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

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

Environmental Risks and Green Economic Opportunities in the Cassava 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 Cassava Subsector

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

Written and Designed by: Chang, S. A.,
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(2017-2018)

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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

Executive Summary

This booklet is written as part the West African Governance and Economic Sustainability in Extractive Areas Project conducted by the World University Services of Canada (WUSC/EUMC) and the Centre for International Studies in Cooperation (CECI) in Ghana, Guinea, and Burkina Faso.

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

This booklet is divided into four chapters:

Section 1 Basic Information on the Cassava subsector, including brief summaries of the state of cassava farming and processing in the Western Region;

Section 2 Environmental Risks of cassava 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 cassava 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 cassava 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. The Environment and Green Economy has additional information that can be useful to better understand the environmental risks associated with cassava cultivation.

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
CRI	Crop Research Institute
Cu	Copper
DAP	Di-ammonium Phosphate
DO	Dissolved Oxygen
GHG	Greenhouse Gas
H2O	Water
HQCF	High-Quality Cassava Flour
K	Potassium
Ma	Manganese
Mg	Magnesium
MOFA	Ministry of Food and Agriculture
MSW	Municipal Solid waste
N	Nitrogen
N2O	Nitrous Oxides
O2	Oxygen
P	Phosphorus
PF	Palm Fibres
PHD	Prestea Huni Valley District
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.
Cyanogenic Glucosides	Naturally occurring sugars that are potentially toxic to humans and animals. Cooking and processing cassava denatures these compounds, making them safe for consumption.

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.
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.
Lotaustralin.	A toxic cyanogenic glucoside that is naturally found in cassava plant and roots.
Linamarin	A toxic cyanogenic glucoside that is naturally found in cassava plant and roots.
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, critical for new leafy growth.
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, an important macro nutrient for structural development in plants.
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, supports plant growth and aids in fending of disease
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

Cassava is one of the most widely cultivated crops in the Wassa East and Prestea Huni-Valley Districts. Cassava is typically grown out of food security concerns rather than commercial and profit purposes. The crop itself is renowned for being able to tolerate and produce a meaningful yield despite drought or poor soil conditions.

Cassava can be processed in a variety of ways and into many staple food-items such as fuf, *gari, kokonte,* leaves stew, pizza, biscuit, *ampesi, yakeyake*, noodles, dough and cake. Medium- and high-end processing by more sophisticated operations can produce industrial starch, High-Quality Cassava Flour (HQCF), refined oil, and soap products.

The value chain for cassava has having five main component (see figure 5):

1. **Input supply** is dominated by private industry, and MoFA and NGOs providing improved planting material, fertilizers and other agricultural inputs.
2. **Cassava production** is done mostly by small-scale farmers, with relatively few medium- and large-scale farmers.
3. **Aggregation and assembly** of cassava is done by middlemen. This stage has several challenges due to the highly perishable nature of cassava, and the difficulties with poor road networks and accessibility to cassava cultivation areas.
4. **Processing of cassava** into other food products is done at the household and commercial level, producing food products for village-level or commercial sale. Many medium-and large-scale cassava farms sell to small and medium-scale agro-processing enterprises. Large-scale starch factories also purchase cassava for additional processing, though domestic supply of cassava for processing is largely unmet.
5. **Marketing and sale** of cassava both domestically and internationally is under explored. Most cassava food items are sold locally. The unmet local demand for cassava has limited the exploration of export markets for cassava food products.

At the aggregate level, there is huge unmet demand for cassava for several different industries, including the: hard liquor industry, beer industry, confectionary industry, starch industry, mosquito coil production, animal feed industry, and

others. These opportunities are avenues for economic development and growth in the cassava subsector.

Presently, the cassava sector faces challenges with cultivation and processing cassava into high-quality market goods. Low crop yields, limited access to improved cassava varieties and agricultural inputs, high cost of land, unimproved processing methods, and poor financial and technical support for farmers are significant challenges to developing and strengthening the sector.

The expansion of cassava farms and growth in local and regional cassava production comes with environmental risks such as land use change (pg. 16), deforestation (19) and soil degradation (19) from cassava cultivation, and pollution (21) from cassava processing. Climate change (12) 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 (pg. 32), the underlying science behind critical environmental cycles, and incorporating the Principles of Green Economy (29) 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.

Cassava Classification and Varieties

Cassava, or *Mantioc Esculenta,* is native to central and south America, and is a very common staple food and a source of carbohydrates for more than half a billion people worldwide. Cassava is known for its ability to grow in drought conditions and in marginal soils. Cassava is classified into bitter and sweet varieties, where both varieties have ant nutritional factors and toxins, bitter varieties having more than sweet varieties. Various methods of cooking and preparing cassava are used to remove or destroy the anti-nutritional factors before eating.

The Council for Scientific and Industrial Research (CSIR), The Ministry of Food and Agriculture - Root and Tuber Improvement & Marketing Programme 2007-2014 (RTIMP), and other research programs in Ghana and elsewhere have developed numerous improved cassava varieties that mature faster, produce

higher yields, and/or have higher resistance to common diseases such as Cassava Mosaic Disease (CMD) (see table 1). The different cassava varieties are also cultivated for specific purposes, where some varieties are produced for food products, starches, or other cassava-derived products. Section of the right variety of cassava depends on the needs of the producer, the region or area of the cassava farm, and the risks of CMD.

A full table of cassava varieties produced in and for Ghana can be found below:

Table 1) List of improved cassava varieties developed in Ghana (1993-2015).

Variety	Year Released	Maturity Period (Months)	Mean Root Yield (T/ha)	Total Dry Matter (%)	Uses	CMD Resistance
Afisiafi	1993	12-15	28-35	32	Starch, flour, gari	Tolerant
Abasafitaa	1993	12-15	29-35	35	Starch, flour, gari	Tolerant
Tek-bankye	1997	12-15	30-40	30	fufu, ampesi, gari	Susceptible
CRI Doku duade	2005	12	35-40	30	Starch, gari	Resistant
CRI-Agbelifia	2005	12	40-45	33	Starch, gari	Resistant
CRI Essam Bankye	2005	12	40-50	35	Flour, gari	Resistant
CRI Bankye-hemaa	2005	9-12	40-50	32	Flour, gari, fufu	Resistant
Capevars Bankye	2005	9-12	30-35	30	Flour, gari, fufu, starch	Resistant
Bankye Botan	2005	12-15	25-30	28	Flour, gari, starch	Tolerant
Eskamaye	2005	15-18	16-23	25	Tua Zaafi, konkonte	Tolerant
Filindiakong	2005	15-18	16-20	28	Tua Zaafi, konkonte	Tolerant

Variety	Year Released	Maturity Period (Months)	Mean Root Yield (T/ha)	Total Dry Matter (%)	Uses	CMD Resistance
Nyeri-kobga	2005	15-18	17-29	30	Tua Zaafi, konkonte, gari, flour, starch	Tolerant
Nkabom	2005	12-15	28-32	32	Starch, fufu	Tolerant
IFAD	2005	12-15	30-35	30	Starch, fufu	Tolerant
CRI Ampong	2010	12	40-50	36	Flour, Starch, fufu	Resistant
CRI Broni Bankye	2010	12	40-45	33	Flour, bakery products	Resistant
CRI Sika Bankye	2010	12	40-45	36	Flour, Starch	Tolerant
CRI-Otuhia	2010	12	35-40	39	Flour, Starch	Resistant
CRI-Lamesese	2015	12	40-50	39	Fufu, flour, and Beta-Carotene	Resistant
CRI Abrabopa	2015	12-15	35-45	40	High-starch	Resistant
CRI AGRA-Bankye	2015	12	35-60	32	Starch, flour	Resistant
CRI Amansan Bankye	2015	12	40-57	38	Flour, Bakery products	Resistant
CRI-Dudzi	2015	12	35-60	38	Flour, Bakery products	Resistant
CRI Duade Kpakpa	2015	12-15	40-60	37	fufu, flour, starch, industrial alcohol	Resistant

Cassava Physiology

Cassava is a short woody shrub, with one or several woody stems protruding from a root bundle below ground. The stem or stems of the cassava plant is used to propagate new cassava plants for the following season. The leaves of cassava are a good source of protein, but low in important amino acids for quality nutrition.

