About the WAGES Project:

The West Africa Governance and Economic Sustainability in Extractive Areas (WAGES) Project is a five-year project implemented by a consortium of the World University Service of Canada (WUSC) and the Centre for International Studies in Cooperation (CECI).

WAGES operates in mining areas in three countries; Guinea, Ghana and Burkina Faso. In Ghana, the project is being implemented in the Prestea-Huni Valley and the Wassa East Districts of the Western Region. The Project's key components are local governance and sustainable and inclusive economic growth, and regional knowledge-sharing on best development practices in mining areas.

The project will identify and focus on the development of key economic subsectors (palm oil, rice, and cassava) within the two districts through an inclusive market systems approach. The ultimate goal of the WAGES project is to 'Enhance socio-economic benefits from extractives industries for communities, especially women and youth, living in West Africa'.

Booklets in this Series:

Environmental Risks and Opportunities in the Oil Palm Subsector
Environmental Risks and Opportunities in the Cassava Subsector
Environmental Risks and Opportunities in the Rice Subsector
The Environment and Green Economy

WUSC EUMC CECI

WAGES
(West African Governance and Economic Sustainability in Extractive Areas)

Environmental Risks and Green Economic Opportunities in the Oil Palm Subsector

Theme: Strengthening Environmental and Green Economy awareness for Entrepreneurs, Community-Based Organizations, and Advocacy Groups.

Global Affairs Canada Affaires mondiales Canada

Environmental Risks and Green Economic Opportunities in the Oil Palm Subsector

Theme: Strengthening Capacity of Citizens and Local Authorities on Green Economy and Environmental Sustainability

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(2017-2018)

West African Governance and Economic Sustainability in Extractive Areas (WAGES)
World University Services of Canada (WUSC)

Printed in:
Accra, Ghana
May, 2018

Cover Image:
Palm Plantation
Malaysia Palm Oil Board, 2015.

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Forward from the Author

Hello and thank you for taking the time to read this booklet. This booklet was prepared by myself, Steven Chang, the Green Economy Advisor for WAGES as part of a series of booklets on the environmental, economic, and development issues selected sub-sectors.

For myself, it has been an incredible experience and opportunity to see firsthand the unique challenges facing entrepreneurs and business owners in the project area. In response, I set out to record the basics of Green economy and environmental sustainability in the sectors WAGES works most closely with. These booklets are intended to serve as a platform for Training Service Providers and other WAGES partners to sensitize and educate beneficiaries on the basics of Green Economy and environmental sustainability.

It is my sincerest hope that these booklets can serve as a useful guide for both WAGES staff and partners, and the hard-working men and women of the Prestea-Huni Valley and Wassa East Districts on various environmental topics relevant to their communities. If even a single person discovers a clever way to green their home, business, and community, then this work will not have been in vain.

Thank you!

Steven Chang
WAGES Green Economy Advisor
World University Services of Canada

Executive Summary

West African Governance and Economic Sustainability in Extractive Areas Project is run by a joint consortium of the World University Services of Canada (WUSC/EUMC) and the Centre for International Studies in Cooperation (CECI) in Ghana, Guinea, and Burkina Faso. In Ghana, the WAGES project works closely with local partners and stakeholders to deliver sustainable local economic development to mining-impacted communities.

Towards sustainable local economic, this booklet written as part of a series of booklets about the environment, Green economy, and sustainability (***2) Environmental Risks and Green Economic Opportunities in the Oil Palm Subsector*** is intended to inform and provide information on topics related to the environment and sustainability in the oil palm subsector.

This booklet is divided into Five (5) Sections:

Section 1 Basic Information on the Oil Palm subsector, including brief summaries of the state of oil palm farming and processing in the Western Region;

Section 2 Environmental Risks of oil palm cultivation and processing and descriptions of general environmental considerations;

Section 3 Green Economy and how it relates to the Economy, Society and the Environment.

Section 4 Green Economic opportunities associated with oil palm cultivation and processing

Section 5 Additional reading materials, books, journal articles, and online resources can be found at the back of this booklet.

This booklet is intended to serve as a starting point for Training Service Providers (TSPs) to understand the complex environmental and risks and opportunities in the oil palm sub-sector. It is not feasible to include all relevant information, specific technical details, and in-depth explanations of the content in this booklet. Rather, this booklet is intended be understood well enough to allow TSPs and project beneficiaries to investigate the environmental risks and opportunities that are applicable to them, and understand the diversity of options for mitigating and avoiding environmental risks, and to capitalize on environmental opportunities.

It is advised to read the first booklet in this series *(1) The Environment and Green Economy* before reading this booklet.

Acronyms and Abbreviations

BOD	Biological Oxygen Demand
Ca	Calcium
CECI	Centre for International Studies in Cooperation
CFC	Chlorofluorohydrocarbons
CH4	Methane
CO2	Carbon Dioxide
COD	Chemical Oxygen Demand
CPO	Crude Palm Oil
CRI	Crop Research Institute
Cu	Copper
DAP	Di-ammonium Phosphate
DO	Dissolved Oxygen
EFB	Empty Fruit Bunches
FFA	Free Fatty Acid
FFB	Fresh Fruit Bunches
GHG	Greenhouse Gas
H2O	Water
K	Potassium
Ma	Manganese
Mg	Magnesium
MOFA	Ministry of Food and Agriculture
MSW	Municipal Solid waste
N	Nitrogen
N2O	Nitrous Oxides
O2	Oxygen
OPF	Oil Palm Fronds
OPT	Oil Palm Trunk
P	Phosphorus
PF	Palm Fibres
PHD	Prestea Huni Valley District
PKS	Palm Kernel Shells
PKSA	Palm Kernel Shell Ash
POME	Palm Oil Mill Effluent
PPE	Personal Protective Equipment
S	Sulphur
UN	United Nations
UNEP	United Nations Environmental Programme
VOC	Volatile Organic Carbon
WAGES	West African Governance and Economic Sustainability in Extractive Areas
WED	Wassa East District
WUSC	World University Services of Canada

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Glossary

Term	Definition
Anthrosphere	An environmental compartment that accounts for human settlements like villages, towns, communities and cities, with all the infrastructure and buildings included.
Atmosphere	An environmental compartment that accounts for air, weather, clouds, and the sky.
Bioaccumulation	The environmental process by which pollutants and toxins increase in concentration through aquatic food chains
Biosphere	An environmental compartment that accounts for all microorganisms, plants, animals, and humans.
Carbon Cycle	De scribes how carbon moves through different environmental compartments and changes into different forms.
Carbon Dioxide	A Greenhouse gas and plays a very important role in Climate Change.
Chlorofluoro-hydrocarbons	Potent, but well-regulated, kind of Greenhouse Gas.
Climate Change	The result of an increasing Greenhouse Effect, resulting in long-term changes to the climate and natural environment.
Compartment	A compartment is a division of the environment, where specific parts of the environment belong to specific compartments.

Condensation	The process of water vapor collecting into clouds in the atmosphere.
Deforestation	The total or near-total removal of trees from a given area, leading to substantial environmental degradation.
Economy	Encompasses all production of goods and services, and the flow of money.
Environment	Encompasses all of Society and the Economy, provides natural resources and is affected by environmental outcomes.
Environmental Footprint	The cumulative impact of an individual or business on the environment, is smaller or bigger depending on the choices and practices of the individual or business
Eutrophication	The process by which excess chemical fertilizers cause damage to natural aquatic and wetland ecosystems
Evaporation	The process by which heat and energy from the sun evaporates water into the Atmosphere.
Evapotranspiration	The process by which forests and plants emit water vapor into the Atmosphere.
Fossil Fuels	Ancient stores of organic carbon deep underground, has been transformed into coal, oil and gas from millions of years of heat and pressure underground.
Green Economy	A Green Economy is one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities
Greenhouse Effect	Greenhouse gases naturally exist in the Atmosphere, trapping some heat and light reflected off the Earth. Today, greenhouse gas emissions have led to an increased Greenhouse Effect and Climate Change.
Greenhouse Gas	Specific types of gases that absorb heat and light in the atmosphere. The largest and most important are Carbon Dioxide, Methane, Nitrous Oxides, and Chlorofluorohydrocarbons.
Groundwater	Water that is stored deep underground and takes many years to move across a landscape. Groundwater feeds boreholes and wells.
Hydrosphere	An environmental Compartment that accounts for all the water in lakes, rivers, oceans, and groundwater.

Inorganic	Being manufactured or processed in such a way that the material wont decompose, or material that is not made from organic matter.
Land Use Change	The process of natural forest or wetland being converted into other uses like farming, development, or mining.
Lithosphere	An environmental Compartment that accounts for rocks, minerals, and soils.
Macro Nutrient	Nitrogen, Potassium and Phosphorous
Methane	CH4, A carbon-based greenhouse gas that comes from decomposing waste, converting wetlands into farms or other uses, and manure.
Micro Nutrient	Minor nutrients needed for plant growth like Calcium, Magnesium, Manganese, Copper, Sulphur
Nitrogen	A Macro Nutrient
Nitrous Oxides	NxO, a nitrogen based greenhouse gas that comes from producing and using NPK fertilizers, burning waste, and decomposing organic waste.
Nutrient Cycle	The environmental cycle in which macro nutrients, NPK, micro nutrients, and organic matter cycle through various environmental compartments.
Organic	Being organic in nature, and easily decomposes into the environment.
Phosphorous	A Macro Nutrient
Pollution	Any material that has serious chemical properties, is dangerously concentrated in the environment, and remains in the environment long enough to cause problems.
Potassium	A Macro Nutrient
Precipitation	The environmental process by which water in the Atmosphere is returned to the Lithosphere, usually through rain.
Runoff	The environmental process through which water moves overland and underground, carrying chemicals and other contaminants with it.
Sink	A place where carbon is stored for long periods of time, such as the oceans, atmosphere, in forests and fossil fuels.
Society	Society is made up of markets, technologies, science, policy, values, and infrastructure. Society encompasses the Economy, and exists as part of the Environment.
Source	A place or process that releases carbon from places of storage to the atmosphere.

Transportation	The environmental process by which water, in the form of clouds, is moved throughout the atmosphere, usually driven by weather patterns and air currents.
Waste	Any matter that is left over and has no further use to an individual or business after a production or refinement process.
Water Cycle	The environmental cycle by which water is moved through various environmental compartments and changes in form.

Section 1: Basic information

Market Overview

Oil palm is one of the world's most important oil producing crops in the world, accounting for more than half of the global import and export of vegetable oil. The palm oil market, including the derivative products of crude palm oil (CPO), were valued at $USD 65.73 billion (GHc 289.21 billion) in 2015, and is expected to grow to $USD 92.84 billion (GHc 408.5 billion) in 2021.

There is a deficit of CPO production in Ghana, with more than 100,000 MT of CPO being imported annually to meet domestic demand, costing more than US $300 million per year. Under current market projections, the CPO deficit is expected to grow to 127,000 MT by 2024.

The palm oil industry is a critical part of Ghana's domestic economy, and is made of mostly private small-scale farms and informal processors. Like many other industries in Ghana, approximately 80% of oil palm plantations are cultivated by private smallholder farmers relying on unimproved planting materials and traditional methods. Oil palm fruit yields are considerably lower in Ghana, averaging between 5-8 MT per hectare, compared to the global average of between 15-20 hectares.

Just as with oil palm farming, around 80% of crude palm oil (CPO) is produced by small-scale and village-level processers, producing approximately 2 tones of fresh fruit bunches (FFBs) per hour. Village-level oil palm cultivation and palm oil processing is done predominantly by women. The remaining 20% of CPO is produced by medium and large-scale processing factories, with more sophisticated technological capacity, capable of processing 10-60 tones of FFB per hour. Small-scale processors often produce a lower grade palm oil, typically sold at local markets or among households. Medium-and large-scale processors produce a higher quality palm oil, suitable for industrial use and commercial sale.

The expansion of palm oil plantations and growth in local and regional palm oil production comes with environmental risks such as land use change (pg. 16), deforestation (19) from oil palm cultivation, and pollution (22) from palm oil processing. Climate change (13) is an additional concern for West Africa, with the risks of changing weather patterns, higher average temperatures, and increases

in flooding and droughts being possible in the coming decades.

Understanding the environment from different perspectives, the underlying science behind critical environmental cycles, and incorporating the Principles of Green Economy (pg. 30) are promising avenues for sustainable development of the sector. Practicing creative methods for reprocessing waste products, and being responsible for maintaining the local environment can also be profitable in the right circumstances.

Classification and Varieties

The Oil Palm tree comes from the Palm family, *Arecaceae*, and the genus *Elaeis*, from the Greek word *elaoin,* meaning oil. There are three known species of *Elaeis (i.e. Elaeis guineensis, Elaeis oleifera,* and *Elaeis odora). Elaeis Guineensis,* the African Palm, is further divided into three commonly cultivated varieties, the *Dura, Tenera, and Pisifera* varieties (see Figure 1, 2).

Each variety of African Oil Palm has morphological (physical) differences in the palm nut, influencing how much oil the palm nuts will produce.

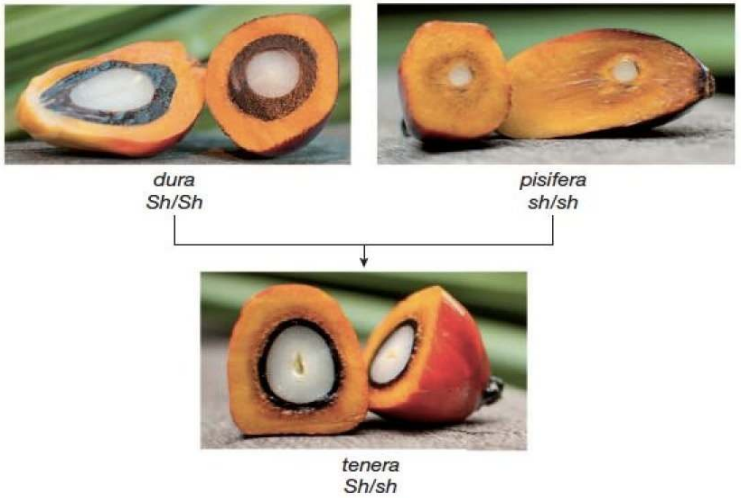

Figure 1) *Left: Hybridization of the Dura and Pisifera varieties of Oil Palm trees. Right: Hybridization of Dura X Pisifera*

- The *Dura Variety* is characterized by a relatively thick kernel shell (2-8mm), and small fruit flesh;
- The *Pisifera Variety* lacks a kernel shell and has a very large fruit flesh;
- The *Tenera Variety* is a hybrid between the *Dura variety* and *Pisifera variety.* It is characterized by an intermediate shell thickness (0.5-4mm) and a large fruit flesh.

The *Tenera* Variety is a hybrid variety between the *Dura* and *Pisisfera* varieties. *Tenera* oil palm trees produce a fruit with a large kernel and high oil content in the pulp of the fruit (see figure 1). *Dura* Variety seeds are produced through controlled pollination of *Dura* palm tree with pollen from selected *Pisifera* palm trees. The resulting fruit of the controlled breeding becomes the *Tenera Variety (see Figure 2).*

Many small-scale oil palm farmers in Ghana and other parts of Africa use traditional or locally available seeds for planting. These seeds, are typically a cross variety between two Tenera plants. The seeds from a *Tenera* X *Tenera* are 25% *Dura*, 25% *Pisifera,* and 50% *Tenera* palms. The widespread use of volunteer seedlings can result in sever economic losses due to the low productivity of dura an pisifera palms. Farmers should always purchase seeds from certified seed or seedling producers, who can verify the quality of seeds and ensure good yields (Oil Palm Production - A Handbook, n.d.).

Dura X Pisifera	**Sh**	**Sh**
sh	Sh/sh **(Tenera)**	Sh/sh **(Tenera)**
sh	Sh/sh **(Tenera)**	Sh/sh **(Tenera)**

Tenera X Tenera	**Sh**	**sh**
Sh	Sh/Sh **(Dura)**	Sh/sh **(Tenera)**
sh	Sh/sh **(Tenera)**	sh/sh **(Pisifera)**

Figure 2) Left: Crossbreeding of Dura X Pisifera. Right: Crossbreeding of Tenera X Tenera.

The Oil Palm Research Institute (OPRI), a division under the Crops Research Institute, are a dedicated Tenera seed producer, providing high-quality seeds and seedlings to oil palm farmers. Formal oil palm nurseries typically produce the Tenera variety as well.

Oil Palm Tree Physiology

The basic components of an oil palm tree are the Roots, Oil Palm Trunk (OPT), Palm Fronds (PF), and Fresh Fruit Bunches. Oil Palm Fronds are further divided into the Petiole (Stem) and leaves. The oil palm fruits, or Fresh Fruit Bunches (FFBs), contain the fruits , the empty fruit bunch (EFB). The fruits themselves contain the fruit pulp, oil palm fibres (OPF), oil palm kernels (OPK). The palm kernels contain the hard shell and the softer kernel cake, which produces palm kernel oil (see Figure 3).

