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

WUSC EUMC CECI

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

Environmental Risks and Green Economic Opportunities in the Rice 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 Rice Subsector

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

Written and Designed by: Chang, S. A.,
WAGES Green Economy Advisor
(2017-2018)

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Emelia Ayipio Asamoah
WAGES Country Coordinator

Steven Chang
WAGES Green Economy Advisor
Steve.chg3@gmail.com

World University Services of Canada (WUSC)
124 Haatso-Atomic Rd, Haatso
Accra, Ghana
+223 30 251 1029

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

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

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

This booklet is divided into Five (5) Sections:

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

Section 2 Environmental Risks of rice 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 rice cultivation and processing;

Section 5 Additional reading materials, books, journal articles, and online resources .

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 rice 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 rice 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
EM	Effective Micro Organism
GHG	Greenhouse Gas
H2O	Water
IMO	Indigenous Micro Organisms
IPM	Integrated Pest Management
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
PHD	Prestea Huni Valley District
PPE	Personal Protective Equipment
RHA	Rice Hull/ Husk Ash
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

Table of Contents

List of Figures

List of Tables

Glossary

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

Economy	Encompasses all production of goods and services, and the flow of money.
Environment	Encompasses all of Society and the Economy, provides natural resources and is affected by environmental outcomes.
Environmental Footprint	The cumulative impact of an individual or business on the environment, is smaller or bigger depending on the choices and practices of the individual or business.
Eutrophication	The process by which excess chemical fertilizers cause damage to natural aquatic and wetland ecosystems.
Evaporation	The process by which heat and energy from the sun evaporates water into the Atmosphere.
Fossil Fuels	Ancient stores of organic carbon deep underground, has been transformed into coal, oil and gas from millions of years of heat and pressure underground.
Green Economy	A Green Economy is one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.
Greenhouse Effect	Greenhouse gases naturally exist in the Atmosphere, trapping some heat and light reflected off the Earth. Today, greenhouse gas emissions have led to an increased Greenhouse Effect and Climate Change.
Greenhouse Gas	Specific types of gases that absorb heat and light in the atmosphere. The largest and most important are Carbon Dioxide, Methane, Nitrous Oxides, and Chlorofluorohydrocarbons.
Groundwater	Water that is stored deep underground and takes many years to move across a landscape. Groundwater feeds boreholes and wells.
Hydrosphere	An environmental Compartment that accounts for all the water in lakes, rivers, oceans, and groundwater.
Inorganic	Being manufactured or processed in such a way that the material wont decompose, or material that is not made from organic matter.
Land Use Change	The process of natural forest or wetland being converted into other uses like farming, development, or mining.

Lithosphere	An environmental Compartment that accounts for rocks, minerals, and soils.
Macro Nutrient	Nitrogen, Potassium and Phosphorous
Methane	CH4, A carbon-based greenhouse gas that comes from decomposing waste, converting wetlands into farms or other uses, and manure.
Micro Nutrient	Minor nutrients needed for plant growth like Calcium, Magnesium, Manganese, Copper, Sulphur
Nitrogen	A Macro Nutrient, 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

Rice is a critically important cereal grain for much of the world and Ghana. Rice is the second most common cereal grain consumed in Ghana, behind maize, where an estimated 24kg of rice per person are consumed annually. The demand for rice is expected to grow dramatically in the coming decades due to population growth, urban expansion and continued development. Presently, Ghana is highly dependent on imports of rice, where the annual demand for foreign rice grew 190% from 2001 to 2010, or 187,256MT to 543,465MT.

Rice and rice production is an emergent sector in the Wassa East and Prestea Huni Valley District, unlike in the Northern Regions of Ghana where rice production is more prevalent. Relatively cheap and high-quality rice has placed smallholder farmers in Ghana at a comparative disadvantage in the market. Despite the reliance on imports of rice from foreign countries, demand for locally produced rice remains high in the Western Region. Buyers of local rice are impressed with the taste and quality of the rice. Because rice production is not common in the Western Region, the sector is largely underserved with producers unable to meet the demands by local traders and individual consumers.

Rice production does not receive the same support from institutions like government departments, non-governmental organizations (NGOs), and private investors, as the cacao, oil palm and the rubber industries. The sector is mostly driven by individuals and youth groups to tap into the opportunities presented by the rice sector. Producers are mostly men farming on 0.5-1 acres of low-lying areas or former swamps and wetlands, located along the Tarkwa-Aboso rail line, or in Dompim in the Wassa East District.

High costs for farm inputs, such as suitable farming land, land preparation machinery, fertilizers and weedicides, bird nets and drying platforms (tarpaulin) are persistent challenges to the sector. Additionally, technical support from District Governments are limited due to few Department personnel, and limited resources to provide supporting services to farmers. Access to credit, improved planting materials, and access to support services, and methods to intensify production can boost yields and improve incomes to farmers.

Rice producers are largely responsible for all the activities related to growing, drying, processing, and marketing rice. Harvested rice is milled, bagged in 50kg sacks by the producers at the local rice mill, and sold directly to individuals and traders. In rare cases, women will come to buy raw rice paddy for milling and sale

elsewhere. There are no significant efforts to standardize quality grades, brand the packaging, or practice value-added methods like par-boiling or waste recycling.

Understanding the relationship between the Environment, the Economy and Society, and how Green Economy can inform and sensitize individuals to their impacts on the environment and the Green Economic Strategies that can be used to improve the business. Awareness of environmental cycles and environmental risks posed by farming and agro-processing can help farmers make better choices about their farms and farming inputs. Improvements in farming practices, sustainable agronomic techniques, waste recycling practices can also improve farmers yields, incomes, and livelihoods.

Rice Classification and Characteristics

Rice is the seed of two grass species, *Oryza Sativa* (Asian Rice) *Oryza Glaberrima* (African Rice). African rice originates in West Africa, but is not commonly grown or sold in West Africa or Ghana today. There are still a few producers growing the indigenous *O. Glaberrima* rice varieties, however the most recent decade has seen the development of several improved varieties of *O. Sativa* rice, with selectively breed traits from *O. Glaberrima rice.*

Rice plants, appearing like long grasses, can grow to be as tall as 1-1.8 meters depending on local conditions, with long and slender leaves. The small flowers are wind pollinated, producing the edible seed or rice grain. The grain itself has several layers that are typically removed during the milling processing to achieve the marketable rice grain.

The rice hull, or husk, is the hard, protective covering on the rice grain. Rice with the hull still intact is known as ‘Paddy Rice’. The rice husk is always removed during the first stage of milling and has specific physical and chemical properties that can allow the husk to be used for construction and building, organic fertilizer, insulation, or fuel if properly recycled. Specifically, rice hull ash (RHA) contain very high concentrations of Silicates (SiO2), which can be used for several productive and novel purposes when it is recycled.

Beneath the rice husk is the Rice Bran, or the thin outer layer of the rice grain. Rice with the bran layer still intact is called ‘Brown Rice’. Rice bran is typically removed during the second milling stage, which leaves behind the pure ‘white or milled rice’ grain. The rice bran is quite nutritious, containing various beneficial antioxidants and essential fatty acids, dietary fibres, and protein. The relatively

high oil content in the bran makes the rice susceptible to spoilage if not removed or treated by par-boiling to improve shelf life. Other bran by-products, from corn and wheat, are commonly used as part of a nutritious animal feed diet.

Rice Varieties

The Government of Ghana, under the Crop Research Institution have developed many new and improved varieties of rice to meet the needs of farmers in all rice producing regions of Ghana. These varieties are developed for several purposes, but generally speaking are breed to improve crop yields, resistance to pests and disease, and improved marketability like improved flavor and cooking qualities.

Table 1 shows a complete list of improved rice varieties and associated characteristics, developed by CRI:

Table 1) List of improved Rice Varieties in Ghana.

Variety	Maturity Period (Days)	Yield	Resistance	Quality	Characteristics
FARO 15	145-150	5.0 MT	Good resistance to common pests and diseases	Preferred by artisanal processors due to high milling rate. Good for Waakye, jollof, omutuo.	Long and bold grain, non-aromatic.
GR 18 (GRUG 7)	132	6.5 MT	Good resistance to common pests and diseases	High consumer acceptability for waakye, Jollof and Omutuo.	Medium and bold grain, non-aromatic
GR 19	125	5.5 MT	good resistance to common pests and diseases.	High consumer acceptability	Long and slender grain, non-aromatic intermediate amylose content.
GR 20	125	4.5 MT	Good resistance to common pests and diseases	Good cooking quality, high consumer acceptability	Long and slender grain, non-aromatic intermediate amylose content.
GR 21	125	4.5 MT	Good resistance to common pests and diseases	Acceptable cooking quality especially for waakye, Jollof and Omutuo	Short and bold grain, non-aromatic relatively high amylose content.
Sikamo	120-125	6.0 MT	Tolerant to Blast, resistant to lodging.	Good cooking quality, non-sticky, high-expansion ratio	Long and Slender grain