The roots are high in starch, and small amounts of calcium (Ca), phosphorus (P), and vitamin C, however is lacking in protein and other dietary nutrients.

The peel, roots and leaves of the cassava plant naturally contains anti nutritional cyanogenic glucosides, Linamarin and Lotaustralin. Bitter varieties of cassava contain more of these cyanogenic compounds than the sweet variety.

Eating raw cassava leaves or tubers can cause several immediate health problems including: Vomiting, vertigo, and collapse. In very rare cases, ingestion of large amounts of raw cassava can cause death. Long-term chronic exposure to cyanide in cassava can lead to the development of Goiter, a nerve-damaging disorder that leads to unsteadiness and incoordination of movement; and Ataxia, a neurological disorder that can cause problems walking.

Cooking, soaking, or drying the cassava tuber is done to decompose the cyanogenic glucosides, making the cassava safe to eat. Fermentation and drying/ fying cassava is also an effective way of making cassava more palatable and safer to eat.

Optimal Soil Characteristics

Cassava is a remarkably durable and hardy plant, acting as a stable food crop and food of last resort for many in Africa, Asia, and Latin America. Cassava is one of the most drought-tolerant crops on earth and can produce meaningful yields in marginal soils, soils where other crops may not be able to grow. However, poor soil quality will invariably have an impact on the tonnage per hectare.

While cassava is grown in a wide-variety of soils across Ghana, Ideal soils are deep to very deep, and have a pH of 4.5-8. Cassava extracts large amounts of soil nutrients, especially Potassium (K) and Nitrogen (N). Soils that have been continuously planted with cassava with minimal soil amendments like fertilizers or green manure are likely devoid of important plant nutrients. Cassava is also especially responsive to Magnesium (Mg) and Zinc (Zn) deficiencies in the soil.
For soil pHs below 4.6, liming of the soils may be necessary.

However, despite the hardiness of cassava, it is best to grow cassava in well-drained sandy loam soils. Avoid soils that are too tightly compacted as this will not allow water to easily drain through the soil. Similarly, avoid soils that are prone to flooding or water logging at any point in the year. This includes planting near rivers or streams which are prone to flooding at least once in a year. (See also: Wastewater).

Various improved crop varieties are designed to work best in one or several specific agro-ecological zones. It is best to always use varieties of cassava or other crop, that is well-suited to the agro-ecological climate. Table 2 shows the optimal agro-ecological zones for each variety of cassava.

Table 2) Preferred Agro Ecologies of Various Cassava Varieties.

Variety	Preferred Ecology
Afisiafi	All agro-ecologies
Abasafitaa	Forest Savannah Transition, Coastal Savannah Forest
Tek-bankye	Forest/Forest Savannah Transition
CRI Doku duade	Forest, coastal and forest- savannah transition.
CRI-Agbelifia	Forest, coastal and forest- savannah transition.
CRI Essam Bankye	Forest, coastal and forest- savannah transition.
CRI Bankye-hemaa	Forest, coastal and forest- savannah transition.
Capevars Bankye	Savanna transitional, deciduous forest Evergreen rain forest
Bankye Botan	Savanna transitional, deciduous forest, Evergreen rain forest
Nkabom	Coastal Savannah, Forest, Forest, Savannah Transition
IFAD	Coastal Savannah, Forest, Forest, Savannah Transition
CRI Ampong	Forest coastal and forest savanna transition
CRI Broni Bankye	Forest coastal and forest savanna transition
CRI Sika Bankye	Forest coastal and forest savannah transition
CRI-Otuhia	Forest, coastal and forest- savannah transition.
CRI-Lamesese	Forest and Costal Savannah
CRI Abrabopa	Coastal, Forest and Forest Savannah Transition
CRI AGRA-Bankye	Forest and Costal Savannah
CRI Amansan Bankye	Forest coastal and Forest Savannah transition
CRI-Dudzi	Forest and Costal Savannah
CRI Duade Kpakpa	Coastal and forest savannah transition

Cassava Yields

Cassava yields in Ghana are typically low. Estimates for average cassava yields vary, between 12 and 16 tonnes per hectare, but are generally far below expected average yields improved varieties of cassava, averaging 20-60 tonnes/hectare. Additionally, low farm gate prices, limited demand, or unfavorable market

conditions may lead some farmers to leave as much as 30% of their harvest in the ground, holding out for improved prices and market conditions.

Improvements in soil nutrients, farming practices, planting material, and access to improved varieties can dramatically improve cassava yields. Cassava responds especially well to additions of Potassium (K), which is usually depleted by the continuous planting of cassava on a plot of land.

Cassava Production and Processing

Cassava must always be processed within a very short period of time from harvesting. Once harvested, Cassava is a highly perishable agricultural product, spoiling within only a few days of harvesting. A significant amount of Cassava grown in Ghana is immediately used for household production purposes, making common staple food products from the cassava. The remaining half of cassava is purchased by traders and aggregators of cassava, who resell to processing factories that create additional food products (see figure 1)

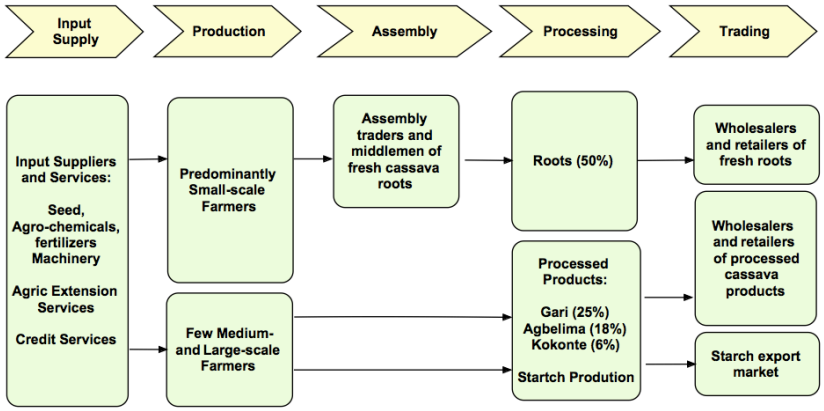

Figure 1) *Diagram of Cassava Sector actors and linkages.*

Small-Scale Cassava Production and Processing

Small-scale familial cassava farms are the most common cassava farm in Ghana. Many families maintain a small plot of cassava for food security purposes, rather than commercial purposes. In these cases, cassava is typically grown on marginal

soils that cannot support other crops. such as maize. Fertilizers and irrigation are rarely if ever used, leading to low yields compared to anticipated yields of improved varieties.

Approximately half of cassava grown in Ghana is immediately used to produce household food items like *fufu, gari, kokonte* and other food-items. Again, the production of cassava at the household- or village-level is done primarily out of concern for food security rather than profitability. Quality of final products and prices are low and often only cover the cost of production and processing. There are some instances when small-scale farmers are contracted as out growers for medium- to large-scale processing centers.

Cassava is typically harvested by hand or simple manual tools. The roots are sold in the market and at the village-level as raw tubers, cassava dough, *gari, yakeyake,* or tapioca. Peeling the tubers before proessing is often done by hand. Grinding is done by hand or simple machine depending on the mill. Often the cassava mill will be a stand-alone enterprise. Pressing of grated cassava is often accomplished with a manually-operated screw press or hydraulic. Frying or roasting various cassava products is also a common procedure and usually relies on traditional clay and mud stoves, simple aluminum pans, and a biomass fuel like wood. Women dominate small-scale production and processing of cassava and are more often exposed to smoke and other persistent health risks associated with cassava processing. The processing method of for *gari,* one of the more popular food items, can be seen in figure 2.

