footprint assessment can be split into four consecutive steps, as represented in Figure 21.

Figure 21: The four steps in a carbon footprint assessment



5.2.1. Step 1: Scoping

STEP 1 - Scoping

- Step 1a: Determine the type of footprint
- Step 1b: Determine the boundaries of the assessment
- Step 1c: Draw a map of the processes included

[12] http://shop.bsigroup.com/en/forms/PASs/PAS-2050

Step 1a: Determine the type of footprint

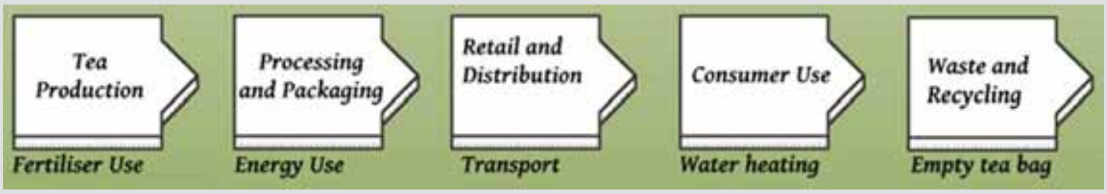
The first step in any type of carbon footprint calculation is to determine what type of carbon footprint is going to be performed; a 'product' carbon footprint or a 'corporate' carbon footprint.

Deciding on the type of carbon footprint is determined by the way in which a company will use the footprint calculation. For example, when the goal is to communicate the emissions related to the production of a certain type of tea to buyers or consumers, a product carbon footprint is performed. Also, when a producer or tea buyer would like to market low carbon tea or carbon neutral tea a product carbon footprint is the required approach. On the other hand, if a company wishes to reduce its emissions so that it can be a 'low carbon business' or wants to measure the impact of a carbon mitigation strategy, a corporate carbon footprint is required.

Product carbon footprint assessment:

A product carbon footprint assessment gives an overview of all the greenhouse gas emissions that are attributable to the production, distribution, use and disposal of a specific product.

Example, the life-cycle of a teabag:



As the example shows, each phase of the products life-cycle involves different processes, inputs and outputs. Each the examples of inputs and outputs will generate greenhouse gas emissions. In a product carbon footprint some or all of these emissions sources are included as defined by the boundary of the analysis.

A product carbon footprint can be reported as follows: *"…g CO_2e per …g of packed tea"*

More information can be found in ITC's publication- **Product Carbon Footprinting Standards in the Agri-food sector,** http://www.intracen.org/Product-Carbon-Footprinting-Standards-in-the-Agri-Food-Sector/

Corporate carbon footprint assessment:

A corporate carbon footprint includes all the emissions from processes and facilities that are owned and controlled by a company. If we look at the example of a tea factory the following emissions have to be included:

Scope 1: Direct emissions from processes and company activities

(i.e. burning of fossil fuels e.g. coal, diesel and petrol)

Scope 2: Indirect emissions from using electricity from the grid

(i.e. for computers and light)

The scope 3 emissions are indirect emissions that are attributable to the operations of a company but are not directly under its responsibility. Scope 3 emissions include **upstream emissions** (e.g. related to the production and transportation of raw materials and commuting of employees) and **downstream emissions** (related to the transportation and use of the products the company produces). Reporting scope 3 emissions is voluntary and most emission sources are often not included in such assessments.

A corporate carbon footprint is reported as follows: "…Tonnes of CO_2e" (for the whole company)

More information can be found in the GHG protocol: http://www.ghgprotocol.org/standards/corporate-standard

Step 1b: Determine the boundaries of the assessment

Once the scope of the analysis has been defined, the boundaries of the analysis need to be set. The boundary simply describes what is being measured and thus defines which greenhouse gas emissions will be included in the carbon footprint assessment.

Setting the boundaries: The type of carbon footprint being performed, e.g. corporate or product footprint is the first indication of the boundary that will be set. For product carbon footprints, all emissions associated with the production of the product are included in the calculation and these emissions may be generated by a number of different organizations. For corporate footprints, all emissions associated with the operations of the organization will be included. The main distinction between these different types of boundaries can be illustrated with the following example:

'KTDA use 1 million KWh of electricity per year. Of this electricity consumption, 800,000 KWh is used by factories to produce tea and 200,000 KWh is used by the head office.'

- A product carbon footprint of tea would only include the 800,000 KWh used for tea production.
- A corporate carbon footprint would include the full 1 million KWh of electricity use.

Boundaries for product carbon footprints: If a product carbon footprint is being performed, the next step is to determine which 'life-cycle' stages will be included in the calculation as it is possible to include all or only certain life-cycle stages of a product in the calcualtion. For example some product footprints calculate the impact from 'farm to gate' i.e. they assess all greenhouse gas emissions associated with the production of the product until it leaves the factory gate. Other studies calculate the impact from 'farm to plate', i.e. all emissions are included until the product is consumed by the consumer. This form of carbon footprint includes the emissions associated with the distribution of the product to retail outlets and emissions generated during product retail. Others go further still and calculate the impact from 'cradle to grave'. This calculation will include the impact of disposing of the product at the end of its lifecycle. Because of this variance in boundary, it is important to clearly report the boundary of the analysis in any carbon footprint study.

Boundaries for corporate carbon footprints: If a corporate carbon footprint is being calculated, a decision also needs to be made on which emissions will be included. For example, if a tea producer was to undertake a footprint analysis a decision would need to be made as to whether the calculation would include emissions only from the operation of the offices and factories or if emissions form the farmers growing the tea would also be included. When calculating a corporate carbon footprint it is acceptable to only include emissions that are generated within the corporation's direct sphere of influence i.e. the emissions associated with the offices, buildings and transport operated by the business. Again, it is vital that all decisions regarding the calculations boundaries are clearly defined and reported.