Variety	Maturity Period (Days)	Yield	Resistance	Quality	Characteristics
Digang	115	4.8 MT	Very plastic (Can be grown across ecologies), adapted to low input systems; Good resistance to common pests and diseases	Acceptable cooking quality especially for waakye, Jollof and Omutuo.	Long and slender grain, non-aromatic.
Gbewaa Rice	110-115	5-6 MT	Good resistance to common pests and diseases	Very high consumer acceptability	Long and slender grain, aromatic intermediate amylose content
Nabogo Rice	120-130	6-7 MT	Good resistance to common pests and diseases	Very good cooking quality. High consumer acceptability	Long and slender grain, aromatic intermediate amylose content
Katanga Rice	130-140	6-8 MT	Good resistance to common pests and diseases	Excellent cooking quality; High consumer acceptability	Long and slender grain, aromatic intermediate amylose content
Nerica 1	90-95	3-4 MT	Drought Tolerant	Average consumer acceptability	medium grain size, aromatic, high amylose
Nerica 2	95-100	3-4 MT	Drought Tolerant	Average consumer acceptability	long and slender grain size, non-aromatic
Mmo teaa	110-115	4.8 MT	Tolerant to Blast, resistant to lodging.	Good cooking quality, high consumer acceptability	Long and slender grain, non-aromatic
Otoo Mmo	115-120	5.6 MT	Resistant to Blast, Good Resistant to lodging.	Good cooking quality, high consumer acceptability	Long and bold grain, non-aromatic.
CRI - Amakawtia	115-120	8 MT	Tolerant to Blast, resistant to lodging.	Good cooking quality, high consumer acceptability	Long and slender grain, aromatic, intermediate amylose content
Wakatsuki	125-130	8 MT	Tolerant to Blast, Good resistant to lodging.	Good cooking quality, high consumer acceptability	Long and slender grain, non-aromatic, intermediate amylose content
Bodia	120-125	8 MT	Tolerant to Blast, Good resistant to lodging.	Good cooking quality, high consumer acceptability	Bold grain, non-aromatic

Variety	Maturity Period (Days)	Yield	Resistance	Quality	Characteristics
Sakai	135-140	8 MT	Resistant to Blast, Good Resistant to lodging.	Good cooking quality, high consumer acceptability	long and slender grain size, non-aromatic
AGRA Rice	-	-	Tolerant to Blast, Good resistant to lodging, Resistant to Iron toxicity	Good cooking quality, high consumer acceptability	Long and Slender grain
CRI-Dartey	120-125	9 MT	-	Excellent cooking quality, aromatic	-
CRI-Emopa	125-130	8 MT	-	Excellent cooking quality, slightly aromatic	-
CRI-Mpuntuo	115-120	8 MT	-	Good cooking quality, aromatic, good processing quality	-
CRI-Aunty Jane	125-130	9.5 MT	-	Excellent cooking quality, slightly aromatic	-
CRI-Kantinka	120-125	8.5 MT	-	Excellent cooking quality	-
CRI-Oboafo	130-135	8.5 MT	-	Good cooking quality, good processing quality	-

Ideal Growing Conditions for Rice

Rice is grown as distinct types, where each type is influenced by variations in land quality, water and rainfall availability, and the potential for drought conditions, determining where and what varieties of rice can be grown, and what growing methods must be used. The three main types of rice cultivation are:

Upland Rice is mainly grown in mountain of the Volta region, between the Volta lake and Togolese border. Upland rice is grown on dry soils rather than flooded rice paddies. This style of rice relies on rainfall for its primary source of water, and is then highly susceptible to drought conditions. Drought tolerant varieties of rice are developed for Upland Rice cultivation.

Lowland Rice is grown in valley bottoms or other low-laying areas. This style of rice cultivation also relies on rainfall as the primary source of water, again making the rice susceptible to droughts. Flooding is an additional concern where low lying areas are prone to floods during intense rainstorms.

Drained swamps, with naturally wet and flooded conditions are like lowland rice cultivation, but do not rely as heavily on rainfall for water and irrigation

Controlled Flooding Rice or Rice Paddy is a technique where a parcel of land is leveled and bermed (to build retaining walls around the perimeter of the farm), and flooded to a shallow depth. These types of farms are typically well-designed for commercial rice production and do require specific machinery for irrigation, and knowledge about rice paddy construction and maintenance.

Soil Characteristics of the Western Region

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.

Forest Ochrosols

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, 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.

Soil amendments like organic fertilizers and manure, and maintenance practices like contour ploughing and terracing, and planting leguminous cover crops can improve the fertility and quality of the soil and counteract erosion.

Forest Oxysols

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 rice.

Like with ochrosols, additions of organic fertilizer to oxysols and good soil management practices can reduce soil erosion and improve the long-term suitability of these soils to support cultivating various crops.

Agro-ecological Zones of Ghana

Ghana is divided into six different agro-ecological zones on the basis of their climate and soil types:

- Sudan Savannah (Upper East)
- Guinea Savannah (Northern, Upper East, Upper West)
- Forest Savannah Transition (Brong Ahafo, Ashanti, Eastern, Volta)
- Semi-Deciduous Rainforest (Brong Ahafo, Western, Central, Ashanti, Eastern, Volta)
- High Rainforest (Western)
- Coastal Savannah (Central, Greater Accra, Volta)

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 rice or other crop, that is well-suited to the agro-ecological climate. Table 2 shows the optimal agro-ecological zones for each variety of rice.

Table 2) Preferred agro-ecological zones for improved rice varieties.

Variety	Preferred Ecology
FARO 15	Deep Lowlands
GR 18 (GRUG 7)	Lowland & irrigated
GR 19	Lowlands
GR 20	Lowlands
GR 21	Lowlands
Sikamo	Lowland/ Hydromorphic
Digang	Lowland/ Hydromorphic
Gbewaa Rice	Lowland & irrigated
Nabogo Rice	Lowland & irrigated
Katanga Rice	Deep Lowlands
Nerica 1	Upland
Nerica 2	Upland
Mmo teaa	Forest, Guinea savanna, Coastal savanna
Otoo Mmo	Forest, Guinea savanna, Coastal savanna
CRI - Amakawtia	Lowland
Wakatsuki	Lowland
Bodia	Lowland
Sakai	Lowland
AGRA Rice	Forest, Guinea savanna, Coastal savanna
CRI-Dartey	-
CRI-Emopa	-
CRI-Mpuntuo	-
CRI-Aunty Jane	-
CRI-Kantinka	-
CRI-Oboafo	-

Rice Yields

Rice yields in the Western Region is low, between 1.3 and 1.7 tones per acre, which is lower than the National averages. Low yields are mostly due to limited access to agricultural support services, credit for improved seeds or other equipment, and high losses to weeds and pests. Farmers are often aware of potentially yield increasing methods, but limited finances and high costs prevent farmers from being able to implement these practices.

Other reasons for low yields could be due to soil nutrient depletion, poor soil conditions, using traditional seed varieties, or diseases and fungus.

Rice Processing

The rice value-chain is largely unorganized in the Western Region, where rice producers are responsible for the cultivating, harvesting, milling, packaging and sale of their rice. The process of harvesting rice had the techniques involved can have a substantial effect on the final yield of white, milled rice. Poor harvesting practices can lead to low milling quality, and high amounts of breakage of the rice grains during milling. Generally, the rice harvesting process is similar to the following:

Rice harvesting, or 'reaping', on smallholder farms is done by hand, with a sickle or other blade. The rice stalk is cut close to the middle or bottom. The rice stalks are collected and stacked together as the field is harvested.

The harvested rice stalks are aggregated and carried to a 'threshing station', where the rice paddy (rice grain and husk) is separated from the residues (stalks, leaves, etc.). This can be done in a variety of ways, such as beating the rice stalks with a bamboo cane, driving over the rice with a tractor, beating the rice against a collecting surface, or by specialized machinery.

The rice plant residues are separated from the rice paddy grains. The rice paddy is then collected and poured from one container to another, or tossed into the air, allowing the wind to carry away lighter particles of dust and straw, known as chaff.

Ideally, within 12-24 hours, the rice paddy is then gathered and taken to an open area for sun-drying. This area can be a tarpaulin or cement patio for drying. Rice paddy is laid in a thin layer over the drying surface and turned very often to allow for efficient and even drying. This process is highly dependent on the thickness of the rice layer, the temperature outside, the intensity of direct sunlight, how often the rice is turned and ambient (natural) moisture content in the air. Generally, the drying time for rice paddy is between 5-8 hours.

Rice paddy is sun-dried to lower the moisture content of the grain to improve the shelf life of the rice paddy, discourage fungal growth and grain spoilage, and improve milling quality. Over-drying rice, or allowing dried rice to become wet again in the rain or at night can increase cracking of the rice grain during milling, and diminish the appearance and value of the grain overall.

Rice that has been properly dried to the right moisture content is then collected and taken to a local rice mill, where specialized machinery grind of the bran and husk of the rice, leaving behind the now white, 'milled rice'. The way the rice was dried prior to milling will have a considerable impact on the milling quality of rice. Rice of poor quality, that did not receive good drying practices, will break easily during milling, reducing the quality and value of the rice.

The milled rice is typically packaged and sold by the producers to small- and medium- scale wholesalers, or to individual consumers.

Rice Quality Grading

Paddy rice, or rice that has been separated from the rice plant residue, has different and separate quality metrics than the final milled rice, called 'head rice'.

The purity of paddy rice is an important quality metric. The presence of sticks, stones, and other debris (usually acquired during the drying stage), immature grains, mold damage from storage after harvesting and before drying, and other poor quality grains affect the quality of paddy rice.

During milling, the final step before the white rice can be bagged and sold, is a key step in determining the quality of rice. Rice that has not been dried properly can suffer from discoloration and cracking and breakage during milling. High-quality rice is a uniform white color, with no signs of discoloration, off-odors or insect and pest infestations, and a low breakage rate or high rate

When milled, grains that have too high of a moisture content cannot withstand the milling pressure and will break. Grains that have too low of a moisture content become brittle and will lead to even greater breakage rates. Rice with long and slender grains are more prone to breakage if the mill is not appropriate for that type of rice.