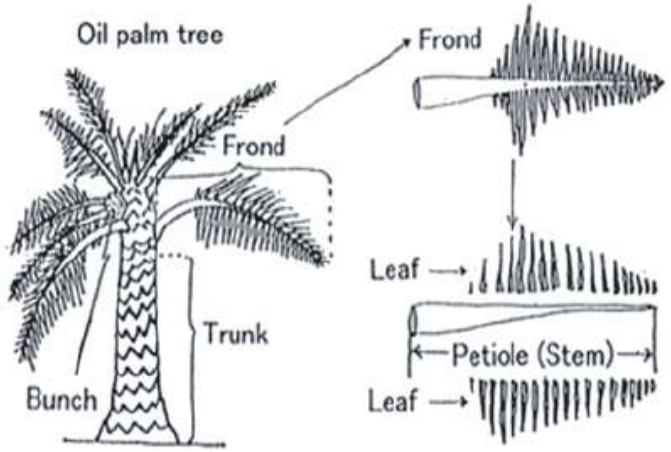

Figure 3) Diagram of a Palm Oil Tree, *Elaeis Guineensis.*

The waste products from the production of CPO are typically the fronds (OPF) that are cut from the tree during the growing season, the empty fruit bunches, oil palm fibres, palm kernel shells, and palm oil mill effluent. Each of these waste products has specific characteristics that make them suitable for different reprocessing methods and uses for recycling (see figure 4).

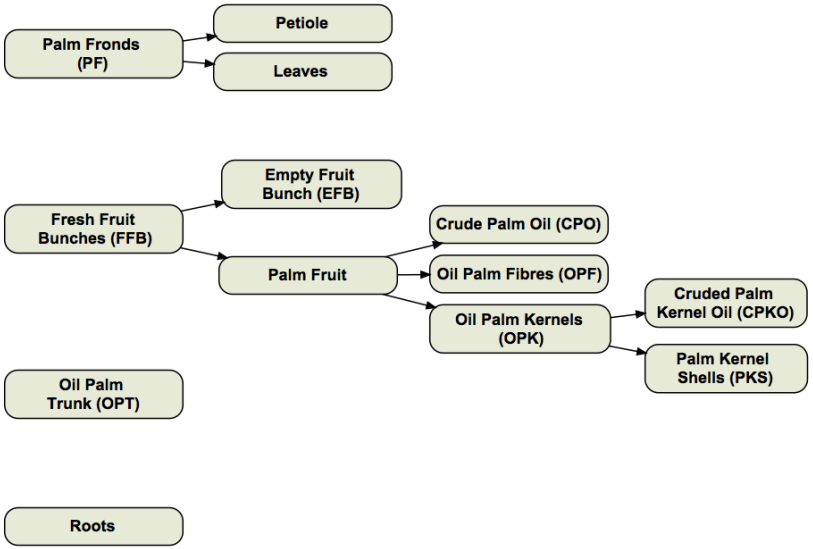

Figure 4) Flow map of products and waste products from oil palm trees.

Ideal Growing Temperature and Climate for Oil Palm

Oil palm grows best in the tropical belt, +/- 10° degrees latitude from the equator where temperatures range between 25-28° Celsius, with an average minimum temperature of 21-24° Celsius and maximum average temperatures between 28-31° Celsius. Sustained temperatures above or below the ideal temperature range (25-28° Celsius) can halt vegetative growth, especially for younger trees. Temperatures below 15° Celsius can cause 'heart rot', when the core of the tree begins to decay, leading to lost productivity for many years. Ghana's average temperature and seasonality is well-suited to oil palm cultivation.

Palm trees require an average rainfall of 150mm/month (1800-2500mm/yr.), with dry spells lasting no longer than 2-3 months. Beyond this, soil flooding, high water tables, and stagnation of soil water can cause the palm tree roots to rot, ultimately reducing yield. The Western region has the highest average rainfall in Ghana, at 1600mm/year, which is suitable for oil palm cultivation.

Optimal Soil Physical Characteristics for Oil Palm

Oil palm trees grow in a wide variety of soils, but grow best in deep soils with good water retention and drainage characteristics. Dense or poorly drained soils prevent the main taproot of the oil palm tree from penetrating deep into the soil, preventing maximum growth.

Growing oil palm on flat, or undulating land is best, as growing on a slope increases the risk of soil erosion, landslides, and loss of soil fertilizers due to slope runoff. Adding organic matter, composted materials or organic fertilizers to the soils can improve soil nutrient content.

Palm Oil Yields

The average yield of oil palm fruit in Ghana (5-20 tons/ha) is relatively low compared to other major oil palm producing countries like Malaysia (18 tones/ha) and Côte d'Ivoire (25 tons/ha). Smallholder farms in Ghana produce even lower yields, averaging 5 tones/ha. Large private plantations and out grower farms produce 15-20 tones/ha and 7-15 tons/ha respectively.

Low yields, especially among poor smallholder farmers, can be caused by one or many different issues including: inadequate or poor-quality planting material; unimproved agronomy and farm management practices; low soil fertility, inappropriate oil palm varieties; diseased or over aged trees; lack of access to inputs like mineral fertilizers or cover crops, and insufficient technical support from MoFA or Agric Extension Agents (AEAs).

Improvements in palm oil yields can be achieved through improving the training that small-scale farmers receive, improved access to farm inputs, better farm management practices, incorporating sustainable agricultural methods, and better understanding of the environment.

Palm Oil Production and Oil Palm Processing

In the Prestea Huni Valley and Wassa East Districts, palm oil cultivation is characterized by small-, medium-, and large-scale plantations. Smallholder farms dominate the sector, making up approximately 75-80% of land dedicated to oil palm and producing approximately 40% of crude palm oil. Medium-scale producers occupy around 5% of land and produce 5% of CPO. Large-scale plantations account for the remaining 20% of land and produce 55% of national CPO output (see Table 1).

Table 1) *Land usage and CPO output for plantations of varying sizes.*

Plantation Size	% Oil Palm Land Use	% of National CPO Output
Small	75-80%	40%
Medium	5%	5%
Large	20%	55%

Small-scale Palm Fruit Growers and CPO Producers

Small-scale palm oil farmers account for between 75-80% of the land currently cultivated for oil palm trees.

There are three predominant models for small-scale producers:

- Nucleus-smallholder farmers (2% of small-scale farmers) cropping on land that belongs to a large estate, where farmers are contractually obligated to sell their produce to the estate. Farmers are supervised to meet specific production and management specifications and receive technical advice during cultivation.
- Out grower farmers (28% of small-scale farmers) receive land under a share-financing model or under contract. Agricultural inputs like fertilizers and equipment is provided (at cost) to the farmer. The farmer is contractually obligated to sell their produce to the estate until the value of the land and the cost of the inputs are repaid.
- Private smallholder farmers (70% of small-scale farmers) have no contractual obligation and are self-organized and self-operated. Smallholder private farmers do not generally receive technical advice or assistance, resulting in low yields.

Approximately 40% of Ghana's total CPO production is done by small-scale or village-level producers. Small-scale and village-level production of CPO is characterized by low milling efficiency, low quality of CPO, and predominantly run on manpower and physically intensive processing methods. Men are often tasked with farm maintenance and women are most often engaged in the processing of the FFBs and production of CPO.

Fruits are collected from smallholding farms are aggregated at the home, or near the palm oil mill, and allowed to ferment for 2-3 days to loosen the fruits from the bunches. Separated fruits are then boiled with water for 3-5 hours, removed, then

gathered in a large drum, clay-lined pit, or large wooden mortar. The fruits are mashed by foot or with a large pestle. The resulting mash may be diluted with water and the oil skimmed off the top, or the fibers squeezed mechanically or by hand to separate the CPO. The oil is then boiled over an enclosed fire to remove the remaining water from the final product.

In Ghana, it is common for small-scale palm oil mill owners to charge a processing fee to the farmers for use of the processing equipment. Farmers do not need capital investment for mill equipment, are entirely responsible for the quality of their final product and retain the profits from selling their CPO. Other times, farmers may simply sell their fruit to small- or medium-scale processing centers at a flat rate, based on the weight of the fresh fruit bunches.

Medium- and Large-scale Palm Fruit Growers and CPO Producers

Medium- and large-scale palm oil farms account for 25% of the land currently dedicated to oil palm cultivation. These estates are mostly privately owned enterprises, using improved seed varieties, good agronomic and management practices, and have access to agricultural inputs like fertilizers and herbicide/weedicides.

Medium- and Large-scale CPO producers account for a significant fraction of Ghana's CPO production, around 12% and 19-20% of the market respectively. Competition between small-scale and medium- and large-scale producers for palm fruits is evident in the WAGES project area.

Large-scale palm oil factories process the fruits from hundreds or thousands of smallholder farmers or a few medium- and large-scale plantations. Significant mechanization and standard processing procedures are needed since the oil being produced is destined for an international market, where quality assurance standards are high. Ideally, the final oil should be neutral, with a bland flavor and nearly white color. To achieve this standard, mechanization and handling procedures are designed to minimize the formation of free fatty acids (FFAs) and oil oxidation.

Palm Oil Production Technology

Palm oil fruits produce two kinds of oil, red oil derived from the pulp of the fruit, and white oil derived from the kernel of the fruit. Traditional processing methods require a significant amount manpower for production However, modern technology on larger plantations and palm oil mills have dramatically improved the efficiency of palm oil production.

Today, palm oil production technology ranges from small-scale operations with simple machines, to large scale industrial operations with sophisticated technologies for each stage in the production process.

Regardless of the scale of technology, the basic steps for producing palm oil are relatively similar (see Figure 5):

1. Separation of individual fruits from the bunch either by manually or mechanically;

2. Boiling or steaming to soften the fruits and loosen the pulp;

3. Pressing and separating the oily liquids from the fibres and kernels;

4. Purification of the crude palm oil by heating or chemical clarification.

Palm Oil Grading

The grades of oil are distinguishable based on Free Fatty Acid (FFA) and moisture content in the CPO. Typically, small-scale producers and artisanal women produce the lowest grade of CPO, grade 3, with FFA above 12% and moisture content above 10%. Village level mills, with improved equipment can produce grade 2 oil, with FFA levels between 5%-12% and moisture content around 10%. Medium- and large-scale mills produce oil to meet international standards, with FFA levels below 5% and moisture levels at 0.4% or lower. This oil is supplied to domestic manufacturing of soap, cooking oil, and margarine.

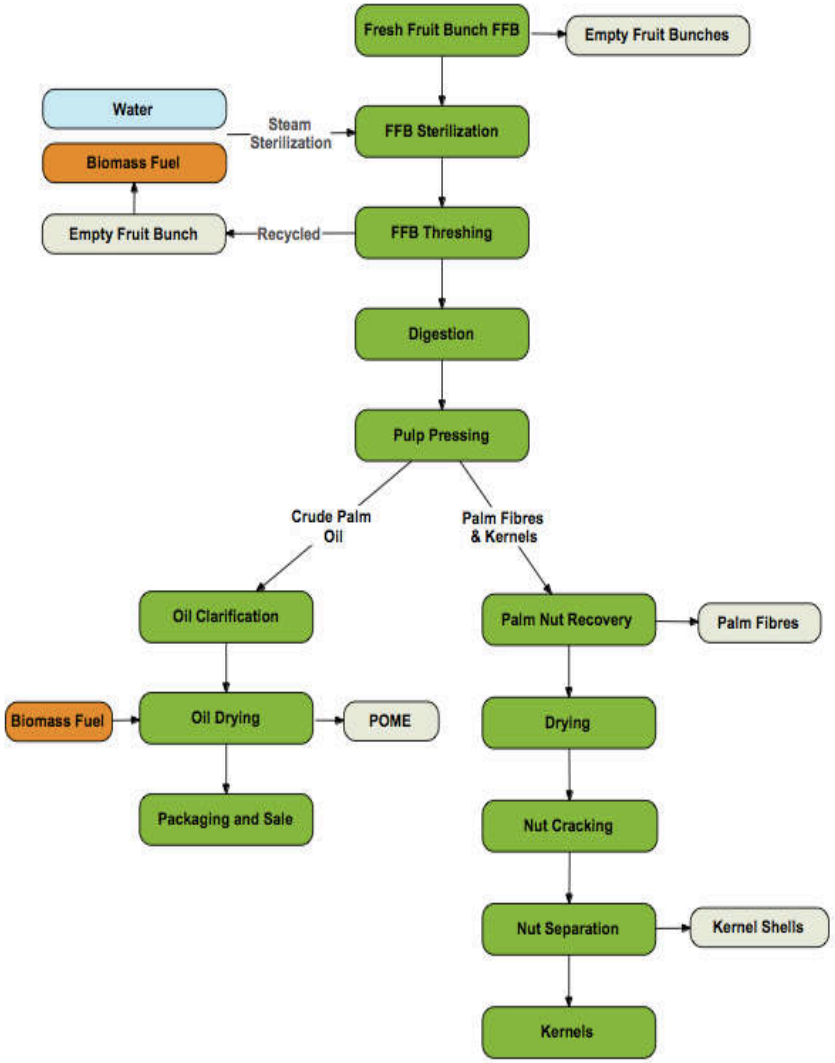

Figure 5) Basic Diagram of Oil Palm Processing.

Section 2: Environmental Risks of Oil Palm Production and Processing

The palm oil subsector is made up of oil palm farms and processing centers for palm oil and palm kernel oil production. Oil Palm farms, being an agricultural, has different environmental implications than palm oil processing, an agro-industrial process. The specific techniques, practices, and methods used during oil palm farming and palm oil processing can contribute to the kinds of environmental risks and damage being created by the individual, business or enterprise.

The environmental damage from a single individual, business or enterprise is small compared to the scale of the Ghana and the Earth. But it is the cumulative actions of all humans that, together, amount to serious and lasting environmental consequences. Every person is responsible for actions that either hurt or help the environment, and it is partially a matter of education and awareness about one's environmental impact that can guide them towards a more sustainable way of doing business.

Oil Palm Farming

Cultivating palm oil and selling the fruits for processing into palm oil is a very profitable business venture. However, like with other kinds of farming, the decisions farmers make about how and where to plant, what agronomic practices are being used, how fertilizers, pesticides, and weedicides are managed, and the mindset of the farmer can all impact the sustainability of a farm.

Climate Change is an important, long term, environmental risk for oil palm farmers. Oil palm farming practices can contribute to the causes of climate change, as well as be exposed to risk and uncertainty from climate change (pg. 13).

However, awareness of the environment and a broader view of using natural organic resources, such as green manure (46) and compost, and improving farming practices can be sustainable and minimize the impact on and from climate change.

Land Use Change and the conversion of forests or other natural land into oil palm plantations has multiple risks involved ranging from: deforestaion (pg. 19), Soil Erosion (20), Land Degradation(16) and Agro-chemical Pollution (22)

Even though the oil palm trees do store carbon, it is less carbon than what is stored in a natural forest. Burning away natural forests to clear the land will release greenhouse gases and degrade the environments diversity and resilience to change.

Oil palm plantations are also less able to support a diverse ecology. Insects, birds, rodents, and other animals who depend on many kinds of plants to survive won't be able to live in areas that have been changed to plantations (pg. 16).

Chemical Pollution is always a risk when fertilizers, weedicides and pesticides are being used on a farm or plantation (pg. 26). To increase the yield of palm fruit, many farmers use fertilizers to unnaturally increase the concentration of plant nutrients in the soil, instead of organic nutrients and green manure. Irresponsible or improper use of chemical fertilizers can cause chemical pollution in the environment leading to several additional environmental risks.

Palm Oil Processing

Processing oil palm fruits into palm oil and palm kernel oil also has unique environmental risks associated with them.

Deforestation partially comes from the use of firewood and charcoal unsustainably during processing of any sort. In palm oil production, using firewood as a fuel adds additional pressure on forests to provide wood in abundance. Often, trees that are cut are not replaced by new trees, contributing to the decline of forests in the area (pg. 19)

Waste Pollution from the by-product and waste products of palm oil processing, such as palm fibres, palm kernel shells, and palm oil mill effluent (POME) have specific physical and chemical properties that can damage the environment. POME is especially harmful to the environment since there is no easy re-use of POME and it can cause serious soil and water pollution if dumped into the environment (pg. 22).

Air Pollution from burning waste, like empty fruit bunches, palm fibres, and palm kernel shells is also a significant concern for the environment. Though often unavoidable, much of the waste can be reprocessed into other products for sale, or at the very least should be burned for productive uses.

