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SUSTAINABLE RURAL BIOENERGY SOLUTIONS IN SUB-SAHARAN AFRICA:

A collection of good practices

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SUSTAINABLE RURAL BIOENERGY SOLUTIONS IN SUB-SAHARAN AFRICA

A collection of good practices

JIRCAS

World Agroforestry Centre

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Abbreviations

ADFD: Abu Dhabi Fund for Development
ADM: Agro-Business for the Development of Mozambique *(Agro-Negócio para o desenvolvimento de Moçambique)*
AfDB: African Development Bank
AFSA: Alliance for Food Sovereignty in Africa
BC1: Backcross-1
BIP: Business Incubation Platform
BMZ: German Federal Ministry for Economic Co-operation and Development
CGIAR: Consultative Group on International Agricultural Research
CO: Carbon monoxide
CO_2: Carbon dioxide
CPTs: Candidate Plus Trees
DEMACO: Design Manufacturing and Construction Engineering Enterprises
DfID: Department for International Development (UK)
DINAF: National Directorate of Forestry, Ministry of Land, Environment and Rural Development, Mozambique
EIAR: Ethiopian Institute of Agricultural Research
FAO: Food and Agriculture Organisation of the United Nations
FFFS: Farm forestry field schools
FFS: Farmer field schools
fNRB: Fraction of non-renewable biomass (NRB)
FRELs: Forest reference emission levels
FRG: Farmer research groups
FRLs: Forest reference levels
FSP: Financial service provider
G: Gram
GBEP: Global Bioenergy Partnership
GDI: Gender-related Development Index
GHG: Greenhouse gas
GIS: Geographic information system
GIZ: German Association for International Co-operation
GJ: Gigajoules
GSIs: GBEP's Sustainability Indicators for Bioenergy
H_2: Hydrogen
Ha: Hectare
HDI: Human Development Index
IC card: Integrated Circuit card
ICRAF: World Agroforestry Center
IFAD: International Fund for Agricultural Development
IFC: International Finance Corporation
IITA: International Institute of Tropical Agriculture
IRENA: International Renewable Energy Agency
ISEES: Institute for Sustainable Energy and Environmental Solutions
ISFP: Intensified Social Forestry Project
IUCN: International Union for Conservation of Nature
IWP: International Water Project
JICA: Japan International Co-operation Agency
JIFPRO: Japan International Forestry Promotion and Co-operation Center
JIRCAS: Japan International Research Center for Agricultural Sciences
JOFCA: Japan Overseas Forestry Consultants Association
Kcal: Kilocalorie
KEFRI: Kenya Forestry Research Institute
KFS: Kenya Forestry Services
Kg: Kilogram
KJ: Kilojoule
KKFCRC: Khon Kaen Field Crops Research Center
Km: Kilometre
kW: Kilowatt
L: Litre
M: Metre
MERET: Management of Environmental Resources to Enable Transition
MW: Megawatt
NBF: Nippon Biodiesel Fuel
NDCs: Nationally Determined Contributions (under the 2015 Paris Agreement)

NEDO:	New Energy and Industrial Technology Development Organization
NERICA:	New Rice for Africa
NFC:	Near field communication
NGO:	Non-governmental organisation
OBANR:	Oromia Bureau of Agriculture and Natural Resources, Ethiopia
OECD:	Organisation for Economic Co-operation and Development
OI:	Oakland Institute
OPIC:	Overseas Private Investment Corporation
OPT:	Oil palm trunk
PAEGC:	Powering Agriculture: An Energy Grand Challenge for Development
PAH:	Polycyclic aromatic hydrocarbons
PHB:	Polyhydroxybutyrate
PJ:	Petajoule
PLA:	Participatory Learning and Action
PM:	Particulate matter
R&D:	Research and development
REDD+:	Reducing emissions from deforestation and forest degradation, along with ensuring forest conservation, sustainable forest management, and the enhancement of forest carbon stocks in developing countries
RH:	Relative humidity
RRA:	Rapid rural appraisal
RRR:	Resource recovery and reuse
SAFE:	Safe Access to Food and Energy
SATBT:	Stakeholder Sustainability Assessment Tool on Bioenergy Technology
SCBFFE:	Support to Community Based Farm Forestry Enterprises (in semi-arid areas of Kenya)
SDG:	Sustainable Development Goals
SEI:	Stockholm Environment Institute
SIDA:	Swedish International Development Co-operation Agency
SNRMP:	Sustainable Natural Resource Management through FFS
TICAD:	Tokyo International Conference on African Development
TJ:	Terajoule
UAV:	Unmanned aerial vehicle
UNDP:	United Nations Development Programme
UNEP:	United Nations Environment Programme
UNFCCC:	United Nations Framework Convention on Climate Change
UN-Habitat:	United Nations Human Settlements Programme
UNHCR:	United Nations High Commissioner for Refugees
USAID:	United States Agency for International Development
USD:	United States dollar
VFM:	Virtual Farmers' Market
VIP:	Village Industrial Power
VOC:	Volatile organic compound
WFP:	World Food Programme
WHO:	World Health Organisation
wPOWER:	Partnership on Women's Entrepreneurship in Renewables
XOF:	West African CFA franc, a regional currency for the African Financial Community *(Communauté Financière Africaine – CFA)*

This collection highlights solutions to strengthen food security, enhance social welfare and ensure environmental sustainability

Executive Summary

Sub-Saharan Africa needs a sustainable supply of rural biomass, along with continued biomass-to-energy innovations and tools, to enhance bioenergy sustainability.

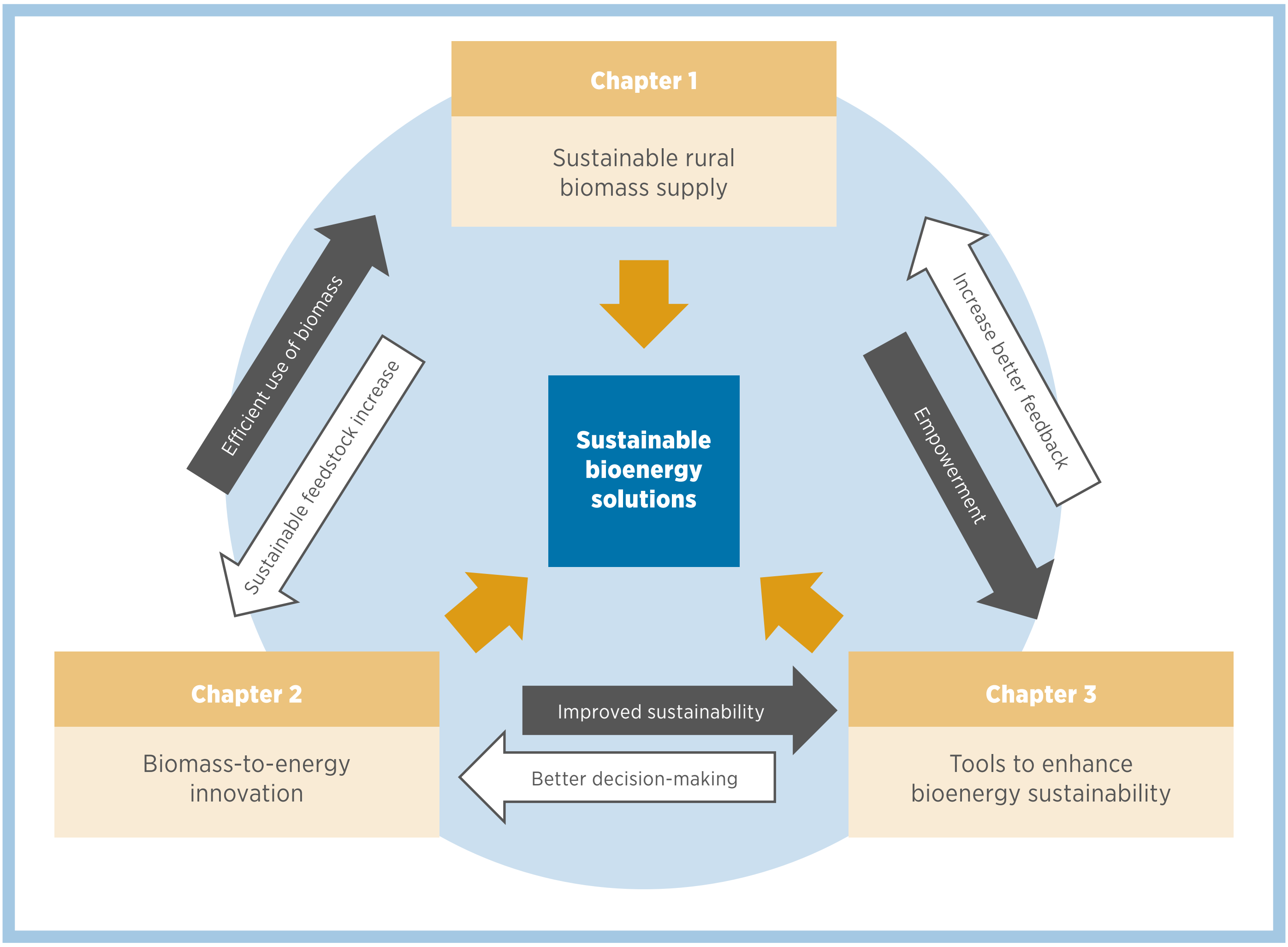
This collection aims to provide a reference for policy makers and practitioners working in areas related to bioenergy in rural areas of sub-Saharan Africa. This encompasses those in the energy, agriculture, forestry, environment, finance and business sectors, among others, who are searching for solutions to diverse issues in the field of sustainable rural bioenergy. These solutions should also enhance food security and benefit social welfare and environmental integrity.

The three main issues in rural bioenergy in sub-Saharan Africa are:

» unsustainable bioenergy feedstock sources that cause deforestation and heavy workloads;
» unhealthy domestic energy production systems that cause respiratory diseases; and
» the lack of a means to ensure the sustainability of better bioenergy solutions.

These three issues are interrelated. The solutions detailed in the chapters corresponding to these issues will contribute to sustainable bioenergy development and are intended to be deployed interactively.

Figure ES1. Sustainable bioenergy solutions: Three themes



Gender-based solutions to ensure sustainable rural biomass supply

To bring about positive change in the area of rural energy, as well as to focus on improving health and sustainability, societal gender roles have to be taken into consideration. Solutions highlighted in this collection include those from Mali, where a participatory approach (Chambers, 1983, 2007, 2017) has empowered female villagers to seek better incomes through a micro-finance scheme and by changing the means of energy for cooking (good practice example 1.1.1). In Ghana, a local non-governmental organisation (NGO) succeeded in improving bioenergy sustainability by targeting various women's groups engaged in cottage industries such as producing dried fish and shea butter (1.1.2).

A gender-centred framework proposed by the Partnership on Women's Entrepreneurship in Renewables (wPOWER) would support female villagers and could be expected to have positive impacts on the livelihood of whole families (1.1.3). Female villagers often take leading roles in Farmer Field Schools (FFSs) and Farmer Research Groups (FRGs). These groups are widely used by farmers to improve agricultural and forestry productivity and acquire new methods of farming through scientific on-farm experiments (1.5.1 and 1.5.2).

The Stakeholder Sustainability Assessment Tool on Bioenergy Technology (SATBT) is useful to ensure that bioenergy deployment is sustainable from a gender perspective – and to select the best bioenergy technology in a target area (3.3.2). It can be used in combination with Global Bioenergy Partnership (GBEP) Sustainability Indicators, also known as "GSIs", and the Project Navigator, a platform provided by the International Renewable Energy Agency (IRENA).

Agro-ecologically sound feedstocks

The sustainable increase of bioenergy feedstock will be achieved through the introduction of agro-ecological farming methods that fulfil subsistence needs and increase business opportunities. Both invented and practiced agro-ecological farming methods for better yield and for reducing risks, costs or workload in an area may be applicable for farming in other areas.

However, small-scale field experiments should be carried out to ensure sustainability and to verify that these practices are suitable for the target areas' ecological features and are economically viable. In Chapter 1, Section 2, various agro-ecological practices are introduced, such as contour management, the push-pull method (good practice example 1.2.1) and the combination of agroforestry and pastoral system in Uganda and in Mozambique (1.2.2 and 1.2.3, respectively).

Soil and water are fundamental sources in the production of food as well as of biomass feedstock for bioenergy. The importance of sustainable management and conservation of these sources cannot be overlooked. Biochar and Kazusabori are two important sources in sub-Saharan Africa.

Biochar can neutralise the acidity of sub-Saharan African soils, helping to retain moisture

Biochar is a by-product of biomass carbonisation that has alkalic and porous characteristics. It can neutralise the acidity of the soil commonly found in sub-Saharan Africa, retain moisture and increase hydration capacity under arid and semi-arid conditions. Furthermore, biochar can accommodate micro-bacterium, which help crops to absorb micro-nutrients well. The use of biochar has been reported to improve the productivity of corn in Ghana (1.3.2) and Kenya (1.3.1). In relation to the need for harvesting groundwater, Kazusabori is a low-cost, manual water well construction method (1.3.3).

In addition, this collection includes examples of tree and crop yield improvements by breeding efforts. For example, the Kenyan Forest Research Institute (KEFRI) is now breeding Acacia tortilis, a tree species useful for agroforestry and energy production (1.4.1). Several new varieties of sugarcane that are useful in the production of ethanol have been registered as a result of breeding research (1.4.2).

Energy security is often threatened in areas experiencing humanitarian situations. Resource recovery and reuse (RRR) has been trialled in communities that host refugees in Kenya (1.6.1). Guidebooks for promoting agroforestry under refugee and returnee situations in co-ordination with local communities are useful for natural recovery and improvement to increase biomass carbon stocks in accordance with the local climatic, geologic, social and ecological conditions (1.6.2). Geographic information system (GIS) tools can be used to match biomass feedstock supply availability and demand prediction, which is important to ensure the sustainability of newly introduced bioenergy technology (3.3.1).

Energy innovation based on biomass

Innovative bioenergy technologies are crucial to ensure sustainable biomass use. The latest examples of these technologies provide practical solutions that are socially, economically and environmentally sound. Bioenergy innovations are evident in two main forms.

The first involves introducing new bioenergy technology using sustainable feedstock sources such as food or processing wastes and residues. This includes briquettes made of waste, ethanol made from agro-processing residues, biogas from animal manure and wastes, and power generation from residues and wastes.

The second way focuses on reducing the use of current wood-based feedstock by introducing new fuel-efficient stoves; these also minimise harmful emissions that cause respiratory diseases. These stoves include units produced by private companies, such as the Cookswell Jiko (good practice example 2.2.1), and those promoted by NGOs, like the Kamado Jiko (2.2.2).

The Kamado Jiko is an in-house, fuel-efficient rocket cookstove production method that can reduce the use of firewood and generates lower GHG emissions. In Uganda, rocket stoves made of sun-dried bricks distributed by an NGO are used by many community members. These adopters see both their workload for collecting firewood and their children's incidence of respiratory disease dramatically reduced by the use of such stoves (2.2.3).

In relation to the use of fuel-efficient stoves, another advance is the development of appropriate technologies and systems that use wastes and residues. These by-products, formerly an emissions source due to decay or burning, can be turned into useful, renewable bioenergy. Examples of this are high-quality and affordable briquettes made from wastes and residues available in sub-Saharan Africa, such as briquettes made of rice husks and peanut husks in Tanzania that are a popular way to meet the energy needs of local hospitals and schools (2.1.1), and briquettes made of wood charcoal waste in Mozambique (2.1.2). Meanwhile, in Madagascar, experiments on a briquette made from combined cow manure and dry grass achieved high energy efficiency (2.1.3). In Nigeria, an environmentally compatible technology has been developed that produces ethanol efficiently from cassava pulp, available in bulk at cassava starch processing factories (2.3.1). As oil palm trees are normally renewed every 20 years because of declining productivity, there is huge potential to derive energy feedstock based on sap from oil palm trunk (OPT) waste, assuming the appropriate technology is used (2.3.2).

Innovative bioenergy technologies are essential to ensure sustainable biomass use

Producing biogas requires the use of biomass wastes and water, where available, for anaerobic fermentation. In Kenya, a biogas generation system that produces biogas for milk chilling using cow manure saves the milk from being wasted (2.4.1), and in Ethiopia, infrared for roasting coffee from biogas produced from coffee husks is used (2.4.2).

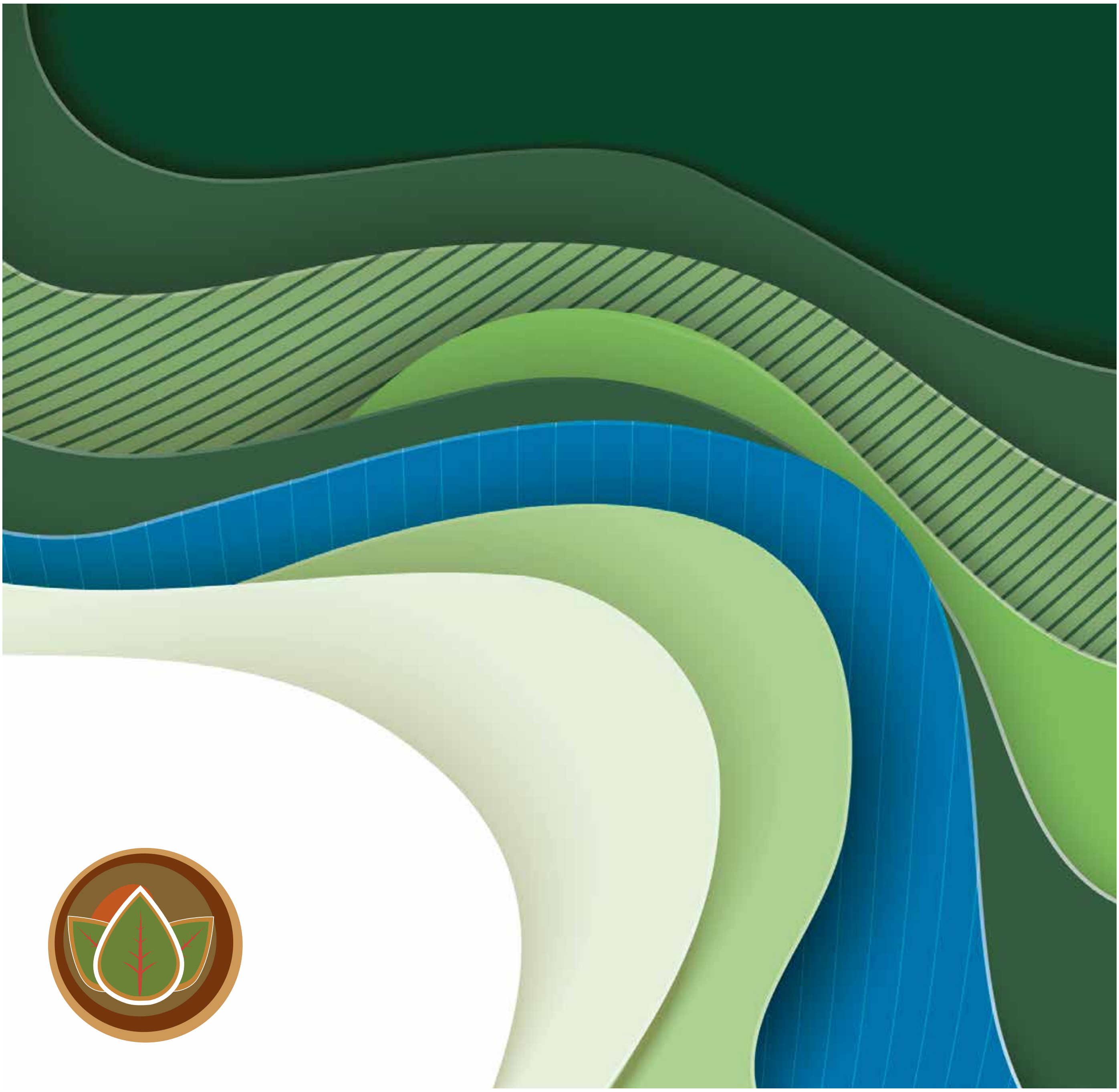
Power generation using biomass waste is another way of producing energy. In Kenya, a portable small-scale power generation system is a useful and popular device for rural cottage industries such as dry fruit production (2.5.1), and in Uganda, a small-scale gasifier power and heat integrated generation system uses farm wastes as feedstock (2.5.2).

Tools to enhance bioenergy sustainability

Various entrepreneurship support programmes are available for people who wish to solve bioenergy-related issues by engaging in innovative venture businesses in sub-Saharan Africa (section 3.2). In Mozambique, a digital money and banking system has been introduced in off-grid areas, where no formal banking systems are available (3.1.1). This system operates using jatropha seeds to produce biodiesel fuel as currency. Paying with jatropha seeds, contract farmers use a digital money system to buy goods, including mobile phone and mobile phone credits, at village kiosks. This system has seen rural economies flourish in a very short time.

Furthermore, countries that make a commitment, including contributing to Article 5 of the Paris Agreement, can focus on renewables to reduce emissions from deforestation and forest degradation. Scaling up renewables within this "REDD+" framework, furthermore, is consistent with broad sustainability efforts and can also form the basis for sustainable rural energy solutions (section 3.4).*

* REDD+: REDD+: Reducing emissions from deforestation and forest degradation, along with ensuring forest conservation, sustainable forest management, and the enhancement of forest carbon stocks in developing countries



Introduction

In rural areas of sub-Saharan Africa, solid bioenergy such as fuelwood, charcoal, dung and waste is the main source of energy for cooking and heating for up to 90 % of the population, or around 3 billion people (World Health Organisation [WHO], 2018). WHO has reported that household air pollution by solid bioenergy cooking causes 600 000 deaths in Africa annually, making it the second-largest health risk factor in the region (WHO, 2012). Growing demands on food and energy from population growth, coupled with the increasing frequency of natural disasters and unstable weather patterns exacerbated by climate change, have increased the challenges rural communities in sub-Saharan Africa face when trying to meet their own food, energy and development needs.

This has substantial implications for poverty alleviation as well as for environmental protection, including forests, ecosystems and biological diversity within the region. Wood resource scarcity makes the market price of fuelwood and charcoal more expensive, which keeps households in poverty. More than two thirds of people in sub-Saharan Africa are still below the poverty line, living on less than USD 2 per day, and nearly half are living on less than USD 1.25 per day (Beegle et al., 2016). For the most part, this underprivileged population also has limited access to modern forms of energy. Infrastructure, including limited grid access, remains a major constraint in rural sub-Saharan Africa. Strengthening the capacity for a sustainable energy supply, however, would provide economic opportunities and increase the resilience of poor people and communities.

Various innovative technologies and tools to produce and distribute renewable bioenergy, which promote the sustainable use of locally available resources without disrupting food and water supply, are affordable and efficient have been emerging within the region. Information focused on three themes – sustainable rural biomass supply, biomass-to-energy innovations and tools for enhanced bioenergy sustainability – was collected by the International Renewable Energy Agency (IRENA) through a “Call for Good Practice” from May to August 2017. This was aimed at exchanging information at the International Workshop on Sustainable Rural Bioenergy Solutions in Sub-Saharan Africa held in Nairobi, Kenya on 19 January 2018. The workshop was organised by IRENA, Japan International Research Center for Agricultural Sciences (JIRCAS) and World Agroforestry Center (ICRAF) with funding support by the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF-Japan) and the Ministry of Foreign Affairs of Japan.

This publication combines the information collected through the “Call for Good Practice” initiative. Some was presented during the workshop in Nairobi, but many more good practices were submitted and are detailed here.

This publication gathers together good practices to form a sound knowledge base. It highlights concepts and practices useful for policy makers and development practitioners, including private-sector actors, non-governmental organisations (NGOs), researchers, extension officers and facilitators on the ground in sub-Saharan Africa.

The collection consists of three main chapters:

1. Sustainable rural biomass supply

The focus is to find a way to achieve sustainable bioenergy feedstock supply to meet the growing demand through ecological, affordable and socially just agriculture, forestry, pastoral and harvesting systems development. Good practices include those that strengthen rural livelihoods and are resilient to climate change while ensuring local food security, promoting efficient use of available water and soil nutrition, and contributing to biodiversity and ecosystem conservation. Special attention is given to the most vulnerable segment of rural societies, including different genders, by strengthening their power and ownership.

2. Biomass-to-energy innovations

This chapter focuses on innovative bioenergy production technologies and systems that are environmentally friendly without disturbing local food security. The fuel-efficient practices and technologies listed in this chapter enable the reduction of fuelwood usage and the heavy workload necessary to collect firewood. They can also cut greenhouse gas (GHG) emissions and thus respiratory diseases, and they are less costly, available locally and maintained easily.

3. Tools to enhance bioenergy sustainability

Newly introduced technologies or practices should be not just economically feasible but also beneficial for the entire local community. Tools that help to enhance sustainable deployment of bioenergy include the use of geographic information system (GIS) analysis to determine supply and demand potential based on local biomass availability, a method to enhance financial sustainability and inclusive participation, as well as digital financing systems and entrepreneurship supports in rural areas.

The overall objective of this publication is to highlight practices that enable rural bioenergy and food supply in sub-Saharan Africa while empowering local people's ownership and the alignment of communities and countries with their development objectives and desired change. In addition, sustainable rural bioenergy solutions should include features that guarantee local food security, health promotion, poverty alleviation, sustainable feedstock supply, affordability, and ecological and local entrepreneurships. The table below provides a summary of future potential sustainability benefits generated by the good practices described in this publication.

This collection does not cover everything; it is a starting point. More good practice examples that promote better livelihoods and sustainable energy access for the people of rural sub-Saharan Africa need to be unearthed and exchanged.

Overview table: Significant sustainability factors*

Major benefits and good practice examples	Sustainable rural biomass supply			Biomass-to-energy innovations			Tools to enhance bioenergy sustainability		
	Sustainable feedstock supply	Affordability	Ecological soundness	Food security	Health promotion	Poverty alleviation	Energy transition	Local entre-preneurship	Strengthen resilience
1.1 Gender	✓	✓		✓	✓	✓	✓	✓	✓
1.2 Agro-ecology	✓	✓	✓	✓	✓	✓			✓
1.3 Nexus	✓	✓	✓	✓	✓	✓			✓
1.4 Breeding	✓	✓	✓			✓	✓		✓
1.5 FFS & FRG	✓	✓	✓	✓	✓	✓		✓	✓
1.6 Humanitarian	✓	✓	✓	✓	✓	✓	✓		✓
2.1 Briquettes	✓	✓	✓		✓	✓	✓	✓	✓
2.2 Cookstoves	✓	✓	✓		✓	✓	✓	✓	✓
2.3 Bioethanol	✓	✓	✓		✓	✓	✓	✓	✓
2.4 Biogas	✓	✓	✓	✓	✓	✓	✓	✓	✓
2.5 Heat & power	✓	✓			✓	✓	✓	✓	✓
3.1 Digitalisation	✓	✓				✓	✓	✓	✓
3.2 Entrepreneurship	✓	✓		✓		✓	✓	✓	✓
3.3 Tools	✓	✓	✓	✓		✓		✓	✓
3.4 REDD+**	✓	✓	✓	✓		✓	✓	✓	✓

* in relation to each section of this report

** REDD+: Reducing emissions from deforestation and forest degradation, along with enhancing forest carbon stock in developing countries

1. Sustainable rural biomass supply

1.1. GENDER AND BIOENERGY

This section highlights the importance of gender issues in relation to the development of bioenergy in rural sub-Saharan Africa. Good practice examples include one from Mali, where an effort has been made to mainstream gender for positive changes in a rural development intervention, as well as an example from Ghana, where clean energy was adopted for cottage industries run by women. The section also proposes a gender-centred renewable energy development framework.

Concept

In many rural areas of sub-Saharan Africa, women play a central role in securing energy and food needs for their family members. They are primary caregivers for all family members including children, the elderly and the disabled, and they bear various responsibilities such as producing food crops, collecting water and firewood, cooking, and providing health care. In addition, women in rural areas generate income for their children's schooling by selling crop residues.

Globally, women spend three times more time performing domestic and care work compared to men, according to a survey conducted in 83 countries (UN, 2015). The UN's Sustainable Development Goals (SDGs) (UN, 2015) are part of a global effort to recognise the value of unpaid domestic work. The SDGs promote shared household responsibilities, the ability and opportunity to participate in decision making comprehensively, and equal rights to economic resources for both genders.

Especially in the poorest countries, numerous deaths and a higher incidence of diseases are caused by indoor air pollution emitted from biomass fuel and kerosene (WHO, 2018a, 2018b). Respiratory disease is a major public health concern in those countries.

Furthermore, deforestation can increase the distance necessary to fetch firewood year by year, increasing the burden of the women and children who carry out this work. Climate change causes more frequent floods and droughts and increases the uncertainty of water availability necessary for food and biomass energy production (WHO 2018a, 2018b). For example, from the end of 2012 to the beginning of 2013, frequent flooding caused 200 000 people to be displaced and evacuated in Gaza Province in Mozambique. From 2014–15, a lack of river water due to drought caused serious food insecurity.

If bioenergy development in rural areas fails to address gender issues in practice, negative impacts on the society can be expected. To avoid potential social risks to livelihoods and health, the prevailing cultural norms must be understood and taken into consideration, particularly in relation to gender roles in the target areas of bioenergy development policies, plans and practices.

Decisions associated with any bioenergy production activities that will impact rural households should be made through strong community ownership by taking into consideration each gender's perspectives equally and in particular by reflecting the desires of all social segments with special attention given to the weak and vulnerable. For example, household surveys conducted prior to interventions often target only the heads of households – who are, in most cases, men. As a result, the interests of the most powerful members of the houses are regarded as the representative views of the communities (Chambers, 1983, 2007, 2017).

In addition, when a farming agreement is made between a private company and farmers, it is customarily negotiated and signed between the company and the head of each household; in most cases, by men (de Schutter, 2015).

The contract may specify the introduction of new commercial farm species that require expensive inputs such as fertilisers and pesticides and may require additional monetary risks to pay back debts as well as require a more intensive workload of watering and tendering, a workload that often falls to women and children. As a result, family members have less time available for subsistence farming or attending school.

This problem can be avoided by collecting information in a gender-considerate way. For example, communicating with women and men separately may encourage women to express their views as well as give them the opportunity to become better informed about the risks and benefits of a given change. Over the last few years, the sustainable bioenergy industry has begun to design and adopt gender-sensitive programmes, especially at the household level (cooking, heating and lighting) of low-income communities.

Considering gender is important not only in bioenergy feedstock production but also in energy distribution for a sustainable rural bioenergy supply. The introduction of a small light in a rural home can make a dramatic difference: it enables children to study after dark, rural clinics to have better facilities and night walks to be safer. The introduction of fuel-efficient stoves can decrease the time that it takes to collect firewood and conserve forests that are the source of water. As such, improvement of energy availability has the potential to bring about positive changes in rural communities, especially for vulnerable segments, including women and girls.

To ensure positive development outcomes, gender-related impacts have to be assessed and monitored. For example, the United Nations Development Programme (UNDP) introduced the Gender-related Development Index (GDI) to measure existing gender gaps in the three components of Human Development Index (HDI): health, education and income (UNDP, n.d.). The greater the gender disparity in basic capability, the lower the country's GDI compared to HDI. Periodical and continuous monitoring of the gender gap situation will be necessary to expedite the positive changes effectively.

Women travel long distances carrying heavy loads of firewood for cooking and heating
Photograph: wPOWER

MAINSTREAMING GENDER THROUGH A PARTICIPATORY RURAL DEVELOPMENT APPROACH IN MALI

(Good practice example 1.1.1)

Organisation	Ministry of Agriculture, Mali
Type of organisation	Government, bilateral international co-operation
Target area	Mali
Type of activity	Gender-considered participatory rural development
Supported by	Japan International Co-operation Agency (JICA), Japan Research and Management Organization

Summary

The continent of Africa has the earth's oldest soil and the longest history of cultivation by human beings. Declining soil fertility because of heavy use and diminished organic matter is causing low productivity in most of sub-Saharan Africa. Climate change increases the variability and unpredictability of rainfall patterns, including extreme storms and hurricanes and droughts, which are becoming more frequent and intense. Segu Province, Mali is not an exception. Rapid population increase and repeated droughts have made combatting desertification a challenge and present a risk to food and energy security. Rural development projects whose targets include women's livelihood and the sustainability of the environment have been conducted with the support of various organisations, including the International Fund for Agricultural Development (IFAD), ICRAF and the German Association for International Co-operation (GIZ). A JICA project, conducted from 2000 08, supported the Ministry of Agriculture in tackling the issue of sustainable rural development.

To reflect the benefits of those less-powerful segments of the society and bring about more democratic, bottom-up decision making for sustainable development, participatory approaches have been developed and adopted as a tool. The approaches evolved from Rapid Rural Appraisal (RRA) in the 1970s, Participatory Rural Appraisals (PRA) in the 1980s and Participatory Learning and Action (PLA) in the 1990s (Beckmann, 1997). RRA aims to comprehend field-level information about local environmental and living conditions collected directly from farmers in the target rural communities to be used for intervention (Chambers, 1983; Beckmann, 1997). PRA is aimed at extracting information through building up participants' analytical skills and enabling them to make planning decisions with the support of a facilitator. PLA is a tool to empower local and subordinate people through interactive mutual discussion and learning processes by enabling them to express their knowledge and take action (Chambers, 2007, 2017). Tools used in such participatory approaches include visuals such as drawings and maps, which enable participants (including illiterate participants) to express perspectives and take leading roles (Chambers, 2007, 2017; FAO, n.d.; IIED and CTA, 2009).

Facilitator trainings have to be undertaken prior to the beginning of participatory consultations in target villages. Facilitators moderate a series of group discussions to analyse current issues group by group in each community. Discussion groups are divided into different categories of people: for example, separate meetings might be conducted for male and female groups, as well as for elder and youth groups. In societies where labour is divided in accordance with traditionally assigned roles by sex or age or any other factor, members of the social segment assigned inferior roles often have difficulty expressing their ideas and feelings in front of those considered superior. For example, female members usually find it difficult to speak out in front of male villagers or to be very active in participating in the discussions. Facilitators encourage people who are less powerful to express themselves as well as to lead discussions.

Themes, analysis and development planning

Each group discusses specific themes and analyses the current situation accordingly. In the next step, the outcomes are compiled with matrixes, figures and tables on a step-by-step basis. Major discussion themes include:

- current economic status (outcome: feasibility and priority mapping)
- living environment for children (outcome: children's life mapping)
- farming in daily lives (outcome: labour calendar)
- relationship between the village and surrounding villages (outcome: flow mapping)
- village society (outcome: Venn diagram)
- agro-pastoralism business management (outcome: life cycle mapping)
- village infrastructure (outcome: transection walk mapping)
- village resources (outcome: transection walk mapping)
- crop calendar (outcome: crop calendar)
- what to do, what to plant (outcome: matrix).

Based on the information analysed in such discussions, development plans are constructed:

- improvement of villagers' project management capacity (plan: literacy education, leadership training, micro-finance system establishment)
- basic human needs establishment (plan: village well construction, village road construction)
- stabilisation of income (plan: compost production, seed stock and supply, small-scale cropping, vaccination for animals, pastoralism improvement)
- natural resource conservation and management (plan: nursery construction, tree planting, soil conservation, land use system decision)
- improvement of women's lives (plan: milling factory construction, irrigation and infrastructure development, improved cookstoves, cottage industry development, livelihood improvement training).