Section 2: Environmental Risks of Rice Production and Processing

The Rice subsector is made up of rice farms, and rice processing centers and rice mills. Rice farms, being agricultural, have different environmental implications than rice milling and processing, an agro-industrial process. The specific techniques, practices, and methods used during rice farming and rice 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.

Rice Farming

Cultivating and processing rice is profitable business venture. However, like with other kinds of farming, the decisions farmers make about how and where to plant, what agronomic practices are being used, how fertilizers, pesticides, and weedicides are managed, and the mindset of the farmer can all impact the sustainability of a farm, and ultimately the performance of the farm to deliver profits. Other long term impacts from and on rice farming are Climate Change and Land Use Change, which are significant for local and global environmental systems.

The major environmental risks facing rice farming are:

Climate Change is an important, long term, environmental risk for rice farmers. Rice farming practices can contribute to the causes of climate change, as well as be exposed to risk and uncertainty from climate change (pg. 12).

However, awareness of the environment and a broader view of using natural organic resources, such as green manure (pg. 46) and compost, and improving farming practices (40) can be sustainable and minimize the impact on and from climate change.

Land Use Change (pg. 15) and the conversion of forests or other natural land into rice farms has multiple risks involved ranging from: Deforestation (18) Soil Degradation (19) Land Degradation, and Agro-chemical Pollution (21).

Burning away natural forests to clear the land will release greenhouse gases (pg. 17, 24), and degrade the environments diversity and resilience to change Wetlands that have been disturbed by land preparation can release significant amounts of methane, also a powerful greenhouse gas (17).

Rice farms are also less able to support a diverse ecology. Insects, birds, rodents, and other animals who depend on many kinds of plants to survive won't be able to live in areas that have been changed to farming land.

Chemical Pollution is always a risk when fertilizers, weedicides and pesticides are being used on a farm or plantation. To increase the yield of rice, many farmers use fertilizers to unnaturally increase the concentration of plant nutrients in the soil, instead of organic nutrients and green manure.

Irresponsible or improper use of chemical fertilizers can cause chemical pollution in the environment leading to several additional environmental risks (pg. 21).

Rice Processing

Processing rice into its final milled product, or other techniques like parboiling have their own unique environmental risks attached to them. Because these kinds of enterprises are agro-industrial, rather than strictly agricultural, the environmental impacts are more closely related to what kinds of fuel and other natural resources are used and the ways that the waste products are managed.

Broadly, the environmental risks from Rice processing are:

Deforestation partially comes from the use of firewood and charcoal unsustainably during processing of any sort. In rice parboiling, firewood is often used as a fuel, adding additional pressure on forests to provide wood in abundance. Often, trees that are cut are not replaced by new trees, contributing to the decline of forests in the area (pg. 18).

Waste Pollution from the by-product and waste products of rice processing, such as the rice husks, and rice stalks, have specific physical and chemical properties that can damage the environment. Re-using these products can

generate new employment and business opportunities, avoiding unnecessary pollution in the process (pg. 21).

Air Pollution from burning waste, like rice husks is also a significant concern for the environment. The small particles, and smoke fumes are also a potential hazard to rice processors and waste disposal workers. Burning waste is often unavoidable, but better understanding of how to recycle and reprocess waste products can encourage more sustainable practices and green business (pg. 24).

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.

- **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 (CH_4)** 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 produce methane.
- **Nitrous Oxide (N_2O)** 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; converting wetlands into new farms disturbs the waterlogged soils and causes the production of methane when the land is prepared for farming;
- 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 1).

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.

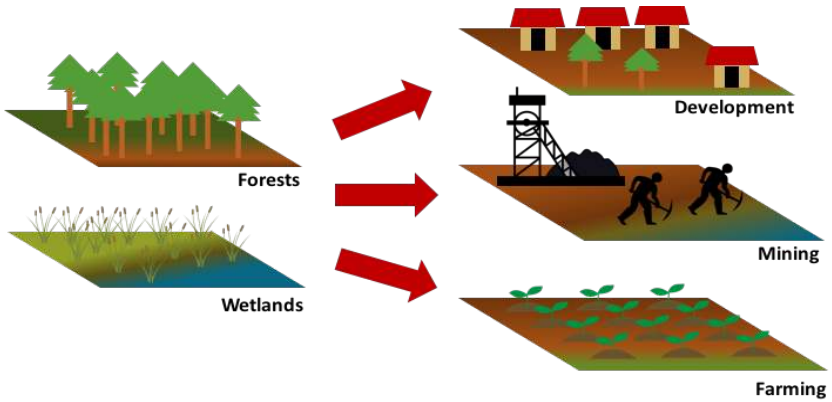

Figure 1) Diagram of Land Use Change of Forests and Wetlands into new land uses.

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.

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, posing a serious risk to the climate.

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. Too many farms and too few wetlands 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.

Rice farms are often started in newly deforested or recently cleared wetland areas. As native lands are cleared to make room for economically productive farms and plantations, the important Beneficial Ecosystem services that are provided by the forests are diminished or destroyed entirely. Rice farms are less ecologically diverse than the forests the replace, reducing the carbon storage capacity of the soils, and increasing the pressure on natural systems to continue to provide beneficial ecosystem services.

Soil Degradation

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

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

- Over tilling, or disrupting, the soil can spread organic matter and bacteria too thinly among the mineral soil, or disturbing the natural balance of soil contents or bury the soil in poor-quality clay.
- Removing plants can expose the soil to rain and wind, which can carry the top soil and leave only the barren rocky clay beneath.
- Soils can lose plant nutrients and organic matter when crops are grown without replenishing the organic matter and nutrients. Chemicals can temporarily replace plant nutrients, but this does little to improve the organic matter content, or soil stability. Chemicals can also be washed out of the soil because of the rain, in a process called 'runoff ' (pg. 25) or leaching.
- Over irrigation can lead to soils becoming too salty to support healthy farms. Natural salt in the water is left behind when the water evaporates, degrading the quality of the soil.
- Soils in low-lying areas that are prone to flooding can become

- waterlogged, where to much water prevents air from reaching the roots. This can cause crops to rot, releasing methane and other greenhouse gases.

Eutrophication

Eutrophication is when a body of water, like a lake, stream or river becomes polluted with mineral fertilizers, plant nutrients, or organic waste products. In rice farms, the closeness with freshwater ways, and the use of flood waters for irrigation makes the risk of transporting high concentrations of mineral fertilizers very high.

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.
3. Natural bacteria in the water consume and decompose the dying algae, which uses oxygen in the process. 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.
4. In the long term, eutrophication can cause significant damage to wetland ecologies, rivers or lakes (see Figure 2).

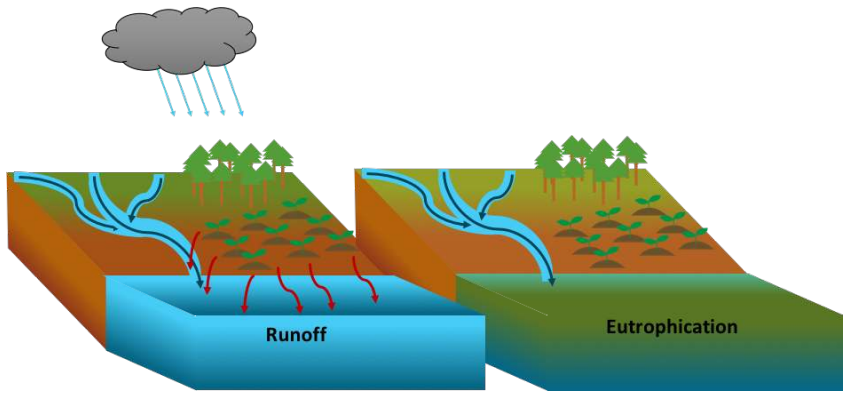

Figure 2) Agro-chemicals and mineral fertilizers can runoff into local waterways, causing eutrophication.

Waste Products and Pollution

Waste products from the rice sector are varied, and include solid organic waste, liquid organic waste, and various types of inorganic waste products (see Figure 3). The various kinds of waste products from farming and milling rice have different chemical properties, and different implications for the environment.

	Solid Waste	Liquid Waste
Organic waste	**Solid Organic Waste** Rice Stalks Rice Chaff Rice Husks Rice Bran Broken rice grains	**Liquid Organic Waste** Parboiling waste water
Inorganic waste	**Solid Inorganic Waste** Agrochemical Containers Plastic packaging	**Liquid Inorganic Waste** Agrochemical Runoff

Figure 3) Four types of waste products can be created from rice production.

The most common types of waste, by volume and mass, are the rice husks and various residues left over from harvesting. Solid organic wastes, by nature, are more durable in the environment, but do offer unique properties that make the wastes useful for other purposes. Alternatively, burning or dumping the waste products with no further use for them is ultimately wasteful and disregards the potential value the waste products have.

Waste Products

Cultivating rice and processing it into a final product produces several organic by-products, or waste products. These waste products include: rice stalks, rice husks, rice bran, wastewater from parboiling, and ash from burning agric residues. Other minor waste products might include plastic containers for fertilizers or pesticides, poly-sacs and tarpaulins that are torn or spoilt, and other kinds of plastics.

The rice straw is a solid organic waste product, consisting of the rice leaves, stems and other residues. When harvesting the paddy rice, the rice plant, with the

rice grains still attached, are removed from the field and taken to a threshing site. After threshing, the remaining waste straw is often burned onsite or used as green manure in the field. Winnowing, or using the wind to blow away smaller bits of debris are a secondary waste product created after harvesting the paddy rice.