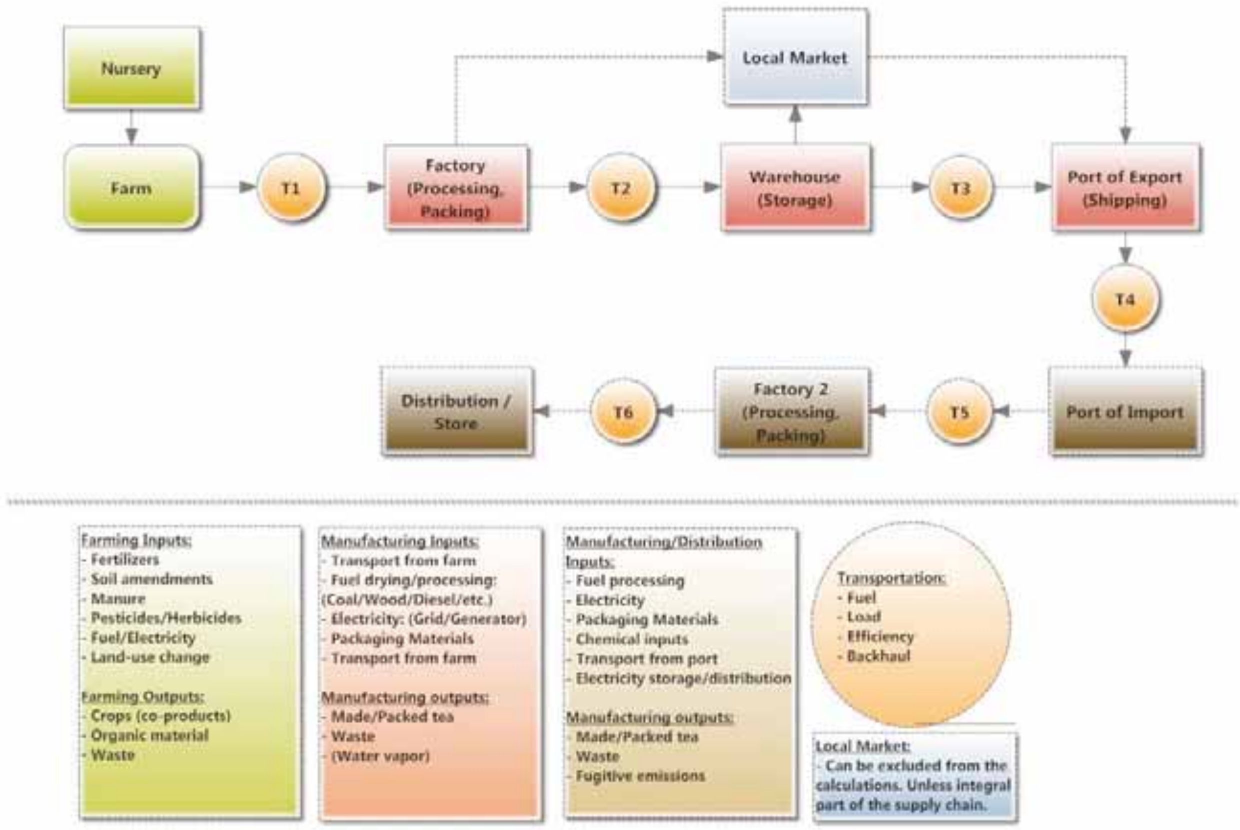
Setting the reporting period: The time period for which the data is gathered also needs to be decided and typically spans a year period for a corporate carbon footprint and a corporate carbon footprint typically measures the total impact of the company over a year period. Similarly, for products, a timeframe for data collection needs to be set and an average impact calculated per unit of product. This means that the impact can be recalculated in different years and the change in impact monitored and measured.

Recording the boundaries: When collecting data for a carbon footprint analysis it is important to clearly define all the emissions that are included and excluded within the calculation. As a general rule, components or materials can be excluded if they are expected to contribute to less than 1 per cent of the total carbon footprint.

Step 1c: Draw a map of the processes included within the calculation

A good overview of the processes involved in the assessment can be visualized by drawing a process map. This map is a schematic drawing of all the processes related to the production of the product being assessed and is used as a basis to list all the inputs, outputs and other emission sources. Figure 22 gives an overview of a standardized process map for tea with an overview of emission sources per process.

Figure 22: Example process map for tea



5.2.2. Step 2: Data collection

Data collection is the next step in a carbon footprint analysis. Data can be obtained from a variety of sources. When collecting data it is important to also accurately record the source and unit of the data and the year that the data has arisen from. This section provides some basic information on data collection and more detailed information is provided in sections 2.3 for factory level data and 2.4 for farm level data.

STEP 2: Data Collection

- Step 2a: Prepare a data collection list
- Step 2b: Gather data
- Step 2c: Record data sources and check data quality

Step 2a: Prepare a data collection list

After the scoping exercise, it will be clear what '**activity data'** needs to be collected to perform the carbon footprint analysis. Activity data refers to the quantities of all the inputs (materials and energy) and outputs (wastes and by-products) required to produce a product or operate an organization. For example, activity data may include the litres of fuel consumed by a transportation vehicle or the number of kilometres the vehicle has travelled.