Small-scale processing cassava processing centers are often too small and too far spread out to create significant environmental risks. However, large numbers of small-scale processors in a small area may create environmental risks without proper waste management.

Medium- and large-scale Cassava Production and Processing

There are very few medium- to large-scale cassava farms, which sell immediately to small-, medium- and large-scale cassava processors. Having improved access to finance and agricultural inputs, yields may be slightly higher on medium-scale cassava farms. Large-scale commercial estates for cassava are very rare in Ghana but have the best access to improved agricultural practices, inputs and

planting materials.

Medium- to large scale processing centers purchase and process much of the cassava from small-scale out growers, and medium- to large-scale farms. Commercial products like *fufu* powder, High-Quality Cassava Flour (HQCF), or *gari* are produced using adequate machinery and hygienic manufacturing and packaging

Large-scale, high-end processing centers have dedicated cassava estates or contract small- and medium-scale out growers for raw cassava tubers. These large-scale factories often produce High-Quality Cassava Flour (HQCF), and cassava starch for other large-scale brewing companies. The capacity of production is very high, and consequently waste product generation is also quite high. Large-scale operations may have the financial and technical capacity to manage their waste production, either through treating waste products before final disposal, or by reusing waste products in the normal processing procedure. However, in the case that responsible environmental practices are not included in the business, significant environmental risks will occur.

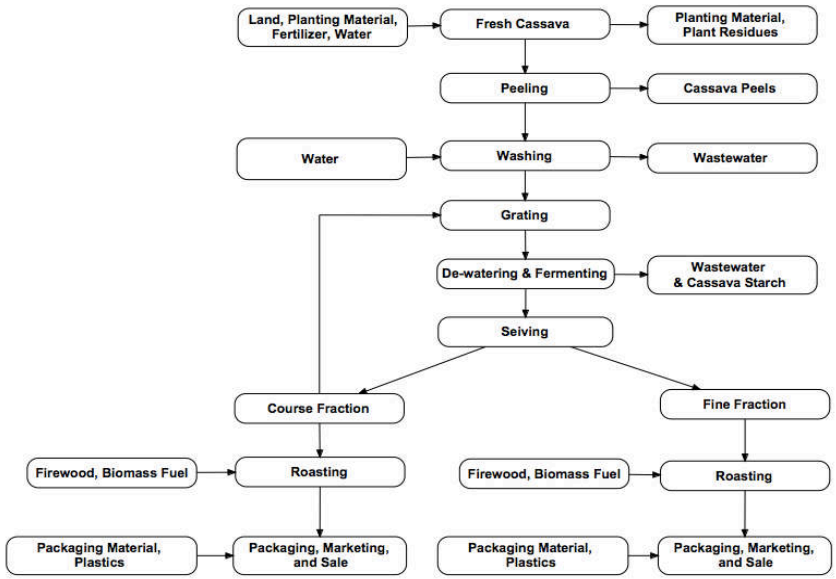

Figure 2) *Flow diagram of the Gari Production process.*

Section 2: Environmental Risks in Cassava

The cassava subsector comprises cassava farms and cassava processing factories or enterprises. Cassava farms, being an agricultural, has different environmental implications than cassava processing, an agro-industrial process. The specific techniques, practices, and methods used during cassava farming and cassava 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.

The following two sections outline the main environmental risks associated with cassava production and processing. Below those two sections are a much more in depth description of environmental risks generally, and underlying environmental systems.

The following two sections outline the main environmental risks associated with cassava production and processing. Below those two sections are a much more in depth description of environmental risks generally, and underlying environmental systems.

Cassava Farming

The development of new cassava farms, and improvements in existing farms presents a unique set of environmental risks. Many of these environmental risks can be adverted or minimized with proper understanding of the environment around the home and business.

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

However, awareness of the environment and a broader view of using natural organic resources, such as green manure 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 land into cassava farms has multiple risks involved ranging from: Deforestation (pg. 19) Soil Erosion (19) and Land Degradation (16). There are also important long term consequences for making decisions about how and where to expand farms.

Understanding the interactions and relationships between expanding and creating cassava farms, developing communities, and living within an environment helps put into perspective the decisions farmers have about cassava farming.

Chemical Pollution is always a risk when fertilizers, weedicides and pesticides are being used on a farm. Cassava, having the ability to grow in spite of poor soil conditions and little fertilizer application, is not usually associated with chemical pollution. Nonetheless, using chemicals improperly or ineffectively can cause chemical pollution (21).

Cassava Processing

Cassava processing, making raw cassava into marketable food products also has its own unique environmental challenges. The waste products from peeling and pressing cassava, fuel needs to heat and fry cassava, the petrol to run machines for grinding and sieving cassava, and other components of cassava processing can cause environmental risks and harm.

Deforestation is partly caused by the high demand for firewood and charcoal to make *gari* or dry cassava. Many times, the trees that are cut are not replaced by new trees. Using firewood, in part, contributes to deforestation and unsustainable fuel use. Using alternative fuels can offset this demand and the resulting environmental consequences (pg. 19, 61)

Waste Products from processing cassava, like the peels and the water pressed out of the cassava have specific physical and chemical properties that can cause environmental damage such as soil degradation, eutrophication (pg. 20), greenhouse gas emissions (13) and cause public nuisances. Some of these waste products can be reprocessed into additional market products or managed in such a way to prevent environmental pollution (39).

Pollution caused by waste products from cassava, such as when dumped in large quantities into the bush or local rivers and wetlands can cause environmental damage like soil degradation and eutrophication. Burning waste products can release greenhouse gases and air pollution (pg. 23).

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. Common greenhouse gases are:

- **Water vapor (H_2O)** is a natural greenhouse gas and comes from evaporating seawater and emission from forests.
- **Carbon Dioxide (CO_2)** 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 3).

The concern today is that mankind has changed the land in ways that are becoming irreversible and have serious and lasting consequences on the environment and for Climate Change. Globally, mankind is changing land faster than it ever has in history. With more than 7 Billion people on this Earth, the demand for natural resources, land, food, water and fuel has caused planet-wide change to delicate natural systems.

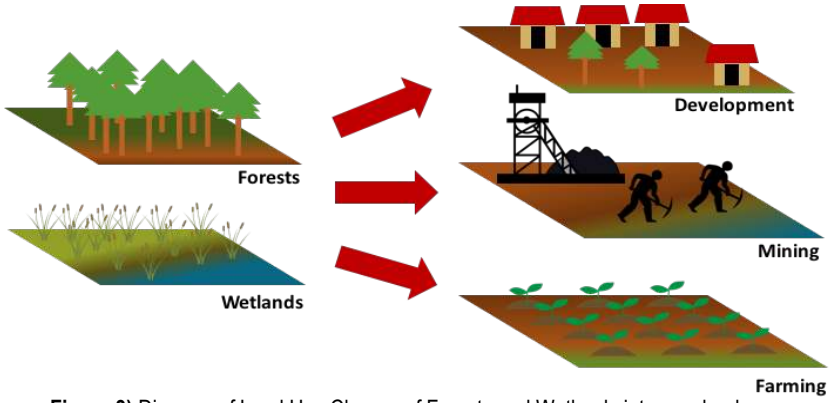

Figure 3) Diagram of Land Use Change of Forests and Wetlands into new land uses.

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.

Addressing nationwide deforestation in Ghana is a complex challenge, requiring coordination and cooperation at national, regional and local levels. Increasing awareness of sustainable farming practices, protecting and strengthen nearby forests, improving fuel efficiency and reducing wood and charcoal use, reducing unsustainable timber mining, and development of environmentally-friendly livelihoods like forestry tours and tree planting are important steps to mitigating and averting deforestation.

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 (pg. 25).
- 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, or waste products from agro-processing cassava.

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 micro organisms;

3. Natural bacteria in the water consume and decompose the dying algae, which uses oxygen in the process;
4. As more algae die and are consumed the water becomes devoid of oxygen in the water (dissolved oxygen), causing stress and possibly death to aquatic plant and animal life.