The waste products come from the milling of rice are mostly solid organic wastes, but parboiling also creates waste water. Large rice mills have dedicated locations where the rice hulls and the bran layer are removed from the rice grain and dumped separately. These waste products are often burned on site or nearby for final disposal. Burning waste products is an inefficient and wasteful method of disposal, and creates large amounts of greenhouse gases without producing any other products or useful purposes. Waste water is a minimal waste product, and has high concentrations of organic matter which, in the right circumstances, can contribute to eutrophication (pg. 20).

These waste products, especially the rice husk, can be recycled and reused in a variety of ways, both on and off the farm. Coordination and organization of waste generated in the field, and waste generated at the rice mill can provide unique green economic opportunities (pg. 40).

Other waste products that may be created from rice farming and processing are various plastic containers or fertilizers, pesticides and weedicides, plastic bits from drying tarpaulins, worn and torn nets for keeping off pests, and other solid inorganic wastes. These waste products are handled like many other kinds of trash in Ghana. Sometimes these plastics maybe handled well and disposed of through formal bins and refuse containers, or otherwise dumped and burned in the environment with the other refuse. This creates toxic smoke and greenhouse gases and is generally an irresponsible way of managing waste.

For techniques like parboiling (pg. 55), the wastewater from the boiling process can be dumped into the environment with no consideration of the environmental impact or potential reuses for the water.

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 rice straw, rice husks, 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 wastewater from parboiling, is also potentially dangerous to the environment. Liquid organic wastes contain large amounts of Organic matter, which can cause eutrophication to nearby water bodies if the waste water is irresponsibly dumped.

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.

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

long-term, exposure to these chemicals can have serious health effects over time.

Burning Waste

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

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

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

These inorganic chemicals are known to be highly toxic and cancerous, especially to woman and children. Long term chronic (long-term) exposure to these 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 4).

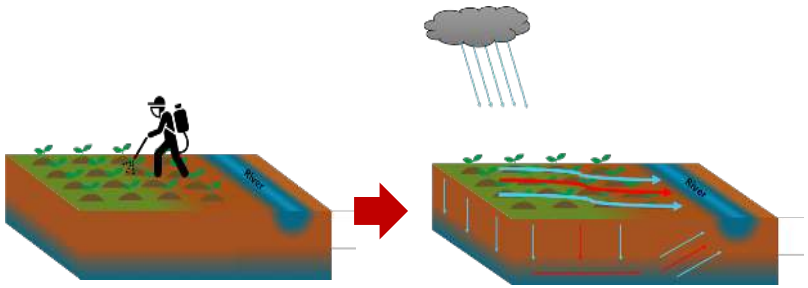

Figure 4) Diagram of Agro-chemicals moving into local waterways via runoff.

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. Some of the chemicals will pass through the body without harm, some of the chemicals will not.

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. Not all of these are relevant to the rice sector, but are nonetheless important to understand:

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

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

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

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

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

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

Section 3: Green Economy

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

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

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

Ghana, as well as many other Nations have begun to understand the pressing nature of climate change, and the immediate need for more sustainable

economies, societies, and environments. Establishing and supporting the Development of a Green Economy requires cooperation from all levels of government, from businesses and enterprises of all sizes, and from individuals in their unique capacity.

The information in this section will guide readers through:

Principles of Green Economy

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

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

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

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

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

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

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

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

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

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

The Economy, Society and the Environment

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 5).

A few basic terms are needed and they are defined below:

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

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

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

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

- **Technology**: Machines and technological equipment help a business operate faster and with more quality control. They allow work to be done more efficiently and with less mistakes or errors.

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

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

- 'Society' collects '**Natural Resources'** from the environment and the 'Economy' distributes these natural resources to various sectors and businesses to produce and manufacture any number of goods, product, and services for sale. The economy consumes (purchases) these products and services
- As businesses process the natural resources, by-products are created and often dumped into the environment or burned. These actions have **'Environmental Outcomes'**, or effects on the environment.

Figure 5 shows the relationship between the three components of a community, the Economy, Society and the Environment.

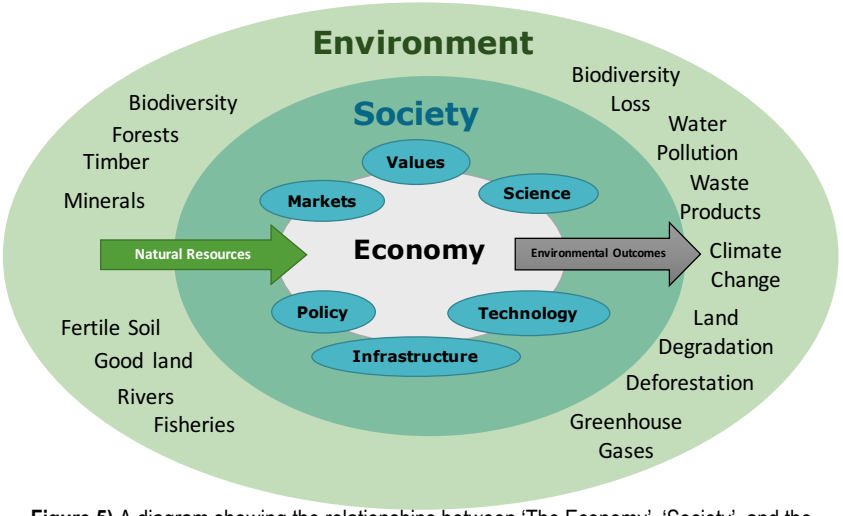

Figure 5) A diagram showing the relationships between 'The Economy', 'Society', and the 'Environment' and how 'Natural Resources' are transformed to cause 'Environmental Outcomes'.

- 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.

Outcomes of a Green Economy

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

- **Building Social Equality** – Equality between women and men; building opportunities for the youth; improving incomes for the poor.
- **Improve Human-well-being** – Healthier living areas for people; using natural resources sustainably so the next generation can use them.
- **Reducing Environmental Risk –** Preventing deforestation; reducing pollution in the environment; recycling waste products instead of dumping.

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

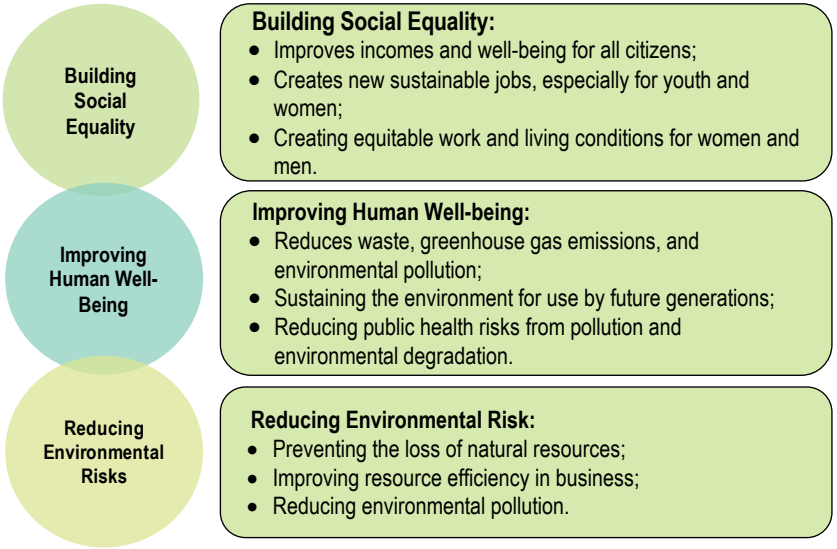

Figure 6) Building social equality, improving human well-being, and reducing environmental risks, are all part of a Green Economy.

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.

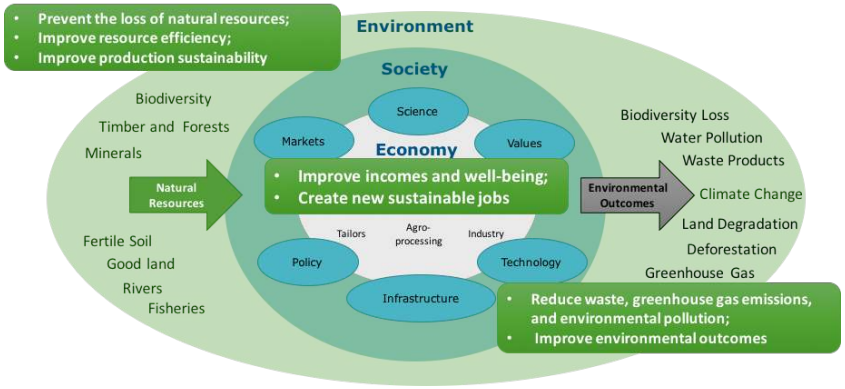

Figure 7) A diagram showing the relationships between 'The Economy', 'Society', and the 'Environment' and how Green Economy can be incorporated.

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 8).

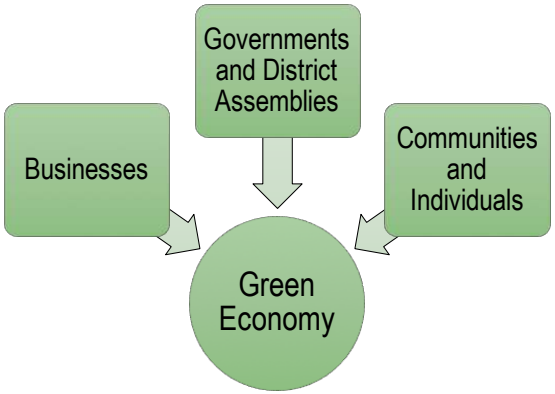

Figure 8) Green Economies need the support of Businesses, local governments, and communities and individuals to grow and be successful.