Climate Change

One of the most important environmental risks in Ghana and for the world is Climate Change. Climate change by itself is a very complex subject, where scientists all over the world still do not fully understand what is causing climate change, or how fast approaching the effects are. Nonetheless, climate change is taking place today at an increasingly alarming rate.

Climate change is the result of an increasing 'Greenhouse Effect', caused by human activities. The acceleration of the Greenhouse Effect is principally driven by a steadily increasing buildup of **Greenhouse Gases (GHG)** in the Earth's atmosphere. In natural circumstances, without modern human influence, the Greenhouse Effect allows the Earth to retain enough heat to support living things. Without the Greenhouse effect, the Earth would be a cold and barren rock in space. Greenhouse gases are:

- **Water vapor (H2O)** is a natural greenhouse gas and comes from evaporating seawater and emission from forests.
- **Carbon Dioxide (CO2)** is released from burning fossil fuels (cars, machines, generators, coal burning etc.), from deforestation, and land use change.
- **Methane (CH4)** is a much more powerful greenhouse gas but is far less abundant in the atmosphere. Decomposing waste in landfills, large-scale livestock operations; rice cultivation and other agricultural operations.
- **Nitrous Oxide (N2O)** is produced from commercially-used soils, commercial and organic fertilizer use, burning fossil fuels and from burning biomass (agric waste).
- **Chlorofluorohydrocarbons (CFC)** are a minor, but very powerful GHG that comes from and industrial factories. The use of CFCs is tightly regulated by national and international laws.

Many human activities accelerate the forces causing climate change:

- The use of **Fossil Fuels** in developed countries and developing countries is emitting large amounts of greenhouse gas into the atmosphere;
- **Global Land Use Change**, and the degradation of natural environments for human purposes, decreases the earths resilience to change and

- degrades environmental systems;
- Severe **Deforestation** in many of the world's most important forests, including in Ghana, is reducing carbon storage in trees and underground and emits greenhouse gases;
- **Increased use of synthetic chemical fertilizers** and increased industrial agriculture contributes to the release of many greenhouse gases from the soil and from chemical production;
- **Large-scale animal rearing operations** and decomposing waste produces significant amounts of methane, contributing to climate change.

Compared to major industrialized cities and countries, rural areas and underdeveloped countries do not contribute nearly as many greenhouse gases as industrial countries like the USA, or Europe. However, practices like burning waste, deforesting native trees, failing to replant forests after timber harvesting, and bad agronomic practices can all contribute to increasing GHGs, or diminishing the ability for nature to sustainably manage GHGs.

The Effects of Climate Change

The full effects of climate change are difficult to predict, even for specialized scientists. However, a few key details are known to us. Climate change will cause:

- On average, the world will become warmer. Some areas will become much hotter, while other areas might not. Ghana and other West Africa nations may start to see more desertification, such as can be seen in Northern Ghana today.
- Changing weather patterns will make some areas dryer, and other areas much wetter. This means that the rainy season may not provide the same rainfall it did in generations past. This could also mean that rain could become much heavier, causing serious flooding.

  This will affect agriculture, where some plants may respond well to increasing CO2. Other commercial crops may fail entirely in certain areas that are no longer suited for that crop.
- As the polar ice caps melt, global sea levels will rise, affecting coastal cities and communities all over the world, including Takoradi, Cape Coast, Accra, and Tema. Coastal storms, like hurricanes could increase in intensity and frequency in these coastal cities.

Environmental Footprint

Like a regular footprint in sand or dust, an Environmental Footprint is the mark left behind on the environment (or climate) by an individual or business. It is a measure of how much environmental damage or protection a person provides to the environment.

Causing unnecessary pollution, wasting natural resources, burning waste products instead of recycling them and other unsustainable activities make a person's or businesses' Environmental Footprint bigger.
Being efficient and mindful with natural resources, taking responsible and active steps to prevent waste and pollution, using sustainable alternative fuels and incorporating green principles into the business makes a persons' or businesses' Environmental Footprint smaller. It is best to have as small of an Environmental Footprint as possible, to cause little or no damage to the environment.

To 'see' one's Environmental Footprint, we need to look at everyday choices about fuel, waste, business practices, personal responsibility, and active measures to reduce one's Environmental footprint and be more sustainable.

- Activities release greenhouse gases and use of fossil fuels (i.e. oil, petrol, gas, diesel, coal), mineral fertilizers (i.e. Nitrates and ammonia), or burning waste should be kept to a minimum.
- Wasting natural resources, or being inefficient with natural resources can increase an Environmental Footprint, especially when the business uses resources like timber, firewood, charcoal, water, or other natural resources.
- Being careless with waste products, like dumping and disposing waste in the bush, or not using appropriate waste management facilities like refuse containers or recycling, can cause pollution and increase the Environmental footprint.

Finding ways of reducing the need for as much fuel, reducing transportation, minimizing how much plastic trash is created, or organic farming can all reduce greenhouse gas emissions.

- Improving efficiency with natural resources and minimizing waste are also useful ways of reducing one's Environmental Footprint.
- Recycling waste products for use in the business or for another person's business can be a good way of reducing waste pollution and reducing an

- Environmental Footprint.
- Using sustainable practices like composting instead of chemicals, being responsible with refuse, reducing how much plastic you use in everyday situations can reduce the Environmental Footprint.
- Incorporating Green Economic Principles into the business, being aware of one's Environmental Footprint, and taking advantage of Green Economic Opportunities can also decrease the size of an Environmental Footprint.

Land Use Change

Land Use is concerned with how and for what purposes land is used and the transition from one type of land use to another, whether farming, irrigation, tourism, housing development, waste dumping or left in its natural state. Land Use Change is a basic part of development and culture where, for centuries, man has used the environment to produce food, structures, settlements and communities (See figure 6).

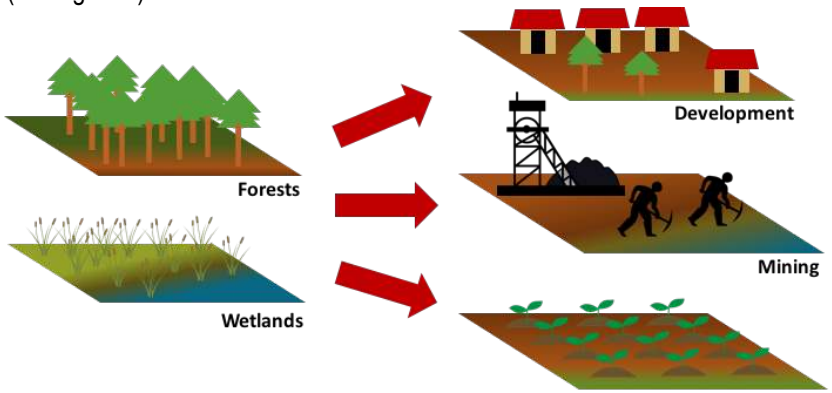

Figure 6) Diagram of Land Use Change of Forests and Wetlands into new land uses

The concern with palm oil plantations is that the rapid expansion of economically productive plantations will rapidly come to replace forests, causing severe losses of important ecosystems and their benefits to the communities nearby. Expansion of palm oil plantations to increase yield, called *Extensification (pg. 36)* is an unsustainable practice that will have lasting consequences if nothing is changed or made more sustainable.

Beneficial Ecosystem Services

Natural environments provide an abundance of 'ecosystem services', which are benefits that we as humans enjoy and rely on for daily activities:

- Rainforests play an important role in regulating the local weather; protect soils from nutrient depletion and erosion; and provide abundant habitat for many animals and plants. Wood and timber are an important fuel source and building material all over the world. Many cultures and peoples place personal and spiritual value in forests for providing a pleasant environment.
- Rivers and wetlands help provide rain and flood control; removes toxins and chemicals from the water; are an important source of fish and other resources; and are critical habitats for aquatic plants and animals.
- The oceans are important for coastal cities to provide electricity, food and other natural resources; oceans regulate global weather patterns and is responsible for managing fluctuations in large-scale environmental systems; and oceans are an important cultural and social component of many communities all over the world
- Groundwater can be safely stored for long periods of time, providing water relief during dry seasons;
- Plants and Animals are sources of medicine, remedies, food, spiritual power, and important genetic diversity.

With the environment naturally providing so many benefits to humans, the threat of Land Use Change is clear. Changing the use lands for non-natural purposes, threatens Earth's ability to provide free ecosystem services. The loss of any ecosystem service will require humans to either adapt to life without the ecosystem service, or devise new ways of obtaining the service without the environment.

Farming and Land Use Change

The transition from natural forest land to agricultural land is not inherently unsustainable. However, extensification (expanding land to increase crop yields) rather than intensification (increasing crop yields without expanding land), utilizing inorganic farming practices, over-use of chemical fertilizers, weedicides, and pesticides and other unsustainable farming practices contribute to degrading and destroying native forest lands.

- Clear cutting forests to make room for more and larger farms will degrade landscapes that once housed native plant and animal species, reducing the suitability of the land to support healthy natural environments for plants and animals;
- The loss of biodiversity will decrease the ability of the natural environment to resist the effects of environmental and climatic change, and decrease the genetic wealth of the area;
- Increasing farmland divides forests into patches and fractures the landscape, reducing the suitability of the land to support healthy natural environments for plants and animals.

Wetlands and Land Use Change

Wetlands are typically low-lying areas with swampy or waterlogged soils, shallow ponds, or interlacing streams and rivers. Wetlands are an important and often underappreciated natural landscape, and play a vital role in hydrological (water) cycles, habitat provision, ecological stability and other beneficial ecosystem services.

- During the rainy season, floods and excess water are retained by wetlands, preventing damage to houses, farms or other structures.
- Water that goes through natural wetlands are cleaned of many kinds of pollution including metals from mining (mercury), mineral fertilizers and sediment.
- Wetlands are also important habitats for birds, frogs, insects, and many other kinds of wildlife that make up the environmental ecology.

Wetlands, because of the quality of land, are often converted to rice farms or other kinds of land use. Draining the wetlands to prepare the land can diminish the role of wetlands in protecting an environment and providing ecosystem services. Animals that once lived and depended on the wetland are pushed out or killed, reducing the environments ecological diversity and sustainability. Rapidly changing wetlands from their natural state to a rice farm or other use, methane is often released in significant quantities.

It will be necessary to convert some wetlands into farm to provide jobs and development to the community. But farmers who have converted wetlands need to be aware of the risks in doing so. To many farms and not enough wetland will disrupt ecological balances and natural systems. Expanding, or extensification, of farm land to produce more crops is not as good as learning to increase yields

without changing more natural land (intensification). Farmers must be responsible for the changes they bring to an environment and work to ensure that ecosystem services are maintained and protected for the sake of the environment, society, and economy.

Deforestation

Deforestation is a special case of Land Use Change. Deforestation is the near-complete or complete removal of trees and forests in an area, and total conversion to non-forest purposes, like farming, mining and development. In Ghana, as much as 1/3 of forests lands have been lost since the 1990's, and forests are continuously lost at a rate of 2.19% annually. If these trends continue, deforestation cause a severe loss of important ecosystems and benefits to Ghana.

- Deforested land is more prone to erosion of topsoil due to rain and wind. The erosion, along with mining or other human activities, can cause rivers to become choked with too much dirt and soil, resulting in sediment pollution.
- Deforestation can also fracture and break apart local habitats for native bird, insect, plant and animal species. Forests that were once continuous, allowing for the free movement of native animals, are split into smaller sections and quickly eroded away, harming native animal and plant populations.
- Forests play important and complex roles in managing and stabilizing local weather conditions, nutrient cycles and soil development, social and communal functions, and Timber products support many different livelihoods.
- Forests are a major carbon sink (see Carbon Cycle), and the loss of forests could accelerate the negative effects of climate change, especially at the local level.

Oil Palm plantations are often started in newly deforested areas. As native lands are cleared to make room for economically productive oil palm plantations the important Beneficial Ecosystem services that are provided by the forests are diminished or destroyed entirely. Palm Oil Plantations are less ecologically diverse than the forests the replace, reducing the carbon storage capacity of the forests,

and increasing the pressure on natural systems to continue to provide beneficial ecosystem services.

Soil Degradation

Soils, especially for agriculture, are complex mixtures of mineral soils and clay, beneficial bacteria and other microorganisms, organic carbon, plant nutrients like nitrogen, phosphorous and potassium. These all come together to allow plants to grow well, producing food and commercial crops. The layer of soil that can support plants is very thin and very fragile. This 'topsoil' sits on top of very hard clay and rock that is not suitable for agriculture

Topsoil can be disrupted and destroyed by irresponsible and unsustainable farming practices, which often means new land will be needed. The constant search for new land drives deforestation and other land use changes.

- Over tilling, or disrupting, the soil can spread organic matter and bacteria too thinly among the mineral soil, or disturbing the natural balance of soil contents or bury the soil in poor-quality clay.
- Removing plants can expose the soil to rain and wind, which can carry the top soil and leave only the barren rocky clay beneath.
- Soils can lose plant nutrients and organic matter when crops are grown without replenishing the organic matter and nutrients. Chemicals can temporarily replace plant nutrients, but this does little to improve the organic matter content, or soil stability. Chemicals can also be washed out of the soil because of the rain, in a process called 'runoff' or leaching.
- Over irrigation can lead to soils becoming to salty. Natural salt in the water is left behind when the water evaporates, degrading the quality of the soil
- Soils in low-lying areas that are prone to flooding can become waterlogged, where to much water prevents air from reaching the roots. This can cause crops to rot, releasing methane and other greenhouse gases.

Eutrophication

Eutrophication is when a body of water, like a lake, stream or river becomes polluted with mineral fertilizers, plant nutrients, or organic waste products from Oil Palm farming or processing.

1. Rain, irrigation or groundwater can transport nitrogen (N) or phosphorous (P)-based fertilizers, significant amounts of animal manure, or high concentrations of organic matter into nearby waterways.
2. The nutrients in the water cause excessive growth of green algae, and other micro organisms in the water.
3. As the algae begin to die, natural bacteria in the water consume and decompose the dying algae, which uses oxygen in the process. As more algae die the water becomes devoid of oxygen in the water (dissolved oxygen), causing stress and possibly death to aquatic plant and animal life.
4. In the long term, eutrophication can cause significant damage to wetland ecologies, rivers or lakes (see Figure 7).

If the source of pollution is corrected and future waste products and runoff pollution are avoided, the wetlands will likely restore themselves through natural processes. However, long term pollution will cause permanent damage to the natural systems in wetlands and water bodies.

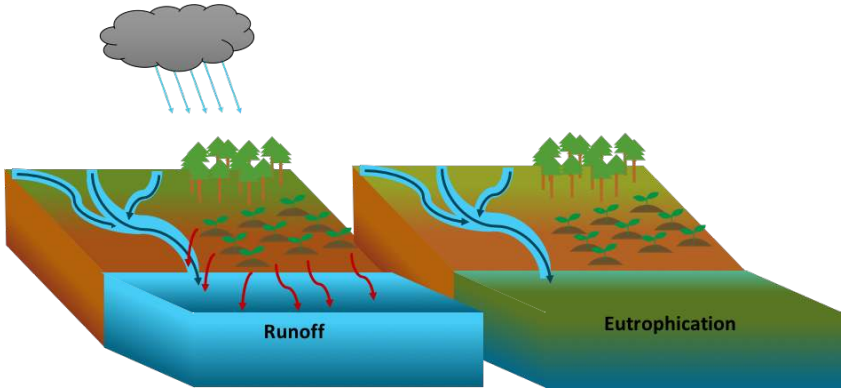

Figure 7) Agro-chemicals and mineral fertilizers can runoff into local waterways, causing eutrophication.

Waste Products and Pollution

Waste products from the Oil Palm sector are varied, and include solid organic waste, liquid organic waste, and various types of inorganic waste products (see Figure 8). The various kinds of waste products from farming oil palm, and processing fresh fruit bunches into palm oil have different chemical properties, and are somewhat durable in the environment.

	Solid Waste	Liquid Waste
Organic waste	**Solid Organic Waste** Palm Fibres Palm Kernel Shells Empty Fruit Bunches Palm Fronds Palm Trunks	**Liquid Organic Waste** Palm Oil Mill Effluent Wastewater
Inorganic waste	**Solid Inorganic Waste** Agrochemical Containers Plastic packaging	**Liquid Inorganic Waste** Agrochemical Runoff

Figure 8) Waste types form Oil Palm subsector.

The most common types of waste, by volume and mass, from oil palm processing are the palm fibres, the palm kernel shells, and the palm oil mill effluent. These three types of waste are solid organic and liquid organic waste, respectively. Solid organic wastes, by nature, are more durable in the environment. The tough fibrous plant material that make up the fibres and kernel shells do not allow these organic waste products to easily decompose, posing possible risks when disposing of these waste products.