In accordance with the chosen development plan, roles and responsibilities of the village committees are defined by the community members. The important part of the planning and implementation phase is to determine the necessary costs and the methods for collecting funds in an equitable manner. Also important to consider is how to make external funds available to carry out such plans.

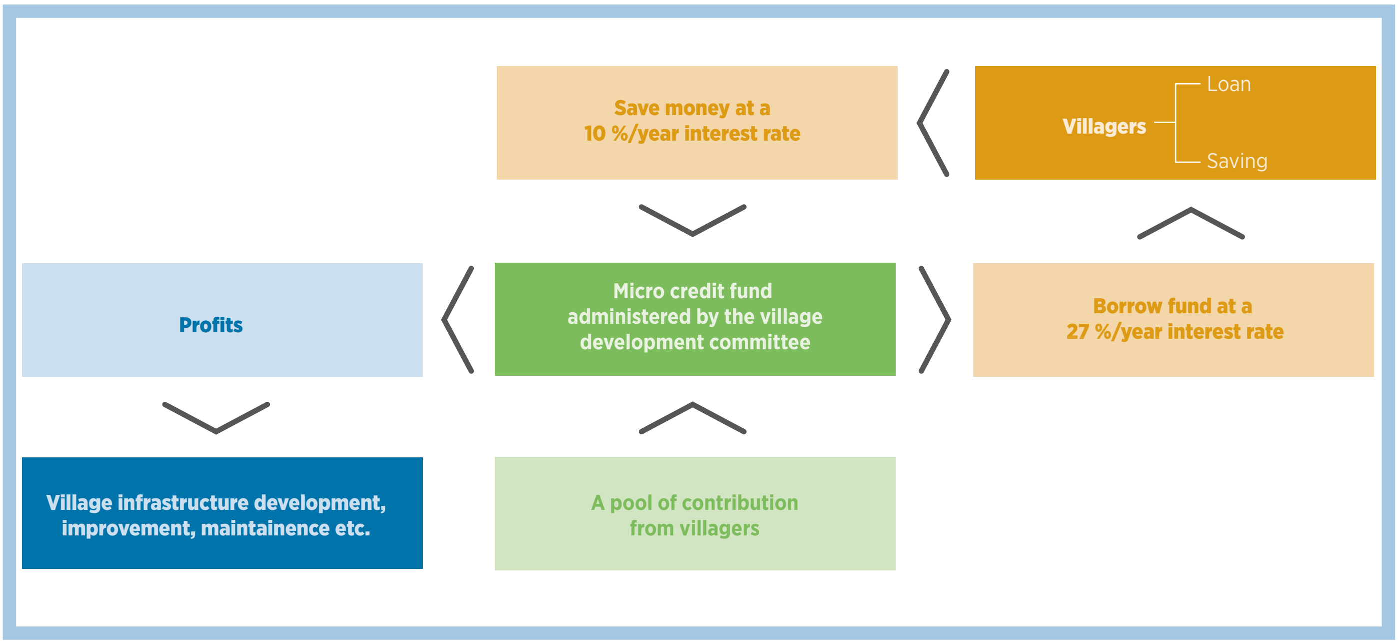
Micro-credit scheme

One of the successful activities is a micro-credit scheme. For example, a female group borrows funds using micro-credit to produce soap from Jatropha curcus oilseeds, and another group borrows funds to produce soap from shea butter to sell at market. Micro-credit can also be used for investing in fuel-efficient stoves for cottage industries to produce the soaps managed by women. The introduction of fuel-efficient stoves made of iron reduces the amount of fuelwood needed and so decreases the workload involved in firewood collection.

The interest rate for the micro-credit scheme was 27 % a year, and the borrowing period ranged from a few months to a half-year. For example, a village woman purchases millet at harvest season at XOF 70 (USD 0.12) and sells it a half-year later when the price of millet increases by 30 %. ("XOF" is the international currency code for the West African CAF franc, a regional currency unit African Financial Community (CAF) currency used in Mali and several other countries.)

The village women pay back the interest to the micro-credit fund at half the interest rate – just 13.5 %; it is quite a profitable business. Villagers may also save money in the micro-credit fund. With an appropriate management system, the fund is also used for the development of infrastructure using the profit earned from this finance system.

Figure 1. Micro-credit system of a rural development project in Segu, Mali



Source: Shimizu (2008)

A woman trains a school on a new fuel-efficient cookstove in Niger
Photograph: Sekiya

CLEAN BIOENERGY FOR AGRO-INDUSTRIES LED BY WOMEN IN GHANA

(Good practice example 1.1.2)

Organisation	Institute for Sustainable Energy and Environmental Solutions (ISEES)
Type of organisation	NGO
Person in charge	Lovans Owusu-Takyi
Target area	Ghana
Type of activity	Biomass gasifier, smoke roaster
URL	http://iseesghana.org/
Co-operators	SNV, Morrison Energy Services, the Food Research Institute of Ghana

Summary

The Institute for Sustainable Energy and Environmental Solutions (ISEES) is a Ghanaian-based non-governmental organisation (NGO). ISEES advocates, builds capacity for and deploys climate-smart, innovative renewable energy technologies (cookstoves and solar and biogas systems) to low-income households and small-scale agro-processing businesses headed by women. These clients would otherwise not have access to such technologies, which ISEES distributes through community-led business and marketing models.

The aim of the organisation in the renewable energy sector is to contribute to climate change mitigation at both the business and household level, mainly targeting the most vulnerable segments of society (the poor). ISEES was named the Clean Air Company of the Year at the Ghana Environmental Excellence Awards in May 2018.

Rural food processing industries rely largely on women's labour. Most of the work – collecting firewood, processing crops, cooking, packaging and selling – is performed by women. ISEES approaches women's groups to observe their activities and determine how they use energy in their cottage industries. The resulting discussions help to understand their needs and find solutions to improve women's working conditions. This can include the benefits of switching to improved household and institutional stoves and providing financing schemes to help drive adoption of such solutions.





Cottage industries led by women's groups in Ghana
Photographs: Owusu-Takyi

One of the technologies promoted by the institute – especially to women performing agro-processing in rural areas – is the biomass gasifier stove. This technology allows for raw agricultural waste to be reused/recycled as fuel for heating during the processing of crops. This is a waste-to-energy concept. Common agro-processing industries in Ghana include cassava, shea butter, palm kernel oil, mushroom sterilisation, palm oil, gari, groundnut, fish, and even fruit and leaf drying. The biomass gasifier stoves are able to burn raw waste without smoke, thus contributing to efficient cooking. The ash from biomass gasifier stoves can also be used to improve soil fertility.

There are also huge numbers of small agro-processing enterprises – palm oil producing industries, shea butter processing industries, etc. – for the deployment of biogas systems in Ghana. One of the successful examples is in Bole, in Northern Ghana. Here, the Community Biogas Plant for Shea Waste Processing was installed by CRIG, Biogas Engineering Limited. Its 50 m^3 fixed dome biogas digester is capable of generating 12 m^3 of biogas daily. Shea butter processing effluent is used as feedstock for the digester and biogas is used as fuel in roasting shea kernels. Biogas is also used to power the shea kernel grinding mill. Female processors are now able to roast shea kernels and boil shea using gas from the biogas, which provides clean energy.


Biogas introduction to the shea butter industry
Photographs: ISEES

The agrowaste may also be pelletised or briquetted and used as fuel. This has implications for livelihood improvement, as profit margins for low-income households rise due to the elimination of expenditure and time spent on gathering cooking fuel. Health and working environments are also improved by reducing smoke emissions.

Another important intervention being actively promoted is the improved fish-smoking stove, locally known as the Ahotor (comfort) oven. The Ahotor was designed locally by a partnership between SNV Netherlands Development Organisation, Morrison Energy Services, the Food Research Institute of Ghana and other partners. With support from the Canadian Fund for Local Initiatives, ISEES has so far constructed about 250 of these ovens across coastal communities in Ghana (including an island community) where fish smoking is a traditional profession. In addition to the advantages listed above, this intervention has the unique health implication of eliminating chemical reactions that produce dangerous concentrations of Polycyclic Aromatic Hydrocarbon (PAH) on the smoked fish, which is a health concern due to its carcinogenic nature.

Providing the poor with access to these interventions

ISEES has an all-inclusive business model that allows for savings for asset financing. This model is particularly important for low-income households in both rural and urban areas that lack the ability to finance such technologies by outright payments. In order to reduce the risk associated with this model, women's groups and associations in the various communities lead in production, distribution and capital recovery. This also makes it easier for ISEES to manage the sales and distribution by reducing the number of staff required.

The future of clean cooking in Ghana

The sector is still under-tapped and has huge potential for further development. The main challenge currently is the low ability of the most relevant societal groups (low-income households) to invest/pay for the acquisition of such beneficial technology. Without support, such interventions may never reach the most marginalised groups.

Policy transformation at the national level may drive governmental interventions that may have a greater impact. For instance, a national action plan for adoption is needed in order to drive all stakeholder involvement. This will involve advocacy and high levels of commitment for civil society organisations acting on climate change mitigation and the SDGs.

Ahotor improved fish-smoking stove
Photograph: ISEES

Presentation and summary provided by: Owusu-Takyi (2018)

WPOWER'S GENDER FRAMEWORK FOR BIOENERGY

(Good practice example 1.1.3)

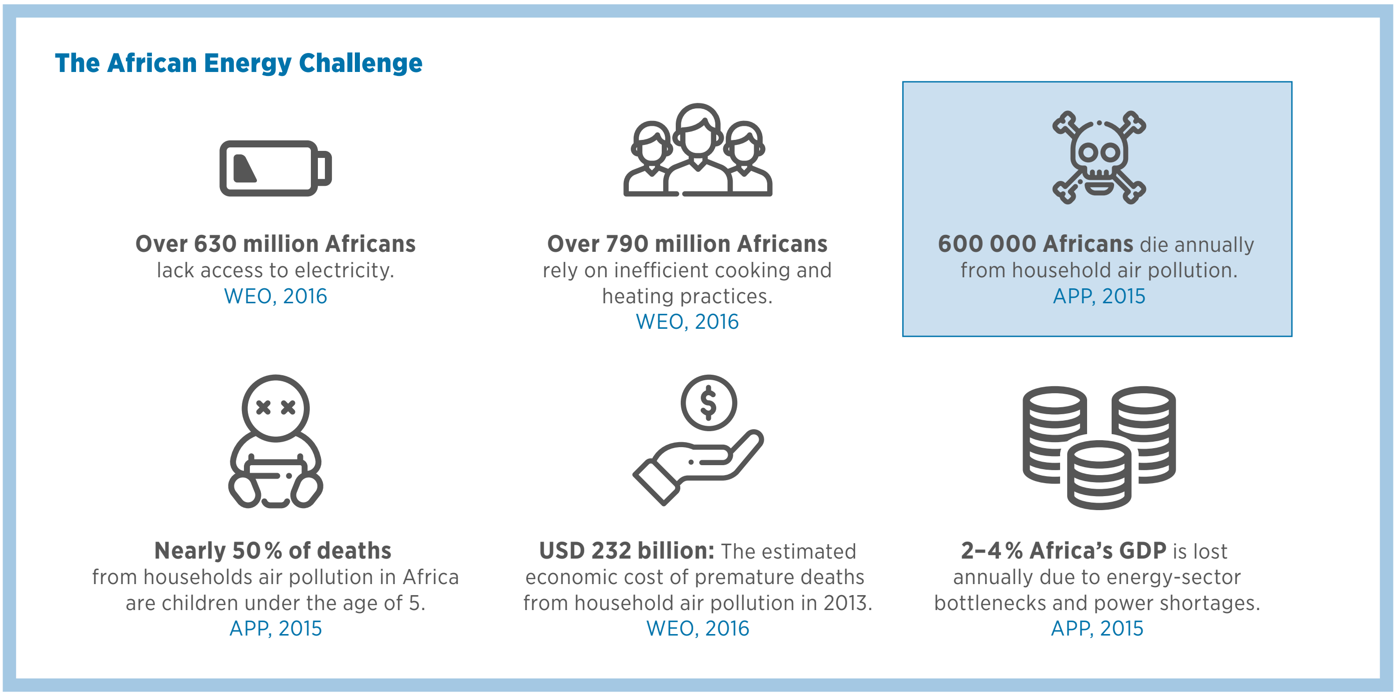
Organisation	Partnership on Women's Entrepreneurship in Renewables (wPOWER)
Type of organisation	NGO
Person in charge	Linda Davis
Target area	Kenya
Types of activity	• Sharing best practices to increase the acceleration of clean energy adoption • Building evidence that supports the business case for women's entrepreneurship • Advocacy to raise awareness on the issue of lack of household energy • Coaching and mentoring to support women's entrepreneurship
URL	http://wpowerhub.org/

Summary

wPOWER encourages women's entrepreneurship both at the grassroots level and across the clean energy spectrum. Not only are women the primary managers of domestic energy consumption, but as members of community organisations and networks they are in a prime position to champion clean energy strategies within their communities. Governmental and organisational influence on these decision makers could be enhanced by engaging and including women in the design, production, sales and promotion of clean energy systems.

> "When we plant a tree, we plant peace and hope" – Wangari Maathai

Figure 2. Inefficient cooking, heating and lighting and their detrimental effects on communities



Source: wPOWER

Government and the acceleration of clean energy adoption

National and local governments must be involved in energy planning and gender mainstreaming across the clean energy spectrum. Leveraging their power to reach into both urban and rural areas of the community, governments and clean energy partners have the ability to promote women as entrepreneurs of clean energy systems. This is especially relevant as many government ministries are already aware of the issues surrounding energy access deficiencies and their disproportionate burden on women.

Governmental ministries that manage energy, health and gender issues urgently require technical support to implement policies that address energy access in an integrated manner.

Gender framework proof points should be included in each government's gender, health, education and energy policies. These proof points make the business cases to involve women across the energy value chains that have been employed successfully by multiple organisations. This will enable funds and supports to be allocated for entrepreneurial opportunities accessible to women, who often lack the capacity to do so without specific interventions. To increase and encourage the involvement of women in clean energy entrepreneurships – which will in turn help reduce energy poverty and improve the well-being of communities – wPOWER has developed eight evidence-based proof points (Figure 3).

Longstanding cultural attitudes and practices relating to women will have to be altered if clean energy entrepreneurship is to be perceived as a feasible livelihood about which women can feel hopeful. This is where governments can act. They can advocate, create incentives such tax breaks, and adopt regulations that ensure quality clean energy products are distributed within communities without negative health or environmental consequences.

Collaboration has to be facilitated among different stakeholders, including the different levels of related governmental organisations from central to regional. Encouraging ministries with different responsibilities to work together will enhance the understanding of other development priorities with energy, e.g., energy and health, energy and education, energy and sanitation, etc., and how these impacts are valuable. For example, households without access to clean energy require more hospital visits, especially by women and children with respiratory illnesses.

By prioritising energy access in energy planning, cross-ministerial benefits can be expected to accrue. National development plans also have to reflect ongoing collaborations regarding mainstreaming gender in actual plans and budgets.

Figure 3. Measures to accelerate women's involvement in clean energy entrepreneurship

Source: wPOWER

Best practice principles for successful clean energy entrepreneurial programmes

County governments need to be engaged and streamlined toward overall priorities. Best practices (Figure 4) should be implemented and extended widely with the support of the government.

Figure 4. Best practice examples to boost clean energy entrepreneurship

Source: wPOWER

Figure 5. Actions required for organisations to develop a strong gender framework

Source: wPOWER

1.2. AGRO-ECOLOGY, ECOSYSTEM, BIODIVERSITY AND BIOENERGY

This section highlights key agro-ecological practices to boost the availability of bioenergy feedstocks through agroforestry, silvopastoral and other sound crop production and management systems. Good practice examples are from Mozambique, Uganda and Zimbabwe.

Concept

In its 2017 revision of world population prospects, the United Nations has predicted that two-thirds of the world population increase by 2030 will be concentrated in South Asia and sub-Saharan Africa. While sub-Saharan Africa is also undergoing rapid urbanisation, it is expected to be the only region where the absolute number of people living in rural areas increases in the coming decades (World Bank, 2018). This population increase will exert enormous pressures on rural resources, including land, soil, water and labour, which will be rapidly dwindling. Unless technologies and practices are adopted to supply both food and fuel to meet growing demand in rural and urban areas sustainably, this trend will lead to declining food availability per capita, food insecurity and poverty.

Global efforts have been made to improve access to "modern" and clean energy options – such as kerosene, liquefied petroleum gas (LPG) and electricity – for people in poverty. In turn, while solid biomass contributes to less than 10 % of primary energy supply, the majority of the population in sub-Saharan Africa still relies on "traditional" woodfuel – firewood and charcoal – for cooking and heating (Iiyama et al., 2014), as either the only, or the cheapest, option available. A complete shift away from reliance on fuelwood to modern energy options among people in poverty in rural and urban areas in sub-Saharan Africa is projected to occur only gradually, due to fiscal and logistical constraints to scaling up subsidies and infrastructure to speed up the shift (Bailis et al., 2005; Iiyama et al., 2014).

Currently, conventional woodfuel production, especially that of charcoal, is based on the exploitation of natural, not planted, trees. Together with inefficient carbonisation technologies and consumption patterns and without efficient cooking devices, this is not a sustainable use of wood resources. Business-as-usual scenarios to supply woodfuel with conventional approaches to meet increasing demand will have significant implications in land use changes, i.e., degradation of wood resources across landscapes and resilience of rural ecosystems (Bailis et al., 2005; Iiyama et al., 2014). Transforming woodfuel systems through a sustainable supply of woody biomass at landscape scale together with promoting efficient processing and consumption practices are urgently needed (Makundi et al., 2004; Iiyama et al., 2014).

Some efforts have been made to promote tree plantation specifically aimed at fuel provision, while energy-efficient technologies such as efficient cooking stoves and efficient charcoal kilns already exist. Uptake of some of these technologies, however, has often been disappointing. They often do not meet users' multi-dimensional needs, in that a technology may consider fuel uses while disregarding the availability of labour or other considerations. Truly innovative and sustainable technologies need to be compatible with local agro-ecology and socio-economic conditions, while their sustained adoption depends on technologies meeting farmers' various livelihoods needs, supported by favourable institutional conditions (Iiyama et al., 2018).

Strategies to promote ecologically sound land management systems that guarantee food and energy delivery – as well as provide a source of income on the same land for the farmers – are needed. In addition, system resilience through the protection of biodiversity needs to be adopted at scale (Iiyama et al., 2018). Multi-purpose agroforestry systems compatible with local agro-ecology are among several promising options for sustainable bioenergy (Willemen et al., 2013; Leakey, 2014; Miller et al., 2016).

This section presents some of the best agro-ecological practices of bioenergy provision within a broad range of agroforestry systems. Additional useful tools developed by ICRAF are available to select appropriate tree species with multiple benefits in specific features of the land. For example, the Agroforestree Database hosted at ICRAF's home page allows users to search for suitable species for a particular agro-ecology for particular purposes (products/services provided) from a wide range of native and exotic agroforestry tree species (ICRAF, n.d.2). The database provides detailed ecological information, including each tree's characteristics, climatic and ecological distribution range, uses, propagation, and management (Orwa et al., 2009).

Presentation and summary provided by: Iiyama (2018)

VARIOUS AGRO-ECOLOGICAL PRACTICES IN SUB-SAHARAN AFRICA

(Good practice example 1.2.1)

Organization	Alliance for Food Sovereignty in Africa (AFSA), Oakland Institute
Type of Organization	Alliance, Research Institute
Target Area	Sub-Saharan Africa
URL	www.oaklandinstitute.org, www.ceguganda.org

Summary

Agro-ecology is defined by practices that increase the circulation of water and nutrition and enhance soil fertility in farm areas (Yoshida, forthcoming). The practice includes various kinds of silvopastoral, agroforestry, and biodiversity conservation methods that increase organic matter and reduce the use of chemical pesticide and fertilisers. It can decrease costs, improve sustainability, strengthen resilience and diversify both crop types and income sources (Yoshida, forthcoming).

Contour management by terracing
Photographs: Inoue

Various agro-ecological good practices – including contour management, the push-pull method, seed banks and organic compost – can increase biomass yield across Africa.

1. Contour management

A case study in Zimbabwe found that a water harvesting approach taken by a farmer resulted in a dramatic change in productivity and in the resilience of farmers' livelihoods (White, 2016; OI, n.d.1). The water harvesting approach is a combination of contour pits and pond-like dam creation that stores water and makes water flow available (OI, n.d.1). Previously, controlling water flow was difficult, because of instability and unpredictability. The inability to control water flow caused erosion, washing away soil nutrients.

The placement of rocks and mounds alongside each contour level and agricultural plot – the location depending on characteristics such as water demand and drainage requirement – produced a rise in overall productivity and strengthened crop resilience.

The Food and Agriculture Organisation of the United Nations (FAO) proposes cross-slope management methods for reducing soil loss and erosion and conserving nutrients and water by using contour management methods such as earth bunds, stone lines and bunds, and vegetative strips (FAO, n.d.5).

2. Push-pull method

The push-pull method is a biological method developed in Eastern Africa that controls pests and parasites by using natural enemies. At the same time, it improves soil quality by nitrogen fixing and biomass inputs, resulting in increased maize harvests as well as animal feeds. Begun in Kenya, the method has been adopted by 96 000 farmers across the region in sub-Saharan Africa (ICIPE, 2018; OI, n. d.2; Yoshida, 2011). The method is far more effective than chemical applications and does not cause any side effects. By using the combination of "pull" and "push" illustrated below, target crops grow better (OI, n. d.2; Yoshida, 2011).

» ***Pull:*** Grass species that attract stem borers, such as Napier grass (Pennisetum purpureum) and Sudan grass (Sorghum vulgare) are removed and planted outside of the maize farm. Molasses grass (Melinis minutiflora) repels stem borers and increases parasitoid wasps, causing stem borers to die of predation.

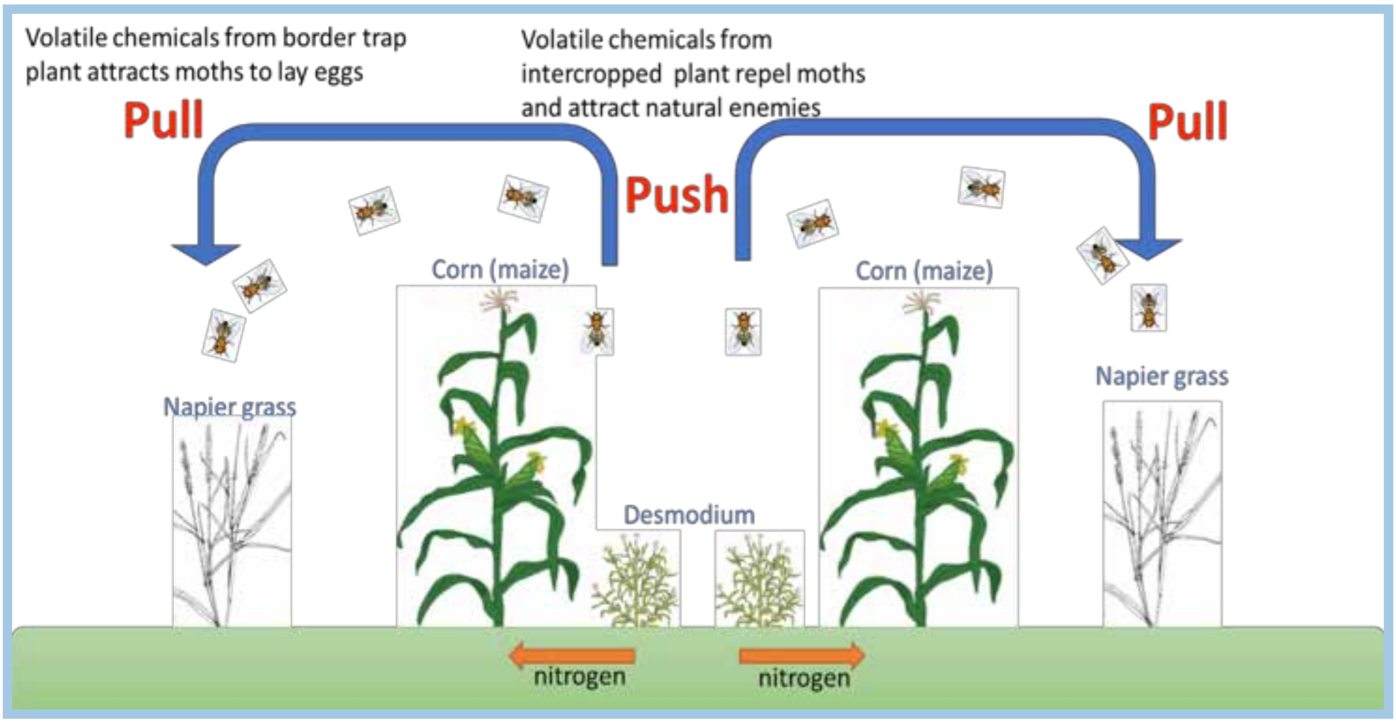
» ***Push:*** Two leguminous plants (Desmodium uncinatum and Desmodium intortum) that repel stem borers and provide nitrogen to maize are planted inside the maize farm. These plants also produce root chemicals that prevent Striga's reproductive success and further invasion.

3. Seed banks

In Zimbabwe, farmer groups set up a seed bank system wherein each farmer contributes 10 % of his or her annual harvest or 50 kilograms (kg) of seed-quality grain (OI, n. d.3). Because hybrid seeds cannot be harvested after harvest for replanting, farmers depend on the seed industry to plant their crops every year. However, after a drought, farmers often cannot afford to buy seeds. Therefore, the ward-by-ward seed bank system enhances the farmers' resilience because deposited seeds play a buffer role between crop failure time and the next harvest season.

The seed bank system also promotes agricultural biodiversity by preserving and facilitating local indigenous seeds. These seeds are both diverse and resilient; they have survived over generations and are hardy enough to endure poor agricultural conditions. Having crop diversity increases communities' adaptive capacities and reduces the tendency of crops to fail from disease, pests, climatic conditions and disasters. It also helps the community with regular food availability and nutritional diversity, which is very important for farming in sub-Saharan Africa.

Figure 6. How push-pull works



Source: wPOWER

4. Organic compost

Organic matter – such as manure, compost and crop residues – is a precious soil supplement. Its use helps to prevent the crop failure frequently experienced on arid, degraded soil in Sudanian and Sahelian semi-arid regions. Soil-carbon loss in the region is estimated at 150 kg per hectare (ha) from the soil every year (OI, n. d.4).

While chemical fertilisers may wash away easily, organic compost remains in the soil and retains moisture. Compost production training carried out by women's associations in Burkina Faso has brought about a significant change, doubling the maize yield. With the use of compost, productivity was dramatically increased; for example, the production of sorghum increased from 408 kg to 1 380 kg per ha. The increased productivity and biomass carbon stocks increased the availability of food and energy.

FAO's ten elements of agro-ecology

The UN Food and Agriculture Organization (FAO) has identified ten elements of agro-ecology that are to be used as guidance for the planning, management and evaluation of agroecological transitions by policy makers, practitioners and stakeholders (FAO, n. d.1). Agro-ecology plays an important role in contributing to the eradication of hunger and extreme poverty and is a means by which to facilitate the transition to more productive, sustainable and inclusive food systems.

Table 1. Ten elements of agro-ecology

Elements	Summary
Diversity	Diversification is key to agroecological transitions to ensure food security and nutrition while conserving, protecting and enhancing natural resources
Co-creation and sharing of knowledge: agricultural	Innovations respond better to local challenges when they are co-created through participatory processes
Synergies	Building synergies enhances key functions across food systems, supporting production and multiple ecosystem services
Efficiency	Innovative agroecological practices produce more using less external resources
Recycling	More recycling means agricultural production with lower economic and environmental costs
Resilience	Enhanced resilience of people, communities and ecosystems is key to sustainable food and agricultural systems
Human and social values	Protecting and improving rural livelihoods, equity and social well-being is essential for sustainable food and agricultural systems
Culture and food traditions	By supporting healthy, diversified and culturally appropriate diets, agroecology contributes to food security and nutrition while maintaining the health of ecosystems
Responsible governance	Sustainable food and agriculture requires responsible and effective governance mechanisms at different scales – from local to national to global
Circular and solidarity economy	It reconnects producers and consumers and provides innovative solutions for living within our planetary boundaries while ensuring the social foundation for inclusive and sustainable development

Source: FAO (n. d.1)

AGRO-ECOLOGY FOR SUSTAINABLE DEVELOPMENT AND FOOD AND ENERGY SECURITY IN UGANDA

(Good practice example 1.2.2)

Organisation	Center for Energy Governance, Uganda
Type of organisation	NGO
Person in charge	Ndyabandiho Saul
Target area	Uganda
Type of activity	Promote good energy governance for people and the environment
URL	www.ceguganda.org

Summary

The Center for Energy Governance of Uganda maintains that agro-ecology is the key to ensuring sustainable biomass feedstock supply and management, which is indispensable to fulfilling food and energy needs in rural areas and to meeting increasing future demand. Agro-ecology involves integrated land-use systems and practices for agriculture production that are suitable for a given local ecological environment. The practices often include planting of indigenous and useful woody perennial plants, i.e., trees, shrubs, palms, bamboos, etc., that are deliberately integrated with crops and/or animals on the same land management unit in some form of spatial arrangement, temporal sequence or synergy. Interaction with each other contributes to increased rural biomass supply, the maintenance of ecosystem stability and improved livelihoods.

Various agro-ecological practices in the western parts of Uganda have proved to be among the best for increasing productivity per area in the country. They have contributed to the estimated annual demand for Uganda's biomass, above 40 million tonnes, which is used for cooking (charcoal and firewood).

The area's main agro-ecology practices are 1) silvopastoral, which integrates livestock and trees; 2) agro-silvopastoral, which integrates annual crops, livestock and trees; 3) agro-silviculture, which integrates annual crops and trees; and 4) other agroforestry systems, such as alley cropping systems, intercropping, hedgerow systems, crop rotation, mulching and so forth.

The interaction of the diverse trees, crops and animals provides multilateral benefits. Trees provide feedstock for production of various forms of bioenergy, and solid biomass from branches obtained from planted trees is used as firewood and charcoal without causing deforestation. In addition, residues like leaves and oilseed cake are used for the production of biogas and charcoal briquettes as well as providing fodder for animals (these animals produce organic manure for stimulating soil productivity) and food for people (fruits, vegetables, nuts and oils) essential to meet nutrition requirements. The interactions also provide ecosystem services, as they help improve water management and soil fertility through maintenance of the nitrogen and water cycles. In addition, they support further environmental services, such as carbon storage, water purification and biodiversity conservation.

One of the good practice examples in agro-silviculture is the planting of the tree species Mugunga (Faidherbia albida) with other food crops and animals. Mugunga (Swahili) and Mutsuangu (Shona) is a fast-growing, nitrogen-fixing leguminous species that foliates during the rainy season and sheds leaves in the dry season (ICRAF, 2018; ICRAF, n.d.1; ICRAF, n.d.2). Mugunga's leafing phenology cycle is opposite to that of general crops; normally, plants grow leaves only during the rainy season. This means that Mugunga sheds leaves that contain a lot of nutrition, especially nitrogen, during the season when crops such as corn need it. Furthermore, when Mugunga's branches are bare, crops are exposed to sunlight. This is important because the shade cast by trees that are in leaf during the rainy season can inhibit crops from absorbing light. Increased crop productivity has been reported by farmers using the Mugunga-crop combination farming practice. For example, farmers in Uganda, Malawi and Zambia using this method have reported threefold productivity gains of corn crops, and increases in sorghum crops have been reported in Ethiopia (IAASTD, 2009; Yoshida, 2011).

Mugunga (Faidherbia albida) in a corn farm
Photograph: Njenga, ICRAF

A woman uses manure collected from goats (dung) reared on the plantation to enhance soil fertlity in Uganda
Photograph: Saul

Goats grazing in a Pinus carribea plantation in Uganda
Photograph: Saul

Scaling up

The practices detailed above can be applied and replicated in the central, east and northern parts of Uganda. Farmers in other countries, such as Kenya and the United Republic of Tanzania, among others, can also adopt these practices if knowledge sharing, applicability studies, development assistance and sustainable investment are made available.

In order for these practices to yield good results, some enabling conditions must be considered.

- farmer-centred approaches in the selection of technologies and the provision of inputs in the initial stages
- diversity of knowledge from both local and traditional knowledge and practices; common and expert knowledge
- community-based participatory research and innovation that facilitates the development of ecological production
- awareness and capacity building in agroforestry, land quality improvement, food and energy security to the farmers could lead to wide-scale adoption of the technology.

Presentation and summary provided by: Saul (2018)

A CROP-LIVESTOCK INTEGRATION SYSTEM TO INCREASE CROP AND MILK PRODUCTIVITY AND NUTRITIOUS BIOMASS AVAILABILITY IN MOZAMBIQUE

(Good practice example 1.2.3)

Organisation	Japan International Research Center for Agricultural Sciences (JIRCAS),[a] Moringa Mozambique Ltd.[b]
Type of organisation	Research institute,[a] Moringa oil producer/exporter[b]
Person in charge	Tetsuji Oya,[a] Tomoaki Yambe[b]
Target area	Mozambique
Type of activity	Development of technologies and production systems by scientific research and development (R&D)
URL	www.jircas.go.jp/en
Co-operator	Agricultural Research Institute of Mozambique (IIAM)

Summary

Agricultural potential in developing regions, including Africa, has not been fully realised because of adverse conditions such as low soil fertility and frequent droughts; therefore, ensuring food and nutrition security is too often a challenge. JIRCAS has a strategic objective of research to enhance agricultural productivity and improve nutrition for countries in need through the development of technologies to improve stability in agricultural productions under adverse environments, especially in the tropics (Nakashima, 2016).

In Mozambique, during the civil wars (1976–80; 1980–92), livestock production systems were severely damaged. Even now the livestock sector is growing slowly, characterised by low productivity due to limited access to the latest technologies, management practices and marketing for the majority of smallholder livestock producers (Hendrickx, 2009; Rutazihana, Hendrickx and Moyo, 2011).

However, livestock is not only the means for farmers to sustain their livelihood; it is also an important financial asset. Farmers in rural areas may not have access to banks in which they may save funds or be guaranteed survival in case of emergency.

To improve dairy cattle's productivity, an effective and efficient crop-livestock integration model must be developed. The model should be holistic, take seasonality into consideration and be applicable throughout the year in tropical savannah areas, which have distinct rainy and dry seasons. Technologies must also be devised to produce animal feeds without disrupting food security, using by-products generated from crop production and food processing. The development of a method to produce compost from livestock waste to enhance soil fertility would be useful to improve food crop production and sustain forage crop production by farmers.