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

- Integrating new values into business like environmental sustainability and practicing resource efficiency. Businesses should value being sustainable just as much as being profitable, and be proud of making their business green and environmentally friendly.
- Protecting the environment from hazardous and toxic waste by re-using and reducing waste. This keeps the environment from being polluted when the waste is dumped and can provide additional sources of income.
- Incorporating new science and technology into the business to make it more sustainable and efficient can be an effective way of reducing waste and creating new green jobs for women and youth.
- Developing new products to support developing new markets for sustainable products and services. When new technologies and business are developed, the markets for new products will develop too. The products from these new businesses can be sold to other businesses to create new opportunities.
- Petition the government to support Green Economy and invest in Green Infrastructure. Speak with local politicians to encourage them to support Green Economy and green investment for the community.

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

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

- Providing education about the environment, sustainability, and green practices supports entrepreneurs to incorporate environmental considerations into their lives and businesses.

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

- Ensuring that children go to school and better their education can be a way to ensure that they receive knowledge to better their lives and environments.
- Participating in government decision making, attending District assembly meetings, and voicing concerns about the environment and Green economy encourages the District Assemblies to make sustainable decisions. If you don't speak up, the government won't listen.
- Practicing sustainability in the home by purchasing sustainable products and properly disposing of household waste can develop a culture of good environmental practices in the community. Being a good example to neighbors helps build a green economy.
- Encouraging family and friends to purchase products from sustainable businesses can create new markets for green products and encourages businesses to continue to incorporate sustainable practices into their businesses.

Section 4: Green Economic Strategies

To develop a Green Economy, it helps to understanding what a Green Economy is (pg. 28), how it functionally relates to various components of a region's Economy, Society and Environment (35) and what means of support can individuals, businesses, and governments can provide to develop a Green Economy (37).

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

Rice Farming

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

Resource, Energy, and Environmental Conservation is about conserving, 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. 15) 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 (pg. 43). 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 (20).

Organic fertilizers (pg. 46) like compost, is a natural form of plant fertilizers. Though not always as potent as artificial fertilizers, organic fertilizers like compost or waste plant material are under-utilized resources and are 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 (47).

Weed and Pest 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.

Organic alternatives for pesticides also exist. Neem extracts (pg. 52) and Integrated Pest Management (IPM) systems (49) are environmentally friendly alternatives to toxic insecticides and pesticides, which have high environmental risks associated with them.

Alternative methods of controlling weeds is possible, and can result in improved conservation of resources and the environment (pg. 50).

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

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

Fertilizers

Because soils in Africa, and Ghana, are very old and fragile, fertilizers often need to be applied to supplement the natural concentrations of Nitrogen (N), Potassium (P), Phosphorous (K), and other trace nutrients. Nutrients for plant growth can come from *artificial/chemical* fertilizers, or *organic* fertilizers in the form of green manure and organic matter. The environmental risks for chemical fertilizers or organic fertilizers differ (pg. 43).

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 (see Table 3).

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

	Moisture	N	P	K	Ca	Mg	S
Organic Fertilizers	%			% of Dry Matter			
Cattle Manure	68.2	1.85	0.81	1.69	1.54	0.62	0.29
Pig Manure	60	2.04	1.38	1.38	-	-	-
Chicken Manure	43	2.91	1.37	1.54	4.56	0.83	-
Sheep Manure	-	3	0.62	2.68	1.72	0.86	0.43
Human Manure	-	1.2	0.06	0.21	-	-	-
City/rural Compost	0	1.16	0.37	0.9	-	-	-
Rice straw Compost	73.6	1.07	0.19	0.69	-	-	-
Peanut Stems + leaves (compost)	58.6	0.81	0.1	0.38	-	-	-
Water Hyacinth	-	2	1	2.3	-	-	-
Wood Ash	-	-	0.87	4.17	-	2.1	0.4
Inorganic Fertilizers							
Urea	0	46	0	0	0	0	0
Ammonium Sulphate	0	21	0	0	0	0	24
Ammonium Nitrate	0	33	0	0	0	0	0
Mono-ammonium Phosphate (MAP)	0	11	21	0	0	0	0
Di-ammonium Phosphate (DAP)	0	18	20	0	0	0	0
Triple superphosphate	0	0	20	0	14	0	0
Single Super Phosphate	0	0	8	0	19	0	11
Basic Slag	0	0	6	0	37	1	0
Potassium Chloride	0	0	0	50	0	0	0
Potassium Sulphate	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
Calcific 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.

Chemical and Mineral Fertilizers

Chemical and mineral fertilizers are known to rapidly and unsustainably increase the yields of crops. Typically, most mineral fertilizers contain a specific ratio of Nitrogen (N), Phosphorous (P) and Potassium (K) that is suitable for the type of crops being grown and the natural concentrations of plant nutrients in the soil.

However, even though the mineral fertilizers can rapidly increase the concentration of nutrients in the soil, other important additions like organic matter are not added with chemical fertilizers. The lack of organic matter in the soils reduces the ability of the soils to retain water and plant nutrients. Rain and irrigation water can wash away the fertilizers and carry them into local waterways via runoff, potentially causing eutrophication. Additionally, the fertilizers must be added every year to obtain the benefits. Yields will rapidly decline the year after fertilizers are added, as opposed to organic fertilizers which can increase yields for several years in a row.

If chemical fertilizers are going to be used, being mindful of several key techniques can lower the amount of fertilizer usage and ultimately fertilizer waste and pollution. 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 or utilizing Fertilizer Deep Placement methods (48);
- Using the correct type and amounts of mineral fertilizers;
- Intercropping with legumes, such as groundnuts or soybeans, and green manuring legume crop residues before rice planting to improve soil fertility and nutrient retention;
- Storing fertilizer containers in cool, dry places ensuring that water is not leaking into the chemicals;
- Properly disposing of used fertilizer containers to prevent polluting the environment.

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

Organic Fertilizers

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

Green Manure

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

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. 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 generally can be made simply by adding 2-3:1 brown compost material to green compost material (see Table 4). Other compost material should be added as well in appropriate quantities. Layer brown and green compost material into a pile with a few shovels of local soil to introduce beneficial bacteria. Water the compost pile regularly, maintaining sufficient moisture (a handful of compost should drip only a few drops when squeezed by hand).

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

Table 4) Basic types of compostable material.

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

Composting Rice Waste

Waste products from rice, such as the rice straw, are low in Nitrogen (N) and Phosphorous (P), but are high in micronutrients like Calcium (Ca) and potassium (K). Rice waste can and should be used as an organic fertilizer, but additions of nitrogen are needed to make a high quality compost for rice farming.

Both the rice hull/husk and the rice straw can be used to make compost, along with other compost ingredients. A good site for making compost should be level ground, shaded, and have good water drainage. Organic wastes like straw should be cut down to pieces about 5-8 cm in length. Making and using a Micro organism solution to keep the compost moist will help decompose the waste into fertilizer quickly.

Rice hulls and straw should be layered with cow manure or legume residues, where cow manure, Effective Micro-organism solution (pg. ##), cow manure slurry (cow manure mixed with water), a diluted solution of urea or other nitrogen fertilizer. Cow manure and legume residues are high in nitrogen and will help balance the nutrient content of the fertilizer. Rice straw and other brown compost should be used in a 2:1 ratio with green manures, like cow manure or legume restudies and other green wastes.

The compost pile should be kept moist. The compost pile should not be draining water, but not so dry that rice straws will crack and break when bent.

With this simple method, a good quality organic fertilizer will be ready for use in 4-8 weeks

Effective Micro-organism Solution

Effective Micro-organism solution is a solution made from a concentrated solution of micro organisms that is mixed with water and molasses to create a large volume of EM solution for composting. EM Solution can be purchased from agricultural supply businesses (often called EM-1) however it is also possible to make a micro-organism solution if commercial products are not available. EM Solution is similar to Indigenous Micro-organism Solution (IMO, Pg. 60), where IMO is an EM solution made with locally available (or *Indigenous)* materials.

Fertilizer Deep Placement

Other techniques like Fertilizer Deep Placement (FDP) utilizes pellet cakes of chemical fertilizers, which are much larger than the granulated fertilizers that are often used by farmers. Most commonly, Urea, as Urea Super granule, are used for rice farms.

A single fertilizer cake (1-3 grams per cake) is centered between 4 rice plants, spaced about 40 cm apart, and buried between 7-10 cm of soil (see Figure 9). This method of fertilizing slowly releases fertilizers for the rice to absorb, reducing runoff and fertilizer loss and minimizing the amount of fertilizer needed. This method is known to be more efficient than broadcasting granulated fertilizers, because it reduces fertilizer losses to the air and water, increasing efficiency and reducing environmental risks.

Figure 9) Basic Diagram of Urea Deep Placement spacing in a rice paddy.

Integrated Pest Management Systems

Pests are a common occurrence on rice farms, lowering yields and causing problems for farmers. Pests in rice farms can include: *Quelea Quelea* Birds (Weaver Birds), various soil-borne insects and other grubs and worms, rats, and fungi.

These pests can damage rice plants during seedling stages, growth stages, reproductive stages, and can damage the rice grains before harvesting. Many different methods for controlling pest outbreaks exist, and can be cultural, biological, genetic, chemical, or a mix of different methods called integrated pest management.