Organic Waste Pollution

Simply because the waste is 'organic' and 'natural' does not mean that these kinds of waste are harmless. Yes, with enough time, the waste products will disappear, but poor management and long-term dumping will become pollution very quickly. Organic wastes, when dumped in large piles and allowed to sit with no other use, can become breeding grounds for mosquitos which transmit

malaria and other diseases, for mice and rats that are pests, and insects like flies and gnats. The smell of decomposing waste can also create foul odors and an unsightly mess, which degrades the environment for the community.

Solid organic waste, like coconut shells, palm fibres, sawdust, and other kinds of waste are usually disposed of by burning them. This releases smoke and fumes that nearby community members breath in, causing harm and polluting the air. When waste products aren't burned for any productive use, like cooking or boiling, the energy that could have been provided as heat and fire, is wasted.

Liquid organic wastes, like palm oil mill effluent (POME) and cassava wastewater, are also potentially dangerous to the environment. These liquid wastes contain large amounts of Organic matter, which can cause eutrophication to nearby water bodies (pg. 21).

Palm Oil Mill Effluent

Palm Oil Mill Effluent or POME, is one of the most environmentally damaging aspects of oil palm farming and palm oil production. POME is a thick, acidic, brownish liquid very high in organic matter, bits of debris and oil, which means that when it is dumped into the environment, there is the risk of causing soil degradation and eutrophication in local waterways.

When dumped onto soils, the grease and oils in the water can clog soils, preventing water from flowing through them, creating waterlogged soil conditions and kills vegetation. When dumped into nearby waterways untreated, the organic matter and solid pieces of debris in the POME can be consumed by micro organisms. In the process, micro organisms take up and use dissolved oxygen in the water is used to digest the POME, leaving the water striped of the oxygen content, causing eutrophic water conditions.

By some estimates, as much as 5-7.5 tonnes of POME are created for every tonne of CPO produced. For small-scale producers of palm oil, treatment of POME and using the treated POME as a source of organic manure and fertilizer is one possibility for mitigating and remediating the damages caused by untreated POME.

Composting POME is likely the easiest solution for small- and medium-scale palm oil producers. Industrial methods of treating POME before final disposal are very technically complex and require specific equipment.

However composting POME, along with chopped empty fruit bunches, sawdust from carpenters, kitchen waste, and sand can create a suitable organic fertilizer (pg. 46).

Inorganic Waste Pollution

Inorganic waste, like plastics, foam packaging, metal, rubber, electronics, motor oil and auto mechanic fluids, agro-chemicals, rock and sediment, are all inorganic. Meaning that they will not readily decompose into the environment. The buildup of these kinds of waste is evident in most parts of Ghana. Trash and refuse litters nearly every street, river, lake, and natural environment. This kind of pollution degrades the beauty and quality of the environment.

Solid inorganic waste products take hundreds or thousands of years to disappear completely. This means that if the waste is not effectively managed in a formal landfill, it will cause unsightly pollution and a risk to animals who might eat the trash, mistaking it for food.

Liquid inorganic waste products like motor oil, salon and beauty parlor waste water has chemicals in them that are unnatural in the environment. These chemicals may not always breakdown and can build up in an environment. The pollution can spread from the soil to the water, to groundwater, and bioaccumulate in animals, contaminating food and water sources for communities. Chronic, or long-term, exposure to these chemicals can have serious health effects over time.

Burning Waste

Burning waste or trash is a common practice in Ghana. Both organic waste, from processing agricultural crops, and inorganic waste like plastic and other household trash releases smoke, greenhouse gases, and harmful chemicals.

Burning wood and biomass fuels, like charcoal and dried plant matter does release greenhouse gases. However, for most rural areas the contribution overall is small. Nonetheless, understanding that if there is a useful way of burning organic waste products, as a cooking or heating fuel, this is better than burning waste to simply get rid of it.

Burning inorganic waste, like plastic, rubbish, tyres and other trash releases many toxic and hazardous chemicals. Burning inorganic refuse, plastic trash and other waste releases fine particles, polychlorinated dibenzo dioxins (PCDDs) and polychlorinated dibenzo furans (PCDFs); and polyaromatic hydrocarbons (PAH), including known cancer-causing carcinogens such as benzo(a)pyrene.

These inorganic chemicals are known to be highly toxic and cancerous, especially to woman and children. Long term chronic (long-term) exposure to these

Chemical Pollution

Waste products, poor management of agro and industrial chemicals and unintended release of pollutants into the nearby environment can all cause pollution.

Potential pollutants include:

- Excess chemical fertilizers,
- Pesticides,
- Weedicides,
- Liquid organic and inorganic waste products,
- Human and animal feces,
- and other materials.

Agro-Chemical Pollution

Agro-chemicals, like fertilizers, pesticides and weedicides can move through the environment, via water and rain. This process, called 'Runoff', can allow agro-chemicals to environment, potentially causing negative environmental outcomes.

Chemicals can be transported by wind and rain and irrigation. Chemicals can flow into surface water or sink into the ground where they're transported by groundwater. Neither groundwater and surface water are localized to a single area - chemical pollutants can move long distances to other communities causing environmental risks through water pollution (pg. 4; see Figure 19).

Chemical Herbicides/Weedicides and Pesticides

Agro-chemicals, designed to kill insects and other pests, can reach the environment through runoff and leaching into nearby soils and streams. Rain and wind can transport chemicals from the farm into the surrounding rivers and groundwater. Once agro-chemicals reach a water body, like groundwater or a river, they are very costly and almost impossible to clean up.

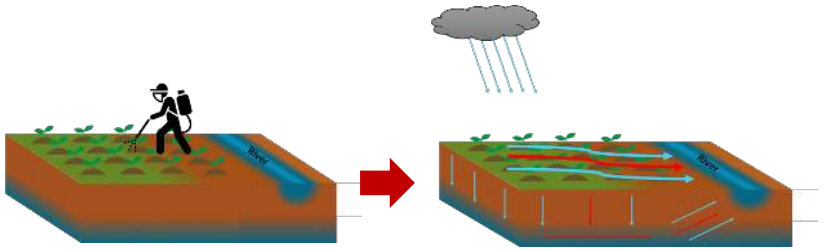

Figure 9) Basic diagram of runoff occurring after application of agro-chemicals.

Chemical pesticides and herbicides can be highly toxic to native birds, fish, beneficial insects, and non-target plants and other food crops. Many chemical pesticides and herbicides are very persistent in the environment, meaning that they can remain unchanged for weeks, months, and even years after application, though concentrations are relatively low (see figure 9).

Human Health Risks of Agro-chemicals

Concentrations of chemicals can increase through natural processes called 'Bioaccumulation'. Bioaccumulation occurs when certain types chemicals, including pesticides and herbicides, as well as mercury from *galamsey,* can accumulate in animals and fish.

Chemicals can attach themselves to small bits of organic matter and debris in the water. Small organisms and insects in the water will absorb the chemicals or eat the small bits of organic matter. Small fish then will eat the insects, concentrating the chemicals in their bodies and fat tissue.

Larger fish eat the smaller fish and other well as the insects, slowly increasing the concentration of chemicals in their bodies. Humans who eat the fish are the final consumers of the chemicals. Some of the chemicals will pass through the body without harm, some of the chemicals will not (see figure 20).

Dietary exposure to chemicals is considered 'chronic' exposure, or exposure to small amounts of chemicals through food over a long period of time. It is worth mentioning that the concentrations are often very small, and pose a very small risk to humans. Nevertheless, the more chemicals that are used, the more chemicals

Chemical Fertilizers

The soils of the Western Region are highly weathered, acidic and often leeched of important plant nutrients for optimal crop growth. Farmers apply chemical fertilizers to offset naturally low nutrient concentrations in the soil. While there is no inherent danger in applying chemical fertilizers, bad management practices such as:

- Over-application
- poor timing,
- ineffective application techniques,
- using inappropriate chemical fertilizers,
- and improper storage of chemicals can lead to pollution of the surrounding environment.

Rainfall, irrigation, and ground water movement can transport excess chemical fertilizers into nearby streams and lakes and result in eutrophication. Eutrophication is a reduction or depletion of dissolved oxygen (DO) in surface waters caused by sudden blooms of algae in response to nutrient runoff. Eutrophication of freshwater can negatively impact the environment by killing fish and other aquatic life that local communities depend on for food (see Eutrophication).

Other Kinds of Pollution

Besides waste and chemicals, there are other kinds of pollution that can have a negative effect on the environment. Not all of these are relevant to the Oil Palm sector, but are nonetheless important to understand.

Sediment Pollution: Sediment pollution is when a very large amount of sediment, clay, or dirt is mixed into the river. This sediment prevents light from reaching the aquatic plants, places stress on fish and other aquatic animals and degrades the quality of water for use by the community.

Galamsey mining, especially on or near rivers cause sediment on the riverbed to be disturbed and cloud the water, turning it brown. Sediment can also come from nearby land that recently been cleared for farming when heavy rains come and wash the fragile topsoil away.

Thermal Pollution: Thermal pollution is a specific type of water pollution where wastewater that has been heated or cooled for industrial purposes is dumped into the environment. Wastewater that is too hot or too cold can dramatically and quickly change the temperature of the natural river or lake. This can cause damage to aquatic ecosystems and kill wildlife.

Noise Pollution: Constant or very loud noises from blasting is considered noise pollution. This can be disturbing to many people and animals. If the noise, like blasting music, is near the bush, the noise can disturb and stress the animals.

Light Pollution: Bright lights near to the bush can be distracting and disorienting to nocturnal (nighttime) animals. Some nocturnal animals can be confused or scared of the lights, stressing them.

Littering: Waste disposal is a bad practice and can amount to pollution and serious environmental damage. But throwing garbage out the car window, or leaving it by the side of the road is littering. It makes the whole community look like a dump and degrades the beauty of the environment. Plastics will not simply decompose and disappear within our lifetimes. Any plastic that litters the environment and is not collected will be in the environment for many years.

Section 3: Green Economy

Green economy is different than just 'Sustainability' or 'Economic growth.' Though these are important parts of what a Green Economy seeks to accomplish, a Green Economy is about holistic growth that appeals to society, the environment and the economy.

The United Nations Environment Programme (UNEP) defines a Green Economy as one that "results in improved human well-being and social equity, whilst greatly reduces the environmental risks and ecological scarcities." (UNEP, 2011). A Green Economy is driven by reallocating investment and resources away from unsustainable industries to ones that reduce carbon emissions and pollution, enhance resource and fuel efficiency, and prevent additional loss or degradation of a nations natural resources.

Green Economy is also enshrined in the mandate of the Government of Ghana in the Ghana Shared Growth and Development Agenda II 2014-2017 (GSGDA II, 2014). The medium-term policy objectives seek to "…[E]nhance the capacity of the relevant agencies to adopt to the impacts of climate change, mitigate the impact of climate variability and generally promote green economy (GGSDA II, 2014).

Ghana, as well as many other Nations have begun to understand the pressing nature of climate change, and the immediate need for more sustainable economies, societies, and environments. Establishing and supporting the Development of a Green Economy requires cooperation from all levels of government, from businesses and enterprises of all sizes, and from individuals in their unique capacity.

The information in this section will guide readers through:

Principles of Green Economy

The Green Economy Coalition, established in 2012 the Nine Principles of a Green Economy in collaboration with NGOs, research institutions, UN organizations, businesses and trade workers' associations. (Green Economy Coalition, 2012). These Nine Principles outline the most important aspects of cultivating a Green Economy:

The Sustainable Principle – A green, fair, inclusive economy is a means to deliver sustainable development. A Green Economy addresses all three dimensions (environment, society, economy) and develops policies and solutions that seek the best results across all of them.

The Justice Principle- A green, fair and inclusive economy supports equity between countries and generations. Green Economy respects human rights and cultural diversity, supports gender equality, and respects the rights of indigenous people to land, territories and resources.

The Dignity Principle – A green, fair and inclusive economy creates genuine prosperity and wellbeing for all. A Green Economy alleviates poverty, provides food security and universal access to basic health, education, sanitation, water, energy, and other essential services. This includes providing dignified self-empowerment and education of women, and recognizing the contributions of unpaid work.

The Earth Integrity, Planetary Boundary and Precautionary Principle A green economy restores lost biodiversity, invests in natural systems, and rehabilitates those that are degraded. It recognizes the dependency of society on the environment and does not overstep ecological boundaries. This includes reducing pollution, increasing efficiency, respecting all forms of life, applies the precautionary principal, and promotes balance between ecological and social relations.

The Inclusion Principle – A green economy is inclusive and participatory in the decision-making process, incorporating transparency, sound science and engagement of relevant stake holders. It empowers citizens and promotes tolerance of all religious views and lifestyle choices. Green Economy gives equal opportunity to, and advocates for the rights of, women and men, poor and low skilled workers, indigenous peoples and ethnic minorities.

The Good Governance and Accountability Principle – A green economy is accountable to citizens and stakeholders. It upholds transparent governance, international human rights standards and environmental agreements.

The Resilience Principle – A green economy contributes to economic, social, and environmental resilience. It supports the development of social and environmental protection systems, and adaptation for extreme climate events. It promotes sustainable and diverse economies suited to local skills, capacity, and context.

The Efficiency Principle – A green economy incorporates sustainable consumption and production, incorporating the true costs of social and environmental externalities. It prioritizes renewable energy and renewable resources, supports a polluter pays principal for businesses, and promotes zero waste and resource efficient business models.

The Intergenerational Principle – A green economy invests for the present and the future. This means promoting conservation of resources and the quality of life in the long term. This requires long-term, scientifically-sound decision making, and equitable education at all levels for children.

Outcomes of a Green Economy

Incorporation of Green Economic Principles and strategies into all aspects of the economy, society, and the environment can lead to three main outcomes for a society:

Building Social Equality – Equality between women and men; building opportunities for the youth; improving incomes for the poor.

Improve Human-well-being – Healthier living areas for people; using natural resources sustainably so the next generation can use them.

Reducing Environmental Risk – Preventing deforestation; reducing pollution in the environment; recycling waste products instead of dumping.

A green economy does not just focus on increasing business profits, but also incorporates social, economic, and environmental growth for all citizens. Building social equality, improving human well-being, and reducing environmental risks and negative outcomes can create a better future for future generations, while building a better life for citizens and communities today.

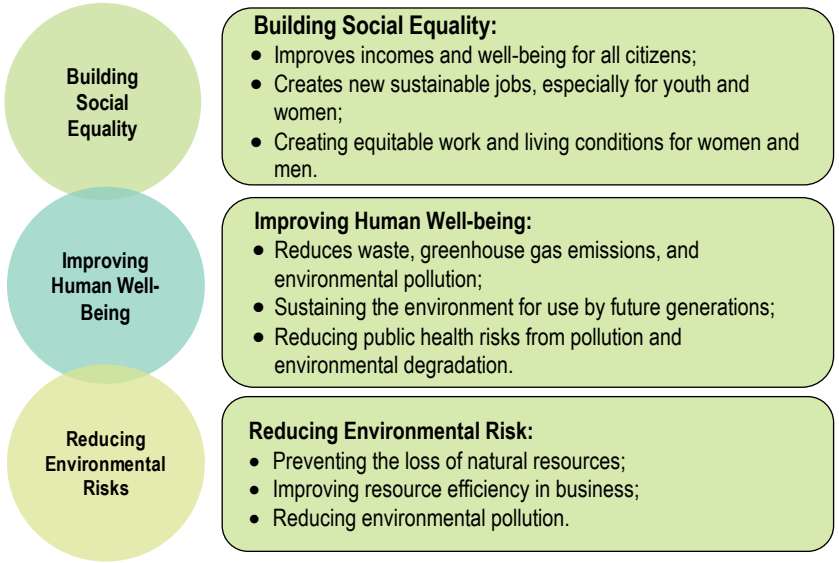

Figure 10) Building social equality, improving human well-being, and reducing environmental risks, are all part of a Green Economy.

The Environment, Society, and the Economy

In order to understand how a Green Economy works it is important to understand the relationship between various components of a community and the interactions between them. Specifically, understanding that 'The Economy', 'Society', and 'The Environment' are not separate spheres of a community, but rather interact with and depend on each other to function effectively, efficiently, and sustainably (see Figure 10).

A few basic terms are needed and they are defined on the following page:

The Economy: The economy is the condition of a country or region in terms of the production and consumption of products (goods) and services, as well as the supply and flow of money. This includes all small-, medium- and large-scale enterprises in a community, district, or region depending on the scale of interest.

The Economy is the result of a functional and supporting Society. The Economy exists *within* Society.

Society: A society is made of many individual people and families living together in an orderly community or town. There are many important components to a society: Markets, Values, Science, Policy, Infrastructure, and Technology.