In the long term, eutrophication can cause significant damage to wetland ecologies, rivers or lakes (see Figure 4).

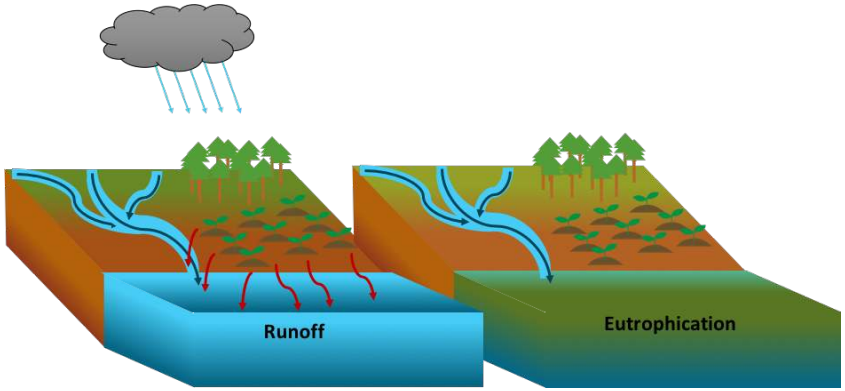

Figure 4) Agro-chemicals and mineral fertilizers can runoff into local waterways, causing eutrophication.

Waste Products and Pollution

Waste products and pollution from human activities are another serious environmental risk. However, it is important to distinguish between 'waste products' from 'pollution'. While waste products and pollution are very closely related, they are two different environmental risks. Waste products can become pollution if managed poorly, but pollution is caused by many other things.

Waste products from the cassava sector are varied, and include solid organic waste, liquid organic waste, and various types of inorganic waste products (see Figure 5). The various kinds of waste products from farming cassava, and processing tubers have different chemical properties, durability in the environment, and affect the environment at different concentrations.

Cassava peels represent the most important, and environmentally significant waste product from cassava processing. The peels, like the tuber, naturally contain high levels of toxic glucosides, which can cause soil degradation and waste pollution. Other waste products, like the water from pressing and fermenting cassava also contain toxic glucosides and represent a significant environmental risk to the environment.

	Solid Waste	Liquid Waste
Organic waste	**Solid Organic Waste** Cassava Peels Agric residue (sticks, leaves) Spoilt or damaged tubers	**Liquid Organic Waste** Cassava press water Cassava washing water
Inorganic waste	**Solid Inorganic Waste** Plastic packaging material Agro-chemical Containers Ash	**Liquid Inorganic Waste** Agrochemical Runoff

Figure 5) Four types of waste products can be created from cassava production.

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.

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 (see Bioaccumulation).

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 chemicals can lead to serious health problems later in life. Young children and the elderly are susceptible to chronic pulmonary (breathing) illness from the release of chemicals and particulate matter from burning waste. Chemicals like dioxins, furans, and PAHs are linked to immune, respiratory, endocrine, and reproductive system damage and cancer.

Whenever possible, waste should be disposed of in a sustainable manner or burned away from homes and where people are working to prevent health impacts from air pollution.

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 (See Figure 6).

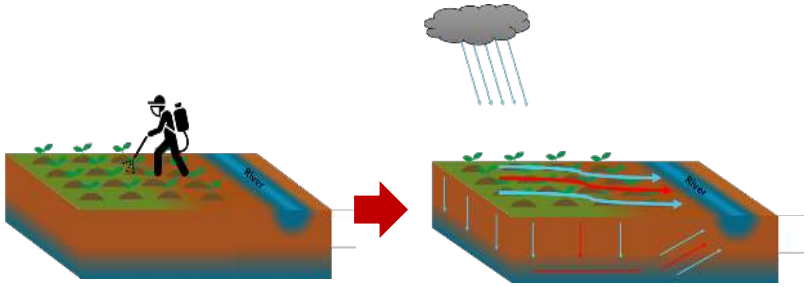

Figure 6) Diagram of Agro-chemicals moving into local waterways via runoff.

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.

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.

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.

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 are in the environment.

In the worst cases, acute, or immediate and high concentration exposure to agro-chemicals, through eating accidental ingestion of chemicals, exposure by inhalation during spraying, or having the chemicals come into contact the eyes and skin has been linked to many health problems such as:

- Rashes
- Dizziness
- Dizziness
- Headaches
- Nausea and Vomiting
- Immune system suppression
- Neurotoxicity
- Birth Defects
- Cancer

It is important to always practice good management of agro-chemical and encourage more organic farming methods as sustainable alternatives to chemicals. Good agro-chemical efficiency and utilizing Personal Protective Equipment can help prevent over-use of chemicals, accidental chemical spills in the environment, and reduce human exposure to harmful 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.

Other Kinds of Pollution

Besides waste and chemicals, there are other kinds of pollution that can have a negative effect on the environment.

- **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.

This section will guide readers through:

1. The Principals of a Green Economy (below)
2. Outcomes of a Green Economy (pg. 31)
3. The Environment, Society and Economy (pg. 32);
4. The Economy, Society, Environment and Green Economy (pg. 35);
5. Supporting a Green Economy (pg. 36);

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 (see figure 7).

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.

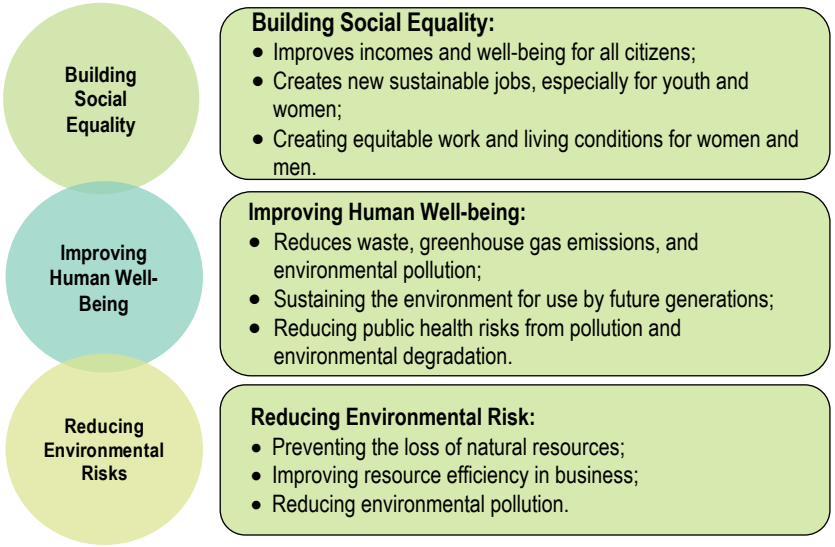

Figure 7) Building social equality, improving human well-being, and reducing environmental risks, are all part of a Green Economy.

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.

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 8).

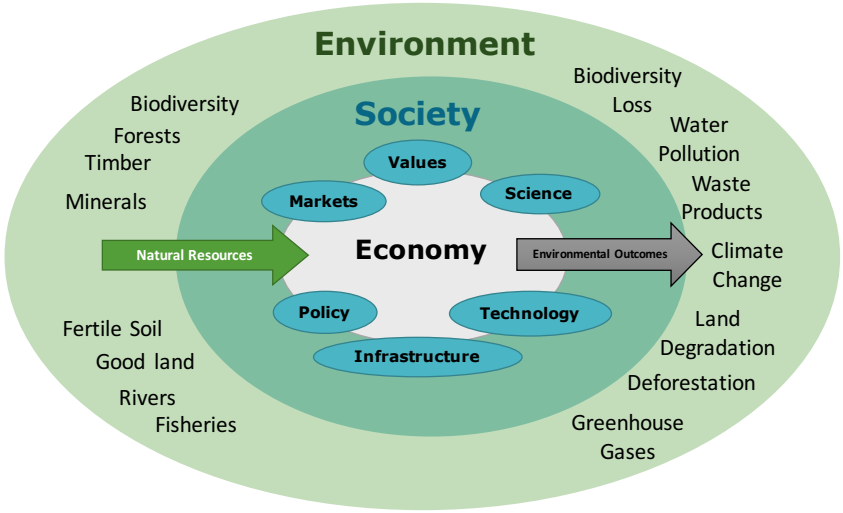

Figure 8) A diagram showing the relationships between 'The Economy', 'Society', and the 'Environment' and how 'Natural Resources' are transformed to cause 'Environmental Outcomes'.