Emissions factors are also required. Emissions factors convert the activity data into a quantity of greenhouse gas emissions. For example, if data has been collected on the KWh of electricity consumed, an emissions factor will quantify the emissions associated with the use of 1KWh of electricity in the country that it was consumed in. Through multiplying the activity data with the emissions factor it is possible to quantify the emissions associated with each specific activity (see section 2.3.3 for more details).

Step 2b: Gather data

Activity data can be collected from two different sources:

1. **Primary** sources provide actual information specific to the activity at the factory or farm. This data can be collected by a factory manager, an extension officer or from questionnaires. This is the most accurate source of data.

2. **Secondary** sources of data include averages, estimations or industry standards. These sources can be used when primary data is difficult to obtain or takes too much time or money. It is important that the secondary data comes from a credible source and that the source is traceable.

Emissions factors can also be collected from a number of sources:

1. **Embedded within carbon footprinting tools:** If a carbon footprinting tool is being used to perform the calculation there will be no need to collect emissions factors as most will be embedded within the tool.

2. **Online Databases:** If a simple carbon footprint is being performed, an online, open access emissions factor database may be sufficient for the calculation.

3. **Specialist databases**: If a carbon footprint is being calculated which needs to be verified by a third party then it is likely that specialist databases will be required to perform the calculation. These are typically used by carbon footprint consultants as most need to be purchased for access.

Key Point: Irrespective of the data source used for the carbon footprint, it is key that the source of the data is accurately recorded and reported in the carbon footprint analysis.

Step 2c: Record data sources and check data quality

Transparency is important when measuring and reporting greenhouse gas emissions. Therefore the data sources for the carbon footprint assessment should be accurately recorded. Carbon footprints are typically repeated every 1 – 2 years so that emissions reductions can be demonstrated. Accurately recorded data sources will assist this process.

It is also important to check the quality of the data. This is particularly important when using secondary sources of data or data collected in a questionnaire. Example data quality criteria are detailed in the box below. Whilst it is not always possible to find data that fits all these criteria, the best data available should be used in the assessment.

Criteria for data quality:

- Is the data precise and complete?
- Is the unit of the data clear (e.g. Kg, L, Tonnes, Ha)?
- Is the data consistent with the boundaries of the assessment?
- Does the data come from a reliable source?
- Is the data collection method described?

5.2.3. Step 3: Carbon Footprint Calculation

The next step is to use the data to calculate the greenhouse gas emissions, i.e. to calculate the 'carbon footprint'. The basic calculation behind a carbon footprint is the simple multiplication of the activity data with the emissions factor:

Activity Data * Emission Factor = GHG (or CO_2e) Emissions

There are 6 major greenhouse gasses that contribute to climate change. The impact that each greenhouse gas has on climate change, called its Global Warming Potential (GWP), is different for each gas. For example, 1 tonne of methane has 25 times the impact as carbon dioxide on climate change. To make sure that the quantities of different gasses can be combined and reported as one figure and to ensure that all carbon footprint calculations are comparable, the quantities of the different GHG's are converted into the unit of 'CO_2 equivalent' emissions (CO_2e).

Using Table 14, 1 tonne of methane equates to 25 tonnes of carbon dioxide equivalent emissions. Thus, if a product is responsible for the release of 2 tonnes of carbon dioxide and 1 tonne of methane, the total emissions impact (carbon footprint) would be 27 tonnes of CO_2e (i.e. 2 TCO_2 + 25 T CO_2e).

Table 14 shows the GWP of the different greenhouse gases. The gasses related to agricultural practices, methane and nitrous oxide have a much bigger impact on climate change than carbon dioxide.

Table 14: The 6 greenhouse gasses considered in the Kyoto protocol and their GWP

Greenhouse gas		GWP
Carbon Dioxide	CO_2	1
Methane	CH_4	25
Nitroux Oxide	N_2O	298
Hydrofluorocarbons	HFCs	124-14,800
Perfluorocarbons	PFCs	7390-12,200
Sulphur Hexafluoride	SF_6	22,800

Using a carbon footprinting tool

To make the calculation of a carbon footprint easier many computer tools have been developed. These tools require the user to input the activity data and the tool will then automatically calculate the footprint.

The majority of tools requires a license fee to be paid to the developer and are used by carbon footprint consultants however there are a number freely available tools on the Internet. One of those tools is the Cool Farm Tool, developed by the Sustainable Food Lab[13]. This tool provides a good basis to calculate the emissions at farm level and is designed for food products.

Even with these tools in place, calculating a carbon footprint remains a complex process. Although this manual provides information and techniques to support carbon footprinting, it is advised that expert assistance is used the first times a carbon footprint is calculated until a good monitoring system is in place and a staff member is competent in using the tools.

[13] http://www.coolfarmtool.org/CoolFarmTool and http://www.coolfarmtool.org/UserGuide

5.2.4. Step 4: Reporting

The final step involves presenting the results of the analysis and using the results to identify ways in which emissions reductions can be achieved.