- **Markets**: Markets are where buyers and sellers are together and can do business with each other.
- **Values:** Values are what is important to an individual or business. Businesses value profits, good prices for their products and services, good relations with suppliers and consumers.
- **Science:** Scientific discoveries allow new products to be created and new technologies to be produced to improve business efficiency and connect businesses to consumers through the internet and digital communications.
- **Policy:** Policies set by the government determine taxes, which businesses are supported for growth and which are not. Policies make it easier or harder for certain businesses to grow.
- **Infrastructure:** Roads, electricity connection, internet, and water supply are all things that help an economy deliver products and allow a society and economy to function.
- **Technology**: Machines and technological equipment help a business operate faster and with more quality control. They allow work to be done more efficiently and with less mistakes or errors.

Markets, Values, Science, Policy, infrastructure, and technology all come together in a society to allow an 'Economy' to develop and thrive. Similarly, changes to society can influence how an economy functions. For example, new government policies can make starting businesses harder or easier; new roads and tele-communications can allow businesses to function better and more efficiently; new markets can provide opportunities to sell goods to new customers.

The Environment: An environment is any natural or man-made area and is the location and setting for any society and economy. 'Society' and the 'Economy' exist within and as one part of a much larger and more complex environment. If there are changes to the environment, those changes will affect society and the economy. Without a healthy and productive environment, society and the economy wouldn't exist in the same way it does.

'Society' collects '**Natural Resources'** from the environment and the 'Economy' distributes these natural resources to various sectors and businesses to produce and manufacture any number of goods, product, and services for sale. The economy consumes (purchases) these products and services

As businesses process the natural resources, by-products are created and often dumped into the environment or burned. These actions have **'Environmental Outcomes'**, or effects on the environment.

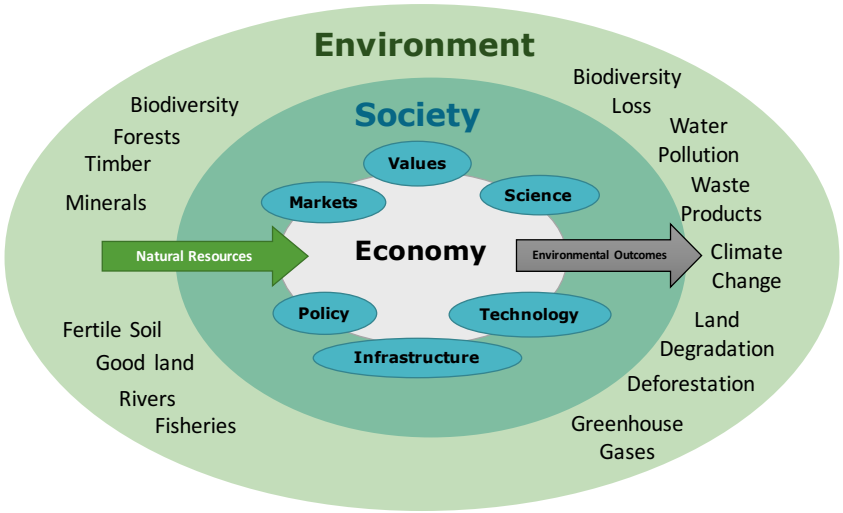

Figure 11) A diagram showing the relationships between 'The Economy', 'Society', and the 'Environment' and how 'Natural Resources' are transformed to cause 'Environmental Outcomes'.

Figure 10 shows the relationship between the three components of a community, the Economy, Society and the Environment.

- The Economy is a collection of all the small-, medium, and large-scale enterprises, and exists within and as part of Society;
- Society makes and governs markets, values, science, technology, policy, and infrastructure development. Society, like the economy, exists within an 'Environment'.
- The Environment can be local, the immediate land surrounding a community, or the environment can be larger, encompassing the entire region or country. There is no society that exists separately from their environment. The values and features of a society can moderate how an economy affects the environment through environmental outcomes.

Societies that do not regard the environment as important for a society are likely to produce negative environmental outcomes, like rampant pollution, indiscriminant dumping of waste, or deforestation and land degradation. However, societies that understand that the economy depends on the environment to provide natural resources, and society depends on a healthy environment to grow are more likely to encourage sustainability, environmental protection, and good environmental stewardship.

It is most important to understand that if an environment is damaged or is spoiled due to persistently negative environmental outcomes, the society and economy that depend on the environment will suffer. Loss of natural resources, loss of beneficial ecosystem services, and damage to the environments ability to restore itself will inevitably have negative consequences for businesses and the community as a whole.

Globally, the continued use of fossil fuels, like coal and gas, have lead to a process of global climate change, which is expected to produce increasingly severe consequences for communities on every continent. Such dramatic outcomes highlight the importance of understanding the integral relationships between the three components of a community and the necessity for sustainability in the economy, society and environment.

The Economy, Society, Environment and Green Economy

Connecting the economy, society, and environment to the outcomes of a Green Economy is not simple, and does not happen quickly. However, individuals,

businesses, local governments, and civil society institutions can all play a key role in incorporating new attitudes, practices, and values into their respective roles in a community.

In an Economy:

- Building social equality can mean working to improve incomes and profits for businesses and creating **new and sustainable jobs** that men and women can work in without discrimination;
- **Decreasing waste from business**, improving sustainable natural resource use, and protecting the environment from negative effects of business can save the planet for our children, improving their human well-being;
- **Preventing pollution** from the business, using more efficient practices to reduce resource consumption, and practicing good environmental practices can reduce environmental risks and improve the natural environment.

In a Society:

- District Assemblies and community organizations can incorporate **new policies and planning** to sustainably develop communities;
- Businesses can encourage new job creation in sustainable industries, and train employees in good and sustainable practices in the business;
- Incorporate **new values into society** like preventing illegal and indiscriminant refuse dumping, and cleaning the environment for future generations;
- **Build new infrastructure** to facilitate a growing green economy, like access to solar panels for electricity, or natural biogas for fuels.

In an Environment:

- Incorporating **new science into community planning** for climate change and other environmental repercussions can protect society from dramatic climatic changes and hardship;
- Promoting businesses that take active steps to **repair the environment**, like planting new trees, cleaning up rubbish and trash, and practicing legal and environmentally friendly waste management practices;
- **Develop new markets for sustainable products**, like bamboo crafts, that are not destructive for the environment and natural resources.

Supporting a Green Economy

- For a Green economy to develop, Businesses, Governments and District Assemblies and Communities and individuals all can contribute to growing a Green Economy. Cooperation between these three groups is important and necessary for green growth (see Figure 12).

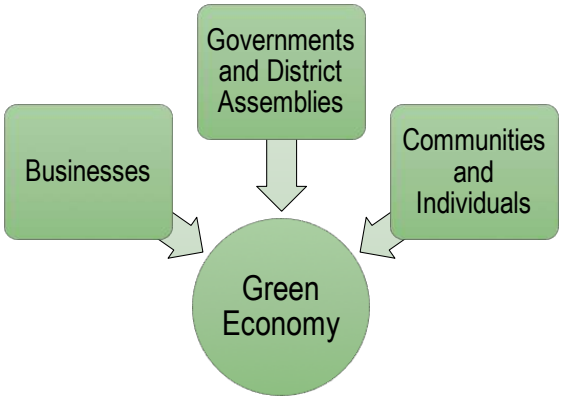

Figure 12) Green Economies need the support of Businesses, local governments, and communities and individuals to grow and be successful.

Businesses: Businesses can support the growth of a green economy in a variety of ways:

- Integrating new values into business like environmental sustainability and practicing resource efficiency. Businesses should value being sustainable just as much as being profitable, and be proud of making their business environmentally friendly.
- Protecting the environment from hazardous and toxic waste by re-using and reducing waste. This keeps the environment from being polluted when the waste is dumped and can provide additional sources of income.
- Incorporating new science and technology into the business to make it more sustainable and efficient can be an effective way of reducing waste and creating new green jobs for women and youth.
- Developing new products to support developing new markets for sustainable products and services. When new technologies and business

- are developed, the markets for new products will develop too. The products from these new businesses can be sold to other businesses to create new opportunities.
- Petition the government to support Green Economy and invest in green infrastructure. Speak with local politicians to encourage them to support Green Economy and green investment for the community.

Government: Local Governments and District Assemblies also play an important role in cultivating a Green Economy:

- Incorporating sustainable policies and planning into district development agendas. Its important that governments work towards long-term sustainability by planning for sustainable growth.
- Investing in green infrastructure like solar panels, clean energy, transportation, agric and environmental extension support, and waste management. This kind of investment can support businesses and individuals to incorporate their own green practices.
- Coordinating and cooperating with private businesses to support green growth, especially mining companies who contribute to the economy of the region. Coordinating with businesses, collecting taxes and supporting policies that help businesses incorporate sustainable business practices, can be an effective way to grow a green economy.
- Providing education about the environment, sustainability, and green practices supports entrepreneurs to incorporate environmental considerations into their lives and businesses.

Communities and Individuals: Finally, though seemingly the least important, individuals play a critical role in supporting the efforts of Businesses and Governments to develop a Green Economy:

- Ensuring that children go to school and better their education can be a way to ensure that they receive knowledge to better their lives and environments.
- Participating in government decision making, attending District assembly meetings, and voicing concerns about the environment and Green economy encourages the District Assemblies to make sustainable decisions. If you don't speak up, the government won't listen.

- Practicing sustainability in the home by purchasing sustainable products and properly disposing of household waste can develop a culture of good environmental practices in the community. Being a good example to neighbors helps build a green economy.
- Encouraging family and friends to purchase products from sustainable businesses can create new markets for green products and encourages businesses to continue to incorporate sustainable practices into their businesses.

Section 4: Green Economic Strategies

To develop a Green Economy, it helps to understanding what a Green Economy is; how it functionally relates to various components of a region's Economy, Society and Environment; and what means of support can individuals, businesses, and governments can provide to develop a Green Economy.

Practical and sustainable solutions for individuals and their businesses can offer a starting point on which societies can re-orient markets, science, values, technology, polities, and infrastructure. As individuals and businesses begin to adapt and practice sustainability to their lives and businesses, Society responds in kind. As the Society begins to incorporate new sustainable businesses and business practices, the negative effects (or Environmental Outcomes) from business on the Environment is reduced.

The Oil Palm subsector comprises two main components: 1) farming cultivating Palm Oil, and; 2) processing the crop harvest into marketable products. Like the Environmental Risks of farming and processing, the Green Economic opportunities associated with oil palm farming and processing are different as well.

Farming, being much more dependent on and interwoven with the Environment, has unique Green Economic opportunities for increasing crop yields without compromising or damaging the integrity and stability of the natural Environment.

Resource, Energy, and Environmental Conservation

As the name suggests, 'Resource, Energy, and Environmental Conservation' is about conserving, or protecting and saving natural resources from the environment, energy in the form of fuel or electricity, and being studious and protective of the Environment.

Resources for farming are very diverse and are needed in abundance to produce high yields and good crop quality. The resources that are critical for farming are:

- Land of good quality and sufficient size;
- Planting material for starting the farm;
- Water, through irrigation or rainfall;
- Plant nutrients, often as organic or mineral fertilizers; Weed control measures, such as weedicides, herbicides, or specialized tools;
- Machinery for preparing the land or harvesting crops;
- Waste products from farming.

Being conservative with the natural resources above means reducing wasteful uses of these resources, using the resources to their full efficiency, and understanding how and why each resource is needed, and how certain farming practices can either conserve or waste these natural resources. When a person conserves a resource, natural or artificial, they are also conserving the resources and energy that went into creating the resource.

Similarly, natural resources are not infinite. No matter how a person uses the natural resources, it is important to know that many other people in the community also depend on the resources as well. Individuals who fail to be good stewards of the environment and natural resources reduce the ability for other people, and future generations, to rely on their resources for their own purposes.

We must remember that *everyone* is using the resource as well for one purpose or another. If everyone choses to use resources unsustainably and wastefully, then mankind will certainly destroy itself, the environment and all the natural resources within only a few generations.

Conserving Land is very important for farmers to conserve natural resources.

Natural land is one of Ghana's most important resources and as discussed in the Land Use Change section destroying natural forests or wetlands to make new farms has serious and lasting consequences for the environment.

Intensification or increasing crop yields through better growing practices, is one of the most important ways of conserving land. *Extensification* is expanding land under cultivation to increase yields. The difference between intensification and extensification is that intensification conserves natural land, while extensification does not.

Improved Planting Materials material for starting the farm is an important part of increasing crop yields without increasing the land under cultivation. The Ministry of Food and Agriculture (MOFA), along with the Crop Research Institute (CRI) in Ghana have developed many improved crop varieties that are designed for local conditions and to increase the yields that can be produced per hectare of land.

The planting material took resources of its own to create, including the time and dedication of scientists and crop researchers. Their work should not be so carelessly wasted by being careless with the planting material.

Water is used for irrigating crops, cooking food, washing clothes, watering animals, waste disposal, cleaning and sanitation and many other uses. Water can come from rain, groundwater (boreholes), or provided to households by the government.

Water is often the most wasted natural resources there is, because of its abundance. However, irresponsible use of water, such as watering crops at the wrong time, wrong place, or the wrong about of water wastes water and the resource it took like fuel and electricity, to transport or distribute the water. It is important for farmers to understand efficient methods of watering crops, and the movement of water through the environment.

Plant Nutrients feed crops and provide specific chemicals and elements that are necessary for plant growth. Most commonly, Nitrogen (N), Potassium (P), and Phosphorous (K) are the most common forms of mineral or spray fertilizers. Secondary plant nutrients that often need to be applied to farms include Magnesium (Mg), Calcium (Ca) and Sulfur (S).

Artificial fertilizers, often in the form of a concentrated liquid formula or as a mineral fertilizer, require a significant amount of energy and massive amounts of raw materials to make. Poor application and management of fertilizers can waste the energy and resources that went into making the fertilizers, and the fertilizers themselves. This also creates the environmental risk for chemical pollution in the environment.

Organic fertilizers or green manure, is a natural form of plant fertilizers. Though not always as potent as artificial fertilizers, organic

fertilizers from green manure or waste plant material is a resource that is commonly burned or dumped in Ghana. This wastes the nutrients stored in the plants and the potential to re-use the waste for other purposes.

Weed Control Measures, such as weedicides and herbicides, are also resources that a farmer might use. These artificially produced chemicals are designed to be deadly to specific types of plants or weeds that are hindering efficient crop production. Like with artificial fertilizers, artificial weed control chemicals took significant amounts of energy and resources to make, and therefore wasting the weedicide chemicals also wastes the time, energy and resources that went into making the weedicide or herbicide.

Irresponsible and careless use of weedicides, herbicides and pesticides can also create significant environmental risks. Alternative methods of controlling weeds is possible, and can result in improved conservation of resources and the environment.

Machinery and equipment for preparing land, harvesting crops, spraying chemicals or another farm task are needed to make work more efficient and cheaper. Often, these machines require gas or diesel to operate, other machines may run on electricity. Being efficient and conscious of the environmental impact of certain kinds of machines on the land and air can be useful for conserving natural resources.

Waste Products are a *result* of farming. Most often the waste products from the farm include agric refuse and organic matter, like dead weeds, leaves, and sticks. These are a resource that has value to farms and, with proper understanding of these waste products and how to use them can conserve the environment by preventing unnecessary dumping or burning of the waste.

Fertilizers

Because soils in Africa, and Ghana, are very old and fragile, fertilizers often need to be applied to supplement the natural concentrations of Nitrogen (N), Potassium (P), Phosphorous (K), and other trace nutrients. Nutrients for plant growth can come from *artificial/chemical* fertilizers, or *organic* fertilizers in the form of green manure and organic matter.

It is the decision of the farmer which kind of fertilizer they will use, but it is necessary to understand the positive and negative aspects of artificial/chemical fertilizers, or organic fertilizers.

Chemical and Mineral Fertilizers

The quantity of fertilizers to be used depends on the age of the oil palm trees. Applying fertilizers in appropriate ratios and at appropriate times can maximize the benefits of using chemical fertilizers and minimize the amount needed to obtain optimal yields (see table 2).

Table 2) *Optimal fertilizer regime for oil palm.*

Fertilizer Type	0-3 Years	4-7 Years	Above 7 Years
Nitrogen (N)	200g	1000g	1500g
Phosphorous (P)	200g	1000g	1500g
Potassium (K)	200g	1000g	1500g
Magnesium (Mg)	-	500g	-

Source: Oil Palm Production – A Handbook, n.d.

Fertilizers ought to be applied once or twice per year. When applying, fertilizer should be evenly sprinkled in a ring approximately one meter from the base of the tree within the weeded circle. If trees are on a slope, care should be taken that a level base or platform be built up around the tree to prevent fertilizer from washing downhill during a rainstorm.