- **Cultural measures** such as planting early maturing varieties of rice that mature earlier than the egg-laying season for common rice pests; plowing the fields while the field is still wet or soon after the harvesting stage can disturb eggs and pest larvae in the soils, reducing their numbers and diminishing their effects on rice yields; Increasing rice density can also lower pest numbers since insects are more prevalent in sparsely planted fields. For birds, using slingshots and clay pellets are one method of keeping birds away as well. However, methods of scaring away birds with loud sounds or sound making devices might also be a non-damaging way to control birds.
- **Biological measures** such as cultivating and growing the natural predators of damaging insects is an effective way of reducing pest numbers. Finding the correct species to cultivate for the western Region will take some expertise and experimentation to develop effective control measures.
- **Chemical measures** such as commercially-available pesticides and poisons are designed to be highly-effective way of killing pests, but these methods can have a negative impact on other animals and beneficial insects. Neem extract (pg. 52) can be a more environmentally friendly pesticide for insects, but could have limited use for different kinds of pests. It is important to understand that reliance on chemical pesticides is dangerous in the long term due to the potential for chemical contamination.
- **Genetic measures** for managing pests include using pest resistant varieties of rice and cultivating species that are the natural predators of pests.
- **Integrated Pest Management (IPM)** is the most sustainable form of pest management since it uses a combination of different pest control measures to keep losses from pests below a certain economically damaging threshold. Different strategies are used during different phases of preparing land and growing rice. The different control measures ensures that the potential damage from various chemicals are minimized and that more sustainable methods of pest control are used as often as possible.

Weed Management

Weeds and other unwanted plants growing on a commercial rice are in direct competition with the young plans for nutrients, root space, and sunlight. Improper or inadequate field maintenance of rice farm can delay dramatically lower yields and reduce income to the farmer.

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

  Integrating sheep or cattle to graze in the plantation can also remove weeds while also adding nutrients through their droppings.
- **Genetic Measures** like growing genetically improved varieties of rice or collecting and cultivating the natural enemies of pests, such as specific viruses or bacteria can be effective weed control measures.
- **Chemical Measures** like pre-emergence herbicides and contact herbicides are designed to target specific varieties of plants, but have very high emotional risks associated with their use. Careful control and management of chemicals is needed to prevent environmental damage.
- **Integrated Control Measures** is any combination of the other four control measures. Farmers will need to experiment with different kinds of weed control measures, incorporating good farming practices and environmental responsibility.

Organic Pesticides

Organic pesticides and insecticides can be prepared at home with commonly available plants. Organic pesticides are a more sustainable choice for reducing insect and various other bacterial and fungal infestations on many kinds of farms and plantations. Unlike synthetic, or artificial, chemical insecticides and pesticides, organic pesticides do not have the dangerous environmental and human health risks. Artificial chemical pesticides have the risk of harming beneficial plants and insect species, and are known to be quite toxic to fish and bird life.

One of the oldest and most widely used plants for making organic pesticides and insecticides is the Neem Tree (*Azadiachta indica).* The active chemicals in the leaves, seeds, and fruits of the neem tree are known to be safe for humans and the environment as they can quickly and harmlessly degrade into the environment, leaving no lasting environmental effects.

The main pesticidal chemical in the neem tree is *Azadirachtin,* which has the effect of interfering with regulating hormones in insects. *Azadirachtin* can block the molting (shedding old skin) of juvenile insects, reduce the feeding and breeding habits of adult insects, and cause other interruptions for harmful pests. This is different than synthetic chemicals in that synthetic chemicals directly attack and disable the nervous system of insects, killing them quickly. On the other hand, neem pesticides reduce the insects ability to grow and reproduce, lowering the insect population more slowly and methodically. To some farmers, it may appear that the neem extract doesn't work as well as synthetic chemicals, but in reality the timescale for the neem pesticide to be effective is much longer.

Neem is non-toxic to humans, plants, and animals, and beneficial insects like pollinators such as bees. This is because the neem pesticide only works if the chemicals are eaten. Neem cake, made from the seeds of the neem tree can be added as a soil amendment, adding organic nutrients to the soil and providing natural defense against soil-borne pests like green leafhopper (Nephotettix spp.), various kinds of root fungal growth, and soil-based nematodes. However, neem extract can be a risk to aquatic insects, it is best to never apply neem directly to water or to wetlands.

Storing rice and other grains in poly jute bags treated with neem extract, stored with dried neem leaves between bags and on the floor, or adding 2% powdered neem seed kernels, leaves, or stems to the harvested rice can all protect the stored rice from insect infestation for many months.

Preparation of Neem Extract

The concentration of the active compound in the neem tree, *Azadirachtin,* can vary from place to place and from season to season. Careful monitoring and controlled experiments of how best to apply neem extracts and insecticides, and which insects the neem is best suited for must be conducted before extensively using neem. Using neem in combination with various other kinds of pest control strategies, or Integrated Pest Management, can be an effective and quite sustainable solution to farmers.

Neem Leaves Extract:

1) Boil two handfuls of Neem leaves with 1 litre of water; this can be scaled up or down depending on the needs of the farmer;
2) Allow the water and neem leaves to gently boil for 30-40 minutes, stirring occasionally; Remove the flame and allow the mixture to cool after the leaves have boiled well.
3) Separate the leaves from the liquid, and compost the leaves. The resulting liquid mixture can be applied directly to the plants through a sprayer pack or other means.

Neem Kernel Extract:

About 3-5kg of neem seeds is needed per acre using this method, fresher seeds are more potent than old seeds. Similarly, 10-15kg of dried neem fruit powder can be used instead. The concentration of the formula can be adjusted depending on the severity of infestation. Before soaking the seeds in the water, be sure to remove the outer seed coat, leaving only the kernel.

1) Collect and shade dry 10kg-15kg of neem fruits in the shade; collect around 5 kg of kernels from the fruit or use the dried and powdered fruits for the extraction. Don't use seeds that are over 8 months old, as they have lost their active chemicals;
2) Soak 5kg of neem seeds in 10 litres of water overnight, or for at least 8 hours;
3) Stir and grind the seeds in the water until the water becomes milky white and very cloudy;
4) Strain the solution through a fine cloth (double layer of muslin cloth) and

squeeze any remaining liquid out of the cloth. The seeds can be composted to protect and improve the soils. To the milky white liquid, add water until a total volume of 100 litres is reached.

5) Add 100 grams of detergent to a small amount of water to make a detergent paste; add the detergent paste to the now diluted neem liquid from the last step. This should be enough to cover well one acre of land.

Always use fresh neem extract for spraying. It is advised to spray the pesticides past 3:30pm for best results. The detergent soap in the formula acts to help the liquid stick to plant leaves.

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 (pg. 15), 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 (pg. 18), soil erosion and degradation (19) 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 (pg. 46);
- 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 (pg. 20);
- Practice intensification rather than extensification to protect against Land Use Change (pg. 15) and deforestation (18).
- 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.

Rice Processing

Rice processing is an agro-industrial process, which differs from rice farming in terms of the Green Economic Opportunities available. Value-added production processes, and various ways of recycling rice waste like rice straw and husks are relatively simple procedures and can help develop new business opportunities.

Par-Boiling

Par-boiling means partially cooking the paddy rice, then proceeding to dry and mill the rice later. Par-boiling is a common practice that has many benefits for improving the quality of rice. When rice is par-boiled, the molecules and proteins in the rice grain will re-arrange themselves, forming a more cohesive rice grain. The boiling water also transfers some of the nutrients from the rice bran, which is normally milled away, into the rice grain.

Par-boing also acts to repair small cracks in the rice grain that may have been caused during or after harvesting, increasing the final quality of the rice. After par-boiling, the milled grains will be harder, appear glassier or whiter, improving the quality. Rice that has been par-boiled will also cook faster, be firmer and less sticky when it is cooked, again improving the overall quality of the rice.

The basic equipment for par boiling rice are:

- Paddy rice (rice with the husk still attached);
- Cooking stove;
- 40L aluminum cooking pot;
- a par boiler (see Figure 10);
- Clean water;
- Firewood or fuel;
- Tarpaulin;
- Two containers for washing;
- A Clean stirring paddle;
- A draining basket;
- And a scooping bucket or bowl.

The parboiler is the most important piece of equipment for this method. A par boiler is a stainless steel or aluminum pot with holes in the bottom to allow steam to pass through the parboiler. The par boiler sits on top of a large cooking pot, where water is boiled into steam. A simple diagram can be seen in Figure 10.

The basic steps of par-boiling rice can be divided into 10 steps:

1) Cleaning the paddy rice must be done to remove stones, sticks, dust, immature grains, insects and other unwanted debris. This can be done by gently tossing the paddy rice into the air, allowing the wind to blow off lighter, and unwanted materials;

2) Pour the paddy rice into a large container and cover the paddy rice completely with clean water. Proceed to hand wash the rice grains by gently

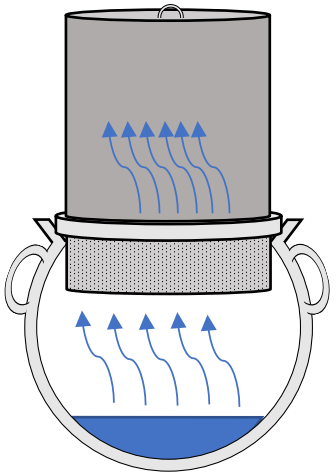

Figure 10) Cross-section diagram of a basic rice par-boiler.

2) (cont.) rubbing large handfuls of rice together. Allow the rice to settle in the water for a moment before removing anything that floats in the water. Immature grains and debris will float in the water;

3) Drain of the water that was used to wash the rice and add fresh, clean water to the rice. Wash and stir the rice again, repeating the washing and draining until there is no more debris or unwanted material left.