Figure 7. Technology development to create a crop-livestock integration model in Africa

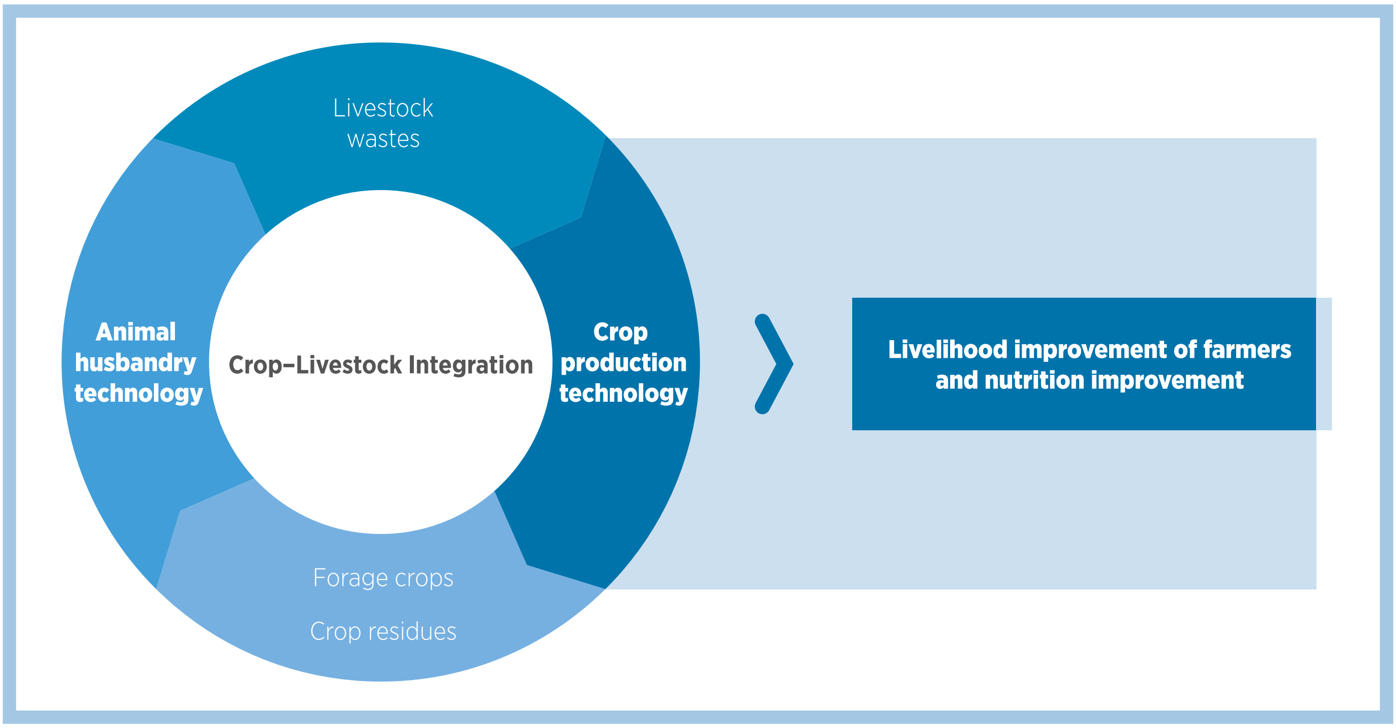
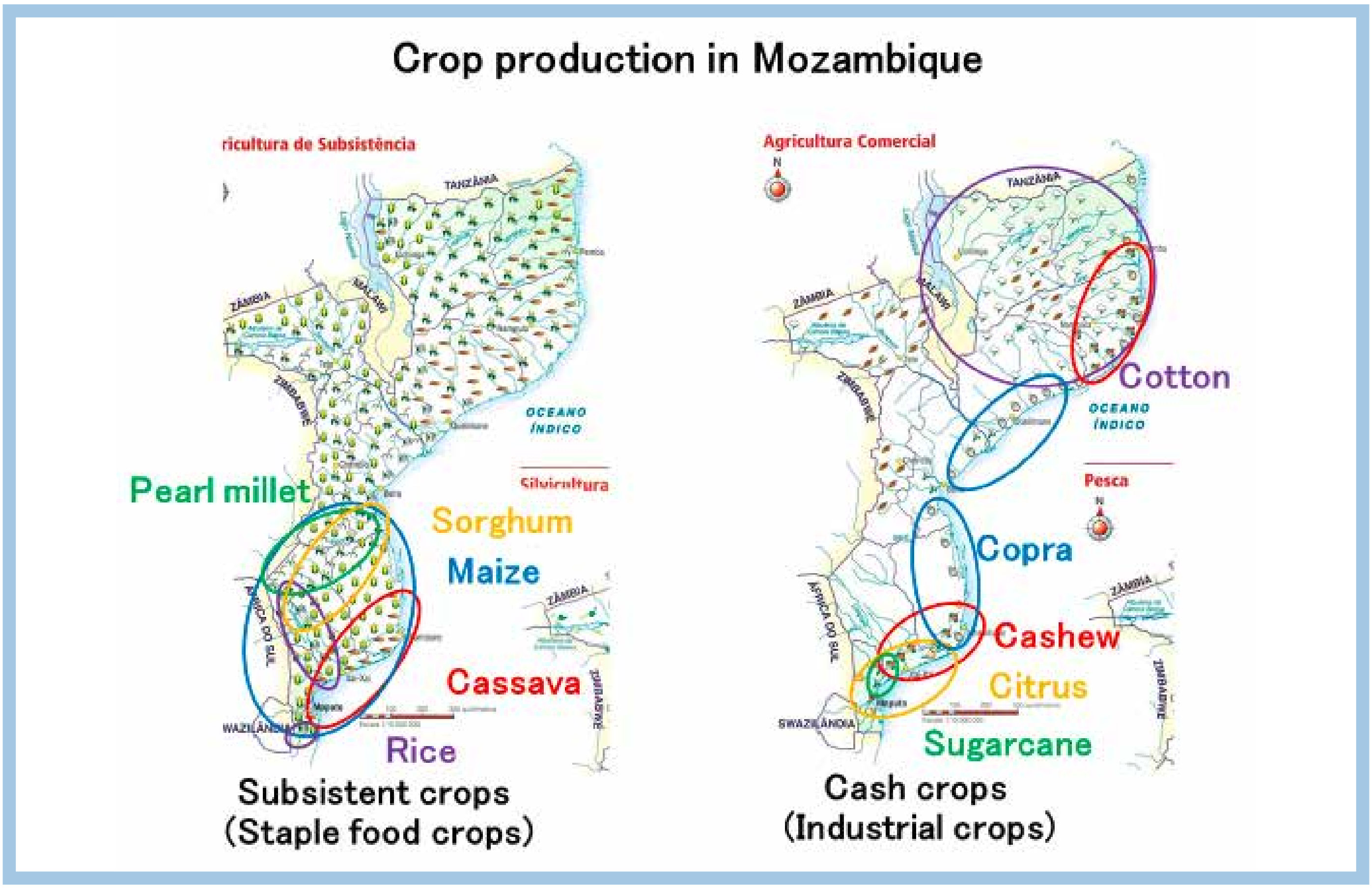


Figure 8. Crop production and availability of residues and by-products in Mozambique



Source: Atlas de Moçambique (2009; modified)

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

The main problem is feed shortage during dry seasons. Silage preparation in the late rainy season and use of crop residues as feed contribute to alleviating this shortage. Appropriate forage crops suitable for silage that have optimum conditions for food and feed production of the dual-purpose crops should be identified and the degree of drought tolerance of forage crops evaluated. Farmers are expected to find it advantageous to grow drought-tolerant forage crops during dry seasons so that they can avoid increased workloads during the busy farming seasons for food crops

Many farmers in Mozambique burn crop residue and animal waste – not as an energy source, but for clearance or to reduce volumes. Incorporation of these unused resources into the crop-livestock integration system will contribute to increased biomass availability.

Clockwise from upper left: dairy cattle, fermented silage, sweet potato at harvest and cowpea at harvest
Photographs: Oya

Potential crop-livestock integration system

Some good practices have been successfully adopted in other African countries. For example, in Rwanda, the Support Project for the Strategic Transformation of Agriculture, supported by the UK's Department for International Development (DfID), introduced the fodder species Mucuna (velvet bean), Cajanus cajan (pigeon pea) and Sesbania magrantha, which fix atmospheric nitrogen in soil by an agroforestry system (OI, n.d.5). Cows and other livestock develop well when fed with these protein- and nutrient-rich fodders. These fodders also increase the amount of cow manure, a useful compost ingredient, and crops grow well using the compost made of the manure.

In Senegal, grasses (Panicum and Andropogon) and nitrogen-fixing leguminous trees (Gliricidia and Leucaena) are planted as feed gardens for cattle, goats, sheep and horses. These tree species enrich the soil with leaf litter in degraded areas where there is limited water availability and in sandy soils that are low in organic matter (OI, n.d.6).

Other tree species that are good for feeding animals in sub-Saharan Africa include Mugunga or Faidherbia albida. Mugunga is a tree species that leafs out during the dry season and sheds its leaves in the rainy season (good practice example 1.2.2). This is the opposite of ordinary species, which defoliate during dry seasons. Mugunga is very useful for feeding animals during the dry season, when other feed is scarce.

Moringa is another tree species with good potential for crop-livestock integration. Moringa oleifera, which grows in Mozambique's northern and southern regions, is well known as a fast-growing species whose nutritious leaves are edible for both humans and animals (Broin and de Saint Sauveur, 2010).

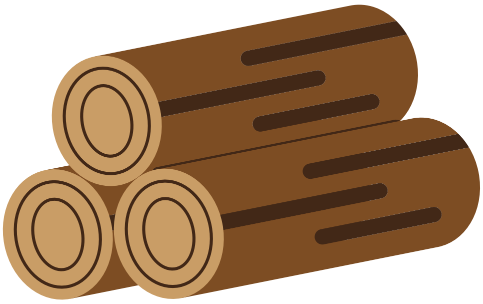
Moringa Mozambique Ltd. grows Moringa trees with a planting density of 1 600 trees per ha. To maintain the height of the Moringa tree, the company prunes 12.67 kg of stems per tree each year (Yambe, 2018). The pruning starts two to three years after planting. In rural areas of Mozambique, per capita firewood demand is estimated at 670 kg annually (Falcão, 2013). With the assumption that a cow needs five tonnes of fodder per year, a 1 ha Moringa silvopastoral plot can feed three cows while providing firewood for a family of five.

Table 2. Nutritional value of Moringa leaves in comparison to other vegetables

Contents in 100 g	Caloric value (kcal)	Protain (g)	Fat (g)	Carbon hdrate (g)	Fiber (g)	Calcium (mg)	Magnesium (mg)	Phosphorus (mg)	Kalium (mg)	Zink (mg)	Copper (mg)	Iron (mg)	Vitamin A (IU)	Vitamin B1 (mg)
Moringa leaf powder	385	25.1	11.2	46	3 087	512	268	1 128	4.29	0.6	9.39	2 587	2 067	1 983
Spinach	25	3.3	0.5	4	49	69	47	690	0.7	0.11	0.9	320	210	140
Tomato	16	0.7	0.1	3.7	7	8	26	210	0.1	0.04	0.2	240	71	25

Source: Japan Food Research Laboratories in Sankou Rich Foods (2009)

Figure 9: A model of crop-livestock integration with firewood production for a family of five



» Moringa trees: 1 600 per hectare
» Pruned material, yearly, from each tree: 12.67 kg
» Biomass per hectare per year: 19.2 tonnes
» Yearly consumption:
  - Each cow: 5 tonnes (= 15 tonnes for three cows)
  - Family of five, firewood needs: 3.3 tonnes per year
» Yearly demand: 18.5 tonnes

Moringa plantation and measurement
Photograph: Yambe

Scaling up

Site-specific suitable technologies should be developed through field experiments, feeding experiments, and chemical analysis at the research stations working closely with farmers and research institutes (on-station). First, the applicability and effectiveness of existing technologies and practices used by local farmers must be assessed.

Such systems have to be evaluated from a socio-economic perspective, as well as by gauging soil fertility improvement. These processes will enable the preparation of manuals to be used for extension. The more trees grown that are integrated with agroforestry, crop and livestock production, the more biomass will be available; hence, feedstock availability for bioenergy will be improved.

1.3. THE BIOCHAR, SOIL, WATER AND ENERGY NEXUS

This section aims to raise awareness about the roles of soils and water in food and energy production, and to highlight the value of biochar. Biochar can add moisture and nutrition to soils and is available as a by-product of bioenergy. Good practices described in this section reflect various integrated agroforestry systems, such as firewood pruning and char production in Kenya; the fertilising effects of biochar in Ghana; and a method to drill wells without the use of machinery.

Concept

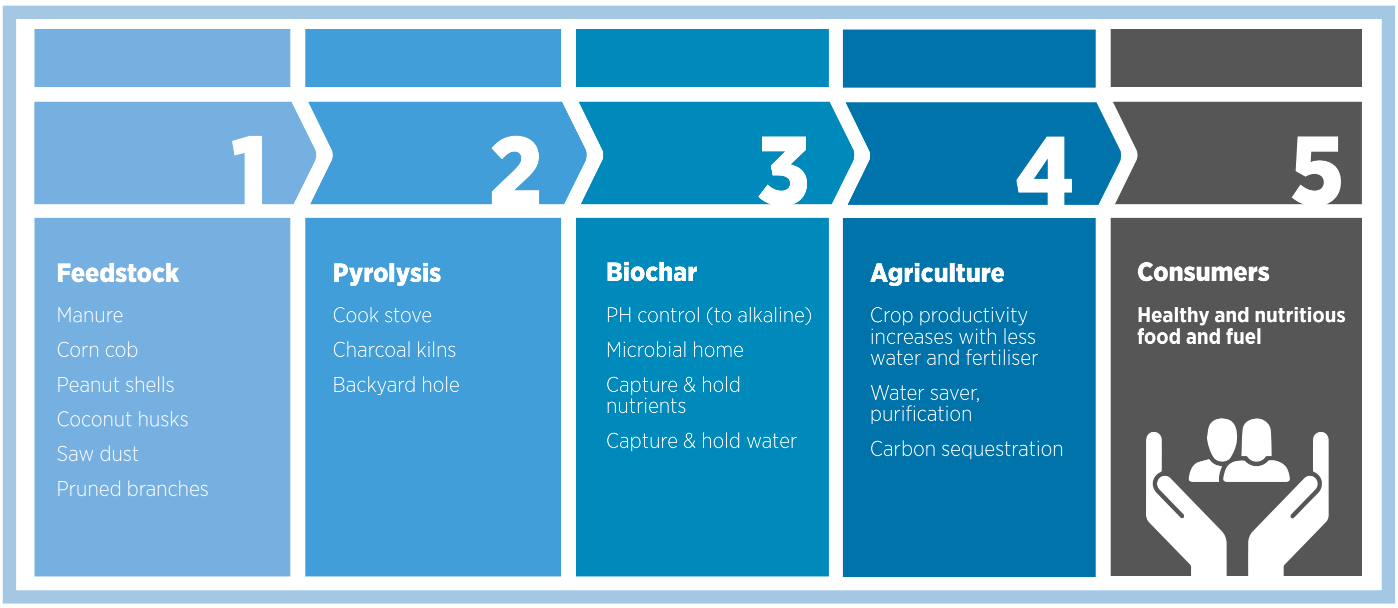
Soil is a key resource for growing crops for food and energy. Soil is home to microbiomes, bacteria, insects, moths and earthworms, among many other creatures. Biological diversity is important for soil health and for the ecosystem. The application of excessive pesticides or chemical fertilisers can kill or weaken millions of microbes and impacts negatively on the chemical and biological environment of soil. Even though bulk application of fertilisers and pesticides may improve productivity for a short time, in the long run they may result in outbreaks of pests arising from an imbalance in the ecosystem and hence less-productive harvests.

Recently, increasing numbers of consumers have begun to choose organic and natural farming agricultural products due to the health and nutritional benefits derived from improved soil health (Montgomery and Bikle, 2016). As seen in Chapter 1, Section 2, such re-discovery is not new for many farmers in sub-Saharan Africa, who have adopted agro-ecological good practices including the use of soils that contain biochar from sifting cultivation.

Biochar is composed of carbonised plant matter obtained as by-products of electricity and/or heat generation through biomass pyrolysis. In other words, through the commonly practiced field burning in their shifting cultivation cycle, farmers in sub-Saharan Africa have traditionally incorporated biochar into their cultivation practices. Studies have shown that mixing biochar into the soil improves crop productivity by retaining soil nutrients and moisture, ameliorating acidic soils, and stimulating microbial diversity and activity (Gwenzi et al., 2017). With improved productivity, an increase in the availability of biomass for energy is expected.

Soil is a key resource for growing food and energy crops

Figure 10. Overall picture of potential biochar production systems and applications in agriculture



Because biochar is porous, it has a large surface area. This gives it a high capacity to preserve water and contain air, which in turn attracts rootlets of plants when it is put into soils. It also has a high capacity to retain natural nutrients from fertilisers and avoid eluviation. Biochar helps improve the durability and effects of fertilisers applied for plants to grow well. Its porous nature enables autotrophic bacterium – or microbes, including root nodule bacteria, which are cohabitants with plants – to live well in it.

On the other hand, because biochar is burned at a high temperature and has alkaline properties, fungus and mushrooms – harmful for the growth of plants – cannot survive or be grown in it. The relationship between plants and microbes is symbiotic. Microbes concentrate on the roots of plants to absorb nutrition by decomposing inorganic materials to ion, which is the form plants need to be able to absorb and to grow. In short, biochar provides a living space for useful microorganisms and preserves water and nutrition effectively via its porous and alkalic features while removing substances harmful for the growth of plants.

Biochar works most effectively in dry areas; in acid, infertile soil; and in less humid soil. Many parts of sub-Saharan Africa have these environmental features, and the addition of biochar to this soil can be expected to increase productivity.

For example, an experiment was conducted on an area with Ultisol soil in Ghana to see how biochar application could increase the yield of maize. The study found that maize production on the biochar applied soil was 5 648.3 kg per ha compared to the control of 3 615.5 kg per ha without biochar (Yeboah et al., 2016). Analysis determined that biochar contributed to a 56 % productivity increase.

Biochar application into the soil has additional positive features for plant growth, including:

» improvement of soil water retention capacity due to biochar's porousness (Karhu et al., 2011)

» capacity for high physical absorption of nutrition through the macrospores to micropores

» provision of room for microbes that consume and digest soil organic matter into cations that are nutritious and necessary for plants to grow.

These features are beneficial for farming in a sub-Sahara African environment, where there is limited availability of water and fertilisers. The application of chemical fertilisers and pesticides impoverishes soil fertility, kills microbes and causes chloride damage. The application of biochar, on the contrary, improves soil structures, which allows the retention of fertility and the growth of healthy and nutritious plants. It has also been reported that biochar is able to remove assorted contaminates (microbial, organic and inorganic) at a low cost (Gwenzi et al., 2014). Areas and countries that lack adequate water-treatment systems may leverage biochar's ability to remedy pollution.

Bioenergy and water resource availability are strongly interrelated because bioenergy production is very much dependent on biomass production (UNEP et al., 2011). Water is not an unlimited resource. Around the world, growing numbers of groundwater pumping irrigation systems for industrial agriculture are reportedly drying up and being abandoned due to an exhaustion of groundwater.

The FAO's Land and Water Division (Hoogeveen, 2016), estimates that the per capita daily water requirement is:

» drinking water: 2 3 litres (L)

» domestic needs: 20 300 L

» food: 2 000–3 000 L.

Hoogeveen also indicates the water requirement figure for agricultural production as 1 kilocalorie (kcal) of food for 1 L of water – so approximately 2 500 litres of water are required for per capita food production (Hoogeveen, 2016). However, higher-calorie foods require more water to produce, for example:

» to grow 1 kg of wheat requires 1 000 L of water

» to grow 1 kg of meat (beef) requires 15 000 L of water.

Children in Bilene, Mozambique, for example, carry approximately 20 L of water each, in jugs on their heads, from the nearest freshwater well, pool or river. To produce 1 kcal of energy, three children from a typical local household make 50 trips from the well to their farm.

Children carrying water in Bilene, Mozambique
Photograph: Inoue

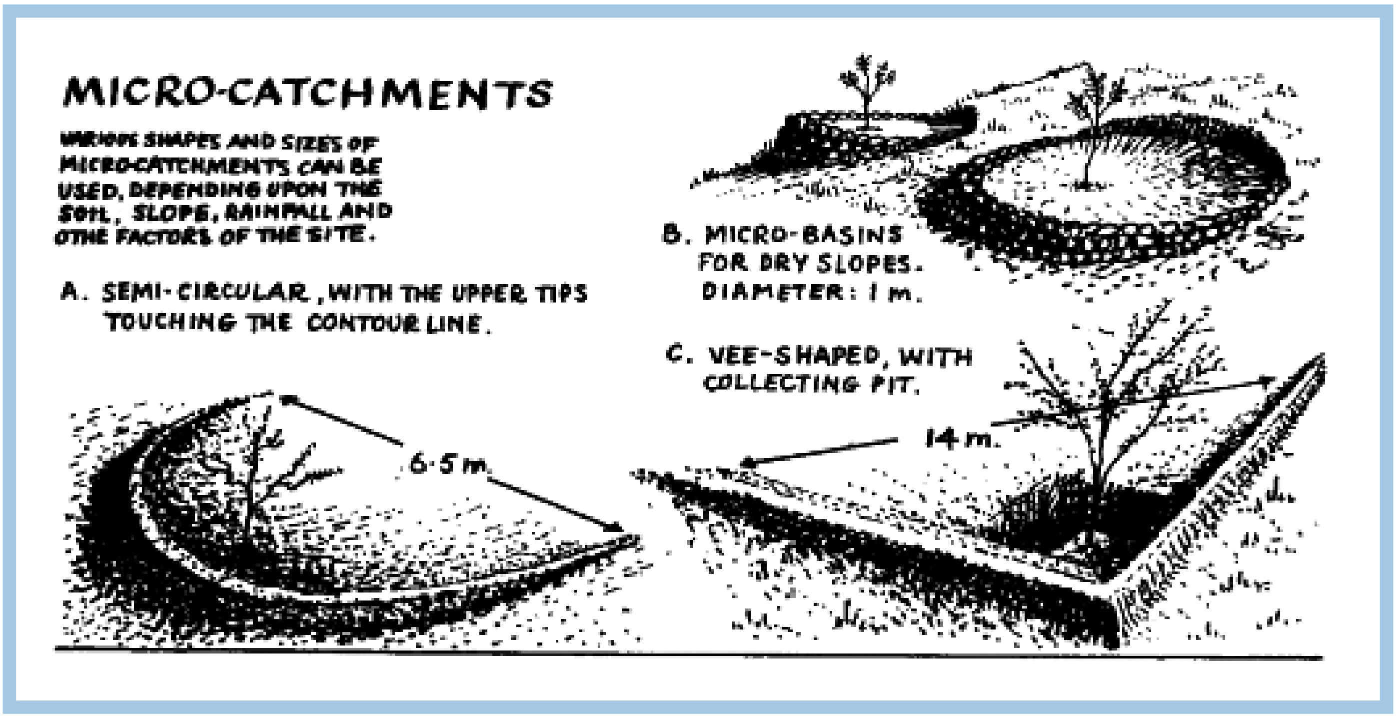
To produce food for one adult human per day, 2 500 L of water is required. This is the equivalent of producing enough biodiesel to drive a car for 15 kilometres (km) (Hoogeveen, 2016). When considering a scale-up of food and energy production to meet growing demand, assessments must also consider water footprint and efficiency.

To date, only 3 % of sub-Saharan Africa's agricultural lands are irrigated (FAO, 2015a). The remainder are rain-fed, leaving crops vulnerable to erratic climatic conditions. Agricultural productivity is highly dependent on water availability. The African continent's total of 5 640 km^3 of fresh inland water comprises the Nile river (6 650 km), the Congo river (4 700 km), the Niger river (4 200 km), the Zambezi river (3 500 km), Lake Victoria, Lake Tanganyika and Lake Malawi/Nyasa, among many others. This total is equivalent to 10 % of the earth's fresh surface water resources. However, only 4 % of this resource is used in Africa because of the high development costs of irrigation.

This publication aims to share "affordable" technologies for the majority of farmers in rural areas. Low-cost water technologies are available for use in rural Africa. For example, in Ethiopia, "water harvesting" systems have been developed in Oromia Province. Water harvesting technology collects effluent water from rain or dew, which is then made available for agricultural, pastoral and domestic needs. There are many kinds of technologies, such as using a hemispherical tank, a trapezoidal-shaped reservoir and drip watering, among others.

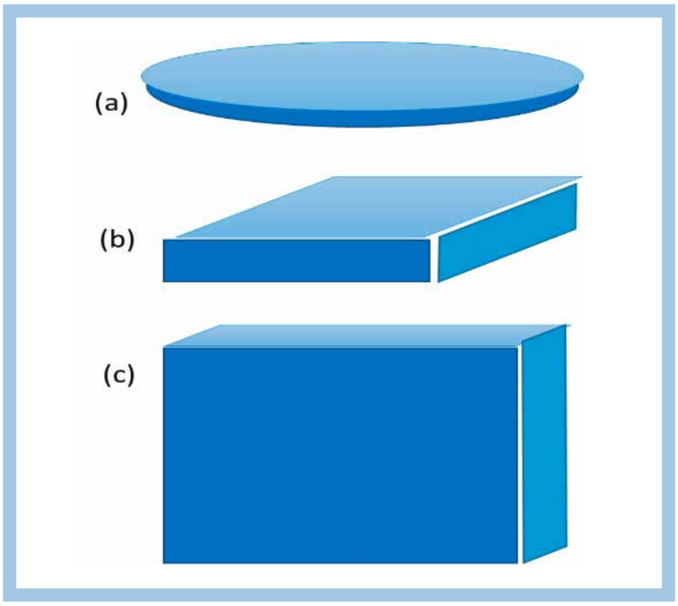
For the purposes of tree planting, micro-catchment technologies are often practiced, such as semi-circular arrangements with the upper tips touching a contour line, V-shapes with collecting pits, micro-basins for dry slopes and others.

Figure 11. Water harvesting system for dryland tree



Source: Rocheleau, Weber and Field-Juma (1988)

Figure 12. Pond shape affects water evaporation



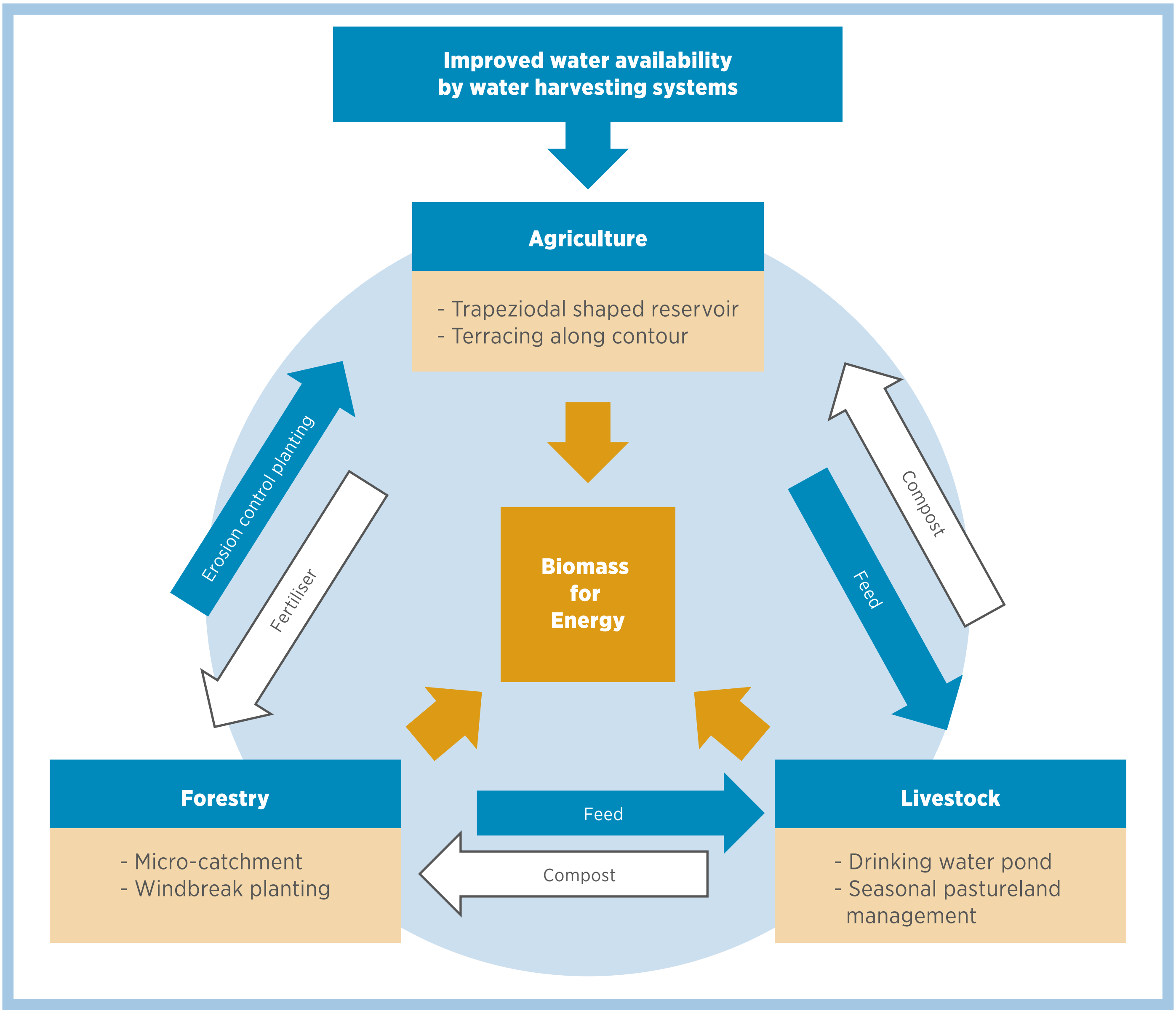
Water is indispensable for producing bioenergy, not only to grow plants and animals but also to produce biogas by an anaerobic methane (CH_4) production system. Bansal, Tumwesige and Smith have shown that 50 L of water is required for a cow and 10 L of water for a pig, or 25 L per capita a day using a digester volume of 1.3 (±0.3) m^3 (Bansal, Tumwesige and Smith, 2017).

Rainwater harvesting is an important technique to increase water availability. After rainfall, if rainwater is left in a shallow pond (as in Figure 12a), water will quickly evaporate. The formation shown in Figure 12b is better than that in Figure 12a, but the storage shape shown in Figure 12c avoids evaporation at the highest rate. The reason for this is the effect of waves on the water: shallow surface water ruffles easily with wind. Figure 12c is therefore the recommended shape for water storage to avoid water evaporation.

Figure 13 explains the interrelation among agriculture, forestry and livestock in sub-Saharan Africa. Most of the farmers who carry out rain-fed agriculture manage their land by this system.

Improving surface water delivery by using water harvesting systems for rain or surface water irrigation from rivers or lakes are starting points for productivity improvements. Positive interactions among agriculture, forestry and livestock can increase biomass residue availability from harvest residues and processing wastes.

Figure 13. Interdependence among agriculture, forestry and livestock in rural sub-Saharan Africa



FIREWOOD FROM ON-FARM TREE PRUNING AND BIOCHAR-PRODUCING COOKING SYSTEMS

(Good practice example 1.3.1)

Organisation	ICRAF,[a] University of Nairobi,[b] Pennsylvania State University,[c] JIRCASd
Type of organisation	Research institutes
Person(s) in charge	Mary Njenga,[a,b] Miyuki Iiyama,[a,d] James Kinyua,[a,b] and Ruth Mendumc
Target area	Kenya (Kibugu Village, Embu County)
Type of activity	Agroforestry, wood energy from pruning of multipurpose trees, gasifier cookstoves
URL	www.worldagroforestry.org/
Co-operators	JIRCAS,[d] the Consultative Group on International Agricultural Research (CGIAR) programme on sustaining rural-urban linkages – Water Land and Ecosystems, the Office of International Programs, College of Agricultural Sciences, Pennsylvania State University and Swedish Research Councils VR and FORMAS through KTH Royal Institute of Technology

Summary

To manage the challenges associated with the heavy reliance on fuelwood for cooking among rural farmers in Kenya, a systematic package of innovations addressing both sustainable tree supply and efficient/healthy consumption is required. On farms, cuttings taken from the pruning of multiuse woody plants, such as fruit trees, can provide households with an affordable and convenient source of firewood. Agroforestry or agriculture with trees for small farms may be carried out in different ways, where trees are planted along boundaries, as live fences, intercropped with crops or pasture or in woodlots. A study carried out in Kibugu village in Embu County showed that 40 % of the farmers depended exclusively on agroforestry for firewood supply (Njenga et al., 2017). Grevillea robusta grown mainly for timber was the main source of firewood. Growing a farm boundary is a common practice among farmers, in which an average of 1 acre had between 15 and 386 trees – an average of 116. Farmers practiced a well-developed pruning regime after every 2 years as a management practice to enhance the quality of timber and stimulate biomass production. Pruning is carried out during the dry season, which allows firewood to dry under the sun and reduce its moisture content and consequently the amount of smoke it creates in the kitchen. Some of the farmers produce surplus firewood that they sell to neighbours as a source of income. Sourcing firewood from farms has the added benefit of easing the burden women experience in gathering other sources of fuelwood, for which they travel an average of 8 km per day.

Biochar-producing cooking systems for efficient energy use and crop yield improvement

Although a recent innovation, gasifier cookstoves are becoming popular for domestic food preparation in the developing world (Torres-Rojas et al., 2004). A gasifier cookstove produces gaseous energy from the burning of dry solid biomass. Biomass such as firewood, coconut shells or maize cob burns under controlled oxygen. As a result, the pyrolysis process – in addition to producing heat for cooking – turns the fuel into charcoal. Compared with a three-stone open fire, a top-lit natural updraft gasifier saves 40 % of fuel and lowers concentrations of fine particulate matter (PM 2.5) and carbon monoxide (CO) by 90 % and 45 %, respectively (Njenga et al., 2016). The gasifier cooking system produces fewer gases and particles as the fuel burns under high temperatures. In addition to acting as cooking fuel, the resulting charcoal produced (biochar) can be added to soil, where it improves fertility and sequesters carbon (Jeffery et al., 2011).

Farmers have identified the following benefits from using the gasifier stove: less fuel consumption and smoke; ease of cleaning, handling and adjusting the heat; no need to push wood; less heat exposure; and charcoal production (Gitau et al., 2017). Some challenges, such as difficulties in lighting, etc., were identified that will guide the redesign of the stove.

Lessons, impacts and replicability

For best results in improving access to fuel and cleaner cooking among small-scale farmers, a systematic approach that combines sourcing firewood from multipurpose trees on farms and the use of efficient cooking systems will have more impact. For example, in the United Republic of Tanzania, on-farm wood supply ranged from 0.5 8 t/ha. Relative to three-stone open fires, households using an improved cookstove consumed 67 % less firewood, saved 50 % of fuelwood collection time and reduced gas emissions (PM10) by 60 % (Sererya et al., 2017). This approach is replicable among small-scale farmers in a wide range of landscapes.

Presentation and summary provided by: Njenga et al. (2018)

(left to right) Pruned and polladed Grevillea robusta trees; cooking with a gasifier stove; charcoal produced using a gasifier stove; biochar application for crop production
Photograph: Better Globe Forestry (far left); Njenga

BIOCHAR IN GHANA

(Good practice example 1.3.2)

Organisation	Africa Biochar Partnership, ECOWAS Center for Renewable Energy and Energy Efficiency (ECREEE), ASA Initiative
Type of organisation	NGO
Person in charge	Veronica AgodoaKitti
Target area	Ghana
Type of activity	Community support for sustainable development
URL	www.ecreee.org/news/launch-africa-biochar-partnership-0
Co-operation with	African Union Commission, NEPAD, European Commission

Summary

A method to produce the Elsa Burner, which makes biochar efficiently from agro-industrial wastes, was developed by the "Biochar Plus: Energy, Health, Agricultural and Environmental Benefits from Biochar Use: Building Capacities in ACP Countries" project. The Elsa Burner's biowaste-burning fire can be used as domestic cooking fuel. The smoke (syngas) from the long, narrow chamber of the Elsa Burner can be lighted to start a secondary combustion with low emissions. In this way, respiratory diseases can be reduced.