A table of average nutrient contents of various artificial and organic fertilizers can be found in Table 3.

Table 3) Moisture and nutrient content of commonly used organic and inorganic fertilizers.

	Moisture	N	P	K	Ca	Mg	S
Organic Fertilizers	%	% of Dry Matter					
Cattle Manure	68.2	1.85	0.81	1.69	1.54	0.62	0.29
Pig Manure	60	2.04	1.38	1.38	-	-	-
Chicken Manure	43	2.91	1.37	1.54	4.56	0.83	-
Sheep Manure	-	3	0.62	2.68	1.72	0.86	0.43
Human Manure	-	1.2	0.06	0.21	-	-	-
City/rural Compost	0	1.16	0.37	0.9	-	-	-
Rice straw Compost	73.6	1.07	0.19	0.69	-	-	-
Peanut Stems + leaves (compost)	58.6	0.81	0.1	0.38	-	-	-
Water Hyacinth	-	2	1	2.3	-	-	-
Wood Ash	-	-	0.87	4.17	-	2.1	0.4
Inorganic Fertilizers							
Urea	0	46	0	0	0	0	0
Ammonium Sulphate	0	21	0	0	0	0	24
Ammonium Nitrate	0	33	0	0	0	0	0
Mono-ammonium Phosphate (MAP)	0	11	21	0	0	0	0
Di-ammonium Phosphate (DAP)	0	18	20	0	0	0	0
Triple superphosphate	0	0	20	0	14	0	0
Single Super Phosphate	0	0	8	0	19	0	11
Basic Slag	0	0	6	0	37	1	0
Potassium Chloride	0	0	0	50	0	0	0
Potassium Sulplate	0	0	0	42	0	0	18
Calcium Sulphate (approx.)	0	0	0	0	0	0	10
Magnesium Phosphate	0	0	0	0	0	10	13
Magnesium Oxide	0	0	0	0	0	32	0
Calcitic lime (approx)	0	0	0	0	30	0	0
Dolomitic Lime (approx.)	0	0	0	0	24	12	0
Elememental Sulphur	0	0	0	0	0	0	100
15-15-15	0	15	6.6	12.5	0	0	0
1-20-20	0	10	8.7	16.7	0	0	0
10-30-10	0	10	13.1	8.3	0	0	0
15-7-18	0	15	3.1	15	0	0	0

Source: Howeler, 2004, 2007, 2014b.

Diagnosing palm trees for specific nutrient deficiencies are another way of improving the efficiency of fertilizers being used on the plantation.

- Nitrogen (N) – Nitrogen is important plants to produce new growth, especially green vegetation;
- Phosphorous (P) – Phosphorous stimulates root growth in plants, especially during early growth stages, and helps transport sugars and proteins throughout the plant;
- Potassium (K) – Potassium improves the overall vigor of the palm tree, helps the plant make carbohydrates and resist disease;
- Magnesium (Mg) – is an important component of chlorophyll, which helps plants convert sunlight into sugars and proteins through photosynthesis.

Farmers should use good agronomic practices on the farm to prevent unintended loss of fertilizers, which is a waste of money and damaging to the environment. Examples of good agro-chemical application are:

- Using organic fertilizers, like green manure or animal manure, in combination with mineral fertilizers and intercropping to provide nutrients to the crops and improve nutrient and water retention;
- Refraining from applying fertilizers before heavy rains;
- Using the correct type and amounts of mineral fertilizers;
- Covering mineral fertilizers with a few centimeters of soil after applying to prevent loss of fertilizers due to rainfall and erosion, especially when the soil is on a slope or near waterways;
- Intercropping with legumes, such as groundnuts or soybeans, and green manuring legume crop residues before planting oil palm trees to improve soil fertility and nutrient retention;
- Storing fertilizer containers in cool, dry places ensuring that water is not leaking into the chemicals;
- Properly disposing of used fertilizer containers to prevent polluting the environment.

Organic Fertilizers

Major plant nutrients (N, P, and K) and other plant nutrients (Ca, Mg, and S) can be sourced from mineral fertilizers. However, mineral fertilizers do not add organic matter to the soil which improves soil structure and water retention. Organic fertilizers, often made from waste products from agriculture and livestock, can improve soil nutrient content, soil structure and organic matter, water retention, and protect from soil erosion and degradation.

Green Manure

Green manure is plant material that is grown and ploughed back into the soil before planting the next crop. Green manure has several benefits to farmers such as improving soil nutrients, soil structure and water/nutrient retention, improving soil microbiology, reducing mineral fertilizer requirements/costs, and proving sustainable alternatives to chemical fertilizers.

Applying animal manure, such as chickens, cows, sheep and pigs can be used as a green manure as well. Animal manures have the benefit of providing plant nutrients and improving soil structure.

See Table 3 for a rough guide to nutrient concentrations in various organic and artificial fertilizers.

Drawbacks of using green manure, especially animal manure, is that weed seeds might be present in the manure, leading to competitive weed growth. Additionally, because organic green manure has high water content, transporting large amounts of green manure may not be easy or cost-effective.

Composting

Composting is simply storing organic waste products, such as kitchen scraps, animal manure or plant residue in a designated place to allow the waste to naturally decompose into rich organic matter. This organic matter can be tilled into the soil during land preparation to add soil nutrients, organic matter and other beneficial material. Typically, composting is a 6-month process and can be done during the growing season to create organic fertilizer for the following season.

Composting waste products from the palm oil plantation or palm oil mill is a very feasible option to offset the use of inorganic fertilizers and to recycle plant nutrients back into the soil.

- Co-composting several waste products together and incorporating worm cultivation (*vermicomposting*) into the composting process produces a rich, organic fertilizer that is easily applied to palm plantations and can improve yields when compared to no fertilizer usage.
- Palm kernel cake, left over from the production of white kernel oil, is rich in proteins and carbohydrates making it a suitable feed for livestock. Combining PKS with manure from goats or sheep and composting can produce a rich and viable organic fertilizer for use on the plantation.
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- Burning empty fruit bunches produces *potash* which is rich in potassium (K), an important plant nutrient, can be used to supplement chemical potassium fertilizers by mixing the ash into the soil at the base of each tree.
- Planting leguminous crops, as an intercrop in the same field as oil palm trees can have multiple benefits, including fixing nitrogen into the soil, providing biological weed control and diversifying income sources for the farmer.
- Biochar, produced from burning biomass under a low-oxygen environment, has been shown to be useful for improving yields on degraded soils. Additionally, incorporation of carbon based biochar is a carbon-negative process that actively sequesters carbon in the soil.

Compost can be made simply by adding 2-3:1 brown compost material to green compost material. Other compost material should be added as well in appropriate quantities. Layer brown and green compost material into a pile with a few shovels of local soil to introduce beneficial bacteria. Water the compost pile regularly, maintaining sufficient moisture (a handful of compost should drip only a few drops when squeezed by hand).

Every 2-3 weeks, the compost pile should be turned to allow fresh air to be incorporated into the pile, and to dissipate heat that is generated from the decomposing compost.

Table 4) Basic types of compostable material

Green	Brown	Other	Do Not Compost
• Vegetable and fruit scraps • Grass clippings • Garden waste • Fresh weeds (no seeds)	• Straw • Dry leaves • Sawdust, Wood chips and sticks • Dried weeds • Paper, tissues • Cassava peels	• Egg shells • Wood ash (small amounts) • Hair • Etc.	• Meat, bones • Weeds with mature seeds • Plastic, metal, trash • Infected plants and planting material

Composting POME

Composting Palm Oil Mill Effluent (POME) has been done successfully in other oil palm producing countries like Malaysia. Experiments in composting have shown that it is possible to compost POME with other kinds of organic waste products from the oil palm subsector and other subsectors to create a sustainable and effective chemical fertilizer alternative. The entire process takes approximately 20 weeks, and requires some degree of care and maintenance to produce a high-quality product.

- Arrange solid organic waste products such as chopped empty fruit bunches, sawdust, kitchen scraps, etc, in a windrow formation (long piles of waste, 1-2 metres high) for several days in a row, periodically adding pome to the pile.
- During the first few days, add POME periodically. The optimum ratio of POME to other materials is 3.2 metres^3 of POME to one tonne Empty Fruit Bunches; and a maximum ratio of 5.3 metres^3 of POME to one tonne Empty Fruit Bunches. This ratio represents the overall amount of POME that should be added over the entire process.
- After building the pile, or *windrow,* of waste, the pile should be turned to allow fresh air to be mixed into the composting pile. Turn the pile at least one or twice per week. Water or POME should be added regularly to ensure the optimum moisture content for up to ten weeks.
- During the rainy season, rain can slow down the decomposition process, so it is advisable to cover the compost with a water-tight sheet during the rains.

- For the next 10 weeks, allow the pile to cure into usable organic material. Do not add any additional POME or EFBs during this time as they will not break down and decompose correctly.

Table 5) Nutrient Content of Compost

Component	Content
N	15.6 [kg/T]
P	3.2 [kg/T]
K	14.1 [kg/T]
Mg	5.4 [kg/T]

Source: (KYOTOenergy, 2010)

Table 6) Composting Schedule for POME and EFBs

Composting Period	Inputs and Actions
Day 1-4	EFB and POME Inputs, Turn pile regularly
Week 1 - 10	POME input only, Turn Pile Regularly
Week 11-20	No Inputs, Curing Period. Turn Pile Regularly.

Source: (KYOTOenergy, 2010)

Studies of compost produced in this way show that the resulting compost is high in Nitrogen (N) and Potassium (K), but lacking in Phosphorous (P). Additional mineral fertilizers may be needed. This compost should be added to soils at a rate of approximately 7-8 tonnes per hectare. Individual experiments for improving the composting formulae and making it suitable to Ghana will be needed.

Intercropping

Intercropping is planting two or more species of plants on the same plot of land at the same time. Oil palm is typically cultivated as a mono-crop, meaning it is the only commercial crop being actively cultivated in a single farm. However, other crops, especially crops with economic value, can be intercropped among the oil palm trees. Intercropping, or planting more than one type of commercial crop on the same field, has several benefits:

- Providing more diverse income sources for farmers, where two different crops can be harvested and sold;
- Reducing the risk of economic disaster of one crop fails or produces an unexpectedly low-yield;
- Developing beneficial plant relationships that provide additional plant nutrients, especially if legumes are planted as an intercrop;

- Intercropping is a more efficient use of land, where the Land Equivalent Ratio (LER) is higher than if each crop were planted individually.

Intercropping oil palm plantations can be easily done with no adverse effects on the yield of oil palm fruit, especially within the first three years of planting oil palm trees. Cultivating economically valuable legumes, such as ground nuts or soybeans, is also an effective way of incorporating additional nitrogen into the soil and increase soil stability. Alternatively, cocoa trees can be planted within the rows of oil palm. Older and taller oil palms provide shade cover to the cacao plants, while leaf litter from the cacao plants adds organic matter and fertilizer to the soils for the palm trees.

The table below shows a basic configuration of intercrops. However, it is the decision of the farmer to decide how and where to intercrop his farm and which kinds of crops to intercrop with (see Table 7).

Table 7) Spatial arrangement of intercrops from oil palm rows.

Cropping System	1st Year	2nd Year	3rd Year
Maize & Oil Palm	1.0m	1.5m	2.0m
Cassava & Oil Palm	1.0m	2.0m	2.5m
Plantain & Oil Palm	1.0m	1.5m	2.0m
Rice & Oil Palm	1.0m	1.5m	2.0m

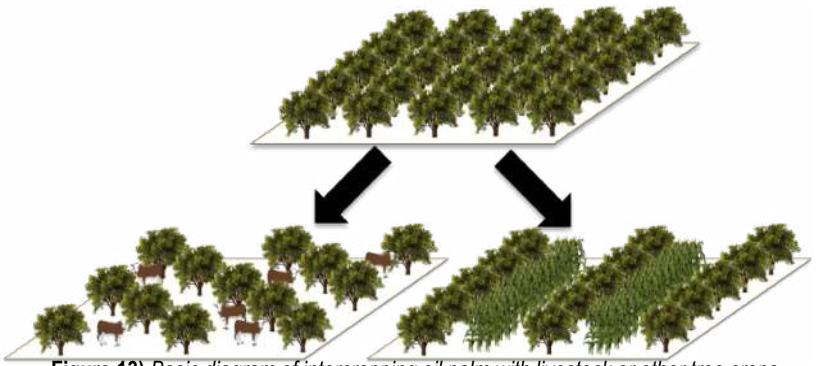

Figure 13) *Basic diagram of intercropping oil palm with livestock or other tree crops.*

Intercropping oil palm with other crops is important to maintaining long-term soil health and fertility, while generally increasing the overall incomes to farmers. Farmers can harvest oil palm fruit as well as the other crops being planted. However, developing suitable combinations of plants for a single farmer requires some degree of experimentation and understanding of the local soil conditions.

Weed Management

Weeds and other unwanted plants growing on a commercial oil palm plantation are in direct competition with the young palm trees for plant nutrients, root space, and sunlight. Improper or inadequate field maintenance of an oil palm plantation can delay the formation of fruits by as much as 2 years.

Managing weeds is an important part of maintaining sanitary and high-yielding oil palm plantation. There are many methods for controlling the growth and spread of weeds that are more environmentally friendly than agro-chemicals like weedicides and herbicides.

- **Cultural Measures** such as hand-weeding on small farms at periodic intervals is very effective for removing and eliminating the threat of weeds. However, this may not be possible on larger plantations. In general, farmers should strive to maintain a clean and sanitary farm.
- **Biological Measures** such as growing a cover crops of beneficial plants can suppress weeds by limiting sunlight and root space. Planting Tropical Kudzu (Pueraria Phasesoloides sp.) around the palm trees can suppress weeds, fix nitrogen into the soil, improve soil structure, prevent erosion and regulate the temperature of the soil.

Integrating sheep or cattle to graze in the plantation can also remove weeds while also adding nutrients through their droppings.

- **Genetic Measures** like growing genetically improved varieties of oil palm trees or collecting and cultivating the natural enemies of pests, such as specific viruses or bacteria can be effective weed control measures.
- **Chemical Measures** like pre-emergence herbicides and contact herbicides are designed to target specific varieties of plants, but have very high emotional risks associated with their use. Careful control and management of chemicals is needed to prevent environmental damage.

- **Integrated Control Measures** is any combination of the other four control measures. Farmers will need to experiment with different kinds of weed control measures, incorporating good farming practices and environmental responsibility.

Other possible control measures for pests (insects and rodents) might include:

- Conserving the natural enemies of common pests like entomopathogens, fungi that attack and kill insects;
  - Eg. *Metarhizium anisoplae, Entomophaga grylli*
- Cultivation of pest resistant varieties of crops;
- Maintaining hygienic conditions on the plantation and nursery sites;
- Collection of naturally occurring viruses, and targeted release against pests;
- Using light traps or nets for larger insects (eg. Rhinoceros Beetles);
- Destroy breeding sites of pests by burning or burying damaged trees.

Soil Conservation

The Western Region is situated in the semi-deciduous and forest belt of Ghana. There are two main types of soil in this region, Forest Ochrosols and Forest Oxysols, with several other minor soil types as well. Generally, soils in the Western Region are highly weathered, and acidic, resulting in low nutrient content.

As discussed with Land Use Change, soil degradation is a very serious issue for Ghana, with important implications for climate change, and long-term sustainability. The principle concern over soils is that poor agricultural practices will permanently damage or destroy the fragile soils in the Western Region.
The two main types of soil in the Western Region are:

Forest Ochrosols are deeply weathered soils found in semi-deciduous forests and the forest-savannah transition zone. These soils are generally slightly acidic to moderately acidic (pH 6.5 -5.1). Under natural conditions, forest ochrosols contain adequate amounts of nutrients. However once the overlying forest or cover crop is removed by deforestation and slash-and-burn agriculture, nutrient levels decline dramatically, adversely affecting crops. These soils respond well to

- …fertilizer amendments and addition of organic matter as a source of nitrogen and phosphorous.

Forest Oxysols occur in the high rainfall forest zones of Ghana, areas that receive >1800mm of rain per year. These soils have a thinner topsoil layer than ochrosols, and more evenly distributed organic matter content. Oxysols are highly acidic (pH <5.0) but still suitable for commercial crop production

In general, Ghanaian soils cannot support irresponsible agriculture and will fail to produce high-yields of commercial crops if poorly maintained. Maintaining soils year after year will prevent the need to cut down and burn natural forest land, reducing the risks from Deforestation, soil erosion, and soil degradation. Failure to do so will inevitably have serious consequences for many farmers and communities that depend on the crops they grow for food and business.