4) Once the rice is cleaned, drain of half the water in the container. Carefully remove the rice by hand and place the rice into a separate container, making sure that the stones and dirt at the bottom of the container are left behind.

5) Fill the large cooking pot with water and start the fire beneath. Add the cleaned rice to the water, allowing the water to heat up the rice. Stir the rice occasionally, making sure it is mixed and heated evenly. Do not allow the water to boil. Use your fingers to check the temperature of the water and to know when to remove the rice. When the water is too hot to dip your fingers into, remove the cooking pot from the fire and allow the pot to rest and cool overnight. Make sure that the rice remains underwater for the whole night.

   If the cooking pot needs to be reused, remove the rice paddy and the hot water to a separate container and allow the rice to cool underwater overnight.

6) The following morning, remove any floating debris from the surface of the water, then remove and drain the rice in a basket.

7) Fill the 40L cooking pot with about 10 centimeters of water, this water will be used as steam for the rice.

   Place the parboiler above the cooking pot, to allow the steam to rise into the parboiler. Do not let the bottom of the parboiler touch the water in the cooking pot.

8) Place the drained paddy rice into the parboiler and cover the rice with a polybag or burlap sack and put the lid on the par boiler. The lid should fit tightly and be secured downward with a stone or strap. Fill the gaps between the cooking pot and the parboiler with a clean cloth – this will prevent steam from escaping. Be sure to leave enough room in the par boiler for the rice to expand.

9) After about 30 minutes of steaming, check the paddy rice. You can tell that the rice paddy is finished if most of the rice grain husks on the top of the pile have opened. Remove the rice paddy from the par boiler when it is finished

10) Spread the rice grains on a cement drying patio, tarpaulin, or drying space. Spread the rice thinly over the drying space and allow to dry according to good drying practices. Once the rice is appropriately dry, the rice is ready for milling.

Rice Husk Ash

Rice hulls are the parchment like covering of the rice grain that is removed during the first stage of rice milling. Rice husks have several important chemical properties that allow it to be used in novel and sustainable ways, creating new opportunities for rice farmers and rice millers.

Rice hulls are a major source of waste from the rice industry, accounting for about 20% of the total mass of threshed rice, before it is milled. One of the most surprising features of rice hulls is that, when burned in a controlled fashion, will produce, 'Amorphous Silicates (SiO2)'. Silicon, the basis for silicates, are an important structural component of rice, but is also a main component of sand, chemically speaking. When rice husks are burned in a controlled fashion, the ash can be added to cement to improve the physical and material performance of

cement blocks and other cement product by helping bind together the stones and cement.

Using rice hull ash can be an economically productive way of recycling rice hulls and offset the demand for cement, which can reduce costs and lower the environmental footprint of businesses.

Rice hull ash, when prepared well, can replace between 15-25% of the cement by mass. This can dramatically lower the raw materials cost for block makers and construction projects by reducing the cost of the cement required. The optimal amount of rice hull ash in the cement mixture will take some experimentation and testing to determine.

Open and uncontrolled burning of rice hull ash does not produce a high-quality building material. However, developing an improved Rice Husk Furnace can improve the burning process, producing a high-quality concrete supplement (see figure 11).

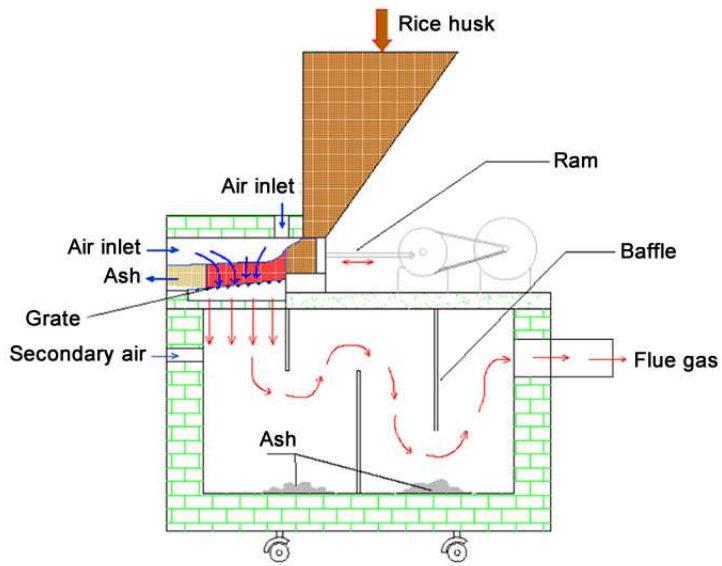

Figure 11) Basic cross-section diagram of the International Rice Research Institute (IRRI) Rice Hull Ash furnace.

Deep-Litter Beds

Deep-litter beds for pigs are a method of producing organic manure, managing waste and manure from pigs, recycling agric waste such as rice husks, groundnut shells, and maize cob. In its simplest terms, edible agric waste, such as rice husks and rice bran, maize cob, ground nut shells, and/or cassava peels, are used to create a deep pig pen. Over time, the organic waste is decomposed by Indigenous Micro Organisms (IMOs) to become high-quality organic fertilizer (see Figures 12,13).

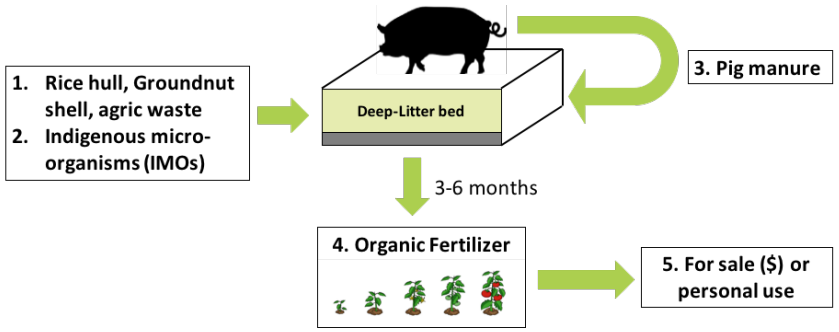

Figure 12) Basic flow diagram of Deep-Littering for pigs.

Deep litter beds can be done in a variety of ways and utilize many kinds of organic matter and be an effective way of managing pig manure. Untreated and raw manure from pig farms can pollute freshwater. Rainfall and irrigation move manure into lakes and rivers through runoff. Raw pig manure contains high levels of, Nitrates and phosphates, Disease-causing bacteria, intestinal worms and parasite eggs. However, using deep litter beds can manage and mitigate the potential risks from pig manure, and create useful organic fertilizer after 3-6 months (see Figures 12, 13).

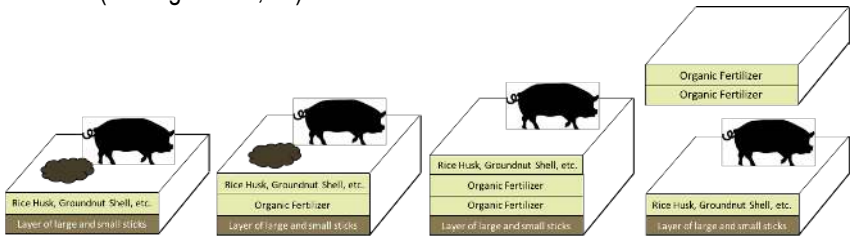

Figure 13) Process of Deep-litter beds creating organic fertilizer.

To make a deep-litter bed:

1) Dig into the ground, about one meter deep, for the whole area of the pig pen;
2) Layer small and large sticks at the bottom of the deep litter bed, about 20-30 cm deep, to create an area for water drainage, and to prevent water logged conditions at the bottom of the pen;
3) Mix 10 parts organic waste, like rice husks, groundnut shells, maize cob, cassava peels, and other organic waste products with 1 part local soil and 0.3 parts sea salt.
4) Apply the IMO solution to the top of the deep litter bed.
5) Add new layers of agric waste and soil to the top of the litter bed every week to cover up feces and wet spots. Water the top of the litter bed after adding new materials with the IMO solution.
6) After continuously adding waste and IMO to the deep litter bed, a sufficient amount of organic fertilizer should be ready for use. Shovel out the fertilizer and restart the deep – litter bed for the next batch of pigs.

Making IMO Solution:

Indigenous Micro Organisms (IMOs) are the key to making an effective deep litter bed for pigs. The micro organisms help decompose the pig manure and agric waste into a healthy organic fertilizer, and will help minimize the smell in the pig pen. The pig pen will also be more sanitary for both the farmer and the livestock. Many different kinds of IMO solutions exist and farmers can experiment to determine which method and recipe works the best for them.

1) Boil 20kg of a carbohydrate food with 200g of salt until ready (Cassava, rice, plantain, banana, yams, potatoes, etc.);
2) After cooling, mash the food into a fine paste and roll into balls about the size of a fist (or ball of Banku);
3) Gather the balls of mash and tie them in a net and bury it about 5-8 cm down, preferably in a shady area, and underneath a tree. Leave the balls of mash to rest underground for 4-5 days.
4) After 4-5 days have past, check the balls. The balls should be covered in a white mold. If the mold is sparse, bury again and wait another day or two. If the mold is not the white color, an inferior mold has grown and the process should be restarted.

5) If ready, these balls of mash are now the starter culture for the IMO solution. For every 2kg of mash, add 500g of brown sugar and mix very well.

6) Put this mixture in a bucket and cover with a net to allow air flow, and let the bucket rest for 5-7 days in a cool, shaded area. During this time the mixture will turn black with no smell.