Elsa stoves, which are a kind of rocket stove, can be produced by anyone using some metals and other materials. There is an explanatory video that explains a simple method for producing biochar by systematic pyrolysis (EU-ACP, 2014). The bio-organic waste burned by the Elsa stove is placed on the sand and covered by the sand to create an anaerobic environment. After leaving it for a short time, biochar is created (EU-ACP, 2014). Biochar feedstock pellets are derived from various agro-industry wastes, including empty palm bunches, fruit peels, nutshells and corncobs.

The porosity of biochar, when applied to agricultural soil, helps increase crop productivity by enhancing water and nutrient retention in the long-term. Biochar also prevents crops from absorbing toxic elements like weedicide and heavy metals.

The ASA Initiative determined that the application of biochar doubled the yield of maize and improved the quality of the crops, due to the following benefits:

- increased water retention
- moderated soil acidity
- increased number of soil microbes
- increased microorganisms that convert inorganic substance to ion, which can be absorbed by plants to grow as nutrition.

Scaling up

The Africa Biochar Partnership provides a framework for collaboration in pursuit of broad strategic goals and a viable approach for technology replication in Africa. In addition, securing the availability of biomass-agro and/or agro-industrial waste, skilled artisans, capacity building for technology transfer, farming communities and other raw materials including steel metal sheets is needed.

Presentation and summary provided by: AgodoaKitti (2018)

- **Without biochar**

- **With biochar: double the yield**

Effect of biochar application on maize yield, Ghana
Photograph: ASA Initiative

KAZUSABORI: UNMECHANISED WATER HARVESTING FOR IMPROVED FOOD AND ENERGY SECURITY IN KENYA

(Good practice example 1.3.3)

Organization	Team Kazusabori for Afrika,[a] International Water Project (IWP),[b] Aid Africa[c]
Type of Organization	NGO
Person in Charge	Hisayo Echigoa
Target Area	Kenya,[a,b] Ugandac
Type of Activity	Well drilling for local communities
URL	http://keiseitoriyajp.wixsite.com/kazusabori-afrika

Summary

Water is required for both bioenergy and food production. However, sub-Saharan Africa too frequently experiences water scarcity seasons. The least costly water harvesting system can aid communities in need of water.

Kazusabori is a water well drilling method traditionally practiced in Japan. Using the Kazusabori method, groundwater located 300 metres (m) underground can be reached without using any machines; all that is required for this method is bamboo, iron tubing and people skilled in the technique.

NGO Team Kazusabori Japan teaches communities how to drill wells manually. The team not only drills the wells, it also teaches the Kazusabori construction method via on-the-job training. This enables local communities to develop their own capacity to plan, construct and repair their wells. Therefore, this is a sustainable practice because people in the communities are able to manage and maintain the wells continuously and at a low cost.

Too often, rural communities suffer from diseases such as cholera caused by contaminated river water – especially the most vulnerable, such as children of families living in poverty. With the fresh water from Kazusabori wells, these people have access to safer water that saves many lives.

IWP also practices a similar method of well drilling in Kenya, drilling more than 100 wells (Government of Kenya, 2017) and similar methods taken by Aid Africa in Uganda (Aid Africa, 2018a).

Water well construction using the Kazusabori method
Photograph: Team Kazusabori for Afrika

1.4. TREE AND CROP BREEDING FOR ENHANCED BIOCARBON STOCKS

This section aims to share insights on how to improve the productivity of key species that can increase biocarbon stocks for energy use. Good practices include the breeding of tree varieties in Kenya and sugarcane varieties in Thailand.

Concept

In sub-Saharan Africa, sustainable biomass feedstock for bioenergy is not widely available. This is because of the land's geological age, which is Precambrian in most areas, except for the Great Rift Valley and Congo basin (Sanchez, 2002; FAO, 2003). In many areas, the soil is exhausted and weathered, and its fertility is quite low. Furthermore, areas with good soil conditions may be occupied by residents and communities (Chambers, 1969; Nana-Sinkam, 1995). Fallow periods are shortened in countries with limited good land area and as populations grow in countries such as Burundi, Ethiopia, Kenya, Malawi and Rwanda (Nana-Sinkam, 1995).

In equatorial areas, high temperatures quickly decompose organic matter and it becomes acid. Organic matter provides porosity, which creates pathways for water and air in the soil and creates capacity to absorb and retain nutrients. In general, plants in sub-Saharan Africa are at a disadvantage in terms of growth, because of the drier environment, limited organic matter, base deficit and quick weathering speed.

Under such hard conditions, farmers in Africa have been making significant efforts to improve the productivity of crop species by on-site breeding to match environmental conditions. One of the most promoted crops to date is NERICA (New Rice for Africa).

Harvested NERICA crop
Photogaph: AGRICS

A rice species called glaberrima has been produced in Africa for 3 500 years around the Niger River basin (Kamishiro and Ikeda, 2008). However, glaberrima was not very productive (Kamishiro and Ikeda, 2008; Africa Rice Center, n.d.).

In 1960, Africa's annual rice production was around 2 000 tonnes, growing to around 16 000 tonnes in 2007 and over 25 000 tonnes in 2016 (FAO, n.d.3). Rice is a high-calorie, nutritious food, and its husks make useful bioenergy feedstock for the production of briquettes and heat and power cogeneration. Breeding efforts have increased productivity and have gained positive attention (see Chapter 2).

In 1970, the West Africa Rice Development Association (renamed the Africa Rice Center in 2009) began performing research for breeding, growing method development, disease control and soil fertility improvement for rice production (Kamishiro and Ikeda, 2008; Africa Rice Center, n.d.). In 1997, the Japanese government, the UNDP and the Rockefeller Foundation co-funded the Africa-Asia Research Co-operation: Africa-Asia rice cross breeding project. Researchers from IRRI, JIRCAS and Tokyo University joined the project and conducted research and testing to develop the drought and acidic soil tolerance species (Kamishiro and Ikeda, 2008).

The project resulted in seven rice species, together given the name "NERICA", which were developed by crossbreeding glaberrima from Africa and sativa from Asia in 2000 (Kamishiro and Ikeda, 2008). The 18 varieties of upland NERICA and 60 varieties of lowland NERICA were developed and registered by 2008. JICA and Sasakawa Foundation also supported the distribution of the NERICAs, which are suited to drylands in sub-Saharan Africa. Over the last five years, the varieties have been distributed and grown on more than 200 000 ha of land in several African countries. These include Benin, Côte d'Ivoire, Guinea, Mali, Nigeria and Uganda, with further expansion planned (Africa Rice Center, n.d.).

BREEDING DROUGHT-TOLERANT TREE VARIETIES FOR CLIMATE-CHANGE ADAPTATION AND BIOMASS SUPPLY ENHANCEMENT IN KENYA

(Good practice example 1.4.1)

Organisation	Kenya Forestry Research Institute (KEFRI)
Type of organisation	Research institute
Persons in charge	G.M. Muturi, J.G. Kariuki, S. Omondi and D.K. Muchiri
Target area	Kenya
Type of activity	Tree breeding by scientific R&D
URL	www.kefri.org/
Co-operation with	JICA

Summary

Dryland forests (woodlands, bushland, grasslands and riverine forests) constitute 49 % of Kenya's forests. For a long time, dryland forests have not been well managed and are therefore heavily degraded in terms of their ground vegetation cover, species diversity and genetic loss of overexploited species. Besides anthropogenic pressure, dryland ecosystems are also experiencing the negative impacts of climate change that manifest in frequent, prolonged droughts and temperature rise, among other impacts.

Genetic conservation of superior genotypes of overexploited species and their improvement for adaption to climate change is therefore a national priority. Acacia tortilis and Melia volkensii are classic examples of dryland tree species that have been overexploited primarily for charcoal and timber, respectively (Yamauchi, 1994). However, their overexploitation provides an opportunity as it signifies their wide acceptance as valuable resources in their natural range; hence their choice as pioneer species for breeding indigenous trees in Kenya's drylands under the KEFRI/JICA project to develop drought-tolerant trees that are able to adapt to climate change.

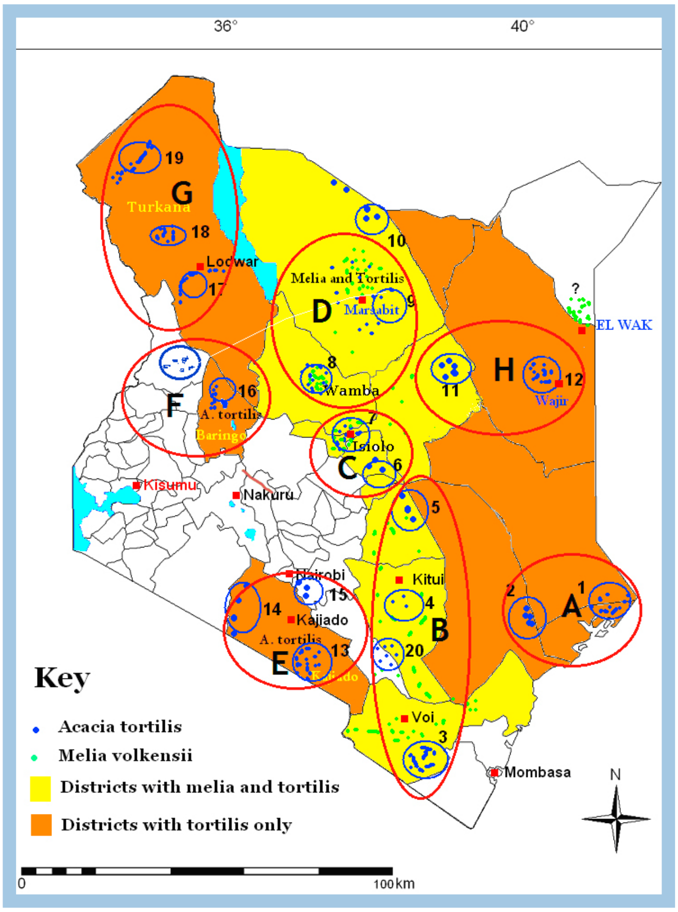
Figure 14. Acacia tortilis, specification and piles of wood charcoal bags in Kenya

A. Tortifis

- provides fodder
- fuelwood and charcoal use
- high calorific value (4 400 kcal/kg)

Source: Muturi et al. (2018)

Figure 15. Selected populations of A. tortilis and M. volkensii



Source: Muturi et al. (2018)

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

Seeds of A. tortilis were collected from the CPTs, seedlings raised in the nursery and two seedling seed stands established at Kibwezi and Tiva. However, the establishment of A. tortilis stands was delayed by poor seeding trends during the project period, and sufficient growth data has not been collected. For M. volkensii, scions were obtained from the CPTs and grafted with rootstocks that were raised from general seed collection. At the end of the nursery period, 60 high-quality grafts of each of the 100 CPTs were selected and used in the establishment of M. volkensii clonal seed orchards at Kibwezi and Tiva. Since all 100 CPTs could not be planted at once, the orchard was planted in stages, with 60 CPTs initially, followed by two plantings of 20 CPTs each.

African farmers have gradually improved crop productivity through selective on-site breeding

Figure 16. Tree breeding project outline

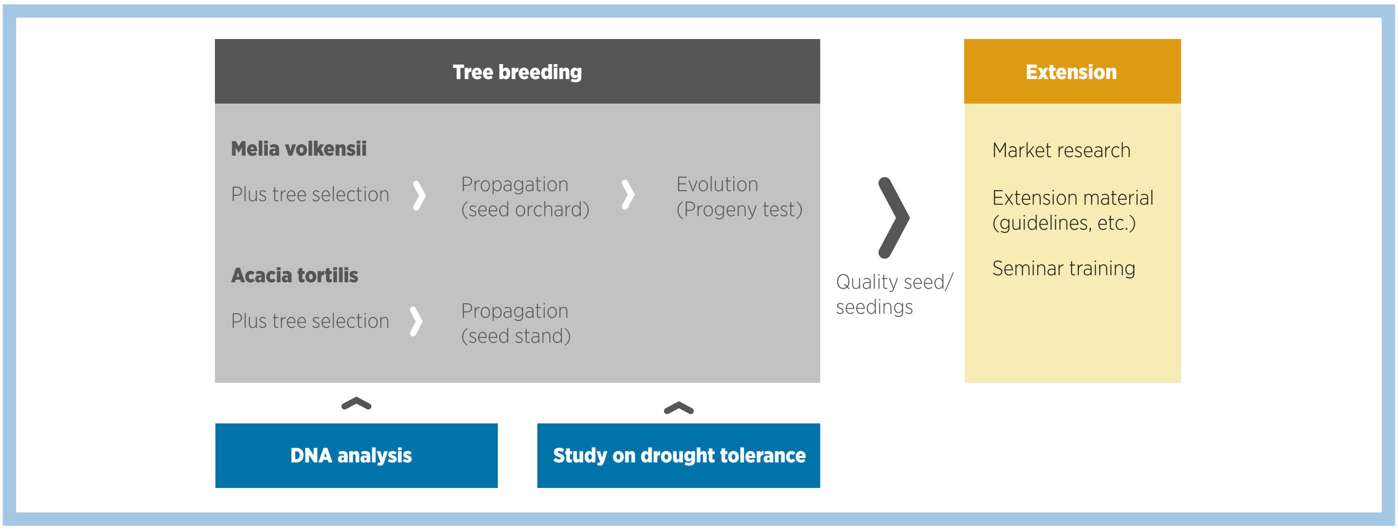


Figure 17. Melia and Acacia

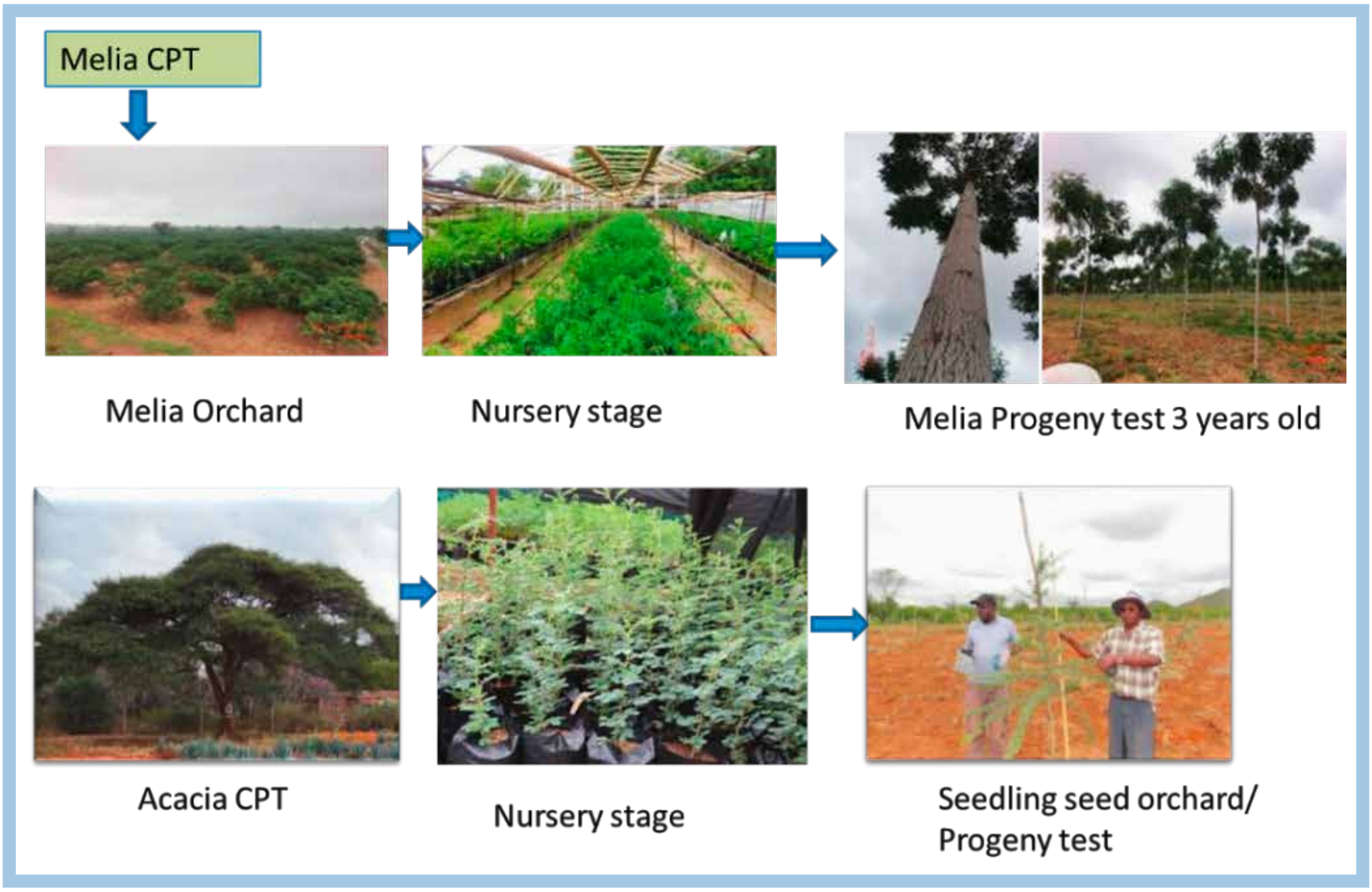
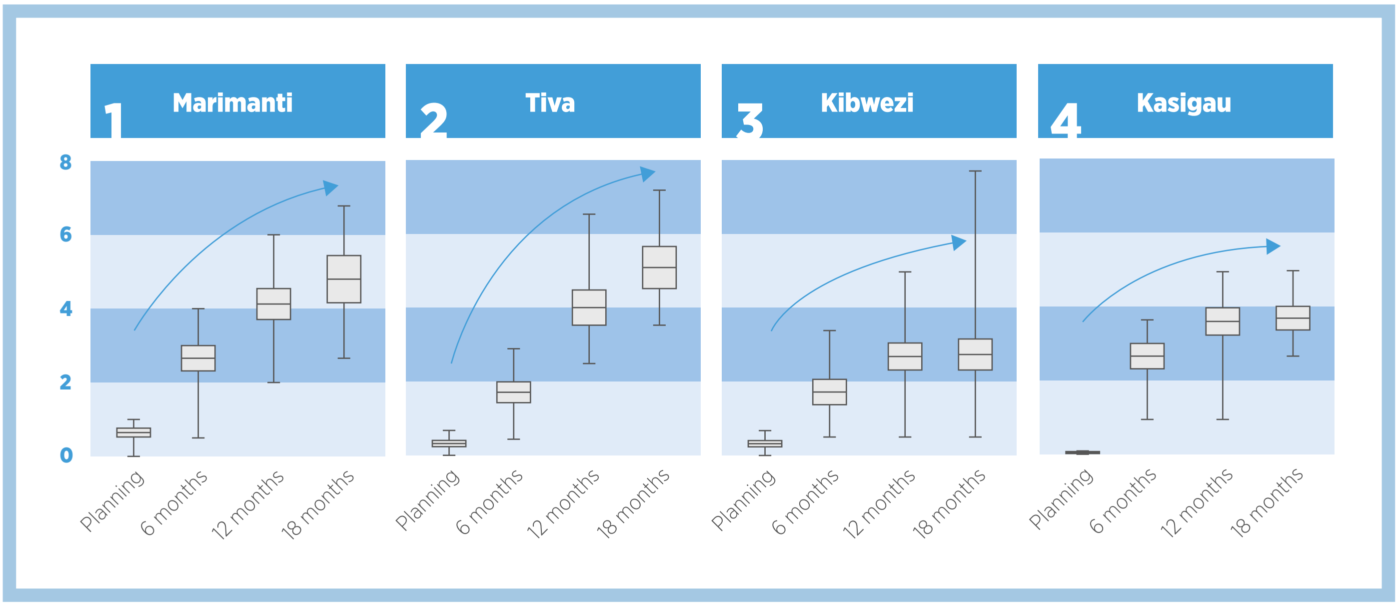


Figure 18. Difference in results of growth by original location of the seed



After two years, seeds of the first 60 CPTs were obtained from the Melia clonal orchard and supplemented with seeds from CPTs in the natural populations and their four main progeny trials established at Marimanti, Tiva, Kibwezi and Kasigau. Subsequently, the remaining 40 CPTs were later planted in the four main progeny trials and other supplementary trials established at Gaciongo, Makima, Ikithuki and Voi. All progeny trial sites represent high ecological diversity desired for testing the varied adaptation of CPTs in Kenya.

Molecular genetic studies revealed higher intra-population than inter-population genetic variation and varied levels of intra-population genetic diversity in both species. The observed high intra-population genetic variation provides the desirable genetic base to support selection of superior genotypes and their subsequent improvement through breeding. At the nursery, inter-genetic variation in A. tortilis manifested in variation of apical dominance, with some populations growing upright and others having varied bending morphology. These characteristics were carried over to the field, thereby requiring support for the seedlings to condition them for upright growth.

Diameter at 30 cm above the ground (D30) for M. volkensii clones was measured in 60 clones planted in 2012 after six months and periodically thereafter for the next three years. Melia CPTs were classified as fast, intermediate or slow growing based on the initial D30 measurement.

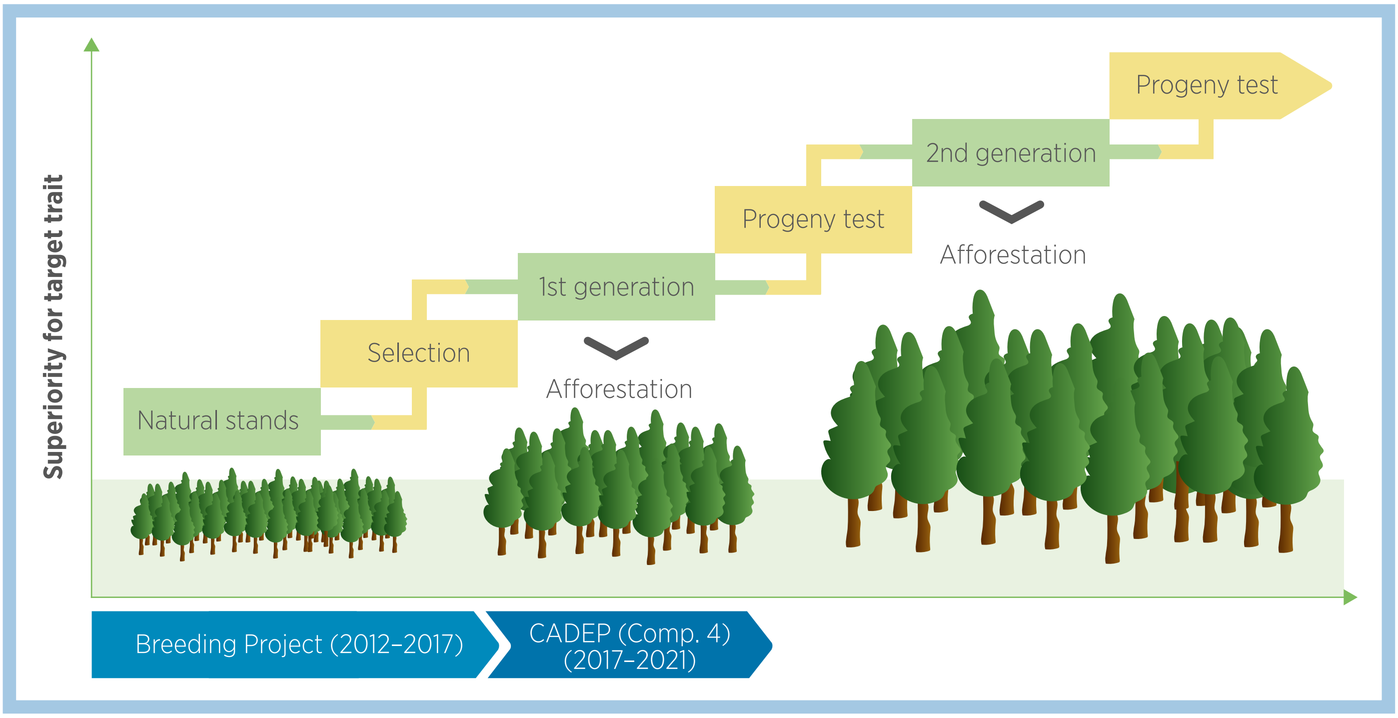
Subsequently, representatives from fast and slow growing clones were selected for drought tolerance studies focusing on chlorophyll fluorescence, xylem pressure potential, photosynthesis and overall growth response to soil moisture using both field and greenhouse studies. Based on these studies, drought-tolerant clones were found to retain significantly higher chlorophyll fluorescence than slow growing clones, suggesting leaf damage tolerance to water stress.

Additionally, fast growing clones had a shorter dormancy period than slow growing clones. Physiological study results will be used to develop a drought tolerance index that can fast-track selection of elite trees for drought tolerance and growth.

Scaling up

In the interim, growth data from the progeny trials have revealed varied site suitability for the tested CPTs based on diameter-height relationships, with Makima, Marimanti and Tiva having better growth than Ikithuki, Kasigau and Voi. Growth data from specific clones are continuously being assessed to inform orchards' improvement through rouging of inferior materials. This will inform the next breeding cycle where controlled pollination of superior genotypes is envisaged.

Figure 19. Roadmap for tree breeding



DEVELOPMENT OF BAGASSE AND INCREASED SUGARCANE VARIETIES FOR BIOENERGY BY COLLABORATIVE BREEDING

(Good practice example 1.4.2)

Organisations	Japan Research Center for Agricultural Sciences (JIRCAS)[a] and Khon Kaen Field Crops Research Center (KKFCRC)[b]
Type of organisation	Research institutes
Persons in charge	S. Ando,[a] Y. Terajima,[a] A. Sugimoto,[a] W. Ponragdee,[b] T. Sansayawichaib and A. Tippayawat[b]
Country	Thailand
Type of activity	Crop breeding by scientific R&D
URLs	www.jircas.go.jp/en www.kkfcrc.org

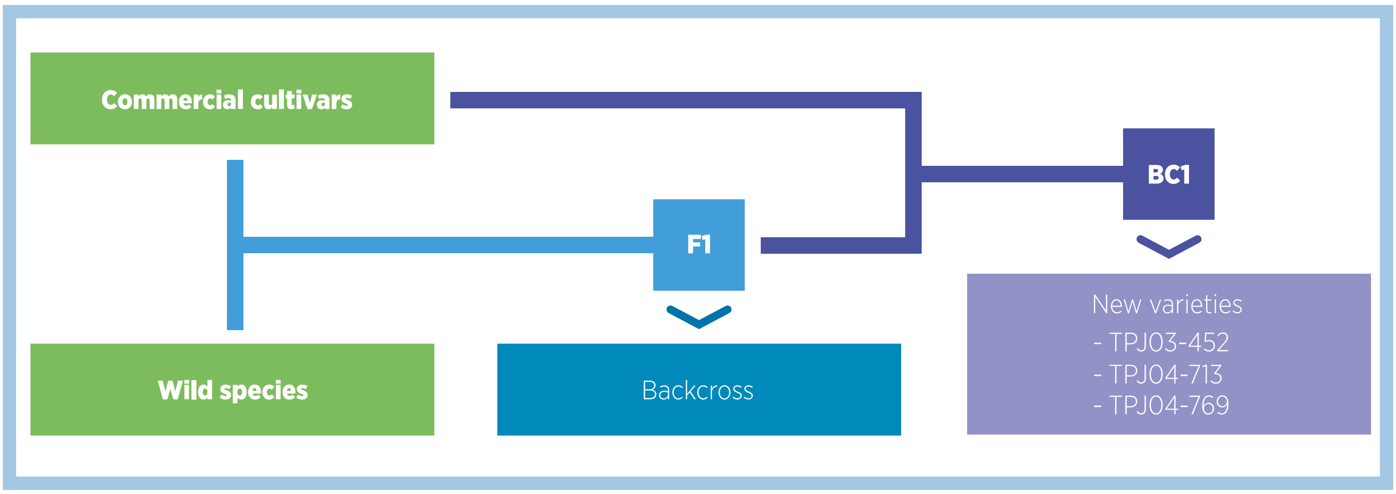
Summary

Along with population growth, the issue of the imbalance between supply and demand of food and energy is increasingly critical globally. The improvement of crop yield on lands of limited soil fertility and under an environment of less water availability is required. Sugarcane is produced worldwide in tropical areas including various areas in Asia, Latin America and sub-Saharan Africa. Its sucrose and fibre are the basis for multiple products, such as sugar, falernum, molasses, rum, fibre and bagasse. This means sugarcane is a source not only of food (as in sugar) but also of energy (as in ethanol, briquettes, electricity and biogas). The aim of this study was to develop a new sugarcane variety with good sugar and fibre yields in Northeast Thailand. In this drought-prone environment, sugarcane productivity is low due to soil infertility and outbreaks of sugarcane white leaf disease.

Because Thailand has adopted a climate change mitigation policy, the country is aiming to increase the use of biofuel content in gasoline to 11 300 kilolitres per day by 2036. Bagasse, which is a processing waste of sugarcane, has therefore become an important resource as it can be used to produce bioethanol – an important resource for biofuel.

The breeding target was to develop a sugarcane variety with the capacity to yield fibre with a significantly larger volume than common varieties without sacrificing sugar yield.

Figure 20: Breeding method



Interspecific hybridisation between Saccharum spontaneum (wild sugarcane) clones collected from across Thailand and commercial sugarcane cultivars was carried out, and F1 populations were obtained. F1 hybrids were crossed with commercial sugarcane cultivars to obtain Backcross-1 (BC1) populations. From the BC1 populations, TPJ03-452, TPJ04-713 and TPJ04-768 were selected. On 5 February 2015, the Department of Agriculture, Thailand registered these new varieties of sugarcane (Table 3).

Comparable amounts of sugar yields with a common commercial sugarcane species (Khonkaen 3 or K88–92) are harvestable from the newly registered hybrid species of TPJ03-452 and TPJ04-768. On the other hand, fibre yields from new species TPJ03-452 and TPJ04-768 are significantly larger than those of K88–92 and Khonkaen3. TPJ03-452's total three-year fibre yield was about 1.9 times greater than Khonkaen3's. The two-year total fibre yield of TPJ04-768 was about 1.6 times greater than that of Khonkaen3 (Table 4). In short, the newly developed species TPJ03-452 and TPJ04-768 have a higher fibre yield capacity than the common species while maintaining sugar yield capacity levels with the common species.

After harvest of the first-year cultivation of plant cane, sugarcane can grow from stubble without planting. The second-year cultivation is called ratoon cane cultivation. In the experiment, the yields of cane, sugar and fibre respectively of the first ratoon cane of Khonkaen3 were smaller compared to those of planted canes. However, in the case of TPJ04-768, the difference between the yields of ratoons and planted canes were smaller than that of Khonkaen3 (Table 4). In terms of shape, TPJ04-768 and TPJ03-452 had higher fibre content and thinner stalks compared to Khonkaen3 and K88–92. TPJ04-768 also had longer stalks than Khonkaen3 (see photographs).

Cane cultivation by ratooning saves labour and costs. The hybrid species TPJ04-768 produces comparable levels of sugar to commercial cultivars. Growing it from ratoon results in a small yield drop. Northeast Thailand's dry season is long and severe, so multiple ratoon cultivations of the TPJ04-768 variety are expected. Ideally, farmers and sugar mills should perform field tests using TPJ04-768 so that they can recommend it. However, introducing a harvester machine would be beneficial to more easily remove thin stalks and leaves. The high fibre content of the new variety, which is a different characteristic from common commercial cultivars, also requires the development of a new method to produce sugar and ethanol.

Shapes of TPJ03-452 (left) and TPJ04-768 (right) at planting in October 2013
Photographs: Ando

Table 3. History of new sugarcane varieties

Name of variety	Mother plant	Father plant
TPJ03-452	Uthong1	F1 interspecific hybrid (K84-200 × S. spontaneum)
TPJ04-713	CP72-5028	F1 interspecific hybrid (88-2-401 × S. spontaneum)
TPJ04-768	94-2-128	F1 interspecific hybrid (88-2-401 × S. spontaneum)

Note: Except for S. spontaneum, names of commercial cultivar or line are indicated.

Source: Ando (2015)

Table 4. Millable cane, sugar and fibre yield of new sugarcane varieties per hectare

Name of variety	Millable cane yield (t/ha)				Sugar yield (t/ha)				Fiber yield (t/ha)			
	1st year	2nd year	3rd year		1st year	2nd year	3rd year		1st year	2nd year	3rd year	
TPJ03-452	105.1	76.0 (72)	58.7 (56)	a	10.7	10.4 (97)	4.6 (43)	a	19.7	12.1 (62)	9.4 (48)	a
Khonkaen3	91.4	64.9 (71)	36.5 (40)	a	13.2	9.7 (73)	4.4 (33)	a	10.8	7.8 (72)	3.4 (32)	b
K88-92	92.9	58.9 (63)	39.0 (42)	a	10.9	7.9 (73)	4.0 (37)	a	9.7	5.5 (56)	3.6 (37)	b
TPJ04-713	76.8	77.2 (101)		a	6.6	6.8 (103)		a	9.6	9.3 (97)		ab
TPJ04-768	77.1	79.5 (103)		a	8.9	10.1 (113)		a	13.3	11.9 (89)		a
Khonkaen3	84.0	61.9 (74)		a	12.2	8.6 (70)		a	8.8	7.0 (80)		b

Source: Ando (2015)

Scaling up

The improved sugar cane varieties (TPJ03-452, TPJ04-713 and TPJ04-768) that have the characteristics of good sugar yield and better bagasse production are developed in northeastern Thailand, which has some ecological similarity to the drier climates and less fertile soils of sub-Saharan Africa. It may be possible to conduct a study to develop new varieties with favourable characteristics to improve the yield of sugar and fibre using indigenous species.

Note: 100 kilolitres of ethanol are produced from 1 300 tonnes (metric tons) of sugarcane bagasse annually (NEDO et al., 2017).

Summary provided by: Ando (2015)

Asugarcane bagasse ethanol plant in Thailand
Photograph: New Energy and Industrial Technology Development Organization (NEDO), Japan

1.5. FARMER FIELD SCHOOLS AND RESEARCH GROUPS TO STRENGTHEN OWNERSHIP IN DEVELOPMENT

This section highlights methods to improve farming by participatory and scientific self-learning approaches that are proven to help boost productivity in a sustainable, environmentally and ecologically sound way that directly responds to farmers' needs. Two good practice examples focus on community-based participatory learning methods: the first from Kenya Forestry Services; and the second from Ethiopia's Institute of Agricultural Research. In both cases, the methods highlighted help to increase biocarbon stocks for bioenergy.

Concept

Farmer Field Schools (FFS) are a participatory and discovery-based non-formal learning approach developed by FAO (FAO, JICA and KFS, 2011). In the target communities, groups of around 20 to 30 farmers organise FFS groups following determined FFS implementation steps. The groups meet periodically; in a typical case, once a week for a few hours at their learning sites in the villages where they conduct FFS learning sessions with the support of trained FFS facilitators. During one year of FFS, members of the groups will learn new practices and how to manage their target crops by doing on-farm experiments planned and managed by themselves. FRGs are participatory in approach for R&D.