Soil conservation practices include:

- Regular additions of organic matter to replace what was removed after harvesting;
- Minimizing the use of chemical fertilizers and pesticides/weedicides. Chemicals will eventually build up in the soil, move into the environment, and contaminate many different spheres of the environment;
- Practice intensification rather than extensification to protect against Land Use Change and deforestation.
- Maintaining cover crops while the farm is being fallowed will prevent wind and water from washing away the fragile topsoil as well as provide green manure before the planting season;
- Minimizing tilling or ploughing the soil will prevent the soil structure from degrading. Over-tilling fields with heavy machinery can compact the soil, reducing the ability of water and air to move through the soil;
- Minimize slash-and-burn agriculture since this very quickly diminishes the soils natural nutrient content and ability to replenish soil nutrients.
- Irrigation with municipal water or water with high salt contents can increase the salinity of soils, making them unsuitable for commercial agriculture.

Oil Palm Processing

Cultivating oil palm is only one part of the oil palm subsector. Processing the raw oil palm into new products for market and sale has unique environmental risks and Green Economic Opportunities associated with it.

The basic components of processing palm oil can be found in the first section of this booklet. Within this process, the most significant environmental risks stem from inefficient resource use poor waste management practice and the resulting pollution.

In terms of Green Economic Opportunities, improvements in resource efficiency and minimizing waste pollution through processing or recycling waste products are the two biggest opportunities.

Increasing Resource Efficiency

Increasing resource efficiency means increasing the amount of final product that can be made with a limited about of resources. By increasing the amount of final product that can be made without increasing the amount of natural or raw materials needed, the farmer or processor can reduce their Environmental Footprint (pg. 15) and improve the financial income to the business by using less resources.

Resources for processing oil palm include:

- Land for the processing center or factory, and for storing the fresh fruit before processing;
- Machines for processing oil palm, and for crushing palm kernels
- Fossil fuels for operating palm fruit presses, and Fossil fuel for transporting the raw materials and final products;
- Biomass fuels, like wood or dried organic waste, for clarifying, or drying, the palm oil.
- Aluminum for the cooking pots;
- Water for washing the fresh fruits and separating the palm oil;
- Electricity for running generators or powering lights;
- Plastics for packaging and sale

The materials that are needed for processing may be partly provided by the farmer or the processor. In either case, both the farmer and the processor have a responsibility to understand how their business uses natural or raw materials to make their final products. To improve resource efficiency:

- Moving around machinery or locations of intake and processing areas can minimize the time and effort it takes to move the product from one stage of processing to the next;
- Locating the processing centre nearer to the farms can minimize the fuel usage and cost due to moving the raw materials from the farm to the processing centre;
- Remembering to turn off lights or machines that are not being used can save on electricity and fuel costs;
- Using alternative fuels, such as dried organic waste, or better still, fuel briquettes can prevent wasteful disposal of these waste products and encourage new, alternative fuel businesses;
- When aluminum cooking stoves or pots crack or become spoilt, recycling them with the local pot-maker can ensure that the aluminum is not wasted and lowers the cost of obtaining a new aluminum stove or cooking pot;

The exact ways in which resource efficiency can be improved is a unique process. It requires farmers and processors to understand what their specific business uses as a resource, how the resource use can be minimized, or how safer and more environmentally beneficial alternatives can be used in the business.

Waste Management and Recycling

Waste products from processing oil palm are a serious problem for much of Ghana. There is little information and little incentive to re-use waste products in the business, and consequently the environmental impact of waste products is quite visible and significant. Waste products and waste pollution (pg. palm oil have unique physical and chemical characteristics that, when indiscriminately dumped into the environment, can cause different kinds of environmental risks.

Palm Oil production has several different kinds of waste products associated with processing;

- Oil Palm Fibres (OPF) from the separation of the palm oil and palm fruits;
- Palm Kernels and Palm Kernel Shells (PKS) from the separation of the palm fruits from the kernel;
- Empty Fruit Bunches (EFBs) from the Fresh Fruit Bunch (FFBs);
- Palm Oil Mill Effluent (POME);

Waste from palm oil processing can easily be recycled in several ways, allowing waste products to be better utilized. This, ideally, will prevent unnecessary pollution of the surrounding environment while also potentially creating new opportunities for palm oil processing enterprises. Other types of waste simply need to be managed better to halt long-term pollution and environmental degradation due to poor waste management practices.

For waste that is created at the farm, such as dead leaves, plant stalks, or sticks, it is better to reprocess the waste *on-site*, or at the farm. Composting and green manure are very effective and sustainable ways of re-using agric residues that would otherwise be wasted.

Roof Tiles and Particle Board

New products like roofing and floor tiles, and particle boards have been developed in South-east Asian counties that incorporate waste products from the palm oil industry.

Palm fibres, empty fruit bunches, palm fronds and other fibrous waste material from the palm oil sector can be used in combination with bamboo, resins, polyurethane, and other binding materials to produce roofing and floor tiles, plywood, particle boards, and construction timber.

These products have potential marketability in the construction industry as well as household uses, and carpentry. Developing a market for such products has the double benefit of recycling and adding value to palm oil waste products, but also reduces demand for traditional wood, which otherwise contributes to deforestation.

Figure 14) Basic diagram of a particle board made from OPF and bamboo rods.

Cement Aggregate and Additives

The use of kernel shells in the construction sector is becoming widely popular in developing countries like Malaysia where there is an overabundance of waste products from the palm oil sector. Studies have found that palm kernel shells, can be used as a light weight concrete aggregate, replacing traditional materials like river sand and stone.

For non-load bearing cement, crushed kernel shells can be added in specific ratios with sand and Portland cement, without changing the structural integrity of the cement. Whole kernel shells can also be added to road concrete or asphalt as a partial replacement for stones and gravel.

Replacing stones and sand with kernel shells provides several benefits to the environment. Using palm kernels offsets the demand for sand and gravel, which may be otherwise mined from local rivers, causing sediment pollution downstream. It may not be feasible to fully replace the use of sand and gravel in cement due to the massive abundance of sand and gravel from large scale mines.

Activated Carbon

Activated carbon is a form of carbon that has been processed to have small, low-volume pores to dramatically increase the surface area. This high surface area provides space for chemical reactions on the surface of the activated carbon, removing contaminants and pollution from waste water.

Activated carbon can be made from any organic or inorganic source of carbon. Palm oil waste products, including fibres, kernel shells, empty fruit bunches, and other part of the oil palm tree can potentially be feedstock for producing activated carbon.

The process of producing activated carbon is not feasible on a small scale and requires

significant knowledge and expertise to produce. However, industrial scale production of activated carbon for wastewater treatment is feasible. Mining companies, like Golden Star Resources (GSR), may be a potential market for activated carbon as large gold mines often produce significant quantities of industrial waste water.

Biogas Reactors

Biogas reactors have great potential to sustainable development in Ghana and provide a variety of social, environmental, and economic benefits. Biogas reactors convert food waste, agricultural waste, livestock manure, and other organic refuse into methane gas to be used for household or industrial purposes such as cooking and Heating.

The basic principles of biogas production are controlling the decomposition of organic waste products with cultivated microorganisms. As the Micro organisms consume and decompose the organic waste, they emit methane gas, which can be captured and used.

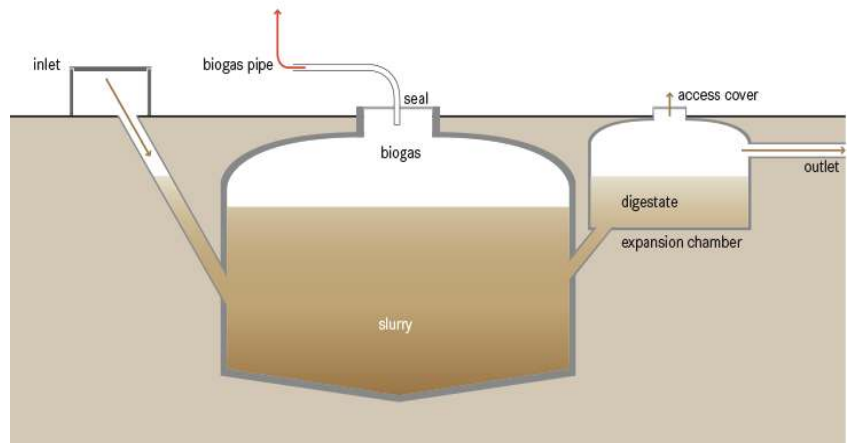

Figure 15) *Basic diagram of a below-ground biogas reactor.*

The benefits of generating biogas include:

- Reducing deforestation by offsetting demand for firewood;
- Diversifying fuel sources used by rural households;
- Creates business opportunities for women and youth;
- Producing organic fertilizer as a by-product;
- Adding value to waste products and creating employment
- Improving the quality of the environment by diverting waste products from landfills and indiscriminant dumping.

Empty fruit bunches (EFBs), POME, and OPF are suitable feedstocks for biogas production. Palm kernel shells and fibres can also be used for biogas production, however they are better served as fuel for boilers or in fuel briquettes.

Producing biogas for commercial sale is not a simple venture and requires a considerable amount of technical expertise and knowledge to construct and operate a medium- to large-scale biogas production facility. However, small-scale, simple biogas reactors can be made by individual families from locally sourced materials and are relatively easy to maintain. A single family can produce sufficient biogas to supplement their use of fuel wood and energy expenses.

Fuel Briquettes

Fuel briquettes have gained significant attention in recent years as a viable and profitable solution to manage municipal solid waste (MSW) and to produce sustainable new products for market. Pilot projects in Rwanda, Kenya, Uganda, and other countries have had great success in developing markets for fuel briquetting.

Fuel briquetting has several advantages over traditional fuelwood and other social and economic benefits:

- Fuel briquettes are a cheap and often cleaner source of cooking fuel;
- Fuel briquettes can generate income and employment opportunities, especially for women and youth;
- Fuel briquettes reduce household spending on fuelwood for cooking;
- Fuel briquettes offer a profitable and sustainable solution for agricultural refuse and municipal solid waste;
- Fuel briquetting can reduce deforestation and degradation of forests and natural resources.

Fuel briquette production can protect and enhance the environment, reduce waste, and increase resource efficiency while also providing sustainable employment opportunities for women and youth.

Fuel Briquette Production

Fuel briquettes are primarily made of two components, dried and/or carbonized organic matter (i.e. agric wastes and residues), and a binder material (eg. waste paper, plastics, starch). The organic matter can be pre-carbonized before processing, changing the heating and performance characteristics of the briquette.
Production requires capital and technology like many other kinds of businesses, however the form and scale of the technology can vary depending on the business. However, the basic machines needed include kilns, grinding equipment, and a compaction machine.

Raw Materials for briquette production can be sourced from many different sectors. Palm oil production yields a considerable amount of waste, much of which is suitable feedstock for briquette production. Other subsectors, including rice, cassava, maize, sugarcane, sorghum, coconut, and timber and carpentry, have waste products that can easily be incorporated into fuel briquettes.

Suitable Raw Materials for Fuel Briquettes :

- Palm Fibres
- Maize Cob
- Dried Manure
- Palm Kernel Shells
- Sawdust
- Cassava Peels
- Empty Fruit Bunches
- Bamboo
- Coconut Husk
- Palm Fronds
- Rice Straw
- Groundnut Shells
- Bagasse

Suitable Binder Materials for Fuel Briquettes:

- Waste Paper
- Plastic
- Ground Rubber
- Clay
- Cassava Starch
- Styrofoam
- Molasses

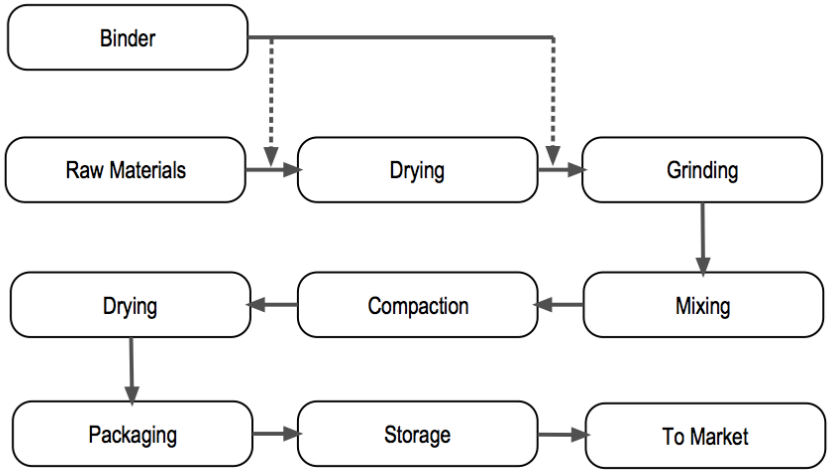

Figure 16) *Flow diagram showing the basic production process of non-carbonized fuel briquettes.*

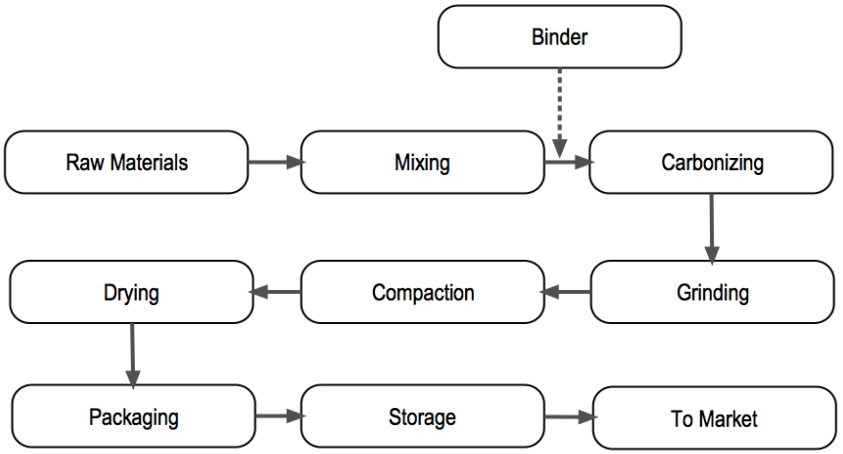

Figure 17) *Flow diagram showing the basic production process of carbonized fuel briquettes.*
Source: modified from A review on production, marketing and use of fuel briquettes, IWMI, 2016.

Fuel Briquetting Technology
The technology and machinery required to produce viable fuel briquettes is relatively simple and scalable to meet the needs of different operations. The basic machinery needed includes:

1. A kiln to carbonize agric material before grinding and compaction (if producing carbonized fuel briquettes);
2. A grinding machine (e.g. A small mill, or large pestle and mortar);
3. Compactor or hydraulic press;
4. Molds for fuel briquettes/

Depending on the scale of the briquetting operation, the machinery needed can easily be manufactured to suit small and medium enterprises and can be fabricated from readily available materials in the Western Region. Kilns, for carbonization, can be made from used steel oil drums. Equipment for compacting and extruding the briquettes may be fabricated from car jacks or hydraulic presses. Industrial-scale compaction machines are available for large-scale briquette production. In a smaller operation, much of the work can be done by hand, like carbonizing the raw material, crushing the charcoal, mixing, and in some cases compaction.

Logistics and Value-Chains for Briquetting
Value chains for briquettes can vary depending on the scale of the business, input materials being used, types of briquettes being produced, and the target markets for the final product.

The basic linkages in the value-chain are:

- Farmers, agro processors, and other waste producing businesses provide the raw materials;
- Raw materials are sorted, processed and stored;
- Fuel briquettes are produced in a factory;
- Briquettes are brought to a market and sold.

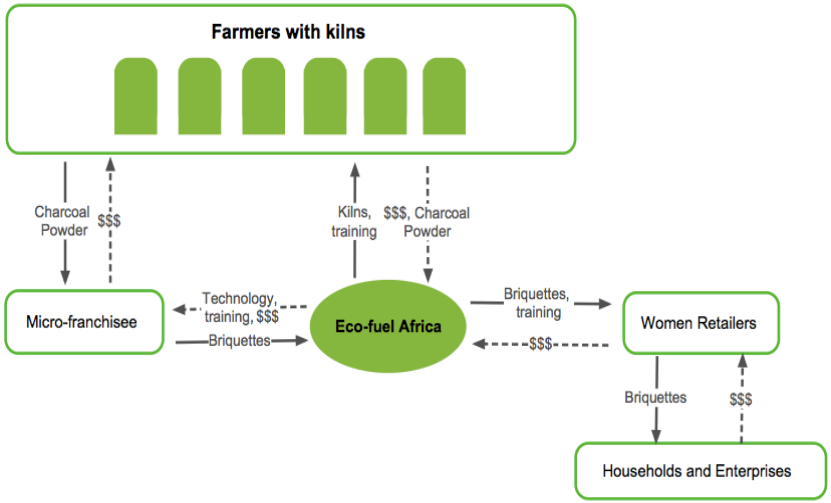

Figure 18) *Ecofuel Africa's value chain for fuel briquette production, modified from A review on production.* **Source:** Modified from A review on production, marketing and use of fuel briquettes. IWMI, 2016.