STEP 4 – Reporting

- Step 4a: Prepare the report
- Step 4b: Present the results
- Step 4c: Identify the hotspots

Step 4a: Preparing the report

A carbon footprint report should include the following components:

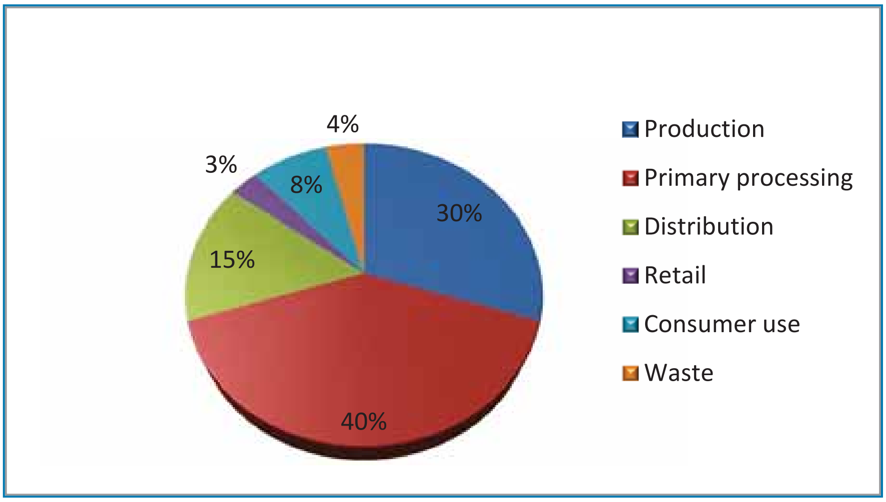
1. An introduction explaining the objectives of the footprint, the standard followed and the boundaries of the project;
2. A description of the data collection process and the data sources;
3. The results of the carbon footprint calculation;
4. An overview of the hotspots (i.e. areas of high emissions);
5. Discussion on how emissions can be reduced (optional);

Guidelines for reporting and communication can be found on the Greenhouse Gas Protocol's website[14]

Step 4b: Presenting the results

When reporting a carbon footprint it is good to give a breakdown of the emissions. The way in which emissions are broken down depends on the type of carbon footprint assessment. When reporting the results of a product carbon footprint, a breakdown of emissions is usually given per phase of the life-cycle that is included. An example is given in Figure 23.

Figure 23: Example carbon footprint results



[14] http://www.ghgprotocol.org/

The results of a corporate carbon footprint are displayed differently. Corporate footprinting guidelines require that **Scope 1 and Scope 2** emissions are included in the report. Other indirect emissions, known as **Scope 3** emissions, can be calculated but should be reported separately. The results are easiest to communicate using a table as demonstrated in Table 15 below.

Table 15: Example results of a carbon footprint analysis

Scope 1, Direct emissions	**Tonnes of CO2e**		
Source 1			
Source 2			
Total Scope 1 emissions			
Scope 2, Indirect emissions			
Purchased Electricity			
Total Scope 2 emissions			
Total Scope 1 and 2 emissions			

Step 4c: Identify hotspots and reduction opportunities

Based on the footprint assessment it is possible to identify greenhouse gas emissions hotspots, i.e. the activities that release the highest proportion of emissions. Looking at these hotspots helps to determine opportunities for emissions reductions.

For example, if a carbon footprint of tea production identified that the highest emissions arise from the use of chemical fertilizers at the farm level; a project could be implemented to prevent their overuse. Likewise, if a carbon footprint identified that the biggest emissions arise from electricity use at the factory level, a strategy could be implemented to update inefficient and old electrical equipment.

5.3. Data collection at the factory level

This section of the manual provides more information on gathering data for carbon footprinting at the factory level. It is anticipated that data gathering is the aspect of carbon footprinting that tea factory staff are most likely to be involved in. Data gathering will be required if a tea factory wishes to report their own carbon footprint for marketing purposes, if they would like to record the impact of implementing climate change mitigation activities or if their clients decide to calculate a carbon footprint of tea production and are thus requesting emissions data associated with the production of tea.

Whether calculating a corporate carbon footprint or a footprint of tea production, emissions quantification at the factory level will be required. The best starting point is to make a schematic overview of all the activities that take place at the factory (see Figure 22). This will help to structure the data collection and to ensure that nothing is forgotten. For each activity the inputs and outputs should be listed. Inputs represent the use of any materials during the activity (e.g. fuels, chemicals or packaging materials). Outputs represent the production of by-products or wastes.

The collected data should then be recorded in a table with the following components:

1. **Activity data** (inputs and outputs): It is important to use a clear and standard description for the inputs and outputs. Using a consistent approach over time increases the credibility and accuracy of the calculations and will allow the comparison of different data collection exercises over time.

2. **Amount**: The amounts/quantity of inputs and outputs related to an activity must be recorded.

3. **Unit**: It is important to accurately report the unit of quantification. If the units are unclear, wrong assumptions can be made and the results of the calculations will be inaccurate.

4. **The emission factors**: The emission factors that convert the activity data into greenhouse gas emissions are entered in the next column. Key emissions factors can be found in the DEFRA database[15].

5. **Data sources**: All data sources should be accurately recorded to ensure that the data can be checked and verified. This is vital in carbon footprinting as it makes the assessment credible and allows the study to be repeated in the future.

Table 16 provides an example of the data that can be collected at a tea factory. It does not provide a complete list of all activity data that should be collected which is likely to be different on a factory-to-factory basis. The emission factors presented in this table could be used by a Kenyan tea factory when calculating a carbon footprint. However, emission factors are updated regularly, often annually, and the sources should therefore be checked to confirm the emission factors used are still applicable.