Common principles shared by both approaches are to ensure the full ownership and decision-making powers of the local farmers to bring about positive and desirable changes in their lives individually as well as collectively. In the past in Ethiopia, the agricultural research and extension systems used a mainly linear model, in which the research generated technologies and the extension services delivered the developed technologies to the farmers, who were regarded merely as recipients of technologies. Technologies developed under such circumstances have often failed to achieve the expected level of adoption by farmers. Although conventional research was still dominant, the importance of more demand-driven research through participatory approaches gained recognition among some researchers in Ethiopia, which brought more holistic approaches based on farmers' needs.

In the late 1990s, FRG was introduced to increase the responsiveness and relevancy of agricultural research and extension to smallholder farmers. It did this by involving smallholder farmers in research planning and implementation as well as the selection of research and extension priorities. Using the FRG approach, a team of multi-disciplinary researchers, extension workers and groups of farmers were able to conduct research on selected topics based on farmers' needs. Furthermore, they performed this research on farmers' fields under their agroecological and socioeconomic conditions so as to provide farmers with practical solutions and to strengthen their capacity to innovate, thereby improving farm management practices and productivity as well as improving the quality of the research itself.

The FFSs and FRGs that are introduced in this section are an effective approach for comprehensive farm productivity improvement that empowers farmers with full ownership and decision-making rights – as well as a strong sense of responsibility for taking the risks that exist in tandem with opportunities. As a result, biomass availability will be increased for food and energy.

Groups of 20–30 farmers form farmer field schools

FARMER FIELD SCHOOLS FOR SUSTAINABLE AGROFORESTRY AND ENERGY IN ETHIOPIA AND KENYA

(Good practice example 1.5.1)

Organisations	Kenya Forestry Service (KFS),[a] Oromia Bureau of Agriculture and Natural Resource (OBANR), IC-Net[b]
Type of organisation	Government and bilateral co-operation agency
Persons in charge	J. Ndeti (KFS)[a] and S. Ogawa (JICA)[b]
Target areas	Kenya, Ethiopia
Type of activity	Tree breeding by scientific R&D
URL	www.kenyaforestservice.org/
Co-operation with	JICA

Summary

Many people living in rural areas of sub-Saharan Africa are small-scale subsistence farmers with limited resources. They cannot easily adopt new and costly practices that require long-term investments such as tree planting or woodlot development. KFS, with support from JICA, implemented the Intensified Social Forestry Project (ISFP) in the three semi-arid areas of Tharaka, Mbeere and Kitui sub-counties between April 2004 and March 2009.

The project employed the Farm Forestry Field Schools (FFFS) extension platform and applied it in promoting farm forestry. Using an interactive, participatory and discovery-based learning approach (FAO, JICA and KFS, 2011), the FFFS platform aims to give farmers a choice in production methods. FFFS training takes 12 months, during which farmers meet once a week for 3.5 to 4 hours. At the end of the ISFP project, about 5 000 farmers from a total of 330 farm forestry schools had graduated. KFS selected the FFS extension methodology from that time. To date, more than 800 schools and about 12 000 farmers have graduated as experts. These schools were funded by other projects and/or development partners and KFS's own resources.

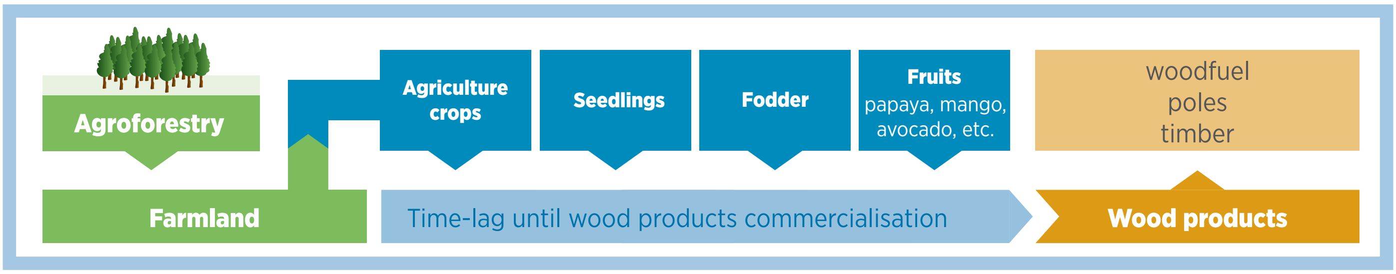
The objective of the project was for farmers to develop tree/wood enterprises in their semi-arid land. Because farmers were willing to adopt natural resource development practices, the good practices and lessons learnt through the project were later fully incorporated and localised widely in Rift Valley areas in the Oromia region of Ethiopia through the Project for Sustainable Natural Resource Management through FFS (SNRMP) with technical co-operation between OBANR and JICA from 2012–18.

Key issues for woodlot establishment with small-scale farmers

Combination with short term crops/agroforestry system

The project promotes agroforestry practices that are combinations of food crops and tree plantings based on ecological adequacy, which strengthen livelihood resilience and economic improvement. Activities can include horticulture, cereal or fodder crops as well as fruit tree orchards by which farmers are able to embark on tree/wood crop enterprises while practicing improved agriculture systems over the period (see Figure 21).

Figure 21. Concurrent food production, income diversification and wood production through agroforestry practices



Source: JICA (2016a; modified)

Seedling production by farmers

Production of tree seedlings by farmers is not common, and this limits wood resource development practices. Some FFS-graduated farmers have become leading producers of tree seedlings during off-farm seasons in various locations including at remote sites.

Tree nurseries developed by FFS-graduated farmers in 2017
Photographs: Kidane

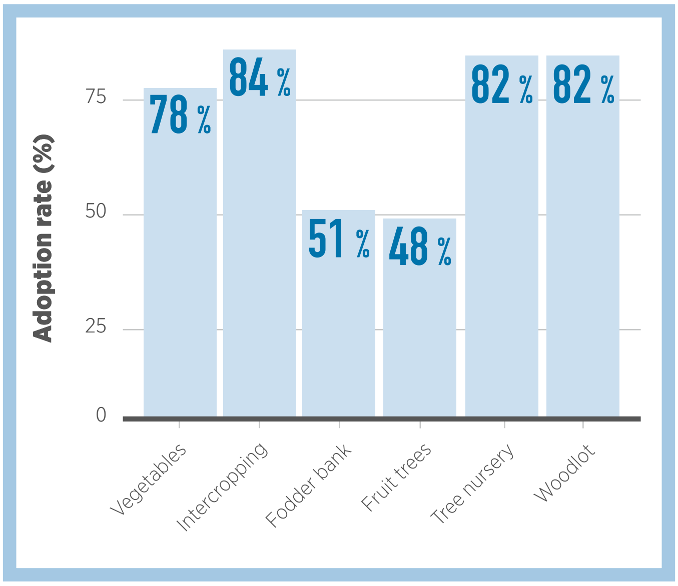
Empowerment of farmers

Farmers may hesitate to initiate new practices due to a general lack of confidence in scientific knowledge or experiments and a lack of financial resources. However, with FFS, farmers can try to evaluate new practices by themselves. Concurrent with comprehensive capacity building and a participatory learning process, farmers become more confident, capable and empowered and aspire to try new ideas and practices.

Long-term continuous interaction with farmers

An FFS natural resource programme takes about 50–55 weeks (one year). Community members learn about developing multiple enterprises. One-year-long interactions through FFS often bring about substantial benefits for farmers and thus a very high rate of adoption of introduced practices among farmers in the area (see Figure 22).

Figure 22. Adoption rates of new practices among FFS-graduated farmers



Source: SNRMP End-line Survey by Farm Africa conducted in 2017

FFS-graduated farmers try new practices: (left) Melia volkensii woodlot in 2016 (Ndeti); (right) Faidherbia albida intercropping in 2017
Photographs: Kidane

Acacia polyacantha and Senna siamea wooodlot for charcoal, Tharaka Nithi County, Kenya in 2016
Photographs: Ndeti

Figure 23. FFS – Tree enterprises working systems

Source: JICA (2016a; modified)

Further development of the activities after the project

FFS graduates who gain knowledge through ISFP in Kenya by the farm forestry-based production systems often encounter serious constraints in scaling up their production. This can be due to a lack of investment capital, a lack of opportunities to learn from the experiences of other groups and/or a long gestation period for tree-based enterprises, leading to a longer planning and investment horizon.

To address some of the issues regarding how to further develop the skills gained after FFS graduation raised by the participant farmers, KFS uses the seed fund grant that was provided by the Japan Social Development Fund. A review of possible farm forestry enterprises that can be funded for improving the living standards of poor rural communities in the three forest zones was carried out. Out of the proposal, the Support to Community Based Farm Forestry Enterprises in Semi-arid areas of Kenya (SCBFFE) project was started.

The SCBFFE project piloted practical interventions to achieve sustainably improved livelihoods of rural people in the Tharaka, Mbeere and Kitui sub-counties. The major activity of the project was to provide financial resources to farmer groups who had the capacity to implement farm forestry-based enterprises to increase forest cover and sustainable biomass supply. After the close assessments and consultations about ongoing activities and proposals prepared by groups, resources were provided in the form of loans on a contributory basis to farmers. Farmers were required to contribute 20 % to ensure the sustainability of the investments in the form of labour, cash and locally available materials. KFS partnered with a Financial Service Provider (FSP) in the implementation of this activity.

KFS's main responsibility was to identify, organise, train and support the beneficiary groups in preparing feasible proposals and implementing the projects. The work of the FSP was to train groups in financial literacy, conduct appraisals and disburse funds. Both institutions partnered to ensure the funds disbursed to farmers were repaid.

At the end of the SCBFFE project in 2015, a total of over KES 53.9 million had been disbursed as loans to 380 groups, with a total of 2 720 farmers benefitting. Over 270 ha of woodlots for fuelwood, timber and fruit orchards had been established. The loan repayment totalled 99.9 %, which is a commendable achievement.

From these experiences and lessons learned, KFS in 2016 started the Forest Investment Facility (FIF) using its own resources. It provides credit and loans to farmers to invest in farm forestry and livelihood enterprises. The organisation is working with an FSP with negotiated loan terms and conditions for the beneficiaries. The main objectives are to increase forest cover through tree planting in farms, create sustainable biomass supply and improve the livelihoods of rural farmers. Currently the FIF programme is being implemented in four counties in Kenya: Embu, Tharaka Nithi, Kericho and Kitui. The facility will be rolled out to other counties in due course.

Due to FFS's extension methodology, the culture of growing trees has been developed by the FFS graduates and their neighbours. The extension of skills from farmer to farmer has been observed, which has resulted in a lot of trees being planted and ensures a sustainable biomass supply that will contribute to sustainable bioenergy deployment. This has been achieved with the support of credit.

Scaling up

To encourage further development, the following issues should be noted:

- Sufficient extension agents trained as FFS facilitators, logistic support, a fund for stationery and farm input for FFS learning are required.
- Enabling policies and laws to implement the innovations of FFS and credit for investment are needed.
- Institutions investing in training their staff as FFS facilitators are needed to facilitate the FFS training of farmers.
- Communities have to be willing to learn together as a group.
- An enabling environment for the unbankable rural communities to access credit to invest in different sustainable biomass supply, energy conservation, Kamado Jikos (cookstoves) and other innovations need to be created to improve living standards as well as conserve the environment.
- Communities need to be willing to take credit for investment, especially on farm forestry enterprises.

Presentation and summary provided by: Ogawa (2018) and Ndeti (2018)

INSTITUTIONALISING PARTICIPATORY AGRICULTURAL RESEARCH IN ETHIOPIA

(Good practice example 1.5.2)

Organisations	Ethiopian Institute of Agricultural Research (EIAR)[a] and Regional Agricultural Research Institutes, Kaihatsu Management Consulting, Inc.[b] and Center for African Area Studies, Kyoto University[b]
Type of organisation	Public research institute
Persons in charge	Dawit Alemu[a] and Kiyosh Shiratori b
Target area	Ethiopia
Type of activity and strategy of institutionalisation	Participatory research in crops, livestock, fisheries and marketing - Development of FRG approach guidelines - Hands-on training on the approach to researchers of the national agricultural research system - Scaling up the approach for diverse agricultural development projects - Establishment of FRG training hubs (three research centres and three universities)
URL	http://eiar.gov.et
Co-operation with	JICA

Summary

Ethiopia's National Agricultural Research System (NARS) was implemented through two projects (FRG I and FRG II) by EIAR with regional agricultural research institutes in collaboration with JICA from 2004–15. The promotion had the objectives of verification, institutionalisation and scale-up of the approach along with the required capacity building for all actors in the NARS. More than 80 FRG-based research activities were implemented in various research areas in different parts of the country, an FRG guideline for researchers was developed based on practical research experiences, six FRG training hubs were established and more than 630 researchers from 93 research centres and universities were trained in the FRG approach.

Steps of the FRG approach

There are seven principles of the FRG approach: multidisciplinary team formation, equal partnership, collective action, building capacity for innovation, members' diversity, information and knowledge sharing, and cost sharing. The basic steps of the approach are shown in Figure24.

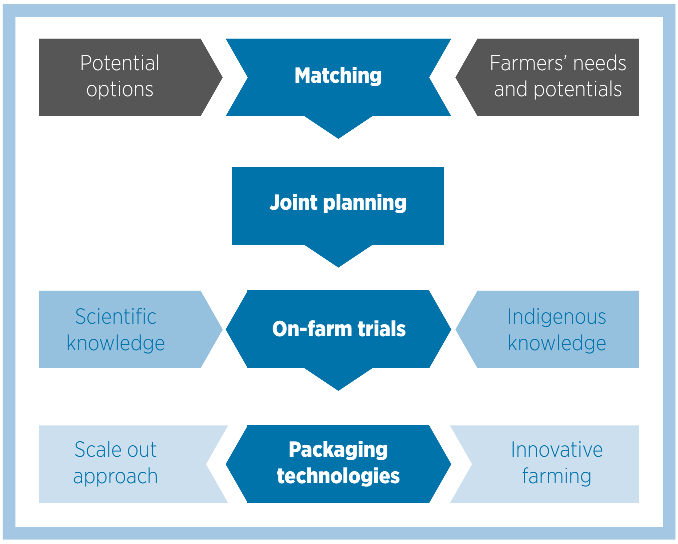
1) Matching: Farmers' needs and/or potentials are matched with potential technical options to choose a research topic.

2) Joint planning: Action planning must take place in the presence of all the stakeholders, who are identified according to the research topic. All the activities and schedules are confirmed, and responsibilities are assigned.

3) On-farm trials: The FRG approach is as much about building farmers' capacity to innovate as about actual trial results. Each field activity must be accompanied by hands-on training, discussion and consultation among researchers, farmers and other stakeholders. The farmers are expected to learn scientific methods of observation in the field trial.

4) Packaging technologies: Trial results including farmers' observations and their opinions are analysed, and a comprehensive set of technologies is incorporated into existing farming systems.

Figure 24. Steps of FRG-based research



FRG outputs: Selected cases

Four cases that follow highlight research conducted using the FRG approach.

Teff seeding rate

The research on the teff[1] seeding rate using a seed spreader in the Central Rift Valley and southern Ethiopia found 10 kg/ha of seed mixed with soil to be the best and most acceptable to farmers, saving 20–25 kg of seeds over the conventional practice of 30–35 kg/ha. This was enough to cover the land and make the crop less prone to extreme weather shocks. This was the farmers' preference, which was borne out later by analysis on grain and straw productivity as well as by economic returns. Weed infestation as a result of using a lower seeding rate was acceptably low and did not present a major concern for the member farmers. This practice promotes efficient use of improved and quality seed while protecting farmers from having to pay for extra seeds (tables 5 and 6).

Top-bar beehive construction by farmers using local materials
Photographs: Fanuel

Table 5. Benefit-to-cost ratio of farmers' preferred teff seeding rates, 2010–2012

Year	5 kg/ha	10 kg/ha	15 kg/ha
2010	4.5	5.3	5.1
2011	6.0	5.9	6.3
2012	9.6	8.9	8.3
Average	6.7	6.7	6.6

Table 6. Farmers' crop stand preference at crop maturation, 2010–2012

Year	5 kg/ha	10 kg/ha	15 kg/ha
2010	3 (1st)	2 (2nd)	1 (3rd)
2011	3 (1st)	2 (2nd)	1 (3rd)
2012	2 (2nd)	3 (1st)	1 (3rd)
Average	2.7 (1st)	2.3 (2nd)	1.0 (3rd)

1 Teff is a cereal crop used as staple in Ethiopia and Eritrea (relevant to the beehive-to-teff seeding rate).

Table 7. Materials required for a top bar bee hive. (FRG 2009)

Material	Number	Purpose	Remark
1 m Wood	4	Lenght framework	
40 cm Wood	2	Upper width framework	
29 cm Wood	10	Height framework	
22 cm Wood	1/4 kg wire	Wall framework	-
Fermented mud	-	Inner Wall	-
120 cm Wood	2	Lid framework	
60 cm Wood	7	Lid framework	
120 cm × 60 cm Iron sheet	1	Lid cover	-
45–48 cm lenght wood with 2–3 cm thickness	30	Top-bar frame	Algee/sisal plants used for the trial

A researcher and an FRG member farmer
Photograph: FRG

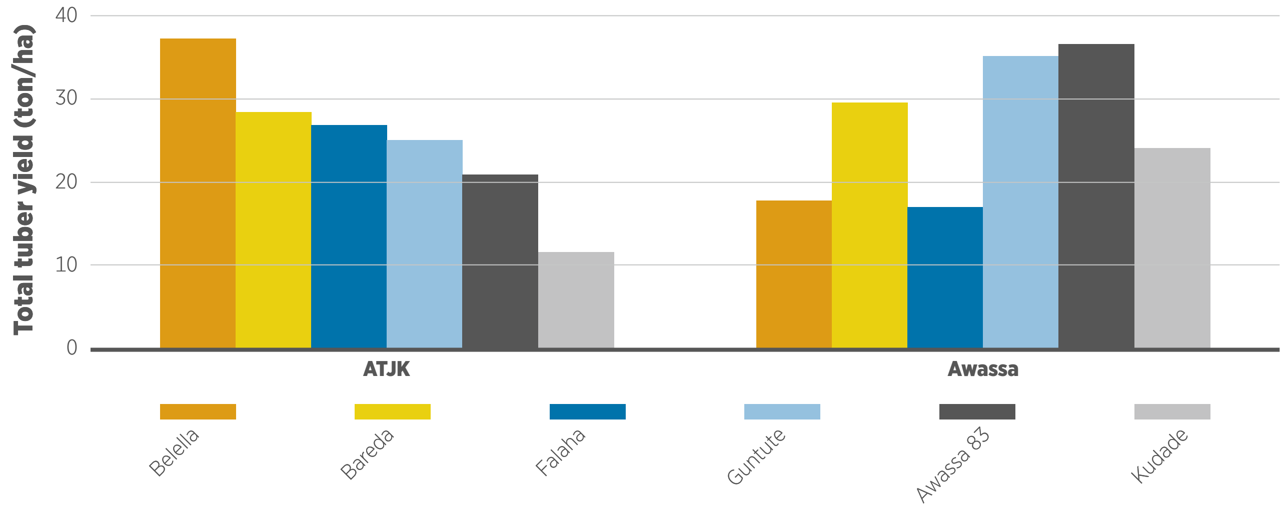
Introduction of sweet potato in semi-arid area

Sweet potato was a new crop to the Central Rift Valley of Ethiopia. Six improved varieties of sweet potato and different plant spacings were tested on farmers' fields. Comparisons were made between the varieties and spacings on growing period, yield and economic return. The trial was supplemented by the introduction of several sweet potato recipes to the farmers for food diversification and marketing of the crop. Four varieties were selected based on yield (tuber as well as vine as fodder), drought tolerance, resistance to diseases and palatability. Vine production was also an important criterion for the farmers' preference.

Top-bar bee hive made from locally available materials

A top-bar beehive made from locally available materials as a transitional technology can be produced by smallholder beekeepers at a cost of ETB 167 per hive, which is one-fifth of the cost of a modern box-type beehive at ETB 360 per hive (Table 7). This hive has different advantages over the modern box-type beehive counterpart: it costs less, its use reduces deforestation and its construction does not require special knowledge or skills. It proved easier to manage and produced twice the yield compared to traditional beehives.

Figure 25. Yield comparison among six sweet potato



Source: FRG (2009)

Figure 26. Yield comparison among different sweet potato plant spacings

Row spacing	Plant spacing				
	20 cm	30 cm	40 cm	50 cm	60 cm
40 cm	15.6	17.4	12.2	9.7	13.1
60 cm	19.7	24.1	15.3	6.5	11.1
80 cm	11.8	7.5	7.4	13.9	9.3
100 cm	12.2	13.9	16.7	9.9	5.1

Source: FRG (2009)

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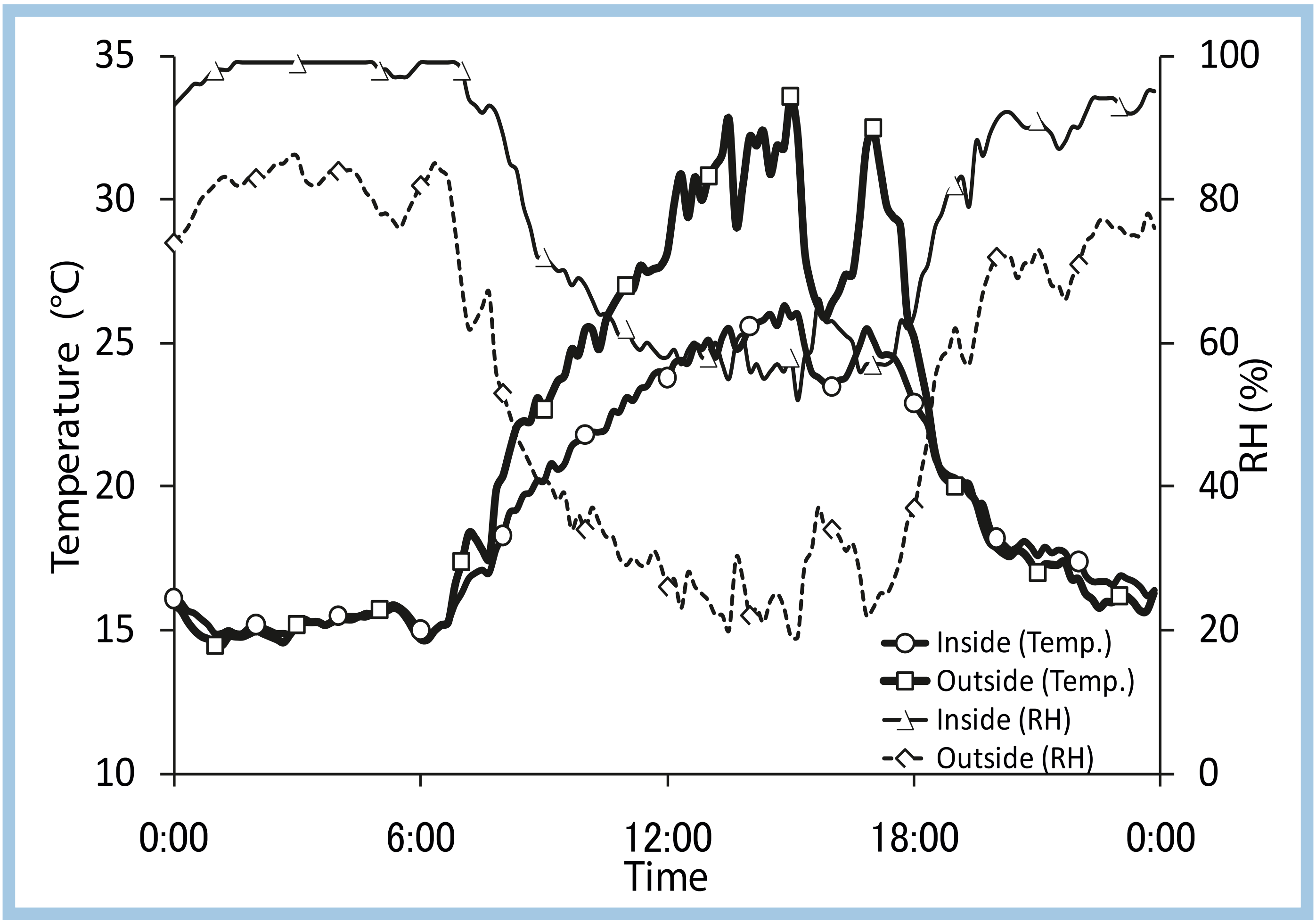
A top-bar beehive made from locally available materials as a transitional technology can be produced by smallholder beekeepers at a cost of ETB 167 per hive, which is one-fifth of the cost of a modern box-type beehive at ETB 360 per hive (Table 7). This hive has different advantages over the modern box-type beehive counterpart: it costs less, its use reduces deforestation and its construction does not require special knowledge or skills. It proved easier to manage and produced twice the yield compared to traditional beehives.

Backyard agroforestry

An FRG was established to disseminate agroforestry for conservation and remediation of natural resources. To establish an appropriate agroforestry management system suitable to the area's climate and social conditions, information concerning the selection of tree species, determination of planting density, survival rate of trees and the effect of agroforestry on micro-meteorology were examined. Acacia salicina showed the highest survival rate. The agroforestry at the trial site showed a potential to mitigate evaporation and extreme increases of temperature through increasing the soil's organic matter resulting from the biomass, low competition of fertiliser extraction between trees and crops, and high-quality building materials due to the upright growth of trees. The FRG activity has enhanced the farmers' capacity to use their inherent experience for innovative actions in the agroforestry management.

Figure 27. Changes in air temperature and relative humidity (RH) inside and outside the agroforestry site



Agroforestry FRG members and researchers (left); the on-farm trial site (right)
Photographs: FRG

Scaling up

The experiences gained in the implementation of the two phased FRG projects indicate that in order to ensure scaling up of the approach, the following areas of intervention are crucial:

- » Develop practical guidelines. FRG guidelines for researchers were developed based on researchers' experiences in consideration with existing research frameworks.
- » Train a critical mass of researchers. The projects trained more than 630 researchers from 93 research institutions including universities through six established training hubs.
- » Collaborate with universities. Universities were among the forums established to discuss and promote participatory research to mainstream the FRG approach.
- » Link with development projects. The FRG approach was adopted by major development projects such as the Rural Capacity Building Project, the East African Agriculture Productivity Project and the Capacity Building for Scaling up of Evidence Based Best Practice in Agricultural Production in Ethiopia; the Pastoralist Community Development Project also adopted the FRG approach in one way or another in their activities.
- » Publish a book on the FRG experience. To document the experiences as references for researchers and development workers, a book was published from an international publisher (Alemu et al., 2016).

Summary provided by: Shiratori and Alemu (2018)

1.6. HUMANITARIAN OPERATIONS AND FULFILMENT OF ENERGY NEEDS

This section looks at ways to bolster energy security as part of humanitarian operations. Good practice examples are introduced, together with useful guidebooks, on sustainable bioenergy production in refugee camps, on planting trees, and on land conservation to reduce environmental impacts and improve food and energy security in Ethiopia.

Concept

Energy access is always a critical issue in humanitarian relief operations such as in refugee camps and recovery assistance. Water and food must be heated to ensure good hygiene levels. Camps are usually selected where there are no or limited permanent settlers. This means that the land is less fertile and has little vegetation compared to more fertile places where local communities are already settled. In such cases, conflicts over limited local resources such as fuelwood may arise. Host communities and countries that accept refugees or migrants often struggle to manage the socioeconomic and environmental impacts involved in supporting large numbers of people for an undetermined amount of time.

While local communities constrained by poverty may have difficulty sharing their limited natural resources, guidelines are available on how to deal with such issues to maintain harmony while fulfilling food needs and providing energy security in an environmentally sustainable manner (UNHCR/IUCN, 2005; JOFCA/JIFPRO, 2011).

In the past, goods and services needed for such humanitarian operations were procured outside of the host country. However, with the initiation of the World Food Programme's (WFP's) Purchase for Progress (P4P) programme in 2009, the facilitation of local procurement of food crops has been increasing.

Distribution of Moringa and cashew nut tree seedlings in Gaza, Mozambique
Photograph: Inoue

RESOURCE RECOVERY FOR BRIQUETTES AND EMPOWERMENT OF WOMEN IN HUMANITARIAN CONDITIONS IN KENYA

(Good practice example 1.6.1)

Organisations	ICRAF,[a] Wangari Maathai Institute for Peace and Environmental Studies, University of Nairobi,[b] UN-Habitat,[c] JIRCAS,[d] The Pennsylvania State Universitye
Types of organisation	Research institute, UN
Persons in charge	Mary Njenga,[a,b] Oana Baloi,[c] Miyuki Iiyama,[a,d] Yuka Teradac and Ruth Mendume
Target area	Kenya
Type of activity	Fulfilment of energy needs in refugee camps
URL	www.worldagroforestry.org/
Co-operation with	University of Nairobi, Office of International Programs, College of Agricultural Sciences and the CGIAR Research Program on Water, Land and Ecosystems

Summary

Severe energy poverty in humanitarian conditions undermines the food security of refugees and host community members.

Northern Kenya's arid climate makes implementing conventional rain-fed agriculture difficult. This area is therefore mainly inhabited by pastoralists. At the same time, the area hosts refugees who have migrated from their homes due to conflicts and famine. The arrival of refugees exerts pressure on the already fragile natural resources in the host communities. Often the donor agencies provide food aid through the provision of grain and cooking oil to refugees. Where fuel is provided, it meets about 10 % of the cooking energy need (Njenga et al., 2015). Thus, a huge deficit of cooking energy exists, which is another aspect of food insecurity and a humanitarian challenge in refugee camps.

For example, surveys at one camp – Daadab, the largest in northeastern Kenya – show that 98 % of households use firewood as their main cooking fuel and spend 24 % of their monthly income of USD 72 on energy (Okello, 2016). At the Kakuma refugee camp in northwestern Kenya, households live below the poverty line of USD 1.25 per day and spend about 15 % of their income on firewood, charcoal and other forms of cooking energy (Kivuva, 2016).

At Kalobeyei, an emerging refugee settlement set up in the last 1.5 years on the outskirts of Kakuma camp, the majority of refugees are forced by circumstances to exchange or sell five days of relief food in return for three days of firewood for cooking food (Mendum and Njenga, 2018).

Host communities are also faced with food scarcity and similarly skip meals or go hungry for days (Njenga et al., 2015). Desperate to put cooked food on the table for their families, women in refugee camps, as well as those from the host communities, are forced to go to the surrounding woodlands to collect firewood. This is an activity that is exhausting, life-threatening and associated with conflict between the refugee and host communities over wood resources (UN-Habitat, 2017).

Unfortunately, the technologies they employ are inefficient (Njenga et al., 2015). These include kilns that waste wood, cause air pollution and lead to land degradation. For example, traditional kilns take many days to produce saleable charcoal, and the amounts produced are about 10 % of the total raw materials (Okello et al., 2001). Urgent interventions are needed to overcome energy poverty, which is deeply associated with food insecurity, unsustainable resource use and risks to women's welfare in the refugee camp environment.

Resource recovery and reuse (RRR) for energy: Community-based briquette technology provides an answer to energy poverty

Community-based fuel briquetting technology is a promising innovation that addresses cooking energy needs in humanitarian conditions while also transforming otherwise unused waste materials into burnable biomass. Briquettes are a type of cooking and heating energy made from compacting biomass material such as charcoal or firewood. The recovery of organic waste from households, institutions, markets and slaughterhouses in refugee camps presents further opportunities for RRR for energy.

This approach does, however, require integrated planning. Briquettes, whose quality is influenced by type and processing of raw materials, burn more evenly and cleaner than other biomass (Njenga et al., 2013). Briquettes made from charcoal dust (80 %) and soil as a binder (20 %) emit one-third and one-ninth, respectively, of carbon monoxide and fine particulate matter compared to lump charcoal. Briquettes are made using various technologies, ranging from molding using bare hands to the use of manual presses/machines and highly automated machines.

Pilot project at Kalobeyei refugee and host community settlement

The Kalobeyei refugee and host community settlement is located in Turkana County in northwestern Kenya. The settlement is allocated 1 500 ha under a new approach aimed at integrating socio-economics in the refugee and host community settlement. Development and other programmes in the settlement have been created based upon the Kalobeyei Integrated Social and Economic Development Programme formulated by United Nations High Commissioner for Refugees (UNHCR) in collaboration with the World Bank and in partnership with Turkana County. The briquette project addresses several key challenges facing the new Kalobeyei settlement: energy poverty among refugees and host community members of between 80–90 %; food insecurity due to lack of income, despite donor contributions; and tension between refugees and host communities because of high levels of need on both sides.

In essence, the settlement is an urban location in the middle of an arid rural space that brings together a diverse group of people, some Kenyan and other refugees. As the settlement grows, it must become economically less dependent on donor aid. At the same time, livelihood strategies must improve the local natural environment rather than degrade the land, as is currently the case. The briquette project achieves these goals.

The community-based programme aims to empower host and refugee communities, reducing reliance on aid and creating opportunities to become self-sustaining communities. According to socio-economic research and mapping published by UN-Habitat, waste management and public space play an important role in potential community-managed projects that can lead to skills and entrepreneurship development. In the energy sector, the lack of adequate access to cooking energy was identified as one of the key challenges faced by the refugee and host communities in Kalobeyei settlement (UN-Habitat, 2017a). The briquette innovation can also reduce the potential risk of conflict between refugee and host communities, as well as the degradation of the natural resources base.

Beginning in July 2017, the team engaged in an initial feasibility study followed by two training sessions in December (UN-Habitat, 2017b). The first training session was for the host community. Five women were identified as trainers, who later joined the project team in training the women at the refugee camp. The interaction between women from the host community and the refugees was considered by both communities as a positive gesture with potential to promote cohesion. The training sessions helped women to process the available raw materials, form appropriate balls of slurry to produce usable briquettes and sun-dry the resulting product. A cooking experiment allowed host and refugee women to try out cooking with the new fuel. Quality analysis for burning and emission properties will be carried out and a marketing and promotion campaign will also be put in place.

Production of charcoal from twigs using a drum kiln (top left); briquettes being dried (right); briquettes burning in an earthen stove (left)
Photographs: Mary Njenga (top left), Takeshi Kuno (right, left bottom)

Lessons and impacts

Teaching women how to make briquettes using waste materials reduces waste accumulation, meets a key need for biomass without increasing pressure on the environment and brings together women in a positive, mutually beneficial relationship. With the continuous development of the settlement (plans are for 60 000 refugee and host individuals), waste generation at the camp is being linked to public space maintenance, waste recovery and reuse, and sustainable cooking fuel production and commercialisation. The livelihoods that are supported by the project can then form the basis for further sustainable development of the settlement into a thriving, productive hub for the region.

Scaling up

This innovation is replicable and can be easily shared and adapted once individuals are trained. It works well in high-density settlements as well as in other urban areas where there is access to municipal organic waste, such as from vegetable markets. In rural small-scale and large-scale farms where farmers have access to any form of agricultural or industrial organic waste, suitable production technologies can be used, ranging from manual machines to automated machines depending on scale.