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 (see figure 8).

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.

(See figure 8)

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 (see figure 8).

Figure 8 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 9).

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.

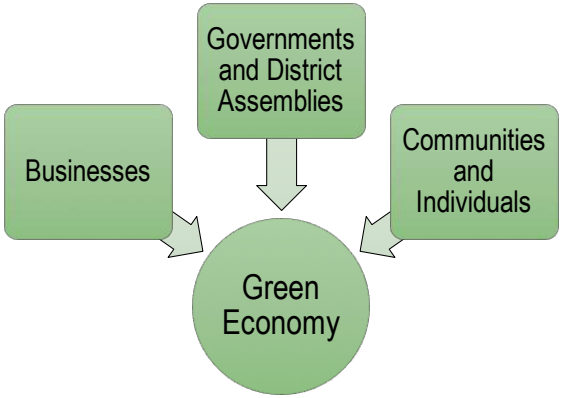

Figure 9) Green Economies need the support of Businesses, local governments, and communities and individuals to grow and be successful.

- 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.

Section 3: Green Economy
Supporting a Green Economy

- 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 (pg. 27); how it functionally relates to various components of a region's Economy, Society and Environment (32) and what means of support can individuals, businesses, and governments can provide to develop a Green Economy (36).

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 cassava subsector comprises two main components:

1. Farming cultivating cassava;
2. Processing the crop harvest into marketable products.

Cassava Farming

Like the Environmental Risks of farming and processing, the Green Economic opportunities associated with cassava 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 (pg. 16) 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.

Other farming practices, like chemical use, organic fertilizer use, machinery and land preparation can have a negative effect on the land.

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 (See table 1).

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 (pg. ##).

Section 4: Green Economic Strategies
Resource, Energy, and Environmental Conservation

Organic fertilizers (pg. 46) 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 (53).

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 (pg. 24) Alternative methods of controlling weeds is possible, and can result in improved conservation of resources and the environment (45, 49)

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 (pg. 53) 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. The environmental risks for chemical fertilizers or organic fertilizers differ (pg. 21).

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

Cassava farms often do not receive mineral fertilizer application due to the cost of the fertilizers and the ability of cassava to grow without the addition of mineral fertilizers. However, cassava removes large amounts of soil nutrients, especially Potassium (K), which can lead to substantial declines in root yield if nutrients aren't replaced after every year.

Most mineral fertilizers have high concentrations of Nitrogen (N), Potassium (P) and Phosphorous (K), and there are several types of fertilizers specifically designed for cassava. However, some fertilizers may lack sufficient micronutrients, such as Calcium (Ca), Magnesium (Mg), and Sulphur (S). Most of the cassavas' NPK requirements can be applied as a mineral fertilizer, but application requires careful monitoring to prevent nutrient imbalances and deficiencies, especially for Ca, Mg, and S.

A table of average nutrient contents of various artificial and organic fertilizers can be found in Table 3.
It is important to understand the role of mineral fertilizers, like NPK fertilizers, for plant growth:

- **Nitrogen (N)** is very important for shoot and leafy growth and moderately important for root growth. Deficiencies in Nitrogen is identifiable by:
  - Stunted growth;
  - Narrow, pale green leaves with yellow discoloration on the leaf tips and margins;
  - Premature, or early, dropping of leaves.

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
Elemental 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.

- **Phosphorous (P)** is normally important for developing efficient root systems in other plant species, however Phosphorus does not seem to play an important role in bulking of cassava tubers. Deficiencies in Phosphorous is identifiable by stunted growth and *violet* discoloration of leaves.
- **Potassium (K)** is critically important for cassava growth, where high K can improve cassava tuber yield and has been shown to improve resistance to cassava bacterial blight. Potassium is quickly depleted from the soil if soil nutrients aren't replaced by the farmer. Potassium deficiencies can be identified by:
  - Stunted growth;
  - Dark leaf color that slowly and gradually turns pale green;
  - Dry, brown spots on the tips and margins of leaves;
  - Dead and decaying spots on the margins of leaves.

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.

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 (see table 3).

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.

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 (see table 4). 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.

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).

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

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.

Intercropping

Intercropping is planting two or more species of plants on the same plot of land at the same time (see figure 10). Crops can be planted:

- *Spatially* - (multiple crops grown at the same time) or;
- *Sequentially/ Temporally* – planting two or more different crops, one after the other, on the same plot of land.

Spatial intercropping can be:

- Strip Intercropping: two or more crops in wide enough rows to allow for independent cultivation, but narrow enough to allow the plants to interact in the soil
- Row Intercropping: two or more crops in well-defined row arrangements
- Mixed Intercropping: two or more crops in an irregular and random pattern;

Temporal Intercropping can be:

- Relay Intercropping: Planting two crops so that the final stages of the first crop coincides with the first stage of the intercrop.

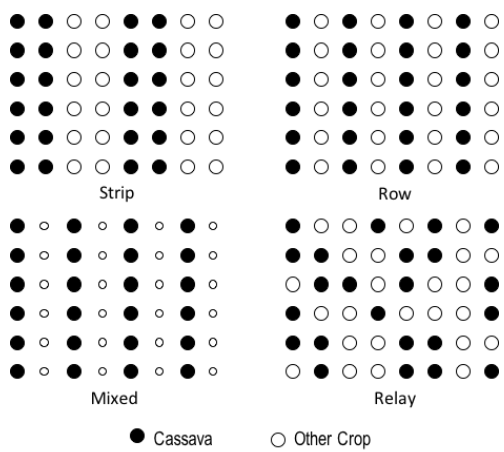

Figure 10) Diagram of various intercropping arrangements

Intercropping, or planting more than one type of commercial crop on the same field, has several advantages:

- 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.

Disadvantages with intercropping are:

- Mechanized harvesting is more difficult with multiple types of crops;
- Fertilizer and pesticide application is more difficult with multiple plants that require different chemical applications;
- More complicated arrangements and management of crops than with a single crop.

Traditional combinations of cassava and other crops are:

- Cassava and maize;
- Cassava and legumes (cowpeas, soybean, groundnuts, pigeon peas, etc.);
- Cassava and market vegetables;
- Cassava, Yam and maize;
- Cassava, maize and groundnut.

When planting cassava on an upland slope and depending on the type of intercrop, plant spacing between cassava plants can range from 100-400 cm. In an inland, or low-lying farm, plant spacing range between 80-100 cm. In general, 10,000- 15,000 plants per hectare will result in good yields. Experimentation about how best to arrange crops, which crops are most marketable, and how intercropping forms part of a larger sustainability strategy, will he needed.

Intercropping cassava with other crops is important to maintaining long-term soil health and fertility, and generally increases the overall incomes to farmers. However, developing suitable combinations of plants for a single farmer requires some degree of experimentation and understanding of the local soil conditions. It is best for a farmer to experiment with different combinations of plants, depending on their particular farm or situation.

Weed Management

Because cassava is slow during the first 3-4 months of planting, cassava farms are susceptible to weed problems early on. Weeds act in competition with cassava to lower canopy development and root development. Some species of weed may also pierce the cassava tuber, leading to rotting and crop loss.

Managing weeds is an important part of maintaining a sanitary and high-yielding cassava farm. 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 3, 8, and 12 weeks is very effective for removing and eliminating the threat of weeds.
- **Biological Measures** such as using growing a cover crop like *Mucuna Pruiens* (velvet beans) the season before cassava is planted can help suppress weeds. The green manure from the velvet beans can be used as organic matter for the cassava.
- **Genetic Measures** like improved cassava varieties are specifically designed to cover the ground with a canopy quickly, limiting the ability of weeds to grow quickly and compete for resources. Fast-growing and early branching varieties of cassava will cover the ground much faster and slow-growing and late branching cassava varieties.
- **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.