Table 16: Example of data collection table for a Kenyan tea factory

Activity data (Inputs and Outputs)	Amount	Unit	Source	Emission factor (KgCO2e / Unit)	Source
Input: green tea leaves		Kg		Calculated	Result of calculations at farm level
Input: transportation of tea from farm (petrol)		L		2.73	Defra database (EU average)
Input: energy use (diesel)		L		3.18	Defra database (EU average)
Input: energy use (charcoal)		Kg		2.567	Based on IPCC default[16]
Input: energy use (wood)		Kg		1.513	Based on IPCC default[17]
Input: energy use (electricity)		Kwh		0.36	Kenya average: International Energy Agency, EcoInvent.
Input: packaging material		Kg		Unknown	Depending on material used
Output: waste		Kg/L		Unknown	Depending on waste from production

The financial records kept at the factory are often a good starting point when collecting climate change data. This is because records are kept on the total amount of expenditure on different items such as electricity and fuel. Bills and invoices may also provide information on the quantity of specific items that have been bought and used.

[15] https://www.gov.uk/government/publications/2012-greenhouse-gas-conversion-factors-for-company-reporting

[16] Based on IPCC/OECD assumption of 0.7 Carbon fraction in charcoal. Only emissions from consumption are included (IPCC) in this emissions factor. Including est. emissions from production would result in an EF of: 9.078 Kg CO2/Kg of charcoal. FAO conversion and Emission Factors

[17] Based on IPCC/OECD default factor, converted by FAO: FAO conversion and Emission Factors

5.4. Data gathering at the farm level

The approach for data gathering at the farm level is in principle the same as for data gathering at the factory level, however the data is often more complex to gather. When collecting data at the farm level data does not need to be collected from all farms but instead from a representative sample. This section of the manual provides an introduction on how to select a sample of farms from which data can be gathered, followed by a detailed overview of the data that needs to be gathered for carbon footprinting purposes.

5.4.1. Sampling

In an ideal world, the calculation of a carbon footprint of tea production would involve collecting data from every farm included in the tea production chain. In reality this is not possible due to the time, costs and complexity involved with such an extensive data collection process. Instead, it is common practice to select a representative sample of farms to collect data from.

Key Point: When collecting data from a sample it is important to register the farms that are included in the sample. In many cases, a re-assessment will be needed to measure reductions in emissions over time.

For a sample to be representative two aspects are important:

1. The sample size should be of a **sufficient size**: According to the guidelines in the PAS2050:2011 (a product carbon footprinting standard), the sample size should be minimally equal to the square root (√) of the total group to be sampled. For instance, to give a credible estimation of the footprint of 1000 farms, data needs to be collected for at least √1000 = 31.6 = 32 farms.

2. The sample needs to be **randomly selected**: If farmers use a range of different farming techniques then the farmers should be grouped before performing the random selection to ensure that a representative sample from each group are selected. This is called stratified random sampling. For example, if some farmers use organic farming techniques and others use chemical fertilizers then a sample should include farmers from each group.

Once the groups have been identified a sample from each group should be taken using the same principle as explained above. For example if a factory is supplied by 1000 tea farms of which 25% are organic farmers, the group can be divided into two: 750 (use fertilizer) and 250 (no fertilizer). Of the first group a sample of 27 farms should be used and from the second a sample of 16.

5.4.2. Emissions associated with farm inputs

For most agricultural products, farming inputs (e.g. fertilizers and pesticides) represent the main sources of greenhouse gas emissions. They therefore also offer substantial opportunities for emission reductions. Before describing how to collect and record data on emissions generated at the farm level, some background information is provided on the emissions associated with different farming inputs.

Fertilizer

Synthetic or chemical fertilizers are responsible for some of the highest greenhouse gas emissions at farm level. During the lifecycle of a chemical fertilizer there are a number of processes that result in greenhouse gas emissions.

Significant quantities of emissions are generated during both the production of fertilizers and during their application. First, during the production of fertilizers, a significant amount of fuel is used to produce the basic chemical components (e.g. ammonia). During this process carbon dioxide is released into the atmosphere. In later stages of the production process, when chemical components are mixed or combined, other greenhouse gasses can be emitted, mainly nitrogen oxide and carbon dioxide. Transportation of the raw materials and the intermediate or final product also causes greenhouse gas emissions[18]. The emissions from production and transportation are typically included in the 'emissions factor' for a specific fertilizer or fertilizer

[18] Emissions from fertilizers, source: http://www.fertilizer.org/ifa/HomePage/SUSTAINABILITY/Climate-change/Emissions-from-transport.html

type. When the fertilizer type and/or brand is known the emission factor can be found on the Internet or in the tool used to calculate the carbon footprint.

There are significant differences between the emissions factors of different fertilizer types and brands. These differences can, for instance, be explained by the type of fuel, technology and materials used for the production of the fertilizer. When looking for strategies to reduce the emissions from tea production, choosing the right kind of fertilizer could be a quick win. It is therefore important that during the data gathering phase as much information as possible on the type, brand and production of the fertilizer is gathered so that opportunities for emissions reductions can be explored.

Emissions are also generated during the application of fertilizers. When fertilizer is applied to soil, a reaction takes place whereby some of the nutrients are absorbed by the soil and used by the crops and others leak into the atmosphere resulting in greenhouse gas emissions. When nitrogen based fertilizers are applied to soils, which include many of the most commonly used fertilizers, nitrous oxide emissions are released which have a 298 times higher impact on global warming then carbon dioxide (see Table 14) and thus have a significant impact on climate change. When gathering data on fertilizers it is important to list, whenever possible, the percentages of the different chemical components (N:P:K ratio) of the fertilizer, or at least the Nitrogen quantity, so that the climate change impact cab be accurately calculated.