Presentation and summary provided by: Njenga et al. (2018)

TREE PLANTING AND LAND CONSERVATION TO EASE ENVIRONMENTAL IMPACTS AND INCREASE FOOD AND ENERGY SECURITY UNDER HUMANITARIAN OPERATIONS IN AFRICA

(Good practice example 1.6.2)

Organisation	UNHCR, UNWFP, JOFCA, JIFPRO
Type of organisation	UN agencies, forestry consulting firms
Target area	Kenya
Type of activity	Fulfilment of energy needs in humanitarian operations
URLs	UNHCR: www.unhcr.org/ WFP: www.wfp.org/ JOFCA: www.jofca.or.jp/e_objective/ JIFPRO: https://jifpro.or.jp/en/
Co-operation with	International Union for Conservation of Nature (IUCN); Ministry of Agriculture, Forestry, Fisheries (MAFF)-Japan; Carbon Free Consulting Co. Ltd.

Summary

To overcome the problem of energy deficits in humanitarian situations, the UNHCR has tried to address issues regarding land management and tree planting activities. In Sudan, the UNHCR has been conducting tree planting over the past 25 years. More than 19 million trees have been planted to respond to the needs of environmental rehabilitation, to fulfil the demand for wood for cooking energy and to construct shelters (UNHCR, 2010). In northern Uganda, some 1.4 million refugees, mostly from South Sudan, are settled in refugee camps. Over 11 million trees are estimated to have been felled in the Adjumani district alone since 2013 (UNHCR, 2018).

The Ugandan government, people and refugees are working together to prevent damage to the environment caused by the emergency response. Each refugee household receives a donated fuel-efficient cookstove, which saves wood for fuel by 50 %. UNHCR plans to provide 1.4 million trees, including neem trees (*Melia indica, Melia azadirachia*), which are useful as fuel and timber, attract bees for honey making and grow fast. It is also a good agroforestry species to grow crops around in combination.

The Management of Environmental Resources to Enable Transition (MERET) programme, a joint effort between the Ethiopian government and the WFP, has been conducting activities in 451 food-insecure communities for 30 years. The programme has rehabilitated more than 400 000 ha of degraded land and assisted 648 000 people during the period 2012–15 (WFP, n.d.1). Food security improvement activities include reconstruction and refurbishment of agricultural terraces and feeder roads, reforestation of barren hillsides, reclamation of gullies, restoration of ponds and springs, and capacity development of communities and government ministries. These productive assets and community-based infrastructures were planned and implemented by community members; therefore, the target communities acquire technical knowledge on implementation, maintenance and rehabilitation by themselves for future needs. Since the project sites were food-insecure, food assistance was provided to fill the food gaps of the participating households, and farm tools and planting materials (e.g., seeds) were also provided to help activity implementation.

An impact study revealed that the programme resulted in positive effects for the communities. This ranged from improving quality water availability for both humans and livestock and reducing the amount of time spent collecting fuelwood, water and fodder. Women and children, who perform this work, spent 2.2 hours less each day collecting fuelwood and 2.0 hours less collecting water, according to the results of a household survey. There is a fast rate of replication of this good practice (ICCG, n. d.).

Since 2009, WFP has been implementing Safe Access to Food and Energy (SAFE) initiatives in their humanitarian operations to eradicate hunger. These initiatives, which include school feeding programmes and refugee camp operations, reached 2.8 million by 2014 (WFP, n.d.2). The initiatives strive to protect women and children who are collecting firewood from violence, minimise the amount of indoor air pollution emitted by cookstoves, curb deforestation and increase self-sufficiency by building more fuel-efficient cookstoves, and boost other income-generating activities. In sub-Saharan Africa, good practices based on SAFE initiatives are found in Burundi, Ethiopia, Kenya, Senegal, Sudan and Uganda, among other countries (WFP, n. d.2).

WFP's MERET Food for Assets project in Ethiopia: Before and after
Photograph: Menghestab

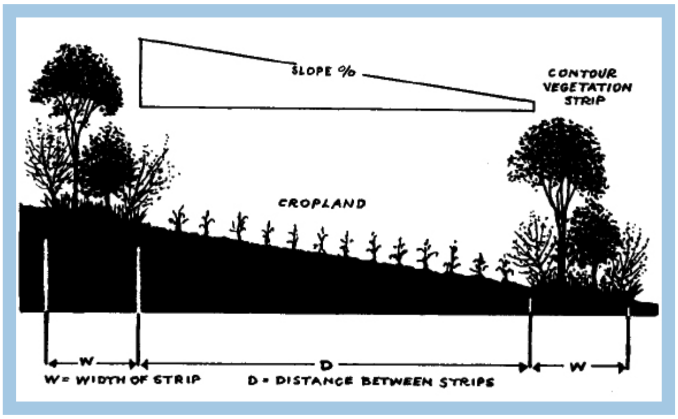
Reference books to plant trees and conserve land for strengthening resilience by securing food and energy under severe humanitarian situations

As WFP conducted contour management for the MERET project in Ethiopia, according to Rocheleau, Weber and Field-Juma (1988), the width of strips of planted trees, needed for erosion control, had to be determined based on slope degree. If contour agroforestry planting is conducted on a 10 % slope, the strip width should be wider than 2 m.

UNHCR forest management handbook

The UNHCR and the IUCN produced "Forest management in refugee and returnee situations: A handbook of sound practices" in 2005 (UNHCR/IUCN, 2005). The handbook provides information, including information about forest management, during refugee and related operations. It also details practical actions to consider and apply in such operations including identification of demand and supply for timber products such as fuelwood and construction and planning strategies for tree planting using co-ordination between local and refugee communities.

Figure 28. Contour planting in dryland Africa



Source: Rocheleau, Weber and Field-Juma (1988)

Table 8. Slope steepness and recommended distance between cultivation strips

Slope	Width of Strip	Distance between Strips (m)	
(%)	(m)	Erodible Soil	Cohesive Soil
5	1.5	45	80
10	2.0	35	70
15	3.0	30	60
20	4.0	26	53
30	6.0	23	44
40	8.0	20	36
50	10.0	17	30
60	12.0	14	26
80	16.0	13	22
100	20.0	10	20

Source: Rocheleau, Weber and Field-Juma (1988)

UNHCR forest management handbook

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JOFCA-JIFPRO guidelines

Guidelines were published jointly by JOFCA and JIFPRO with financial support from the Forestry Agency of Japan (JOFCA/JIFPRO, 2011). The guidelines provide information about tree planting methods to conserve forests and natural resources, natural regeneration enhancement, local needs assessment, suitable tree species selection of both indigenous and fast-growing species, and land preparation such as terracing and water catchment. A special focus is placed on building local capacities and group organisation management to ensure sustainability.

One of the solutions introduced in the guidebook is the use of Prosopis juliflora. This is known as an invasive species that was introduced to increase vegetation in arid areas in the latter half of the 19th century. With its strong drought tolerance and high fertility (60 million seeds are produced annually per ha), Prosopis juliflora is a dominating species.

The introduction of Prosopis juliflora to farmland can decimate other species growing on the land. In addition, the leaves and branches of Prosopis juliflora are not suitable for feeding to domestic animals. However, Prosopis juliflora can be planted in an environment where no other species can be grown, and it can contribute to the recovery of vegetation.

There are ongoing efforts to remove Prosopis juliflora from Kenya's Turkana Lake area, but Prosopis has advantageous features for use as fuelwood/charcoal because it is hard and heavy. Therefore, it is used to produce charcoal, and the shrubs are regarded as an income-generating plant because they can be used to produce and sell charcoal. However, careful maintenance is necessary to curtail Prosopis's expansion into farmland areas.

Table 9. Conservation and rehabilitation of degraded woodlands around communities

Conservation of forests and the natural environment | **Encouragement of self-help activities and improvementof the lives of local residents**

Conservation of the natural environment and improvement of the lives of local residents in the vicinity of refugee camps

Conservation of forests and the natural environment
- Tree planting
- Natural regeneration
- Nursery

Involvement of the local residents
- Workshops to building good relationships with the local residents
- Capacity building training for the local residents
- Group organization reinforcement

Area-based efforts
- Choice of tree specials suitable for the local natural conditions
- Techniques suitable for the local natural conditions
- Revegetation that is appropriate for the characteristics of the area
- Effective use of local resources
- Local marketing of cash crops

Importance of respecting the sustainability of all activities
- Utilization of local resources available on a sustainable basis
- Continuous cultivation and management by clarifying utilization rights
- Continuous protection and management of the planted trees

Sustainability through motivation of the residents
- Fruit tree planting
- Fast-growing tree specials
- Cash crops

Project operations

Considerations for project operations around refugee camps
prior access to information, ensuring access to the site, selection of partner organizations, coordination among the parties concerned, activities after the camp is closed, proper schedule management, and ripple effects of the activities

Source: JOFCA/JIFPRO (2011)

2. Biomass-to-energy innovations

2.1. BRIQUETTES FROM WASTES AND RESIDUES

This section discusses feedstock and how to produce briquettes. Good practice examples include producing briquettes from rice and peanut husks, from charcoal dust, and from animal waste mixed with straw.

Concept

In sub-Saharan Africa, most farm residue is needed to feed domestic animals or to replenish organic nutrition by burning the biomass after harvests and before the rainy season. This is achieved by adding biochar to the soil as fertiliser for the next farming season.

This system is particularly important for farming in sub-Saharan Africa to cope with the characteristics of the land, climate and soil. In most parts of sub-Saharan Africa, the soil is not fertile, with the exception of the Lift Valley areas in East Africa, where there are relatively fertile soils of Ultisol, Vertisol, Andisol and Inceptisol (ESDAC, 2014). In 70 % of the land in sub-Saharan Africa, there are infertile and degraded soils such as Oxisol, which contains an abundance of oxidised iron and aluminium, and Ultisol, which is already exuviated. Therefore, a majority of farmers have adopted a soil recovery system that alternates cultivation with a tenyear fallow period to keep productivity levels up (ESDAC, 2014). To strengthen food and energy security to support the growing population, major efforts are required in soil improvement and irrigation system installation.

Meeting the demand for agroresidues and wastes to be used as fertiliser for the next crop season, as well as for animal feed, is of primary importance. Abandoned or burned waste from agro-processing industries is usually available for feedstock to make briquettes and pellets, including the following, among many others:

- sawdust
- coconut husk
- coffee husk
- rice husk
- cotton stalks
- maize cobs
- peanut shells.


Pellets (left) and briquettes (right)

Sources: Yoshida (left), Tromso (right)

Depending on the characteristics of the raw material, there are also various processing methods to make briquettes. For example, sawdust briquettes are made after pressing sawdust into a cylindrical form and then carbonised. To produce coconut husk briquettes, the coconut husks must first be burnt, then triturated and finally pressed into briquette shapes.

The potential exists to produce many kinds of briquettes by using various feedstocks from farm residues and processing wastes. Briquette manufacturing machines were quite expensive in the past, but their prices are falling. As these machines become more affordable, briquettes from waste materials are more likely to become an alternative to firewood and wood charcoal. This shift would have a high potential to contribute to reducing forest resource losses. Feasible market expansions are expected to be adopted by collective buildings or cottage industries such as hospitals, schools, hotels and bakeries, which need energy in bulk.

BRIQUETTES MADE FROM RICE AND PEANUT HUSKS IN THE UNITED REPUBLIC OF TANZANIA

(Good practice example 2.1.1)

Organisations	Tromso Co. Ltd.[a] and DEMACO Co. Ltd.[b]
Type of organisation	Private company
Persons in charge	T. Makihata[a] and K.S. Kazema[b]
Target area	United Republic of Tanzania
Type of activity	Briquette production from rice husk and other farm and processing residues
URL	http://tromso.co.jp/
Co-operation with	E-Square Inc.

Summary

Deforestation caused by depleting wood resources to produce solid biofuel is rapidly increasing in response to increased energy demand. JICA and SIDA have assisted the government of the United Republic of Tanzania in its efforts to redress the situation by introducing Tromso's briquette-producing machine to process the thousands of tonnes of rice husks in rice milling factories. In Tanzania, about 300 000 tonnes of milling waste was available in 2013, an amount thought to be gradually increasing (FAO, n.d.3). This constitutes a green technology not only because the briquettes from rice husks are sustainable alternatives to the fuelwood that is causing deforestation, but also because rice husks used to be treated not as resources but as wastes to be burned, a practice that released GHG emissions and pollution into the air.

Tromso Co. Ltd.'s briquette-producing machine was invented in Japan. The procurement of a portion of the parts and assembly works of the machines is conducted in the United Republic of Tanzania in partnership with Tanzanian company Design Manufacturing and Construction Engineering Enterprises (DEMACO). This system results in lower prices and allows improvements by reflecting local needs, making the machine more userfriendly.

For example, DEMACO observed that the pure rice-husk briquettes did not meet "user-friendliness" criteria for domestic family users, who are the prime target of the products. Difficulty in starting the fire and the relatively low calorific value were found to be deficits. After trial and error, the briquettes were improved by combining readily available materials such as Allanblackia seed cake power, sawdust and a small amount of coal powder with the rice husks to make briquettes.

The addition of 50 % of sawdust increases not only the calorific value but also completely burns the briquette into ashes. The addition of a small amount of coal powder not only increases the calorific value, it also increases the time of glowing after the flame is out. The addition of Allanblackia powder increases the calorific value and makes it easy to start the briquettes. These additions significantly reduced the time required to start a fire, raised its calorific value and reduced the odour of pure rice husk briquettes.

In addition, Tromso has developed a movable carbonisation kiln that can produce charcoal from up to 200 kg of rice husk briquettes in five hours without electricity. Charcoal made from rice husk briquettes is ideal for making activated charcoal, which can be used for water purification and other purposes.

Rice husks (left), Tromso's briquette machine (middle) and Tromso's briquette (right)
Photographs: Kazema

Four types of briquettes have been produced by the briquettemaking machines. These include 1) briquettes from pure rice husks; 2) briquettes from a combination of rice husks, coal and Allanblackia powders; 3) briquettes from 50 % rice husk and 50 % sawdust; and 4) charcoal from carbonated rice husk briquettes.

Scaling up

Tromso has started overseas assembly of the briquette machines and procurement of less-expensive parts to reduce manufacturing costs.

Tromso's rice husk briquette machine can also be used for producing briquettes from peanut husks. The potential exists to produce peanut husk briquettes in sub-Saharan Africa because of the large volume of available feedstock. The soil improvement effect of peanuts' nitrogen-fixing capacity has proven to be an incentive for farmers to grow peanuts, especially in areas with degraded land across Africa.

Presentation and summary provided by: Kazema (2018)

Briquettes from rice husks offer a sustainable alternative to the fuel collection that cause deforestation

VERDE AFRICA'S CHARCOAL DUST-BRIQUETTES MANUFACTURED AND SOLD IN MOZAMBIQUE

(Good practice example 2.1.2)

Organisation	Verde Africa, Lda.
Type of organisation	Private company
Person in charge	Junko Arisaka
Target area	Mozambique
Type of activity	Briquette production from charcoal dust
URL	www.facebook.com/verdeafrica1101
Issued a support from	Japan Entrepreneurship in Africa Consortium (Entre Africa Japan)

Summary

Verde Africa, Lda. manufactures and sells briquettes made from charcoal dust and waste. In general, 15 % of charcoal used in commercial processes becomes waste in small pieces, which sellers usually discard. Verde Africa buys and recycles the charcoal into formed briquettes without adding chemicals. Verde Africa targets southern urban areas in Mozambique, although the practice of briquette production is widely replicable in all of Africa, depending on the price of wood charcoal and the availability of biomass.

Cheaper and cleaner than wood charcoal: Briquettes designed for the bottom-of-pyramid population

Switching from traditional wood charcoal to briquettes as a main energy source is difficult for many Mozambican families. Many people believe that charcoal cooks traditional food better and more affordably than modern cooking energy can. Affordability and cost-effectiveness are key to expanding the market. The new source of energy must be much more attractive and advantageous than traditional wood charcoal. The Verde Africa briquette, Macamanene, is priced more than 3 % lower than wood charcoal, depending on seasonal variations. Macamanene lasts on average over 1.5 % longer than wood charcoal. Customers also enjoy smoke-free cooking using Macamanene.

Expanding the market also depends on adequately explaining new and unfamiliar products. Customers need to understand, for example, that unlike charcoal, Macamanene cannot be shaken, and that water should not be poured onto the briquettes for later use.

Face-to-face discussion with users to improve quality and meet their needs
Photograph: Arisaka

Table 10. Price of Macamanene in comparison of wood charcoal

Size	1 kg	4.5 kg	40 kg	80 kg
Retail price	MZN 12 (USD 0.2)	50 mzn (0.9 $)	390 mzn (6.6 $)	750 mt (12.7 $)
Price (wood charcoal)	MZN 20–30 (USD 0.30.5)	60–80 mzn (1–1.4 $)	500–1000 mzn (8.5–16.9 $)	1200–2500 mzn (20.3–42.4 $)
Delivery	×	∆ Only to the markets	O	O
Target customers	Households	Local eateries	Local eateries, households	Local eateries, restaurants, households
Price per kg	MZN 11.6	10.9 mzn	9.6 mzn	9.2 mzn

Note: x = pick-up by customers; ∆ = sold at market areas; O = door to door delivery Market research by Verde Africa, Lda. conducted between October 2016 and January 2018. MZN = Mozambican metical. Exchange rate = MZN 59 to USD 1.

Source: Xenon Laboratories Incorporated (n. d.).

Quality control

The main quality-control components for Macamanene briquettes are the quality of the raw material and their moisture content. Charcoal dust is the raw material and the amount of sand contained in it makes a significant difference in the caloric levels of the final product. The moisture content is significant because fully dried briquettes perform best in terms of burning temperature and speed. Macamanene briquettes are packed after seven days of sun drying.

Scaling up

Between 2018 and 2020, Verde Africa aims to scale the production up to 100 tonnes per month. During expansion, the product line will be diversified, targeting different customer groups such as supermarkets in Maputo City and sales agents located on the outskirts of the district. In the medium-term, the company also plans to invest in carbonised industrial briquettes.

Presentation and summary provided by: Arisaka (2018)

Verde Africa's Macamanene

Source: Arisaka

BIO-BRIQUETTES AND FUELEFFICIENT STOVES TO UNLEASH THE POTENTIAL OF NEW COOKING METHODS IN RURAL MADAGASCAR

(Good practice example 2.1.3)

Organisation	TH Köln – Cologne University of Applied Sciences
Type of organisation	Research institute
Persons in charge	Deepak Kumar Mohapatra, Yaremi Cruz Rivera
Target area	Madagascar
Type of activity	Briquette production from dried grass and cow manure

Summary

An effective way to achieve the SDGs by 2030 is by increasing collaboration between academic researchers and local field workers. One such effort to bring about positive change is the KlimaBlick 2016 Project by L-H-L e.V from Düsseldorf, Germany. It was established to support and promote sustainable development at the Andalamengoke village in Madagascar.

A major portion of the population living on less than USD 1.90 a day has very limited or no access to modern energy supplies in Madagascar. Traditional biomass makes up more than 80 % of this population's overall energy consumption. Furthermore, Madagascar is one of the ten most climate-change affected countries, according to a 2015 climate risk index (Kreft, Eckstein and Metchior, 2017).

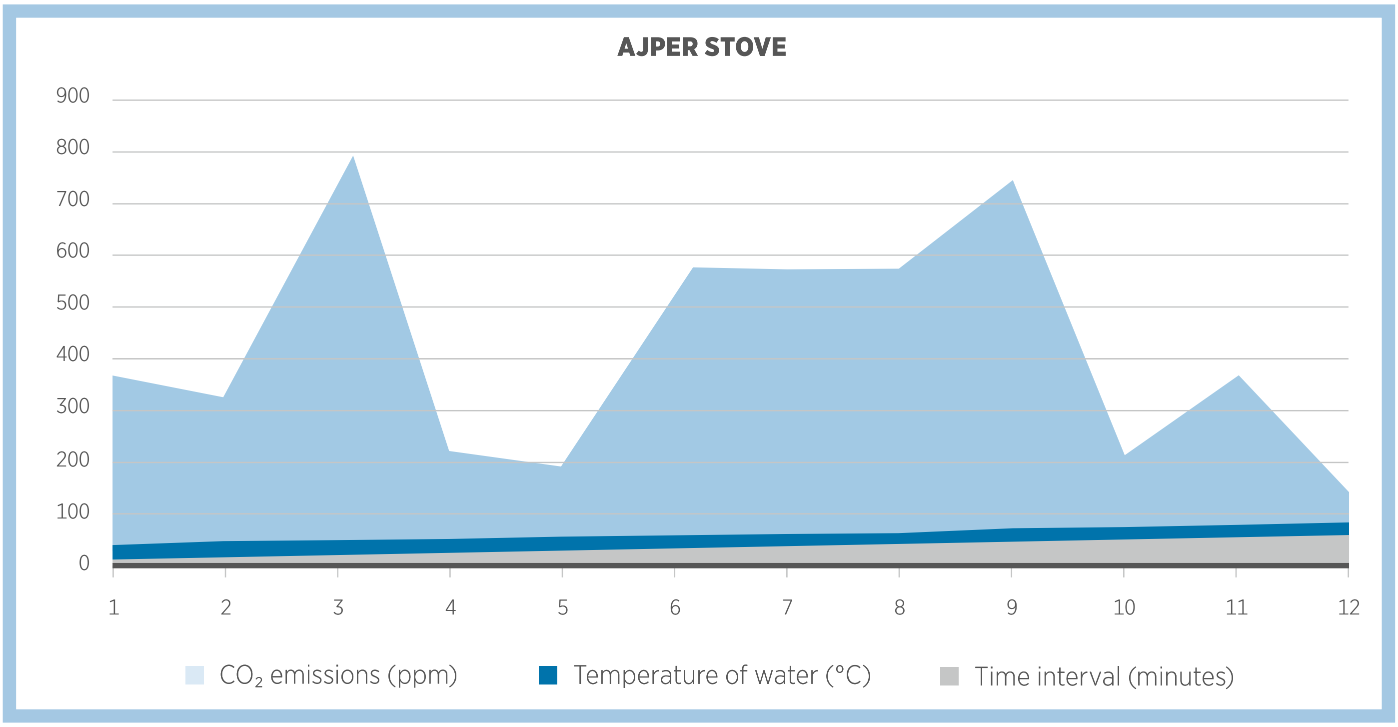
Fuel-efficient stoves and biomass briquettes are tools to make a positive contribution to SDGs 7 (affordable and clean energy), 11 (sustainable cities and communities), 12 (responsible consumption and production), 13 (climate action) and 17 (partnerships for the goals) as an alternative to current energy use issues. New models of fuel-efficient stoves are developed in Germany and sent to Madagascar for testing in local conditions by partner organisation AJPER. A biomass press was built in 2016 and taken to Madagascar for producing briquettes, which were tested as substitutes for charcoal.

During the project, six different mixtures of biomass briquettes were tested using two types of efficiency stoves: a German prototype and a local stove from AJPER. As a result, a mixture containing manure and grass was found to be the best combination as it took less time to boil water and emitted less CO_2 in comparison to the other combinations. Biomass briquettes and fuel-efficient stove models are expected to be manufactured in Madagascar, with local materials to make these key bioenergy products more affordable.

Energy production potential

The energy produced per briquette depends on its size and the calorific values of its composition. In this project, as mentioned above, several different mixtures of components were used to create different types of briquettes. The best combination of components was found to be 23 % dry grass and 77 % cow manure, which was being tested in the AJPER stove.

Figure 29. Test results from the best bio-briquettes



Note: X-Axis: number of events; Y-Axis: values obtained

Source: Mohapatra (2018)

Table 11. Calculation (Mohapatra)

	Dry grass	Cow manure
Calorific value	14.6 KJ/g (gram)	4.215.5 KJ/g
Quantity used	225 g	750 g (wet)

Source: Mohapatra (2018)

Suitable locations in Africa

The biomass briquettes can be used as an alternative fuel to charcoal and firewood in sub-Sahara African households where enough biomass is available, and an appropriate manufacturing method is established. Countries in eastern Africa are predominantly promoting the usage of briquettes because of their benefits and easy manufacturing methods. Use in such areas can be fruitful because biomass briquettes are renewable, sustainable, inexpensive, efficient, safe and geographically diversified. The decisive factors are whether they reduce indoor pollution, thereby improving the health of users, and whether their use helps to prevent environmental degradation. Rural areas where people use charcoal and/or timber to cook and areas with limited economic resources could be potential users of biomass briquettes as fuel.

Scaling up

Enabling factors for diffusion include:

» a commitment to reducing total dependence on oil and gas, energy security and waste management
» proper policy, technological and financial schemes to bolster the process
» the willingness of the people to embrace environmentally friendly methods of energy usage.

Presentation and summary provided by: Mohapatra (2018)

1. Assembling of biomass press prototype in Germany. Location: Leverkusen, Germany
2. Comparison of German and local efficiency stove prototypes. Location: Fianarantsoa, Madagascar
3. Testing of biomass press model. Location: Andalamengoke, Madagascar
4. Production of biomass briquettes. Location: Andalamengoke, Madagascar
5. Testing of briquettes with the efficiency stoves. Location: Andalamengoke, Madagascar
6. Different stove models and biomass briquettes. Location: Andalamengoke, Madagascar

Photographs: Mohapatra

2.2. INNOVATIVE COOKSTOVES

This section introduces cookstoves that provide a more fuel-efficient and less-polluting alternative to three-stone stoves. Three good practices are introduced. Various innovative fuel-efficient stoves and heaters that are mobile are introduced in Kenya, and the importance of caring for wood resource recovery by tree plantation toward sustainable feedstock management is shared. In Tanzania, the use of Kamado Jiko, an in-house built-in type of rocket stove, is facilitated by an NGO. In Uganda, an NGO is distributing another type of rocket stove made of sun-dried bricks. Use of these innovative stoves could reduce by onethird to twothirds the amount of wood-based feedstock required, as well as the heavy labour of carrying wood – especially by women and children – and the risk of respiratory diseases.

Concept

Energy for cooking is an integral component of human life, but improved energy sources for cooking are lacking in rural areas of sub-Saharan African countries. The efficiency of energy for cooking depends on both the source of energy and the technology (cookstove). Smoke production to a large extent, however, depends on the combustion efficiency of the cookstove, which may result in varying volumes of smoke emissions. Most of the technologies (traditional cookstoves) currently being used in conjunction with fuelwoods are crude and lacking innovation.

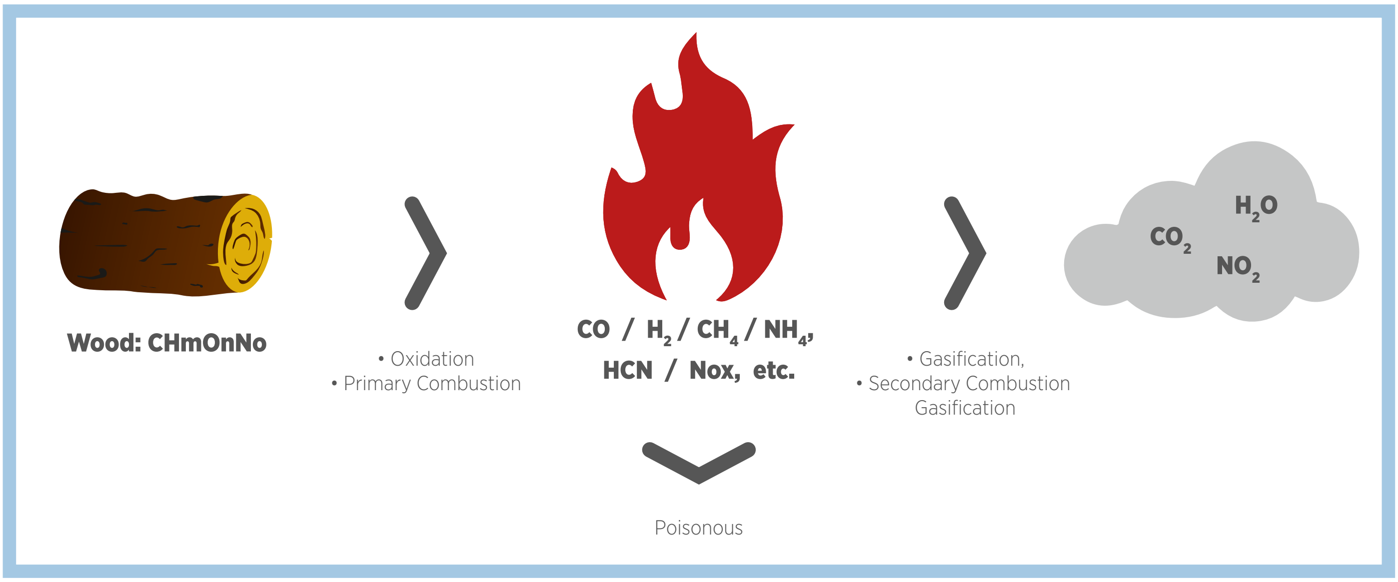
Indoor air pollution from the use of traditional stoves and open fires causes the premature deaths of approximately 4 million people annually, according to estimates by the WHO (WHO, 2018). Traditional cookstoves, which are commonly used by low-income households, are a great threat to the health and well-being of humans as well as to the environment because they have high fuel demand and produce large amounts of smoke. The high fuel demand creates heavy workloads carrying large quantities of fuelwood, which cause GHG emissions from deforestation and negatively impacts climate mitigation efforts. The inefficient combustion processes in these stoves incur high energy losses and high smoke production. The health implications of long-term exposure to smoke include bronchitis, asthma, heart and lung diseases and, ultimately, death (WHO, 2018). The smoke may even lead to deposits of dangerous chemicals (such as PAH) into the food, as is the case during fish-smoking activities (WHO, 2018).

These poisonous emissions are most likely to affect women and children, who use traditional cookstoves for cooking every day. In addition to domestic cooking, many women are also engaged in small-scale businesses or cottage industries such as smoked-fish production to sell in local markets. Long-term smoke inhalation has adverse effects not only on women but also their children (including unborn babies), who often spend long hours helping their mothers in their business activities. The WHO also estimates that about 50 % of under-five deaths from pneumonia are caused by soot from household air pollution (WHO, 2018).

The adoption of fuel-efficient cookstoves for households and cottage industries has the potential to improve the health and environmental situation in rural sub-Saharan Africa.

The main issues of the most common stove, the three-stone stove, are energy inefficiency and negative health impacts. Due to its open-air structure, the bulk of the heat generated by such stoves for cooking is dissipated and more firewood is needed. Mothers may hold babies while cooking, which unfortunately exposes them to smoke. This smoke may contain CO, volatile organic compounds (VOCs) and PAH.

Figure 30. Pollutant emissions from burning wood



A three-stone stove
Photograph: Inoue

To avoid inhaling poisonous gas and wasting energy, secondary combustion can be achieved via a stove system, the inside of which reaches a temperature of more than 600 °C (Ortega, 2008). Some gasifier stove types such as rocket stoves can realise this combustion mechanism. By the second combustion, the poisonous gas from the primary combustion is burned off and emissions are reduced. The stove, which can introduce secondary combustion at a high temperature, produces more energy with less fuel and dramatically reduces emissions. The improved cookstove, which enables high-temperature secondary combustion, should be promoted for emission reduction and the protection of children and women from respiratory diseases.

The new stoves also have to be culturally, socially and economically acceptable to households. According to GIZ, the key elements of cooking energy interventions and the role of the government include securing improved, efficient, quality stoves; marketing stoves that consumers can afford to buy; making improved stoves available in both rural and urban areas; and ensuring consumers are aware of improved stoves' availability and their benefits.

INNOVATIVE, FUEL-EFFICIENT STOVES IN KENYA

(Good practice example 2.2.1)

Organisation	Cookswell Jikos
Type of organisation	Private company
Person in charge	Teddy Kinyanjui
Target area	Kenya
Type of activity	Innovative, fuel-efficient cookstove producer and retailer
URL	http://cookswell.co.ke/index.php

Summary

Cookswell Jikos is a family-owned, growing small and medium-sized enterprise. It manufactures and sells stoves (wood-fuelled and charcoal), improved charcoal-making kilns, portable convection ovens, barbeques and smokers, and space heaters.

The company promotes "Seed to Ash Cycle" as a green energy solution for East Africa. A general lack of reforestation is causing deforestation and environmental disasters. Cookswell Jikos distributes a free tree seed packet with each cookstove, co-sponsored by Bunsen Travel Kenya, with a message to share the importance of sustainable forest resource production for cooking. Improving access to high-quality and low-cost, multi-use indigenous tree seeds is one of the ways to promote cyclic management of forest resources.

Cookswell Jiko cookstoves
Photographs: Cookswell Jikos

Figure 31. Seed-forest-fuel-stove cycle

Source: Cookswell Jikos

Wood resource sustainability is important for fuelwood cooking. With support from the Tamarind Kenya Group, Cookswell Jikos established the Woodlands 2000 Trust to foster dryland commercial agroforestry in Kenya and East Africa to create fuelwood security.

Figure 32. Reforestation for sustainable fuelwood

Tree seeding nursery at the Woodlands 2000 Trust demonstration woodlot in Isinya

Food, fuel and fodder agro-forestry systems

A 3.5 year old acacia tree, only the branches will be used for firewood and charcoal

Cookswell Jikos also sells small kilns to produce charcoal at home from readily available agrowastes such as maize cobs, tree branches and coconut husks with the goal of reducing the demand of wood-based charcoal. It is a low-cost, high-efficiency, portable charcoal kiln that is easy to use.

Cookswell Jikos provides customers with seedballs to assist in maintaining wood resources through reforestation and sustainable forest management. By pelletising tree seeds in a biochar/clay mix, the chance of seed predation is greatly reduced and the chances of germination increased.

Scaling up

Widescale expansion of the use of various types of Jiko stoves is possible by sharing information about their high quality and environmental soundness.

Presentation and summary provided by: Kinyanjui (2016, 2018)

Improved Kinyanjui "Green Cap'' barrel kilns
Photograph: Cookswell Jikos

Seedballs
Photograph: Shutterstock

Germination from seedballs
Photograph: Cookswell Jikos

Sub-Saharan Africa needs sustainable feedstock sources, healthy domestic energy systems and the means to adopt and maintain good, modern rural bioenergy solutions

KAMADO JIKO IN KENYA AND THE UNITED REPUBLIC OF TANZANIA

(Good practice example 2.2.2)

Organisation	Tanzania Pole Pole Club
Type of organisation	NGO
Person in charge	Shunsuke Fujisawa
Target area	United Republic of Tanzania
Type of activity	Innovative fuel-efficient cookstove producer and retailer
URL	http://polepoleclub.jp/

Summary

Kamado Jiko is a fuel-efficient and built-in-room type of rocket stove for cooking that can reduce the use of fuelwood by 54 % (Tanzania Pole Pole Club, n. d.). It was introduced in Enzaro village, Kenya in 1991 and is based on a traditional Japanese Toono Kamado.

A Kamado Jiko consists of clay soil, adobe bricks and stones. If clay soil is not available, cow dung can be substituted for Kamado Jiko construction. Kamado Jiko-style stoves have been introduced and are used in 200 000 houses in rural Kenya, Tanzania and Uganda.

One of the promoters distributing Kamado Jiko stoves is the NGO Tanzania Pole Pole Club, which is raising funds through the Internet from the Japanese public. They provide training for Kamado Jiko construction to manufacturers in communities that request Tanzania Pole Pole Club to co-operate in this regard. The trained manufacturers can sell and distribute the fuel-efficient stoves in their communities. To date, 140 Kamado Jiko stoves have been constructed by this system with the support of the Tanzania Pole Pole Club.