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.

Cassava Processing

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

The basic components of processing cassava can be found in the first section of this booklet (pg. 7). Within this process, the most significant environmental risks stem from inefficient resource use, poor waste management practice, and the resulting pollution (21, 53).

In terms of Green Economic Opportunities, improvements in resource efficiency (pg. 52), and minimizing waste pollution through processing or recycling waste products (53) 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. 14) and improve the financial income to the business by using less resources.

Resources for cassava processing include:

- Land for the processing center or factory, and for storing cassava before processing;
- Machines for processing cassava;
- Fossil fuels for operating machinery like the grinding/grating machine and sieving machine, and fuel for transporting the raw materials and final products;
- Biomass fuels, like wood or dried organic waste, for gari frying stoves;
- Aluminum for frying stoves;
- Water for washing cassava after peeling;
- 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 (61) such as dried organic waste, or better still, fuel briquettes (61) 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;

- Water used for washing cassava can be recycled as irrigation water, though basic processing might be needed (pg. 57).

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 cassava 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 from cassava have unique physical and chemical characteristics that, when indiscriminately dumped into the environment, can cause different kinds of environmental risks.

Cassava processing has two main waste products associated with it:

- Wastewater from washing and pressing cassava;

- Cassava peels from peeling cassava.

Waste from cassava 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 cassava 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 (46) and green manure are very effective and sustainable ways of re-using agric residues that would otherwise be wasted.

Animal Feed from Cassava Peels

Cassava peels have a higher protein content than the flesh of the cassava tuber and are known to be suitable as animal silage, as one part of a varied animal feed diet. Cassava peels can be re-processed with similar methods as gari production, making an animal safe, (see Figure 11, Table 5), and high-quality animal feed with a good shelf life.

International Livestock Research Institute – High Quality Cassava Peel Feed

1. Always use fresh cassava peels, since stored cassava peels start to ferment and become unsafe for animal consumption.

2. Sort the peels by hand or by tossing in a large bowl to remove large woody stumps, soil, stones, and other unwanted debris. This protects the grater (raspier) from damage.

3. Grate the peels three times either by machine or by traditional methods. Peels are more difficult to grate than the flesh of the cassava, so grating must be done several times to achieve the desired particle size.
   a. Grating the cassava can be done on the same machines used to grate cassava roots., such as with *gari;*
   b. If using the same machinery, be sure to clean the grater before and after processing cassava peels to prevent cross-contamination.

4. Pack the grated cassava peel into tightly woven polyester or jute bags in small quantities (8-12 kgs per bag). Flatten and stack the bags into a hydraulic or screw press and press the peels to remove excess water, just as you would when making gari.

a. Use a wooden board to evenly and uniformly distribute the pressure from the hydraulic or manual screw press.
b. This dewatering process removes almost 50% of the total weight of the starting material.

5. Leave the pressed bags in the press overnight (8-12 hours) to allow them to ferment. This step produces an intermediary product, 'Cassava Peel Cake' with a 38%-42% moisture content.

6. Wet cassava peel cake can be fed to cattle, sheep, pigs, and goats.
   a. The cassava peel cake can be safely stored for up to seven (7) days without spoiling.
   b. The cassava peel cake can also be re-grated to improve the texture.

7. To produce dried cassava peel feed, the intermediate cassava peel cake is loosened by re-grating.
   a. This will improve the granularity of the product and help it pass through a sieve.

8. Sieve the cassava peel cake to separate the course and fine fraction.
   a. The fine fraction, that passes through the sieve is lower in dietary fibre and higher in energy content
   b. The course fraction is higher in dietary fibre and lower in energy content.

9. The fine and course fractions of cassava cake are spread onto a concrete drying patio or plastic tarp and allowed to dry for 6-8 hours.
   a. Spread the cassava peel cake out in a thin layer (1-2cm) and turn a few times during the drying process to allow the cassava to dry evenly.
   b. On rainy or cloudy days, the cassava peel cake can be toasted in a metal pan similar to how *gari* is toasted.
   c. Once dried, the material should have between 10%-12% moisture content.

10. The dried material can be safely stored for 4-6 months without any spoilage.

Table 5) Products derived from processing cassava peels.

Wet Cassava Peel Cake	High-Quality Cassava Feed, Fine	High-Quality Cassava Feed, Course
Suitable for cattle, sheep, pigs and goats.	Suitable for poultry, fish, and pigs.	Suitable for pigs, goats, sheep, and cattle.
Shelf life of 7 days.	Shelf life of 4-6 months.	Shelf life of 4-6 months.

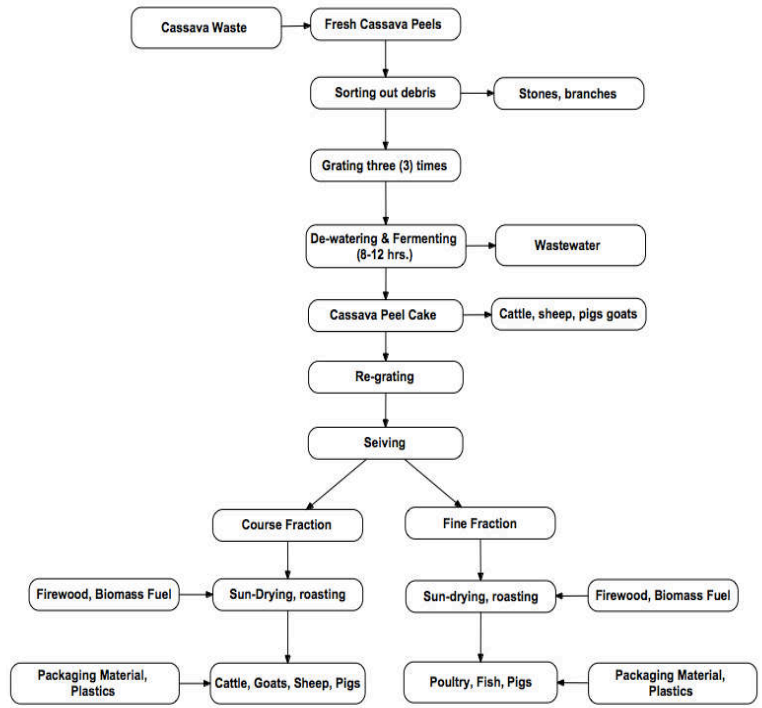

Figure 11) Flow diagram of High-Quality Cassava Feed

Nutritional Characteristics

Cassava peels can be a valuable feed, and can give satisfactory performances when fed as a supplement to ruminants. However, cassava peels should not be fed alone, as their protein and mineral content cannot support optimum rumen function and productivity, and their optimal utilization requires sources of readily fermentable protein and by-pass protein as well as micronutrients including Sulphur, phosphorus, and B vitamin.

Cassava peels could be introduced at up to 30 percent in piglet diets without affecting growth performance. In older pigs (35 kg), up to a 57 percent level of inclusion had no deleterious effect on daily weight gain, feed intake, feed conversion ratio and carcass characteristics and the use of cassava peels as a partial replacement for maize in young pig diets was shown to be cost effective.

Poultry Cassava peels can be used for poultry feeding after sun-drying, as well-processed peels contain HCN levels that are acceptable for poultry. Fermentation of cassava peels has been tested by several authors, either to lower HCN or fibre content or to increase crude protein content (Heuzé et al., 2012a).

The recommendation for broiler chickens is to limit the incorporation of cassava peel meal to 5- 10 percent depending on its quality, with appropriate feed formulation. In layer chicken diets, cassava should have low inclusion rates of about 5 percent (Heuzé et al., 2012a). As a source of energy and replacement of maize dried cassava peels can be incorporated up to 30 percent in balanced feeds for growing rabbit.