Eco-Fuel Africa

Eco-fuel Africa (EFA), an organization based in Uganda specializing in fuel briquette production, relies on a micro franchisee model (See Figure 18). EFA provides kilns and training to farmers to produce dried raw materials for briquetting. EFA and micro franchisees purchase the carbonized charcoal dust from the farmers and produce their fuel briquettes. Micro franchisees sell directly to the market, and EFA provides fuel briquettes and business training to women retailers.

Alternative Value-Chains

Alternatively, collection and transport of raw materials may be outsourced to an external logistics company. The raw materials are aggregated and processed into briquettes and sold to distributors in bulk and retailers for market sale (Model 1) (see figure 19).

The briquetting business can internalize the collection and transport of raw materials themselves. The business would conduct door-to-door or farm-to-farm collection process to aggregate raw materials (Model 2) (see figure 19).

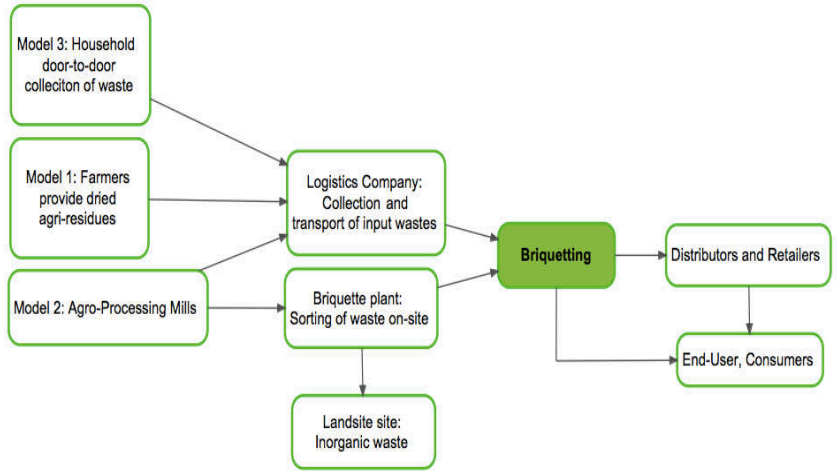

Figure 19) *Schematic of the value chain for fuel briquette production.* **Source:** Modified from A review on production, marketing and use of fuel briquettes. IWMI, 2016.

The briquetting business can internalize the collection and transport of raw materials themselves. The business would conduct door-to-door or farm-to-farm collection process to aggregate raw materials (Model 2) (see figure 19).

Training may be provided by the briquette producers to train farmers to partially process raw materials by kiln drying the materials to a moisture content of >15% before being transported. This step not only saves on transportation and processing costs, but can increase farmers' participation and gain from the briquette production process. Wastes may be free to collect or a payment scheme can be negotiated depending on the cost of transporting and collection. At the processing facility, waste needs to be sorted, dried/carbonized, and made into briquettes.

Markets for Fuel Briquettes

Market for fuel briquettes are not fully matured in the developing world, but growing concern for deforestation, climate change, and sustainability is quickly changing that. Rising prices for fuel wood and charcoal, due to diminishing

resources is opening a market for alternative and sustainable products, like fuel briquettes.

Fuel briquettes are suitable replacements for fuelwood in domestic, institutional, and industrial settings. Markets like catering, baking, palm oil production, *gari* production, and other sectors that rely fuelwood or charcoal as a primary source of energy could benefit from fuel briquettes.

For small businesses and households, the addition of fuel briquettes to the fuel stock may be better than outright replacing firewood with briquettes. For large businesses and industrial uses, adoption of fuel briquettes depends greatly on the availability, consistency, price per unit energy output, and compatibility with existing capital.

Partnerships with private municipal waste collection businesses, District Assemblies, local business training centers and private businesses that produce organic waste can help facilitate the development of a sustainable briquette market.

Section 5: Additional Resources

This final section is intended to provide additional resources for the Training Service Providers or other persons looking for further information about anything covered in this booklet. Contained within this section are links to:

- Scientific journal articles, especially those from Kwame Nkrumah University of Science and Technology (KNUST), University of Ghana, University of Cape Coast and other local Universities and collegiate institutions;
- Video links further explaining various technologies and concepts addressed in this booklet;
- Books that are accessible from local NGOs or downloadable from the internet, free of charge.

Green Economy

Books	**UN - A Guidebook to the Green Economy** https://sustainabledevelopment.un.org/content/documents/GE%20Guidebook.pdf
Online Resources	**Green Economy Coalition** http://www.greeneconomycoalition.org/ **UN Green Economy Scoping Study – Ghana** http://www.un-page.org/files/public/ghana_ge_scoping_study_low_res.pdf **UN Green Economy Fiscal Policy Analysis – Ghana** http://www.greengrowthknowledge.org/sites/default/files/downloads/resource/Green_Economy_Fiscal_Policy_Analysis%20_Ghana_UNEP.pdf **UN Green Economy Assessment Report – Ghana** http://www.un-page.org/files/public/ge_ghana_assessmentreport_web.pdf

Fuel Briquette Making

Scientific Journal Articles

Evaluation of the physical properties of composite briquette of sawdust and palm kernel shell.

Obi, O. F. (2014). Evaluation of the physical properties of composite briquette of sawdust and palm kernel shell. Biomass Conversion and Biorefinery, 5(3), 271-277. doi:10.1007/s13399-014-0141-7

Characterization of fuel briquettes made from a blend of rice husk and palm oil mill sludge.

Obi, O. F., & Okongwu, K. C. (2016). Characterization of fuel briquettes made from a blend of rice husk and palm oil mill sludge. Biomass Conversion and Biorefinery, 6(4), 449-456. doi:10.1007/s13399-016-0206-x

Physico-chemical characteristics and market potential of sawdust charcoal briquette.

Akowuah, J. O., Kemausuor, F., & Mitchual, S. J. (2012). Physico-chemical characteristics and market potential of sawdust charcoal briquette. International Journal of Energy and Environmental Engineering, 3(1), 20. doi:10.1186/2251-6832-3-20

Online Resources

Briquette Making Demonstration for small scale entrepreneurs:

https://www.youtube.com/watch?v=fT1dkSRIKQk

How to make charcoal briquettes from agricultural waste:

https://www.youtube.com/watch?v=LqI63IEg3MM

Fuel from the fields: Charcoal from Agricultural Waste:

https://ocw.mit.edu/courses/edgerton-center/ec-711-d-lab-energy-spring-2011/wind-micro-hydro/MITEC_711S11_read5_fuel.pdf

Books

A review on production, marketing and use of fuel briquettes.

Asamoah, B.; Nikiema J.; Gebrezgabher, S.; Odonkor Njenga, M. 2016. *A review on production, marketing and use of fuel briquettes.* Colombo Sri Lanka; Internatioal Water Management Institute (IWMI) CGIAR research Program on Water, Land and Ecosystems (WLE). 51p. (Resource Reuse and Recovery Series 7) doi: 10.5337/2017.200

Tiles and Particle Boards

Scientific Journal Articles

Production of Environmentally Friendly Roofing Tiles Using Palm Oil as a Binder.

Nadeem, H., Habib, N. Z., Aun, N. C., Zoorob, S. E., Mustaffa, Z., & Nadeem, S. (2017). Production of Environmentally Friendly Roofing Tiles Using Palm Oil as a Binder. Green Materials, 1-43. doi:10.1680/jgrma.17.00011

Sustainable and Eco-Friendly Vege Roofing Tiles: An Innovative Bio-Composite.

Habib, N. Z., Nadeem, H., Ng, C. A., Zoorob, S. E., & Mustaffa, Z. (2017). Sustainable and Eco-Friendly Vege Roofing Tiles: An Innovative Bio-Composite. Materials Science Forum, 882, 71-76. doi:10.4028/www.scientific.net/msf.882.71

Bamboo Based Biocomposites Material, Design and Applications.

Siti, S., Abdul, H., Wan, W., & Jawai, M. (2013). Bamboo Based Biocomposites Material, Design and Applications. Materials Science - Advanced Topics. doi:10.5772/56057

Case Studies

Project profile on the establishment of particle board producing plant

http://www.ethiopianembassy.org/AboutEthiopia/InvestmentProjectProfiles/Manufacturing/Paper%20and%20Paper%20Products/Particle_Board_Project.pdf

Production of Particle board Using Sawdust and Plastic Waste

http://ir.knust.edu.gh/bitstream/123456789/7051/1/AZUMAH%20OSCAR%20KOFI.pdf

Biogas Reactors

Scientific Journal Articles

Small-scale Minimal-maintenance Anaerobic Digestion of Food Waste for Solids Reduction and Methane Production: Feasibility Study

Scantlebury, Leland C., "Small-scale Minimal-maintenance Anaerobic Digestion of Food Waste for Solids Reduction and Methane Production: Feasibility Study" (2014). Civil and Environmental Engineering Undergraduate Honors Theses. 3.

http://pdxscholar.library.pdx.edu/cengin_honorstheses/3

Online Resources

Anaerobic Digestion (Small-Scale)

Sustainable Sanitation and water management, Eawag (Swiss Federal Institute of Aquatic Science and Technology), Dorothee Spuhler (seecon international gmbh)

https://www.sswm.info/content/anaerobic-digestion-small-scale

How to Install a Small Sized Biogas Plant: https://www.youtube.com/watch?v=Qp39KDlkGp4

Solar CITIES IBC Biogas System Tutorial Complete:

https://www.youtube.com/watch?v=Cwm5Rm8uIsk&spfreload=10

Activated Carbon

Scientific Journal Articles

Urea adsorption by activated carbon prepared from palm kernel shell.

Ooi, C., Sim, Y., & Yeoh, F. (2017). Urea adsorption by activated carbon prepared from palm kernel shell. doi:10.1063/1.4993328

Preparation and Characterization of Impregnated Activated Carbon from Palm Kernel Shell and Coconut Shell for CO2 Capture

Hidayu, A., & Muda, N. (2016). Preparation and Characterization of Impregnated Activated Carbon from Palm Kernel Shell and Coconut Shell for CO2 Capture. Procedia Engineering, 148, 106-113. doi:10.1016/j.proeng.2016.06.463

Organic Fertilizer

Scientific Journal Articles

Landscape-scale assessment of soil response to long-term organic and mineral fertilizer application in an industrial oil palm plantation, Indonesia.

Comte I., Colin F., Grünberger O., Follain S., Whalen J., Caliman J.P., 2013. Landscape-scale assessment of soil response to long-term organic and mineral fertilizer application in an industrial oil palm plantation, Indonesia.Agriculture Ecosystems and Environment, 169: 58-68. Doi:10.1016/j.agee.2013.02.01

Composting of waste from palm oil mill: a sustainable waste management practice

Singh, R. P., Ibrahim, M. H., Esa, N., & Iliyana, M. S. (2010). Composting of waste from palm oil mill: a sustainable waste management practice. Reviews in Environmental Science and Bio/Technology, 9(4), 331-344. doi:10.1007/s11157-010-9199-2

Effective composting of empty fruit bunches using potential Trichoderma strains.

Siddiquee, S., Shafawati, S. N., & Naher, L. (2017). Effective composting of empty fruit bunches using potential Trichoderma strains. Biotechnology Reports, 13, 1-7. doi:10.1016/j.btre.2016.11.001

Effective composting of empty fruit bunches using potential Trichoderma strains.

Siddiquee, S., Shafawati, S. N., & Naher, L. (2017). Effective composting of empty fruit bunches using potential Trichoderma strains. Biotechnology Reports, 13, 1-7. doi:10.1016/j.btre.2016.11.001

Online Resources

Sustainable Palm Oil- Good Agricultural Practice Guidelines, Unilever

Sustainable Palm Oil- Good Agricultural Practice Guidelines . (n.d.). Unilever.

https://www.unilever.com/Images/sustainable-palm-oil-good-agricultural-practice-guidelines-2003_tcm244-424244_en.pdf

Online Resources

How to Make and Use Compost, Food and Agricultural Organization

Edwards, S., & Araya, H. (2011). HOW TO MAKE AND USE COMPOST. Food and Agriculture Organization. Retrieved from: http://www.fao.org/docrep/014/i2230e/i2230e14.pdf

Soil management: compost production and use in tropical and subtropical environments.

Dalzell, H. W. (2007). Soil management: compost production and use in tropical and subtropical environments. Rome. Retrieved from: http://www.fao.org/3/a-s8930e.pdf

Climate Change

Videos

The Human Impact of Climate Change: Personal Stories from Somalia, Ghana, and Kenya
http://y2u.be/Bg9GXLoLpiQ

Climate Change Explained
http://y2u.be/ifrHogDujXw

Online Resources

National Climate Change Adaptation Strategy – Ghana, UNEP and UNDP
http://www.adaptation-undp.org/sites/default/files/downloads/ghana_national_climate_change_adaptation_strategy_nccas.pdf

Climate Change, Effects and Impact on the Ghanaian Economy, Ghana Web (Sept 30, 2014)
https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Climate-Change-Effects-and-Impact-on-the-Ghanaian-Economy-328061

Effects of climate change on forests in Africa: Why Ghana must protect her forest cover, Government of Ghana
http://www.ghana.gov.gh/index.php/media-center/features/2633-effects-of-climate-change-on-forests-in-africa-why-ghana-must-protect-her-forest-cover

Composting

Videos

Farming with compost in Africa (Ghana)
http://y2u.be/yM0HMl3qWHA

Quick compost for west Africa
http://y2u.be/Um07cEViUFU

Black Gold: The Secrets of Compost, Garden Africa
http://y2u.be/byNnJ1KRWDU

Deforestation

Videos

Deforestation in Ghana
http://y2u.be/do7Kkvgx1zk

Deforestation Effects on Climate
https://youtu.be/Nc7f5563azs

Wikipedia

https://en.wikipedia.org/wiki/Deforestation

Eutrophication

Wikipedia

https://en.wikipedia.org/wiki/Eutrophication

Videos

Eutrophication explained
http://y2u.be/KJ6QjjuAPuU

What Is Eutrophication
http://y2u.be/6LAT1gLMPu4

Integrated Pest Management

Scientific Journal Articles

Pest Problems of Oil Palm and Management Strategies for Sustainability.
Kalidas P (2012) Pest Problems of Oil Palm and Management Strategies for Sustainability. Agrotechnol S11:001. doi:10.4172/2168-9881.S11-001

Integrated pest management for oil palm in Papua New Guinea.
Caudwell, R., & Orrell, I. (1997). Integrated pest management for oil palm in Papua New Guinea. Integrated Pest Management Reviews, 2, 17-24. Retrieved from: https://link.springer.com/article/10.1023/A%3A1018420211050

Environmental Cycles

Wikipedia

https://en.wikipedia.org/wiki/Biogeochemical_cycle

Videos

The Water Cycle
http://y2u.be/al-do-HGuIk
The Carbon Cycle
http://y2u.be/nzImo8kSXiU
Nutrient Cycles
http://y2u.be/L2yb1ERU9p4

Soil Degradation and Conservation

UN FAO Webpage

http://www.fao.org/soils-portal/soil-degradation-restoration/en/

Videos

The Value of Soil
http://y2u.be/403sT9CGRI0
Lets Talk about Soil
http://y2u.be/invUp0SX49g

Greenhouse Gases

Videos

How Do Greenhouse Gases Actually Work?
http://y2u.be/sTvqIijqvTg

Greenhouse Gas Sources
http://y2u.be/iUb2G-w_BOk

Land Use Change

Wikipedia

https://en.wikipedia.org/wiki/Eutrophication

Videos

How Does Land Use Change Affect It? - The Water Cycle
http://y2u.be/-xNP2Y6Sr0Q

The Effects of Land Use on Ecosystems
http://y2u.be/dRVHm3jvsQo

Waste and Pollution

UN FAO Webpage

http://www.fao.org/soils-portal/soil-degradation-restoration/en/

Videos

Solid Waste Managment
http://y2u.be/nL354fxAfBk

Pollution: Crash Course Ecology #11
http://y2u.be/kdDSRRCKMiI

Pollution Chokes African Lives, Livelihoods
http://y2u.be/1Ovv3yU02UE

What Is Water Pollution
http://y2u.be/Zk1J2EW-nmQ

Pollution Non-point source and Point Source
http://y2u.be/RVkHwV39BFs

Understanding Bioaccumulation
http://y2u.be/fdTV3F9k1IA

The Unintended Consequences of Pesticides
http://y2u.be/p2xR5EK8m7I

Recycling in Accra: Ghana's 'waste to wealth' ambition
http://y2u.be/dxD4FqRBJVQ

Making profit from plastic waste collection & recycling in Ghana
http://y2u.be/k-K5psKRzyE

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