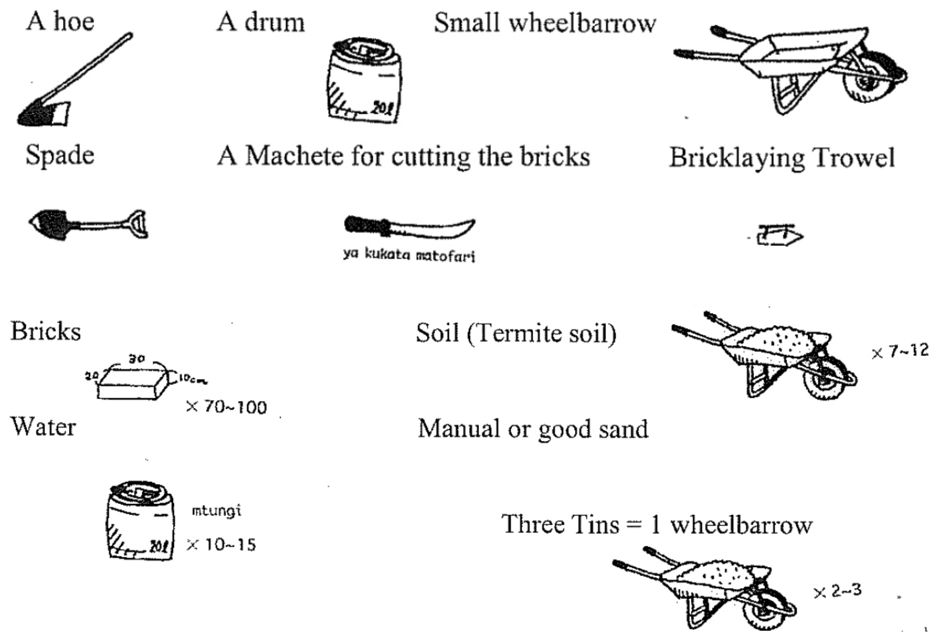
The Tanzania Pole Pole Club is promoting three types of Kamado Jikos: cement, brick and stone. The cement type is the most expensive and the stone type is the least. Villagers can select a type depending on their financial availability and preference.

The manual for constructing the Kamado Jiko follows.

Tools

The equipment necessary to construct a Kamado Jiko stove includes a hoe, a drum, a small wheelbarrow, a spade, a machete for cutting the adobe bricks and a brick-laying trowel. The materials needed are bricks, which are made from clay soil in the area, soil and water. Most of these materials are quite common in rural areas of sub-Saharan Africa.

Figure 33. Equipment and materials to construct a Kamado Jiko stove



Wind direction and the suitable position to place Kamado Jiko

Kamado Jiko stoves are indoor stoves. The Jiko must be positioned in the appropriate direction of air circulation. A Jiko stove should be located to the left of the door through which wind. It should not be located on the opposite side from where the air enters the room.

Bricks are made from local clay and soil

Figure 34. In-house position of Kamado Jiko

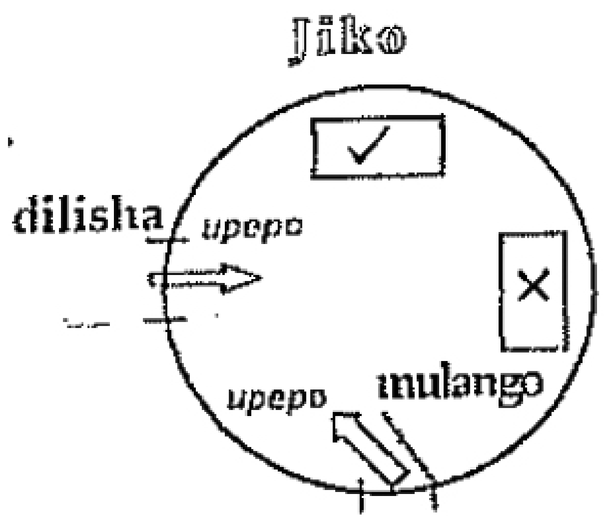
Swahili word

Jiko: Cookstove

Dilisha: Window

Upepo: Wind

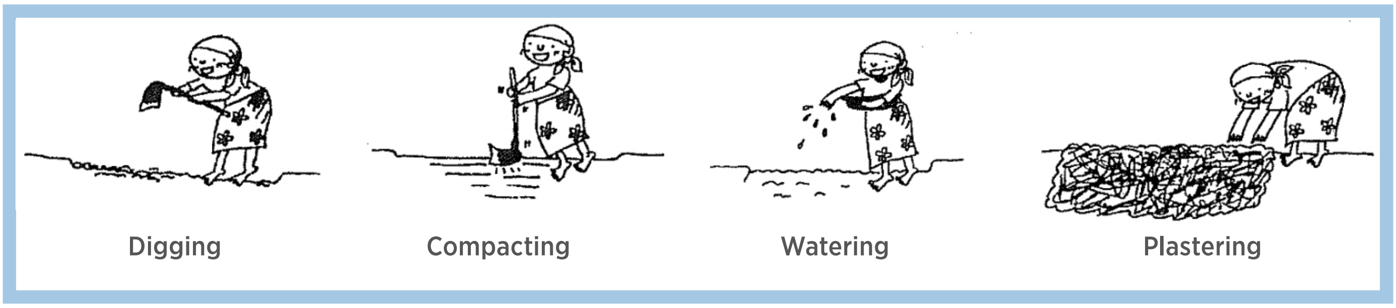
Mulango: Door



Strengthening the foundation

A solid base is created by digging, compacting, watering and plastering the designated area of the Jiko.

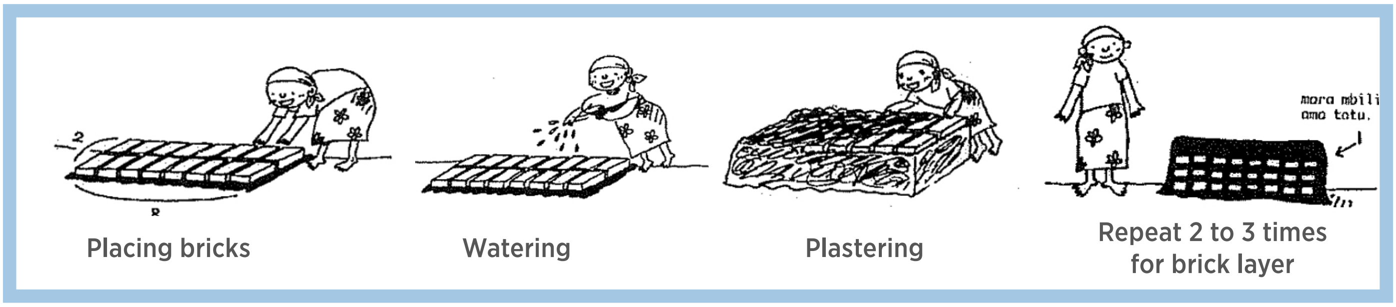
Figure 35. Foundation compaction for a Kamado Jiko stove



Constructing the foundation

Adobe bricks are then placed, plastered and watered. Repeat the cycle two or three times to build up the foundation.

Figure 36. Placing bricks and plastering to make a Kamado Jiko stove



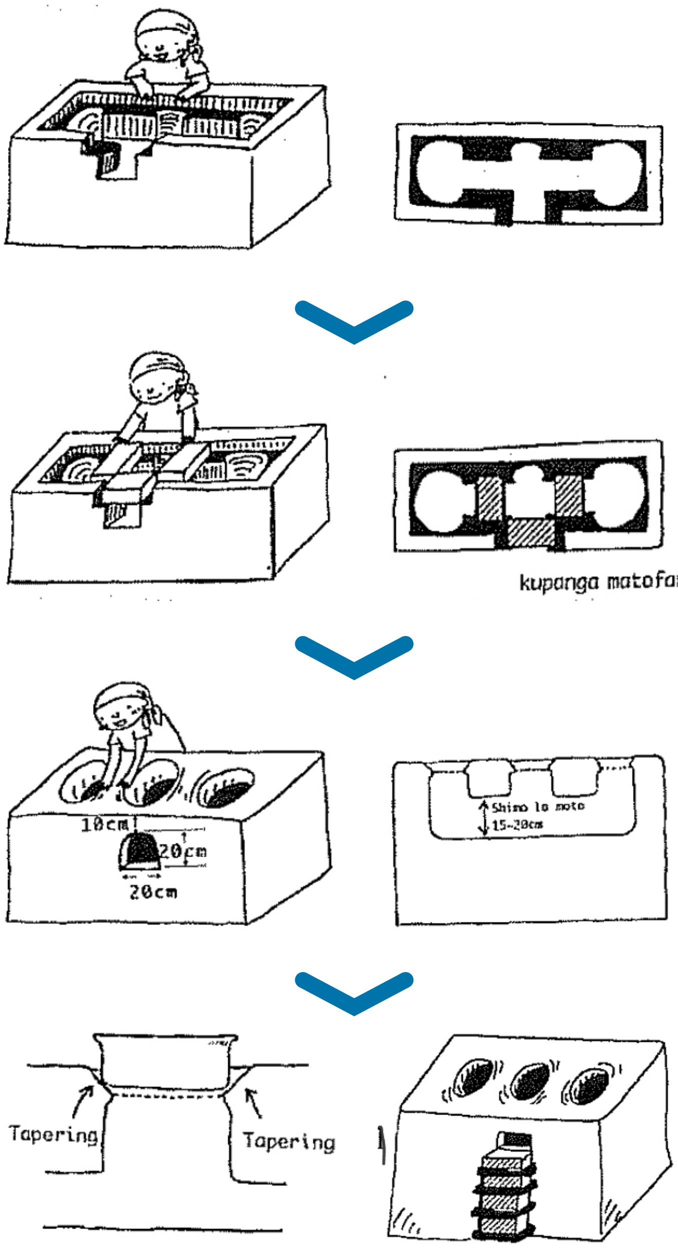
Constructing a fireplace

Then make a fireplace using bricks and plaster.

Figure 37. Making a fireplace for a Kamado Jiko stove

Make three holes that have 15cm-deep channels by plastering. Then make three fireplaces on top of the holes whose size is 20 cm in a trapezium shape.

Figure 38. Plastering a Kamado Jiko stove



Maintenance

If any cracks appear, they can be repaired with clay soil paste.

Kamado Jiko
Photograph: Tanzania Pole Pole Club

Brick Kamado Jiko
Photograph: Tanzania Pole Pole Club

Cement Kamado Jiko
Photograph: Tanzania Pole Pole Club

Local manufactures produce high-quality stoves

Scaling up

Co-operation with local extension services will be helpful for scaled distribution. Tanzania Pole Pole Club provides Kamado Jiko production training to manufacturers in local communities that request co-operation with Tanzania Pole Pole Club.

The construction quality of the Kamado Jiko is very important if it is to achieve its primary objective of reducing the use of firewood. If the quality of the Kamado Jiko is low, fuel use may increase. The training Tanzania Pole Pole Club provides enables local manufacturers to produce high-quality stoves for community members and to realise actual fuel use savings.

ROCKET STOVES IN UGANDA

(Good practice example 2.2.3)

Organisation	Aid Africa
Type of organisation	NGO
Person in charge	Peter Keller
Target area	Uganda
Type of activity	Innovative rocket stove that can be handmade, fuel-efficient and cheap
URL	www.aidafrica.net/rocket_stoves/

Summary

Wood has the highest calorie content of any biomass because of its carbon density and lower moisture content. Cooking using rocket stoves allows efficient use of wood by burning it in a simple tube-shaped combustion chamber. The heat is funnelled into an insulated vertical chimney, atop which water or food is heated or cooked.

Rocket stoves' combustion system is quite efficient compared to the ubiquitous three-stone stoves. Three-stone stoves burn fuelwood at temperatures of 200260 °C and emit and spread a lot of smoke due to incomplete combustions. Rocket stoves can reduce smoke emissions dramatically, because the closed chimney-shaped chamber of the rocket gas becomes a heat riser and causes a strong updraft wind, which induces strong absorptive air flow including oxygen into the chamber. At the entry point, the temperature of the wood feedstock is 200260 °C, but inside the chamber the temperature reaches 600 °C when secondary combustion occurs, which burns off all the poisonous smoke. Therefore, the air surrounding the rocket stove is cleaner.

Nearly complete combustion of wood fuel is achieved due to the efficient structure of rocket stoves, which burn off feedstock before flames reach the cooking surface. Rocket stoves are about three times more efficient compared to traditional stoves (Aid Africa, 2018b). Small wood feedstock, such as sticks and twigs from tree pruning, can produce high-calorie energy, which may reduce the demand for wood feedstock and its environmental impacts – such as forest degradation – and minimise emissions.

There are various types of rocket stoves. The one introduced by Africa Aid is efficient and constructed with materials that are readily available and affordable in rural Uganda.

Aid Africa's rocket stove

Aid Africa is an international NGO working to help people in need in Uganda by providing efficient, cleaner-burning cookstoves and rocket stoves. It has also been carrying out reforestation and clean water provision activities since 2006 (Aid Africa, 2018b).

Aid Africa's work also aims to stamp out respiratory and eye diseases, which kill significant numbers of infants annually around the world, as well as to lighten women's and children's heavy daily workload of collecting firewood. Using the high-calorie power of fire reduces the time it takes to cook by half, freeing up the time women have to spend on other tasks, which can reduce poverty.

The rocket stove is made of six adobe bricks made from clay and organic matter, with the assembly tightened up by two strings of wire.

Figure 39. Aid Africa's locally made adobe brick rocket stove

Image provided by Aid Africa

A 24-brick rocket stove
Photograph: Survival Common Sense

Another simple rocket stove for areas where clay is insufficient

Another type of rocket stove, made of concrete bricks in a different shape, can be constructed in areas where the clay necessary to make adobe bricks is not available. This stove, made by piling 24 concrete blocks in a certain order, costs approximately USD 1020.

Survival Common Sense has provided instructions for an easy and simple way to construct a concrete rocket stove (Survival Common Sense, 2013).

Scaling up

Many other kinds of rocket stoves are in use, such those made from stainless cans and adiabatic materials. However, stoves made from clay and cement blocks have the advantage of holding up better in high temperatures than those made from metallic materials.

2.3. WASTE-TO-ENERGY INNOVATIONS FOR SUSTAINABLE RURAL BIOETHANOL

This section focuses on the process and the inputs needed to produce bioethanol. One innovative production method uses agrowastes. Good practices include technologies to produce bioethanol using only non-food agro-product residues and wastes so as not to compromise food security. Feedstocks for these include waste from a cassava processing factory and oil palm trunks (OPT), subject to replanting in 20–25-year cycles. In both cases, much waste is available. Such wastes would otherwise be burnt or left to decay, and harvesting energy from them can help greatly to curb greenhouse gas (GHG) emissions.

Concept

Sub-Saharan Africa is experiencing growing demand for bioethanol for transport and heating, both to meet the needs of climate change mitigation policies as well as to absorb shock from the volatile prices of fossil fuels. Ethanol can be efficiently made from various potential biomass resources available in the region, such as cassava, sugar cane and maize. However, to produce bioethanol in a sustainable way with locally available materials (substrates, microorganisms and fermentation equipment) under local environmental conditions, suitable technologies and operation systems must be developed through appropriate R&D.

Producing biofuels often requires a large area of land for monoculture farming to supply feedstock efficiently. However, the amount of grain necessary to fill a car's 24gallon fuel tank with ethanol is equivalent to the amount of grain consumed by one rural villager in Africa for one year. Considering that a fuel tank is refilled at least once every two weeks, the amount of grain used for one car per year equals 25 African villagers' annual staple of food and nutrition.

Under these circumstances, bioethanol production may increase competition and conflict over land, water and soil nutrients that are necessary to grow crops. There is also a risk of displacing indigenous farmers from their productive land to give way to commercial agribusiness for limited job opportunities and restricting subsistence farming. This will result in food scarcity and price hikes, with vulnerable people in poverty most affected. This section highlights technology that uses agro-product residues and wastes sustainably and efficiently.

Cassava storage at starch factory in Nigeria
Photograph: Ogbonna, Murata and Omae

PRODUCTION OF ETHANOL FROM CASSAVA PROCESSING WASTE IN NIGERIA

(Good practice example 2.3.1)

Organisations	JIRCAS and University of Nigeria
Type of organisation	Research institutes
Persons in charge	J. Ogbonna, Y. Murata and H. Omae
Target area	Nigeria
Type of activity	Development of ethanol production technology from cassava processing wastes
URL	www.jircas.go.jp/en/top www.unn.edu.ng/internals/staff/viewProfile/MTgyOQ--

Summary

Nigeria is renowned as the world's largest producer of cassava. The country produces 57 million tonnes per annum (about 20 % of the world production). Most of the cassava tubers are processed into garri, fufu, flour and starch, which generate 290 kg, 290 kg, 320 kg and 670 kg per tonne of waste (peel, pulp, etc.), respectively. Garri and fufu are produced mainly by cottage industries and household processors, and the generated wastes are hardly economical to collect. There are many cassava starch and flour companies in Nigeria that process more than 10 tonnes of cassava tubers per day, and thus generate enough waste that can be economically converted to ethanol (Ogbonna, Murata and Omae, 2018).

There is a huge market for industrial ethanol in Nigeria. According to the National Bureau of Statistics, Nigeria consumed 54.3 million L of Premium Motor Spirit daily within the first quarter of 2017. Currently, Nigerian local refineries are producing only about 8 million L of Premium Motor Spirit per day. This requires only 800 000 L of ethanol per day (292 000 000 L per annum), which can be supplied by converting wastes from only 5.84 % of the cassava produced in Nigeria.

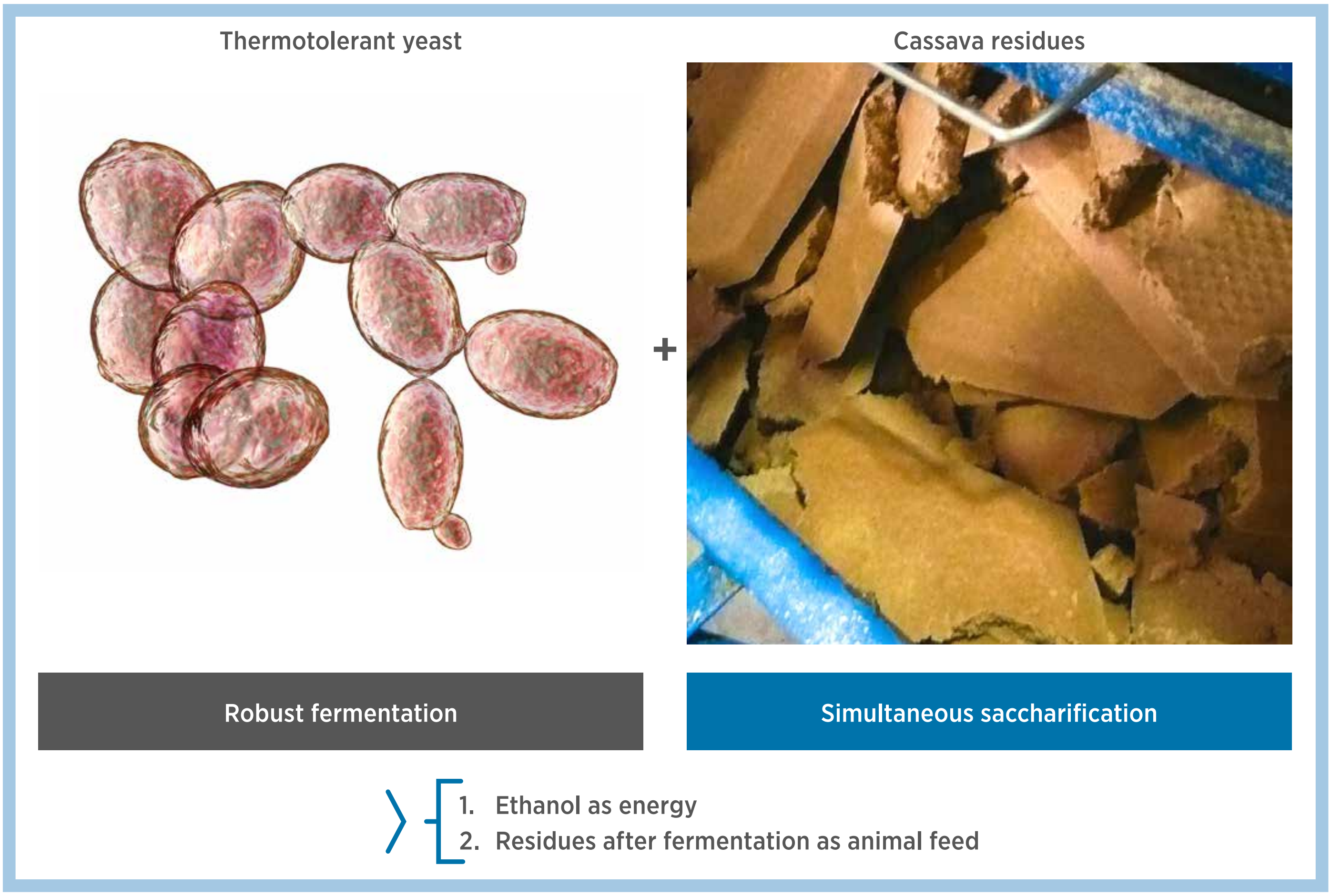
Development of efficient systems for the conversion of cassava peels and pulp to ethanol is achieved by isolating many strains of thermo-tolerant yeasts. The most promising strains have been identified as Pichia kudriavzevii and Saccharomyces cerevisiae. The production of ethanol from cassava pulp and cassava peel was investigated and optimised in terms of the effects of temperature, pH, nitrogen source and substrate concentration under simultaneous saccharification and ethanol fermentation using an enzyme cocktail composed of alpha amylase and amyloglucosidase (Nwuche et al., 2018). Under optimal conditions (pH = 6, substrate concentration = 20 %, temperature of about 40 °C and yeast extract as the nitrogen source), 5.8 % ethanol was produced from 20 % cassava pulp in flask cultures. This is equivalent to 0.29 g-ethanol/g-pulp. Using a 5-L jar fermenter, the ethanol concentration increased to 6.9 %, corresponding to a yield of 0.345 g-ethanol/g-cassava pulp.

Scaling up

These ethanol processors are scattered all over the middle and south of Nigeria, and the wastes deteriorate very fast. Rather than collecting wastes at a central ethanol production company, therefore, small-scale low-ethanol concentration (~60 %) production facilities should be established very close to cassava processing factories. A central ethanol re-distillation/rectification company can then be established to buy raw ethanol (~60 %) from the small-scale producers, rectify, dehydrate and sell to oil refineries to blend with gasoline for production of E10.

Cassava pulp has less value due to its poor nutritional profile. However, the fermented residues after ethanol production would be priced higher due to high proteins and vitamins from yeasts. Furthermore, fermented cassava pulp has an antiphlogistic effect on mastitis of dairy cattle (Murata et al., 2017). Both the ethanol and animal feeds (the fermented cassava pulp) are thus important products, thereby making commercialisation of the process feasible. This system is economically viable, will solve the problem of cassava waste disposal and treatment, and will contribute significantly to a reduction in carbon dioxide emission into the atmosphere.

Figure 40. Sustainable model of ethanol production from crop residues



Based on Murata et al. (2018)

Presentation and summary provided by: Ogbonna, Murata and Omae (2017)

OPT WASTE: A PROMISING AND SUSTAINABLE BIO-RESOURCE FOR RENEWABLE ENERGY PRODUCTION

(Good practice example 2.3.2)

Organisation	JIRCAS
Type of organisation	Research institute
Person in charge	Kosugi Akihiko
Target area	Thailand
Type of activity	Development of various bioenergy production technologies from abandoned OPT
URL	www.jircas.go.jp/en/top

Summary

With global production reaching 5.8 million tonnes in 2015 (ISTA Mielke GmbH, 2016), palm oil is the world's most produced plant oil. Biodiesel and bioplastics have potential as novel uses for palm oil. Indeed, small-scale production of these products has already begun in sub-Saharan African countries such as Ghana, Nigeria and Guinea (Table 13).

The bulk of palm oil is produced in Indonesia and Malaysia, where combined palm oil production totals about 88 % of global production. In 2007, oil palm (Elaeis guineensis) was planted on about 4 million ha in Malaysia and almost 7 million ha in Indonesia (Janurianto, 2010), where the practice is to plant about 142 oil palms per ha. To maintain oil productivity, replanting is required every 2025 years (Figure 41).

As a consequence of the required replanting interval, between 450 000 ha and 560 000 ha of oil palm plantations are expected to be replanted every year over the next 25 years, producing an average of 6 480 million OPT every year. These OPT represent a vast amount of biomass waste: about 2030 million OPT of waste is generated annually, the equivalent of the annual amount of all Japan's city waste (Kosugi et al., 2010).

Felled OPT contains large amounts of high-glucose sap (Table 12) (Kosugi et al., 2010) as well as numerous minerals, vitamins, amino acids and organic acids. Fermentation of the sap produces biofuels (ethanol and methane) and promising bioplastic materials (lactic acid and polyhydroxybutyrate [PHB]) with the use of microorganisms, but without the addition of nutrients at a comparable rate and yield (Kosugi et al., 2010).

Post-logging, sugars in the sap increased remarkably. After 20–40 days of storage, total sugar in the sap rose from 8.3 % (w/v) to 14.3 % (w/v). This concentration is equivalent to that of sugarcane juice (Yamada et al., 2010). The inner part of OPT contained sugars fermentable by the ethanol-producing yeast S. cerevisiae and lactic acid bacteria, making oil palm sap from this part of OPT a good feedstock for ethanol and lactic acid (Figure 43) (Yamada et al., 2010). In addition, to utilise the fibre after sap was extracted from the palm trunks, biopellets were prepared from the squeezed fibre residues of OPT (Figure 45).

There is therefore a strong indication that proper aging after logging can make OPT into a promising source of sugars and sap and that OPT residues can make good feedstock for biofuels by biomass refinery. Pilot scale demonstration tests of biogas production and high-quality pellet from OPT are being conducted in Malaysia (Figure 46).

Figure 41. Using OPT and saving forests

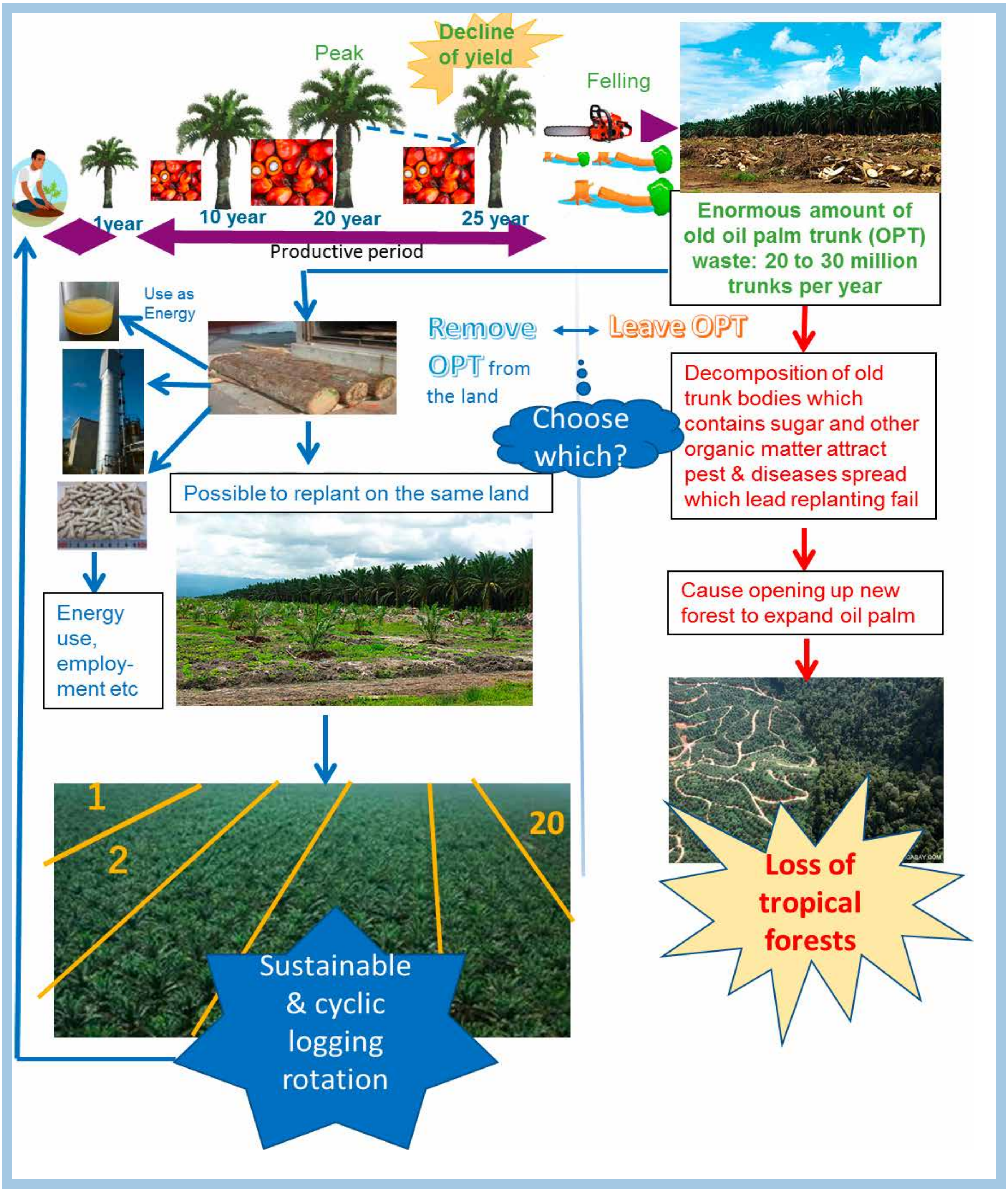
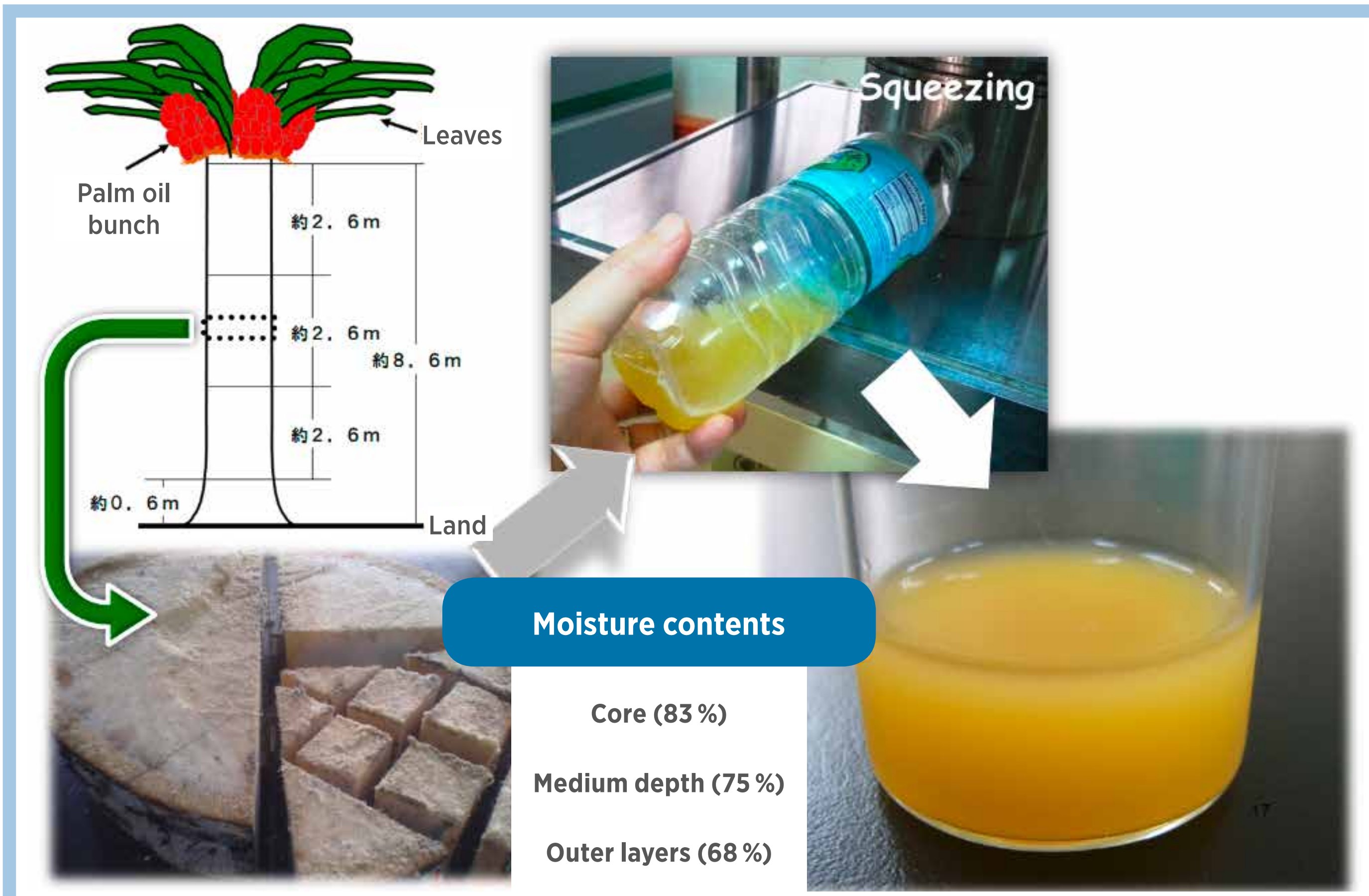


Figure prepared by research team.

Figure 42. Felled OPT and sample preparation for analysis



- Trunks sliced crosswise produce disks, allowing differentiated sampling from (a) core, (b) medium-depth and (c) outer layers, with approximate moisture content of 83 %, 75 % and 68 %, respectively (see also Table 12).
- wOPT contains far more moisture than wood timber. OPT's moisture content is normally 40–50 %, indicating large amounts of sap.
- OPT sap contains various sugars – predominantly glucose, with significant amounts of sucrose and fructose.