Wastewater

For all levels of processing, and all types of processing, the simplest way of reducing the environmental impact from wastewater discharge is controlling and limiting the use of water during the processing of cassava. Recycling water, whenever possible without compromising factory hygiene, and reducing the amount of wastewater will reduce the environmental impact of cassava waste water.

Small-scale producers, spread out over a large distance, do not cause any substantial amount of environmental harm from dumping wastewater onto the

ground. However, when one or several medium and large-scale factories are in close proximity, there is the potential for the area to be a 'pollution hotspot', where wastewater can contaminate the groundwater, nearby rivers and streams, the soil. Simple methods for managing and treating waste water are possible:

Irrigation: Using waste water from the production process to irrigate crops must be done in a very controlled fashion. High cyanide concentrations in the waste water can cause long-term soil degradation and damage the surrounding environment. Dilution of waste water and very careful monitoring of irrigated plants is necessary to ensure that no damage is being done.

Seepage Pits: A seepage pit is designed to temporarily store wastewater, and allow the water to slowly seep into the surrounding ground. The slow of release of water allows natural bacteria in the soil to biologically treat the wastewater before it reaches nearby waterways. Seepage tanks are often used to treat human wastewater and water from septic tanks (see Figure 12).

Basic design of a seepage pit

- A large pit is dug into the ground and lined with 50-60cm of gravel on the bottom.
- Many holes (2-3 cm in diameter) are drilled into a plastic or concrete tank. The tank is lowered into the pit and 50-60cm of gravel is placed around the outside of the tank.
- The tank is filled with loose gravel or stones and a lid is placed on top with a hole or pipe attached to allow wastewater to be directed into the tank.
- The tank and pit are covered, ensuring that inflows of water are not blocked or obstructed. An above ground or underground pipe transports waste water from the factory to the seepage pit.
- Seepage pits must be made far enough from rivers, streams, lakes, and groundwater wells (places where groundwater is extracted). Local soil conditions will ultimately determine how far to place a seepage pit from local water sources, but a good rule-of-thumb is to have the seepage pit 60 meters from the nearest water source plus an additional 2.5 meters for every 375 liters above 3750 Liters of wastewater generated per day.

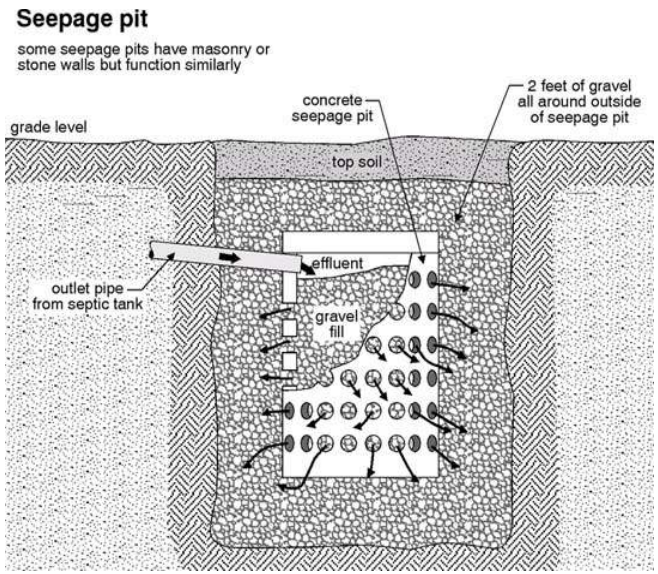

Figure 12) Basic Diagram of a below-ground seepage pit for waste water treatment.

Settling Tanks: A settling tank is simply a large tank that wastewater can flow into. The water is kept still to allow organic particles to sink to the bottom of the tank before the wastewater can be dispersed into the environment. Allowing the particles to settle to the bottom of a tank for several days allows

Fuel-Efficient Stove Designs

Frying *gari* (or other cassava food product) is an important step for the transformation of cassava-mash into a marketable product. Traditionally, *gari* and *kokonte*, is fried in a shallow aluminum or cast iron pan over a wood fire. The process of frying *gari* or *kokonte* can take anywhere between 30 minutes to one hour depending on the moisture content of the cassava-mash, fuel efficiency of the frying stove, and other factors.

Improved *gari* frying stoves have two key advantages if implemented into cassava processing:

- Improved *gari* stoves can increase fuel efficiency and reduce the cost and amount of fuels used during the frying process.

- Fuel efficient stoves include designs to reduce the amount of smoke generated from the frying process. This can improve the health and safety conditions of cassava processors, the majority of whom are women.

Several basic improvements can be made for *gari* stoves and fryers using locally sourced materials and simple technologies:

- Enclosing the fire on at least three sides will increase the heat retention and fuel efficiency of the fryer. Less wind blowing on the fire will reduce heat loss and will concentrate the heat onto the frying pan;

- Utilizing improved designs made from locally sourced materials, such as cement blocks, can improve the fuel efficiency of the business;

- Ensuring that there is a vent for smoke to blow away from the operator. Be sure that the roof of the shed covering the fryer is not covering the smoke vent, this prevents smoke from blowing at the operator, causing health problems from smoke inhalation.

Improved Stove Designs

Several improved designs can be made using locally sourced material that can improve the fuel efficiency of the stove and reduce smoke production and health problems from smoke inhalation (see figure 13).

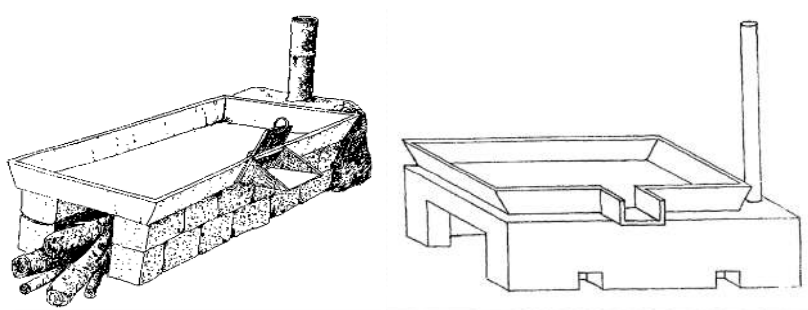

Figure 13) Improved Gari frying stoves, made from locally sourced materials.

Alternative Fuels

Alternative biomass fuels for frying gari or other cassava products is another way to reduce the environmental impact from the cassava processing sector. Reusing biomass waste from other agro-businesses can reduce demand for firewood and reduce pressure on nearby forests, while recycling waste products from other businesses.

Waste products from a variety of agro-business sub-sectors can be used as alternative fuels:

- Sawdust and wood offcuts from saw millers and carpenters;
- Sun-dried Coconut husks
- Bamboo Charcoal
- Non-Carbonized or Carbonized Fuel Briquettes.
-

The exact fuel characteristics of each type of alternative fuels differ and a certain amount of experimentation should take place to see which alternative fuel will be the best for the circumstances. However, the overall goal of using alternative fuel sources is to offset the use of firewood, which may not be sustainable long into the future.

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

The raw materials for briquette production can be sourced from many different sectors. Cassava cultivation and processing yield 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 Fibre
- Palm Fronds
- Maize Cob
- Dried Manure
- Palm Kernel Shells
- Sawdust
- Cassava Peels
- Empty Fruit Bunches
- Bamboo
- Rice Straw
- Groundnut Shells
- Bagasse
- Coconut Husk

Suitable Binder Materials for Fuel Briquettes

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

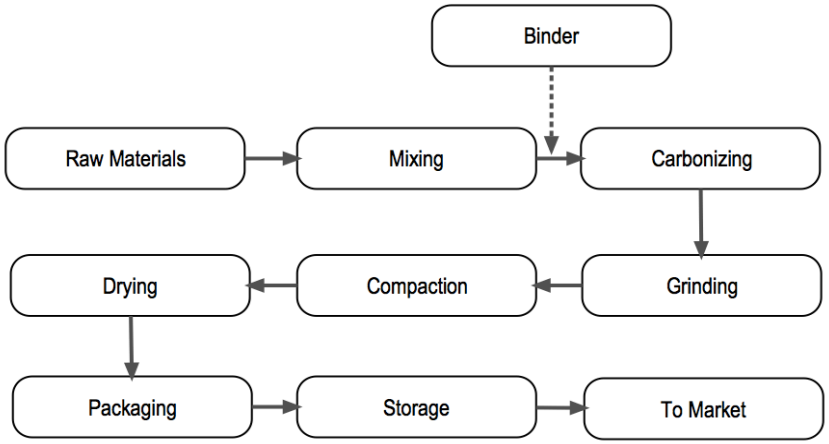

Figure 14) Flow diagram showing the basic production process of non-carbonized fuel briquettes.