Overview of the percentage of nitrogen in some of the most commonly used N-based fertilizers:

- Ammonium Bicarbonate - 30% N
- Ammonium nitrate - 35% N
- Ammonium sulphate - 21% N
- Ammonium sulphate nitrate - 21% N
- Calcium ammonium nitrate -27% N
- Calcium nitrate - 15% N
- Diammonium phosphate - 14% N; 44% P2O5
- Urea - 46.4% N

Compost

In addition to fertilizers, farmers often use compost to feed their crops. As with the production of chemical fertilizers, compost production also generates greenhouse gas emissions, however these are minimal in comparison to fertilizer production. Thus, through using compost in place of fertilizers, emissions can be reduced. Actively managed compost production can reduce farm emissions that would arise from decomposing crop residues and organic waste and composting results in the better uptake of nutrients into the soil. Because of these reasons, composting can be seen as an emissions reduction strategy and can lower the carbon footprint.

However, there are still emissions associated with composting that need to be included in a carbon footprint calculation and data on compost production and use needs to be collected at the farm level. Specifically, data should be collected on the quantities and types of organic material and manure used in the compost, and they type of composting practice used.

For the production of compost, three different greenhouse gasses need to be considered: Methane (CH_4), produced during anaerobic decomposition; nitrous oxide (N_2O) and carbon dioxide (CO_2). Also, during compost application, N_2O can leak into the air. The nitrogen contents (on average 1% to 2%) of compost can be used to calculate the emissions associated with its application. In most tools the calculations for the use of compost are located in the section on crop residue or waste management.

Manure

Manure is another important source of emissions at the farm level. Many smallholder tea farmers also have animals on their farmswhich will produce manure. To calculate the emission impact from this manure, carbon footprinting tools require information on the type of animal/manure, the number of animals and how the manure is managed. A method to gather the data from manure production is presented in the example questionnaire in Appendix B.

Pesticides and herbicides

Pesticides and herbicides have low emissions and therefore the number of applications is sufficient for calculating the emissions.

Other farm inputs

Other inputs that occur at farm level are similar to inputs at factory level and can include electricity and fuel use. If the farmers use these, they should be recorded.

5.4.3. Data collection

Based on the above described inputs and the questions in the questionnaire in Appendix II, a table can be produced to log the data gathered at the farm level. An example is provided below (Table 17) which includes examples of where supporting emissions factors can be found.

For most of the commonly used fertilizers, online tools provide the emissions factors associated with the nitrogen content. If a fertilizer is not listed in a tool the emissions factor can often be found in open source databases or on the Internet. If the fertilizer is unknown, the N:P:K ratio of the fertilizer can be used to account for the emissions from application. This will be found on the packaging.

For calculating the emissions from compost both the amount of compost produced as well as the nitrogen content of the compost is required to calculate the impact.

Table 17: Overview of emissions sources at farm level

Input	Amount	Unit	Emission Factor	N:P:K ratio or N-content
Input: Fertilizer type 1		Kg	(In Tool/database)	N/A
Input: Fertilizer type 2		Kg	(In Tool/database)	N/A
Input: Fertilizer unknown		Kg		Use N:P:K ratio in combination with emissions factor
Input: Fertilizer unknown		Kg		Use N:P:K ratio only
Input: Compost		Kg/Ton		Use N-content (often ca. 1 – 2 %)
Input: Manure		Kg/Ton	(Depending on type of animal)	N/A
Input: Pesticide type 1	Number of applications	N/A	(In Tool/database)	N/A
Input: Pesticide type 2	Number of applications	N/A	(In Tool/database)	N/A
Input: Herbicide type 1	Number of applications	N/A	(In Tool/database)	N/A
Input: Fuel / Energy use		L/KWh	(See Table 14)	N/A

When collecting data on the fertilizer, compost and manure inputs it is important to consider that only the inputs used on the tea bushes should be included. Often farmers produce other crops which will also require inputs including fertilizer and pesticides. Including all inputs into the calculation for tea production would result in an overestimation of the impact of tea.

Land use change

Land use change can have a big impact on the emissions attributable to a product because deforestation has a big impact on climate change. Recording land use change is therefore required when performing a footprint assessment. The emissions are calculated based on what percentage of land was changed, how long ago this occurred and what the previous land use was. Any land use change that happened within 20 years of the assessment should be included.

Questionnaires

To assist in the collection of data a questionnaire can be developed. In Appendix II an example questionnaire has been provided to support data collection at the farm and factory level. It should be recognized that good quality data is required for an accurate carbon footprint and thus it is recommended that extensions staff, factory management or an agronomist who can sense check data is present to assist the filling out of the questionnaire.

Appendix I: Fertilizer use

Fertilizers are described in terms of the amount of key nutrients they contain. The three major nutrients are Nitrogen (N), Phosphorous (P) and Potassium (K). Fertilizers are quoted in terms of the ratio of these different nutrients that are contained within the compound or mixture. For example, the commonly recommended fertilizers for tea are NPK in the formulation of 25:5:5 or 26:5:5. Other nutrients should be present in low levels and under recommendation.

Important information on fertilization in tea from TRFK

1. The magnitude of the increase in yield tends to diminish as the total level of fertilizer nutrient increases (*law of Diminishing returns).*

2. Soil amendment materials (high with Ca^+ and Mg^+) are not recommended for mature tea. They depress uptake of potassium. Therefore CAN formulation is not recommended for tea in the country.

3. Soil amendment materials are only recommended during planting or replanting of tea if soil analysis shows that the soil is very acidic.