7) Add 5% by weight, maize bran, wheat bran, or rice bran to the black IMO solution and mix well. This is now the concentrated IMO solution. The solution should be diluted down to 1 part IMO Solution to 200 parts of water. Once mixed with water, the solution is good for 10 days.

This recipe for IMO can also be used to make Effective Organism solution (EM solution).

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. Rice 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

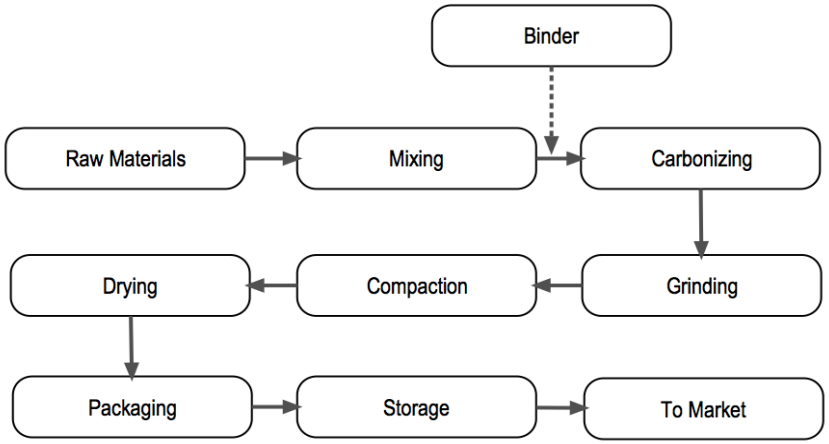

Figure 14) Flow diagram showing the basic production process of non-carbonized fuel briquettes.

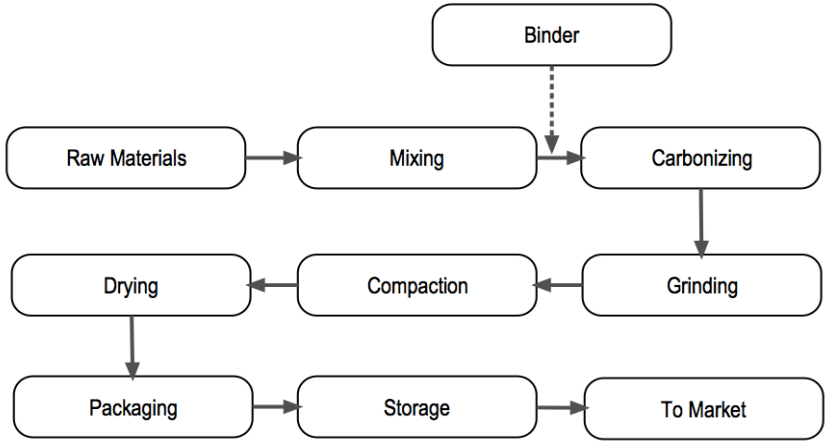

Figure 15) Flow diagram showing the basic production process of carbonized fuel briquettes.
Source: modified from A review on production, marketing and use of fuel briquettes, IWMI, 2016.

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).

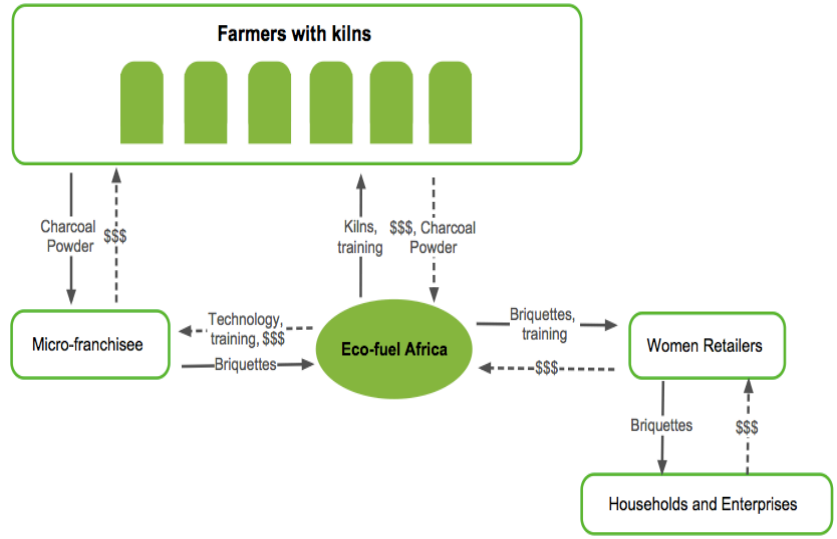

Figure 16) *Ecofuel Africa's value chain for fuel briquette production, modified from A review on production.* **Source:** Modified from *A review on production, marketing and use of fuel briquettes. IWMI, 2016.*

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.

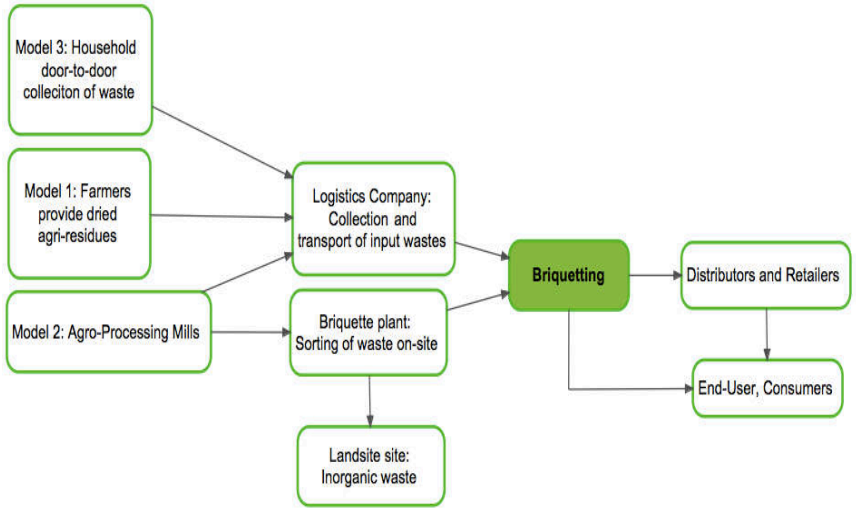

Figure 17) Diagrams of potential value chain for fuel briquette production.

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

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

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

Par Boiling Rice

Online Resources

GEM Parboiling

http://www.ricehub.org/RT/post-harvest/gem-parboiling/

New video on AfricaRice GEM rice parboiling technology

http://y2u.be/XKAfK1WXLo0

Videos

Parboiler & Husk Stove
http://y2u.be/H5P4C5MuvEE

Cashing in with parboiled rice
http://y2u.be/bNUlsnIO_1A

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

Deep Littering for Pigs

Videos

Deep Litter Pig Pen
http://y2u.be/BKlkHLVU3VI

Online Resources

Natural Pig Farming
http://www.naturalpigfarming.com/deeplitterbedflooring.htm

Pigs: The Deep-Litter Solution
http://www.thepigsite.com/articles/3464/pigs-the-deeplitter-solution/

Deep litter
https://en.wikipedia.org/wiki/Deep_litter

Deep litter system / KNF : progress pics
https://permies.com/t/69798/critters/Deep-litter-system-KNF-progress

Integrated Pest Management and Neem Extracts

Wikipedia

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

Videos

Natural Insecticide from Neem Seeds in English
http://y2u.be/t_LruzIC6vQ

How to make Organic Neem Pesticide
http://y2u.be/8rnhY1lVbuY

Online Resources

KNOWLEDGE LEVELS OF FARMERS AND USE OF INTEGRATED PEST MANAGEMENT PRACTICES IN HOHOE MUNICIPALITY

Heh, P. (2014). *KNOWLEDGE LEVELS OF FARMERS AND USE OF INTEGRATED PEST MANAGEMENT PRACTICES IN HOHOE MUNICIPALITY* (Master's thesis, University of Ghana, 2014). LEGON: UNIVERSITY OF GHANA.

Integrated Pest Management (IPM) Strategies for Nerica Rice Varieties
http://www.africarice.org/publications/nerica-comp/module%208_Low.pdf

Fuel Briquette Making

Scientific Journal Articles

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

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

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

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

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=Lql63IEg3MM

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

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

Deforestation

Videos

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

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

Wikipedia

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

Rice Hull Ash Cement

Online Resources

Recycling Blends of Rice Husk Ash and Snail Shells as Partial Replacement for Portland Cement in Building Block Production*

Nkrumah, E. and Dankwah, J. R. (2016), "Recycling Blends of Rice Husk Ash and Snail Shells as Partial Replacement for Portland Cement in Building Block Production", *Ghana Journal of Technology,* Vol. 1, No. 1, pp. 67 - 74. Retrieved from: http://www2.umat.edu.gh/gjt/index.php/gjt/article/view/11

Use of Rice Husk Ash in Concrete

Abbas, S. M., Patil, D., & Raje, S. (2015). Use of Rice Husk Ash in Concrete. *International Journal of Scientific & Engineering Research,* 6(12). Retrieved from https://www.ijser.org/researchpaper/Use-of-Rice-Husk-Ash-in-Concrete.pdf.

Videos

Rice Hull Ash
http://y2u.be/SgA3pJe9CpU

Demonstration of IRRI's semiautomatic-fed downdraft rice hull furnace (dRHF)
http://y2u.be/Um07cEViUFU

Rice husk as a by-product for concrete
http://y2u.be/p4NcwPLhykc

Making Rice Hull Charcoal
http://y2u.be/VerTekILA5c

Note Page

Note Page

Note Page

World University Services of Canada – WAGES
Line 2

World University Services of Canada – WAGES
Line 2