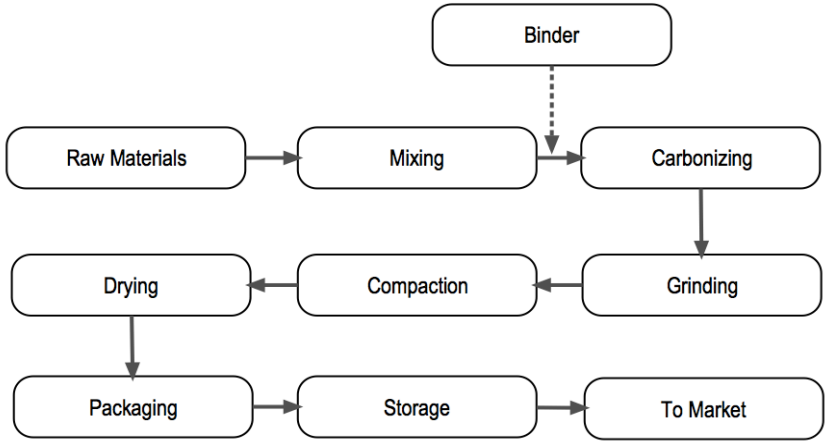

Figure 15) Flow diagram showing the basic production process of carbonized fuel briquettes.
Source: modified from A review on production, marketing and use of fuel briquettes, IWMI, 2016.

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. Metal 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.

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.

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 16). 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 17).

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 17).

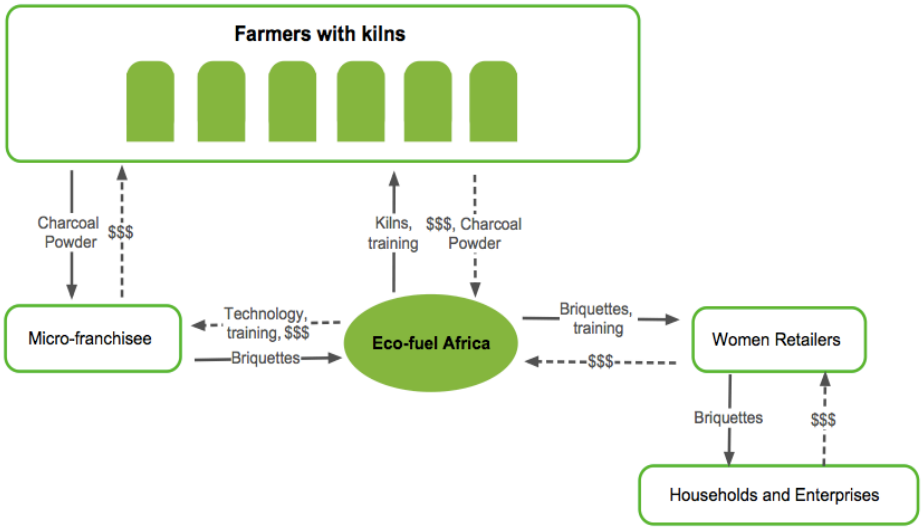

Figure 16) *Ecofuel Africa's value chain for fuel briquette production, modified from A review on production.* **Source:** Modified from *A review on production, marketing and use of fuel briquettes. IWMI, 2016.*

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 17).

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.

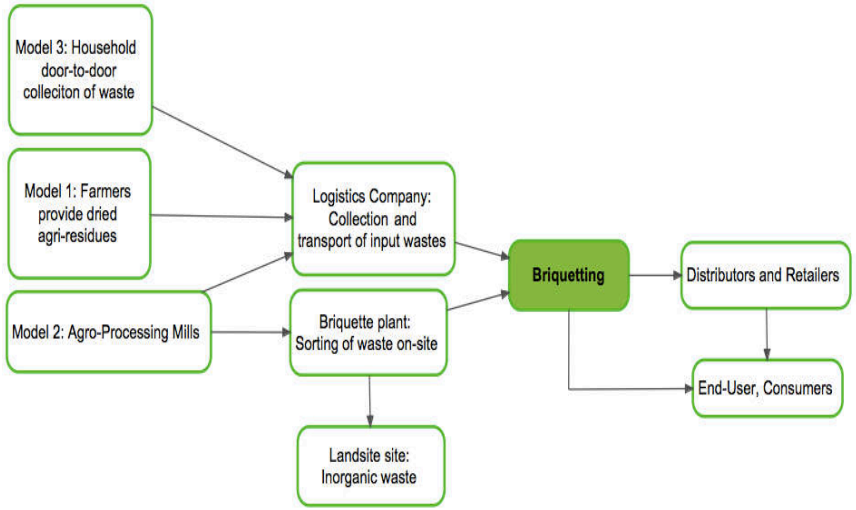

Figure 17) Diagrams of potential value chain for fuel briquette production.

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 **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
Online Resources	**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

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

Integrated Pest Management

Booklets

Save and Grow Cassava
http://www.fao.org/ag/save-and-grow/cassava/en/6/index.html

Pest Control in Cassava Farms
https://www.agriskmanagementforum.org/sites/agriskmanagementforum.org/files/Pest%20Control%20-%20en.pdf

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

LULUCF an introduction
http://y2u.be/NOU1bJqfmoQ

High-Quality Animal Cassava Feed

Videos

Transforming cassava peels into animal feed
http://y2u.be/jkvHYqPLvyc

Earthfile Focuses On Making Better Use of Cassava Waste (PT1)
http://y2u.be/OunLjhlFObk

Earthfile Focuses On Making Better Use of Cassava Waste (PT2)
http://y2u.be/FkMimHhv9ck

Earthfile Focuses On Making Better Use of Cassava Waste (PT3)
http://y2u.be/azx8nG6eseU

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

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

Videos

Briquette Making Demonstration for small scale entrepreneurs:

https://www.youtube.com/watch?v=fT1dkSRIKQ

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

Briquettes from Ghana by LAT Development Ltd.

http://y2u.be/SSCw_Qj3XtQ

Briquette Project

http://y2u.be/wc1gbfyEpOs

The innovator making a fortune out of charcoal

http://y2u.be/1cfA2btPdXA

How to make charcoal briquettes from agricultural waste

http://y2u.be/wed4NutcAsQ

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

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

Greenhouse Gases

Videos

How Do Greenhouse Gases Actually Work?

http://y2u.be/sTvqIijqvTg

Greenhouse Gas Sources

http://y2u.be/iUb2G-w_BOk

Eutrophication

Wikipedia

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

Videos

Eutrophication explained

http://y2u.be/KJ6QjjuAPuU

What Is Eutrophication

http://y2u.be/6LAT1gLMPu4

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

Composting

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
Videos	**Farming with compost in Africa (Ghana)** http://y2u.be/yM0HMI3qWHA **Quick compost for west Africa** http://y2u.be/Um07cEViUFU **Black Gold: The Secrets of Compost, Garden Africa** http://y2u.be/byNnJ1KRWDU

Eutrophication

Wikipedia	https://en.wikipedia.org/wiki/Eutrophication
Videos	**Eutrophication explained** http://y2u.be/KJ6QjjuAPuU **What Is Eutrophication** http://y2u.be/6LAT1gLMPu4

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