4. Apply foliar fertilizer in case of deficiency especially during the dry and cold months. Use the rates on the label.

5. Apply zinc oxide at a rate of 3 kg per hectare in 200 litres of water or zinc sulphate at a rate of 10 kg per hectare in 200 litres of water. *(Most soils in Kenya have zinc deficiency.)*

6. For mature bushes apply two (2) doses of 600 kg/ha (as NPK 25:5:5) after pruning and when soil is moist and the rain intensity is low *(mostly in June and July).*

7. Apply 600 g/m^3 of single super phosphate (SSP) or 300 g/m^3 of triple super phosphate (TSP) to cutting nursery. Double super phosphate is not preferable because it does not contain sulphur.

8. Apply 12 g/sleeved plants of NPK 25:5:5 six (6) weeks after planting and subsequently 36 g of the same spread in 6 intervals after every 8 weeks in the year.

9. Apply SSP or TSP in the planting mixture in the rates given below for the planting hole size:

Planting hole size (depth (cm) x width (CM))	Amount of SSP/TSP per hole (g)
45 x 22.5	30
50 x 25	40
60 x 30	54

10. Apply NPK 25:5:5 in first and second year after transplanting as follows

Year	NPK 25:5:5	Remarks
First	8g	6 months after transplanting and after every 8 weeks. (*No application during drought)*
Second	480 kg/ha/year	Split in 3 applications of 160 kg or 4 applications of 120 kg/ ha in wet seasons

Appendix II: Product carbon footprint assessment questionnaire

Dear participant,

Thank you for taking the time to complete the questionnaire. To calculate a product carbon footprint, collecting the right data is extremely important. The following three aspects are important to consider when completing the questionnaire:

1. **Try to answer all questions and give the information in the format requested.**
2. **Please pay attention to the units in which the data is required. This is important for calculations.**
3. **Whenever there is insufficient space to answer the questions, there are uncertainties in the answers or there is additional information you would like to share, use the space '*additional information*' to elaborate.**

General questions:

(Company/Cooperative/Association/Farm) Name:	
Location:	
Footprinted product:	
Data collection period:	
Person who completed the questionnaire:	
Date of completion:	
Contact information (email/phone):	

Additional Information:

Farm level questions:

Please answer the following questions. If the unit requested is not known please specify the unit in which the answer is given.

(If different from above) Farm Name:	
Farming management system (*select*):	Conventional Monoculture – Organic Monoculture – Agroforestry – Organic Agroforestry – Intercropping – Shifting Agriculture – Other
Farm size (Hectare):	
Climate zone (*select*):	Temperate – Subtropical – Arid/Semi-Arid – Tropical – Mountainous (high-alt.)
Average annual temperature (°C):	

Please write down all the different crops grown on the farm including the yield, the area harvested and the average price per Kg of crop sold:

Crops produced:	1:	2:	3:	4:	5:
Yield per Crop (Kg):					
Area harvested (Ha):					
Price per Kg of crop:					

Crops produced:	6:	7:	8:	9:	10:
Yield per Crop (Kg):					
Area harvested (Ha):					
Price per Kg of crop:					

Additional Information:

*List the **total amount of all fertilizers** used per year in Kilograms. Whenever possible specify the ratio of Nitrogen (N) Phosphorus oxide (P) and Potassium oxide (K) in the fertilizer.*

Fertilizer name/type:	1:	2:	3:	4:	5:
Amount (Kg/Yr.)					
N:P:K Ratio:					
Crops applied to:					
Percentage of total applied to tea:					

Fertilizer name/type:	6:	7:	8:	9:	10:
Amount (Kg/Yr.)					
N:P:K Ratio:					
Crops applied to:					
Percentage of total applied to tea:					

*Please list the **type and amounts** (Kg) of any additional inputs for soil improvement/fertilization. (E.g.: Pure N, P_2O_5, K_2O or Calcic limestone ($CACO_3$), Dolomite, other applications)*

Application type:	1:	2:	3:	4:	5:
Amount (Kg/Yr.)					
Crop applied to:					
Percentage of total applied to tea:					

Additional Information:

*List the total number of pesticide **doses** applied over the reporting period. Give the total amount of **active ingredient** (not deluded) applied.*

Number of doses applied per year to tea	
Total Kg active ingredient applied to tea	

Number of doses applied per year to other crops	
Total Kg active ingredient applied to other crops	

*Please list the **type** of herbicide used and give the **amount** (in Kg) of each of them.*

Herbicide type:	1:	2:	3:	4:	5:
Amount (Kg/Yr.)					
Crop applied to:					
Percentage of total applied to tea					

Herbicide type:	6:	7:	8:	9:	10:
Amount (Kg/Yr.)					
Crop applied to:					
Percentage of total applied to tea					

Additional Information:

Farm electricity and fuel use:

Please register the total amount of electricity used on the farms. Give a breakdown per source (grid, solar, generator, etc.) if multiple sources are used.

Electricity Source:	1:	2:	3:	4:	5:
kWh					

*Please select the **types of fuel** used on farm and the **amounts** (litre or tonnes depending in fuel type) used annually.*

Fuel type:	1:	2:	3:	4:	5:
Liquid fuels (L)					
Fuel used for…					
Fuel type:	1:	2:	3:	4:	5:
Solid (biomass) fuels (Tonnes)					
Fuel used for…					

Additional Information:

Farm manure and compost production and crop residues: please give the requested information on **manure** and crop residue as detailed as possible.

- Please list the number of different livestock on the farm.
- What type of manure management system is used?
- What percentage of the manure is used on the assessed crop?
- What amount (kg) of feed (dry matter) is consumed by the animals annually?
- Please also answer the first three questions for manure imported to the farm.

Type of livestock:	1:	2:	3:	4:	5:
Number of head:					
Manure Management: (e.g.: solid or pit storage/ dry lot/ deep bedding/ liquid slurry)					
Animal feed (Kg)					
Manure used on tea crop (%)					

Imported manure:

Type of livestock:	1:	2:	3:	4:	5:
Number of head:					
Manure Management: (e.g.: solid or pit storage/ dry lot/ deep bedding/ liquid slurry)					
Animal feed (Kg)					
Manure used on tea crop (%)					

*If manure is used as input to **compost** produced on farm please include the amount in the questions about composting below.*

Type of organic fertilizer:	**Sewage N:**	**Compost N:**	**1:**	**2:**	**3:**
Amount used (Kg Nitrogen / year)					

*List the total amount of **crop residue** (Kg dry matter per Ha) and select the type of treatment of residue.*

Tea crop residue					
Type of treatment: **(left on field/ burned/ composted/ organic waste)**	1:	2:	3:	4:	5:
Amount of crop residue (Kg/Ha):					

Crop resulting in crop residue	1:	2:	3:	4:	5:
Type of treatment: **(left on field/ burned/ composted/ organic waste)**	1:	2:	3:	4:	5:
Amount of crop residue (Kg/Ha):					

Land use change:

If any land use change occurred on the farm within the past twenty years please answer the following questions:

Ha or % of farm where land use has been changed:	
Specify the previous land use:	
Specify current land use:	
If previous land use was forest; please give the age/type of the forest when it was felled:	

Additional Information:

Soil information:

Soil texture (select)	Fine – Medium – Coarse
Soil organic matter (select if known)	SOM < 1.72 – 1.72 < SOM < 5.16 – 5.16 < SOM < 10.32 – 10.32 < SOM
Soil moisture (select if known):	Dry – Moist
Soil drainage (select if known):	Poor – Good
Soil PH:	

Water use:

Amount of fresh water used annually (L)	
Source of fresh water	
Type of water use	
Amount of waste water produced	
Treatment of waste water	

If desired; please give additional information on water quality, pollution, access, etc.

Additional Information:

Sequestration:

Please describe briefly the management of tillage, crop residue, compost and manure on the farm. List which practices are implemented and how long ago they were implemented.

Management type:	**Tillage (specify system used below)**	**Cover cropping**	**Compost incorporated**	**Manure incorporated**	**Residue incorporated**
Implemented … Yr. ago:					
Implemented for which crops					

Please collect the following data on ***tree species grown on the farm****:*

- *Number of trees per hectare.*
- *Diameter at Breast Height (DBH) can be provided in cm or inch (please select the correct unit).*
- *Group average data per type of tree, choose between (a combination with e.g. timber trees and tropical pines is possible): shade trees, Timber trees, fruit trees, palms, tropical moist hardwood, tropical wet hardwood, temperate/tropical pine, coffee, eucalyptus.*
- *If known please list the tree species you have included in each category.*
- *The data should be collected over at least a one year period, measuring at the beginning of the year and again after 12 months.*

Measurement 1 (Last Year)				
Type of tree:	**Trees/Ha:**	**DBH:**	**Cm/Inch**	**Tree species:**
1:				
2:				
3:				
4:				

5:				

Measurement 2 (This Year)				
Type of tree:	**Trees/Ha:**	**DBH:**	**Cm/Inch**	**Tree species:**
1:				
2:				
3:				
4:				
5:				

Additional Information:

Transport:

How are products/labourers transported to/from the farm for the production of tea?			
What type of vehicle(s) is (are) used for transport?			
What is the average distance covered per vehicle type?			
How many times per year is this distance covered? (or)			
What is the total distance covered per year?			
What fuel types are used for transportation?			
What is the total annual fuel use per type?			

Additional Information:

Processing/Manufacturing:

*Please list **all** the fuel, material, chemical and other inputs and outputs of processing or manufacturing. It is important to also provide the unit in which the information is given.*

Input/Output:	Annual Amounts	Unit
Fuel Inputs (specify type): 1: 2: 3: 4:		
Electricity use (specify source): 1: 2: 3:		
Biomass use (specify type): 1: 2: 3:		
Wood/Charcoal:		
Coals:		
Oil:		
Gas:		
Chemical Inputs (specify): 1: 2: 3: 4: 5: 6:		
Material Inputs (specify): 1: 2: 3: 4: 5:		

6:		
Input/Output:	**Annual Amounts**	**Unit**
Water:		
Output, intermediate product:		
Output, Co-products (list all): 1: 2: 3: 4:		
Output, Waste (list all): 1: 2: 3: 4: 5: 6:		

Please use the space below for additional information on the processing and if you have inputs/outputs which didn't fit in the table above:

Additional Information:

Transport to processing facility/factory:			
What type of vehicle(s) is (are) used for transport?			
What is the average distance covered per vehicle type?			
What is the total distance covered per year?			
What fuel types are used for transportation?			
What is the total annual fuel use per type?			
Total weight annually transported (Tonnes):			

Transport to storage / auction:			
What type of vehicle(s) is (are) used for transport?			
What is the average distance covered per vehicle type?			
What is the total distance covered per year?			
What the average empty backhaul (%)?			
What fuel types are used for transportation?			
What is the total annual fuel use per type?			
Total weight annually transported (Tonnes):			

Intercontinental transport:

Please give the mode of transportation used for intercontinental transport and present information on the total load transported, the distance between ports and the total distance covered annually.

Mode of transportation:	Total weight (Tonnes):	Port of Departure:	Port of Arrival:	Distance Km (PoD – PoA):	Total distance (Km) per year:
Air freight					
Sea freight					
Rail freight					

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