Source: Kosugi et al. (2010)

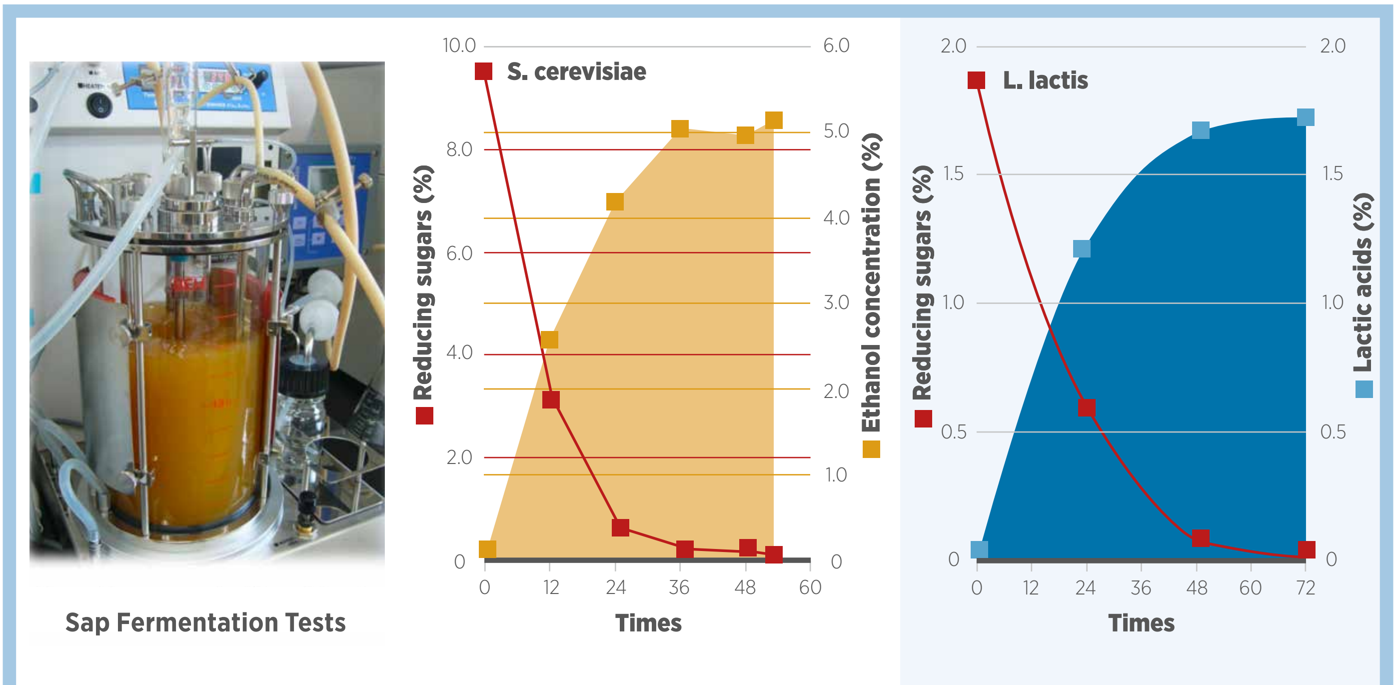
Table 12. Free sugars contained in the sap from a felled OPT

Free sugars	Trunk section*		
	Core (a) g/L	Medium-depth (b) g/L	Outer layers (c) g/L
Sucrose	6.5±1.1	3.0±0.4	1.9±0.1
Glucose	85.2±2.5	52.2±3.4	13.1±2.6
Fructose	4.1±1.2	3.1±1.0	2.1±1.7
Xylose	0.7±0.1	0.8±0.1	1.4±1.1
Galactose	0.9±0.1	0.8±0.3	1.0±0.8
Others	0.7±0.3	0.6±0.1	0.6±0.2
Total	98.1±5.5	60.5±3.3	20.1±1.1

** Sap levels vary between outer layers and core of trunk.*

Source: Kosugi et al. (2010)

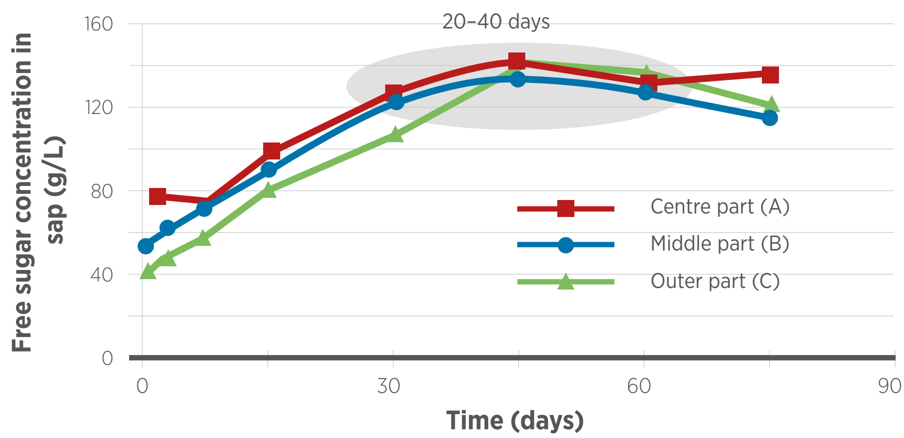
Figure 43. Time course of ethanol (middle) and lactic acid (right) production using sap from felled OPT



Note: (Middle) Saccharomyces cerevisiae was grown statically at 30 °C on the sap containing 55 g/L glucose without the addition of nutrients. Blue circles indicate ethanol produced from sap; red circles, glucose in sap culture. (Right) Lactobacillus lactis ATCC19435 was grown statically at 30 °C on the sap containing 16.7 g/L glucose without addition of nutrients. Blue circle, lactic acid produced from sap; red circles, glucose in sap culture.

Source: Kosugi et al. (2010)

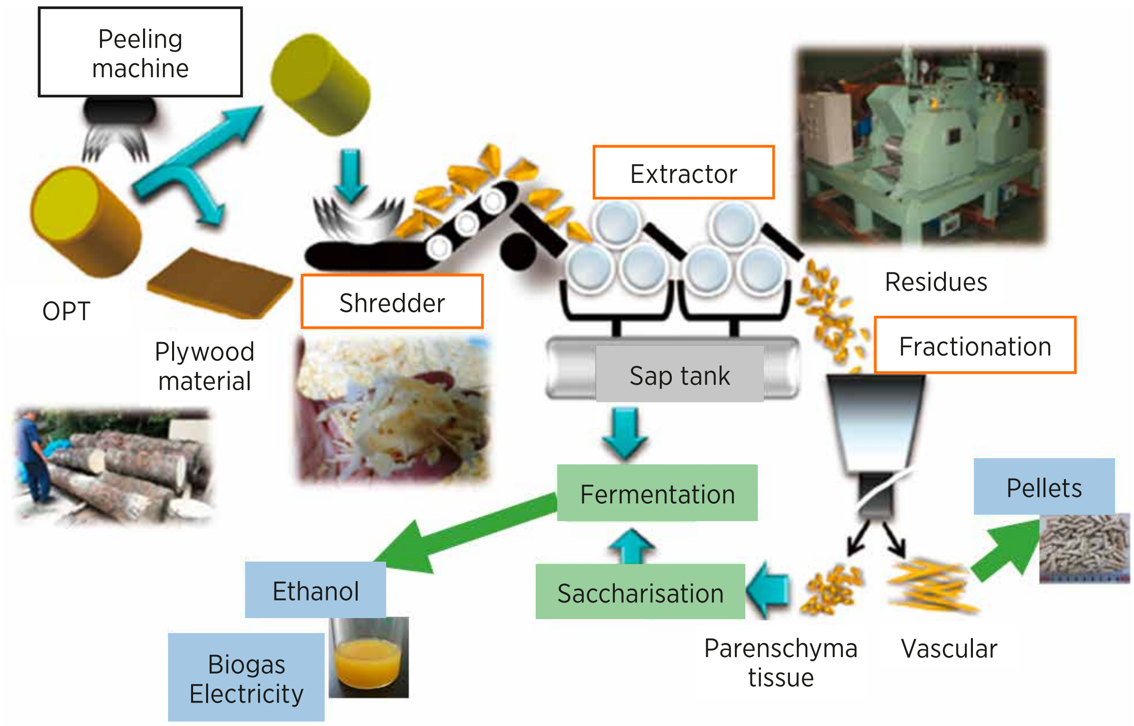
Figure 44. Change in moisture content among different sections of an OPT



Note: Examination took place during 90 days of storage. Of the three sections, the centre the trunk (part A) had the highest moisture content. Moisture declined toward the outer section (part C). Changes in the sap's total sugar content from each OPT section were plotted against days of storage. Concentrations of the sap sugar in parts A, B and C just after logging were 83, 55 and 40 g/L, respectively. During storage, sugar concentration increased sharply for parts A, B and C, reaching 143, 136 and 140 g/L, respectively, after 40 days.

Source: Yamada et al. (2010)

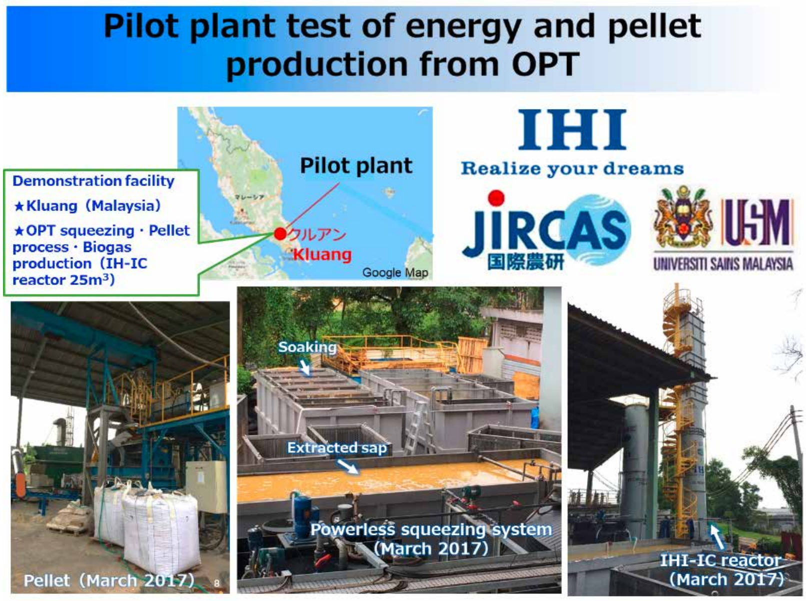
Figure 45. OPT compressing system



Note: The compressing system is composed of a shredder and a compressing mill.

Figure prepared by research team.

Figure 46. Pilot scale demonstration tests of biogas production and high-quality pellet from OPT



Note: For biogas and pellet from OPT, Japanese engineering company IHI, University of Science Malaysia and JIRCAS are starting demonstrations in Kluang, Malaysia

Source: Takada and Raghu (2018)

Application potential for Africa

In Africa, the area of planted oil palm is gradually expanding. In 2015, the total area was 4.5 million ha. The largest oil palm panted area in Africa is in Nigeria (3 million ha) followed by Ghana and Guinea (approx. 0.3 million ha each) (FAO, 2015b). Table 13 shows an estimate of future ethanol production potential from available OPT wastes in these countries.

Scaling up

Wasted OPT can be processed for use in biomaterials – or energy, as in this example. Using OPT in this way has the potential to improve employment opportunities, meet energy needs and enable countries to manage the environment and land sustainably. This includes forests, farms and pasture lands, which are precious resources for the people of sub-Saharan Africa.

Table 13. Ethanol production potential from OPT waste by 25 years sustainable felling rotation in Africa

	Oil Palm Plantation (ha) FAO STAT	Annual felling area for 25 years' sustainable rotation	Number of OPT waste annually*	Ethanol production potential from the OPT waste annually (litter)** and Peta Joule (PJ)***
Nigeria	3 074 571	122 983	12 298 284	639 510 768 liter ≒ 13.56 PJ
Ghana	349 040	13 962	1 396 160	72 600 320 liter ≒ 1.54 PJ
Guinea	313 814	2 553	1 255 256	65 273 312 liter ≒ 1.38 PJ

Note: * This assumes that 100 oil palms per ha are planted. **52 L of ethanol per 1 OPT can be produced (Kosugi et al., 2010). ***Ethanol 21.2 MJ per L.
Source: FAO (2015b)

Summary provided by: Kosugi (2018)

2.4. BIOGAS FROM WASTES AND RESIDUES

This section examines small-scale biogas production systems. Good practice examples from Kenya for household milk chilling and from Ethiopia for the coffee industry are introduced.

Concept

Biogas is a gaseous matter derived from biomass. Biogas is composed of water and organic matter. The easiest way to produce biogas is by placing organic matter in an anaerobic place. Anaerobic bacteria decompose the organic matters and biogas is generated. The process to generate biogas is called anaerobic digestion or methane fermentation. Biogas consists of both methane (60 %) and carbon dioxide (40 %). Various kinds of organic matter can be used as feedstock for biogas, including agro-processing residues, food waste and animal dung, among others.

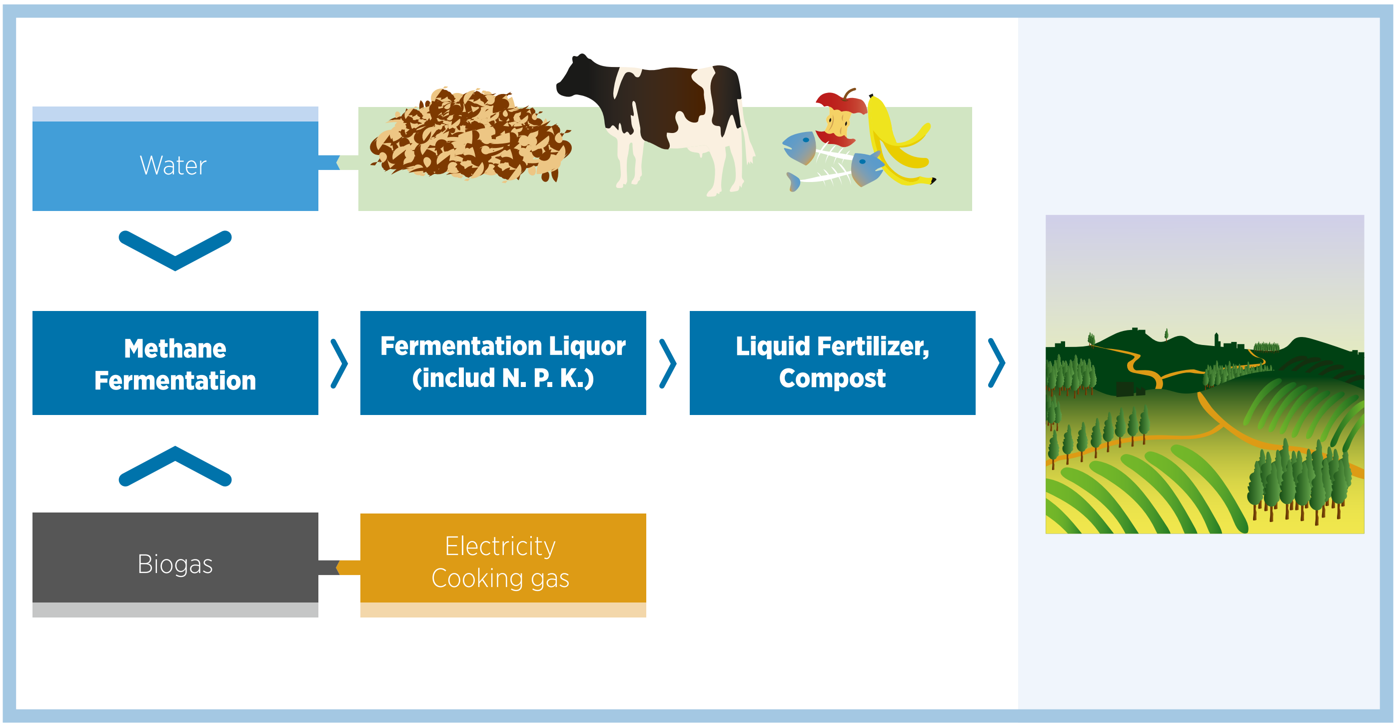
The anaerobic methane fermentation process also produces fertilisers as by-products. Fermentation liquor produced by methane fermentations includes the three major nutrients for plants to grow. These are nitrogen (N), phosphorus (P), and kalium (K).

Another merit of biogas is its ability to improve health by using it for cooking as an alternative to traditional three-stone stoves, which emit air pollution. To date, the daily task of collecting fuelwood is a critically heavy task mainly assigned to women and children. By introducing biogas cooking as an alternative to fuelwood, their workload can be dramatically lessened. Biogas also can reduce the pressure on forest resource depletion while also efficiently and effectively using agrofood waste.

However, an important condition is necessary to take into consideration before installing biogas digesters. Biogas production requires the addition of water to biomass. Therefore, biogas digesters should not be introduced in areas where water is very scarce. At minimum, they require the addition 10 L of water per day to pig manure and 50 L per day to cow manure with a digester of 1.3 cubic metres (±0.3) (Bansal, Tumwesige and Smith, 2017). An efficient and sustainable water harvesting system is necessary for a biogas system to be installed.

Biogas production and use has become popular in sub-Saharan Africa. Various feedstock is used to produce biogas. For example, in Uganda, the water hyacinth, an invasive aquatic weed introduced from South America, is used as unused biomass to generate electricity along Lake Victoria. Since water hyacinth has no natural predators, 40–80 tonnes of dry matter per ha per year is harvested. In 2010, a project to promote the use the water hyacinth for biogas was started (SNV and FACT, 2013). Biogas is generated from feedstock of water hyacinth, and animal manure is used to produce electricity and rechargeable batteries in off-grid areas of Ssese Island, Uganda.

Figure 47. Methane fermentation produces both biogas energy and fertilisers



IRENA has produced two useful reference publications on biogas:

» **Biogas for domestic cooking (IRENA, 2017)**
This is a technology brief on biogas for domestic cooking. It explains the technology and its environmental, economic and social performance. An overview by region is included, covering Asia and Africa, as well as the costs of and barriers to the uptake of biogas for cooking.

» **Measuring small-scale biogas capacity and production (IRENA, 2016)**
This is a guidebook to measure and estimate the capacity and production of biogas plants, mainly focusing on small-scale, household, communal or farm biogas plants that produce biogas.

BIOGAS FOR CHILLING MILK

(Good practice example 2.4.1)

Organisation	SimGas
Type of organisation	Private company
Person in charge	Dorine Poelhekke, Head of Business Development
Target area	East Africa
Type of activity	Cooling milk by biogas generated from cow manure
URL	www.simgas.com/
Co-operators	FAO/GIZ, SNV, Mueller, BoPInc, Powering Agriculture, EEP, OFID, IDEO.org, Amplify

Summary

SimGas's biogas-powered milk-chilling technology enables off-grid dairy farmers to store, deliver and sell milk in the highest quantities possible. It is the missing piece in the cold chain, and it benefits stakeholders throughout the chain.

With the biogas digesters, SimGas currently serves 2 500 East African dairy farmers who now cook with clean biogas instead of wood. Biogas can also be used for chilling. This solves a problem dairy farmers face every day: uncooled evening milk does not survive the heat overnight and cannot be sold the next day. Post-harvest milk losses are estimated at 30–50 % (Gustavsson et al., 2011), and only 15 % of milk in Africa reaches the formal sector (IFC, 2013). This creates a lost income opportunity for 2 million East African dairy farmers.

Figure 48. SimGas system

Source: SimGas

How it works

Every day, dairy farmers put cow manure in their biogas digesters to generate biogas. Every evening, these farmers put their churn with fresh milk into the chiller, which cools it down fast. It is kept cool until the next morning, when it is delivered and sold to the dairy co-operative. Dairy co-operatives collect more milk, attract more members and can meet supply targets set by processors. Processors receive more milk at more consistent volumes, enabling them to meet consumers' increasing demand. Dairy farmers pay for the chiller with milk: monthly payments are deducted from monthly milk income, using the existing financial infrastructure of dairy co-operatives.

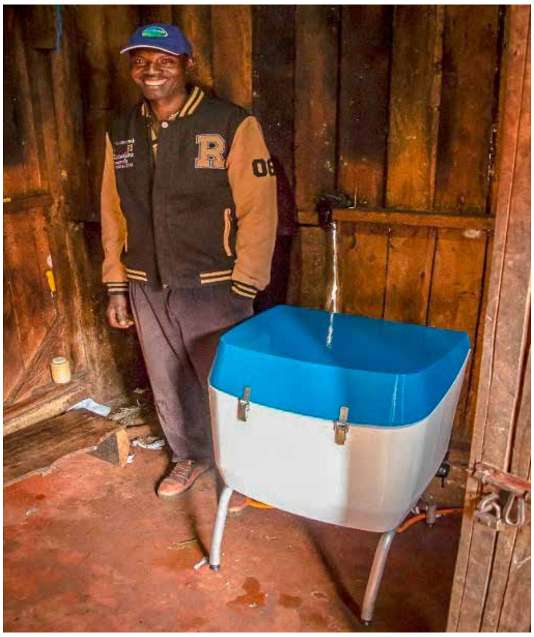
Unique value proposition

» No other solution available at this scale can cool milk fast enough to maintain quality (Energypedia, 2018). Refrigerators cool 21 times slower, and electric chillers require reliable electricity, which rural East Africa lacks (REN21, 2016).
» This solution caters to farmers with less than ten cows. With only two cows, a milk chiller is already viable.
» Using biogas proves that daily cooling and cooking on biogas is feasible.
» Partnering with dairy co-operatives enables farmers to pay with milk money.

Scaling up

SimGas's own investment and grants from donors covered the development phase. Further grant investment is sought to cover a large-scale pilot. Over the next five years, SimGas plans to include the milk chiller in a product portfolio next to SimGas's biogas digester, stove and rice cooker – all sold without subsidies. The target customer is the same, which enables the use of SimGas's existing sales and marketing channels in East Africa. A greater impact could be achieved by partnering with international dairy processors, milk cooling equipment distributors, national biogas programmes and dairy development programmes around the world.

The biogas milk chiller will be useful for any dairy farmer with two to ten cows who owns a biogas digester (to date, this includes 56 000 farmers in East Africa, 265 000 in southeast Asia, 4.7 million in India and 43 million in China). While SimGas's first target market is in rural East Africa, the company plans to wholesale the product worldwide.




SimGas refrigerator for milk chilling (left); a biogas digester (right)
Photographs: SimGas

BIOGAS FOR INFRARED PROCESSING OF COFFEE USING WASTED HUSKS

(Good practice example 2.4.2)

Organisation	Horn of Africa Regional Environment Center and Network, Addis Ababa University
Type of organisation	Autonomous institution of Addis Ababa University
Person in charge	Etsub Assefa
Target area	Ethiopia
Type of activity	Infrared for processing coffee at small-scale industrial level
URL	http://hoarec.org/
Co-operators	University of Hohenheim, University of Massachusetts Boston, and the Oromia Coffee Farmers Co-operative Union

Summary

Ethiopia exports about 700 million tonnes of coffee every year. Coffee accounts for more than 60 % of the country's export earnings. In Ethiopia's Oromia State, one of the largest coffee production states in Africa, a sun-drying process has traditionally been used to dry coffee. This system typically takes days to complete and can result in post-harvest losses.

The Horn of Africa organisation has invented a system to produce infrared to dry coffee from biogas, produced using coffee pulp and husk. This system reduces the drying time for coffee pulp to a few hours, a timesaving that means farmers can turn their attention to other, more productive, activities. The faster drying time also minimises the losses that can occur during the sun-drying process.

Another major benefit of the project is the expected improvement in work conditions for women and children, who are primarily responsible for managing the traditional sun-drying process and who subsequently spend entire days exposed to the sun. Furthermore, the project is expected to provide women with alternative livelihoods, such as growing mushrooms from coffee husks.

To power the bioreactors, biogas – produced anaerobically from coffee waste (husk) – is used as a carrier gas. Converting this waste product into useful energy has the side-benefit of reducing GHG emissions. The results showed that the moisture level of dried coffee using infrared decreased to the required humidity level.

Scaling up

Horn of Africa has identified two sites, including a large privately owned coffee farm, to pilot this technology. Beneficiaries of the technology will include eight coffee co-operatives, comprising 7 000 coffee farmers who will be able to sell a larger quantity of coffee due to the reduction in drying time.

Future plans include the integration of the infrared dryer and the biodigester units, following the optimisation of the dryer.

Presentation and summary provided by: Assefa (2018)

Traditional sun-drying system
Photographs: Assefa

Coffee production waste – huge biomass availability

Horn of Africa Regional Environment Center and Network system

2.5. SMALL-SCALE POWER GENERATION

This section introduces small-scale heat and power technologies that can help to fulfil the needs of rural communities. Good practice information includes a Kenyan small-scale power generation system – useful for rural cottage industries or community agro-industry development – and a Ugandan small-scale integrated power and heat generation system.

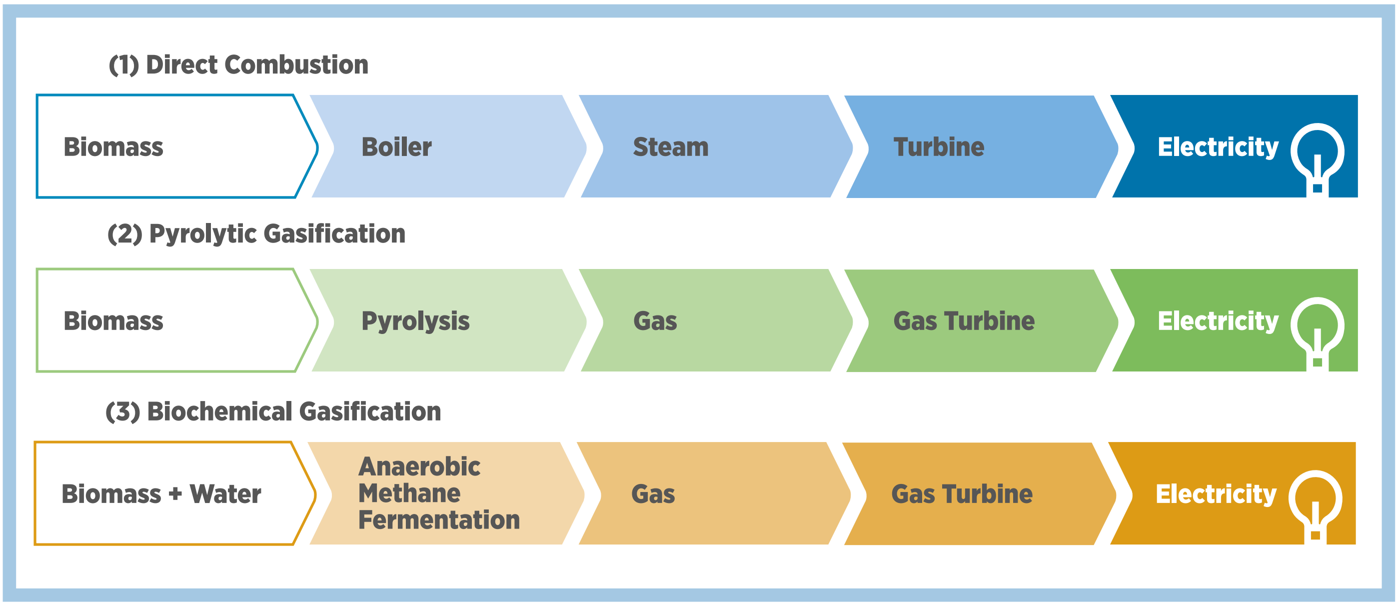
Concept

There are three main types of power generation systems from biomass feedstock: steam turbine, thermal gasification and biochemical gasification. Using a direct biomass combustion system, heat is generated in a boiler, which is used to produce electricity by a steam engine.

- Direct combustion drives a turbine to create electricity by the steam generated by the combustion of biomass. The waste heat produced in electricity generation can be recovered by heating water with the high-temperature steam as co-generation.
- Pyrolysis gasification is a pyrolytic decomposition of biomass from high-molecular to combustive gas. Wooden biomass mainly consists of lignin and cellulose, which starts thermal decomposition at a temperature of 200 °C. When the temperature reaches 600 °C, more than 8 % of the biomassis decomposed and is almost completely gasified to CO, CO_2, hydrogen (H_2), CH_4, and CH_2H_6 and other gasses and reaches to 800 °C for complete gasification.
- After refinement, gas is sent to a gas turbine to generate electricity. Liquid fuel can also be generated from the gas through a catalytic process. Biochar can also be produced through the pyrolysis process.
- Biochemical gasification generates biogas through methane fermentation by yeast that live in an anaerobic environment (see Chapter 2, Section 4).

In Africa, the first grid-connected biogas power system, with 2 megawatts (MW) of capacity, started operation in 2017 in George Farm, Kenya, 76 km northwest of Nairobi. It meets the needs of 5 000 to 6 000 rural families (Kariyuki, 2015; Tropical Power, 2018). Consistent biofeedstock availability is key to providing stable power generation. The George Farm system's feedstock comprises 50 000 tonnes of vegetable and rose production residue annually. In addition, 35 000 tonnes of biofertiliser, which contains NPK, are also available as by-products. A few biogas energy plants have started operations. The company set the selling price of the electricity lower than that of diesel fuel to ensure feasibility.

Figure 49. Three types of electrification systems from bioenergy



A POWER GENERATOR USING AGROWASTE IN KENYA

(Good practice example 2.5.1)

Organisation	Village Industrial Power (VIP): The engine of rural development
Type of organisation	Private company/Social enterprise
Person in charge	Maggie Flanagan
Target area	Kenya and India
Type of activity	Small-scale heat and power from waste
URL	www.villageindustrialpower.com/

Summary

VIP aims to increase opportunities in rural communities by providing reliable and affordable power to farmer groups, entrepreneurs and small and medium-size enterprises. VIP's platform technology is a modernised steam engine that produces threephase electricity (up to 10 kilowatts [kW]), mechanical power (up to 12 kW) and thermal energy (up to 40 kW). Crop waste, such as maize cob, nutshells or bagasse, is the fuel source for the engine, which consumes roughly 2 040 kg per hour, depending on the fuel type. The engine has a 60 % energy conversion rate and has a simple design that is easily operated, repaired and maintained in a village setting.

By combining this energy platform with ancillary equipment like irrigation pumps, grain mills, dryers, refrigerators and pasteurisers, rural-based businesses are able to increase production and perform primary processing closer to the production site. Currently, customers use the technology in combination with fruit and vegetable dryers and mills to preserve mango, banana, cassava and other crops. They are able to reduce the post-harvest losses of highly seasonal crops, like mango, which drop drastically in price when in abundance. The first pilot users reduced their losses by 80 % and increased their income fivefold in their first season of using a VIP-powered dryer and milling solution.

VIP's heat and power generation
Photograph: VIP

Enabling conditions

This technology is most appropriate where there exists 1) a cottage industry with an opportunity to scale operations; 2) nearby biomass availability, either as a direct by-product of the processing or as a result of high-density agricultural production or processing; and 3) users who are off-grid or lack a three-phase electrical connection required for more robust, industrial machinery and also have need of either dry- or steam-based process heat.

Scaling up

VIP ran proof-of-concept testing in Kenya in 2017 and is now offering a commercial solution in that market with plans to expand to Uganda and the United Republic of Tanzania. Currently, jaggery processing pilots are being launched in Maharashtra, India, where manufacturing is based.

Local children gathered around the VIP system (top); maize cob being fed into the power system (bottom left); mango drying cottage industry supported by the power system (bottom right)
Photographs: VIP

A GASIFIER FOR AN INTEGRATED POWER AND HEAT GENERATION SYSTEM FROM AGROWASTES

(Good practice example 2.5.2)

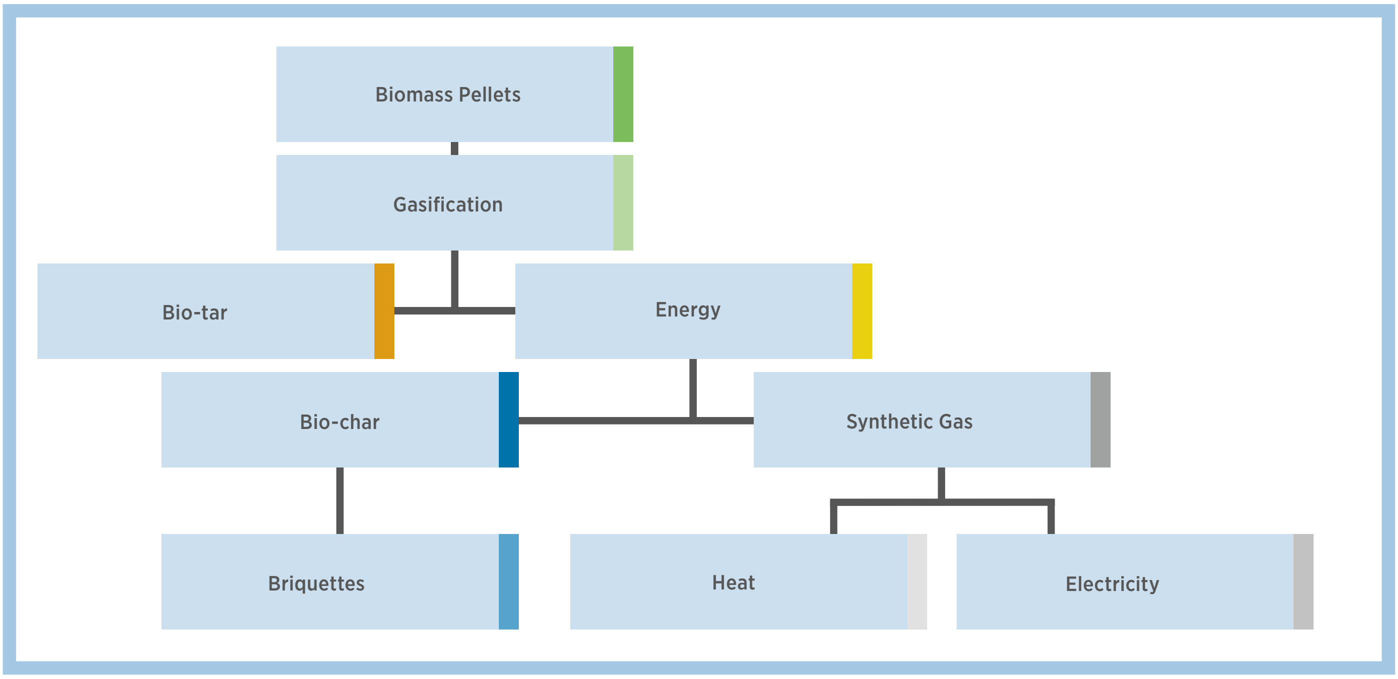
Organisation	Mandulis Energy
Type of organisation	Private company/Social enterprise
Person in charge	Elizabeth Nyeko
Target area	Uganda
Type of activity	Small-scale gasifier for heat and on-off grid power and other materials generations from agrowaste
URL	www.mandulisenergy.com

Summary

Mandulis Energy developed a biomass gasification system in co-operation with Imperial College London by thermochemical conversion of solid biomass in a low-oxygen environment into a synthetic gas (Syngas) as well as biochar as a by-product. Mandulis Energy aims for a "zero-waste" business approach. Syngas is used to drive a gas or stream turbine to generate electricity as well as heat. Biochar is used to make briquettes as an alternative to wood charcoal.

Mandulis Energy has already started 8 MW (16 sites of 500 kW) of off-grid and 20 MW on-grid power generation sites as well as briquette production. Off-grid power generation has investment by the Founders, Angels & Norgesvel/Nordic Climate Facility, GIZ GmBH. On-grid generation is approved by the Ugandan government and the Uganda Electricity Regulatory Authority. Grants are provided by KfW (German government) and UECCC (Ugandan government).

Figure 50. Monetisation of biomass



Source: Mandulis Energy (2016)

Pilot plant (left) and feedstock yard (right)
Photographs: Mandulis Energy

Scaling up

Mandulis Energy is working in partnership with more than 15 000 farmers, who have been recruited as feedstock suppliers. Mandulis Energy is also working in co-operation with ACTED, a French NGO. This partnership aims to supply electrification to off-grid agricultural areas in Uganda that is reliable, affordable and productive. According to Uganda's Ministry of Energy, the aggregation of agro-processing centres across Uganda has the potential to generate 1 650 MW of power, which would nearly double the current power generation capacity (Nyeko, 2016).

3. Tools to enhance bioenergy sustainability

3.1. DIGITALISATION AND BUSINESS MODELS THAT INCREASE BIOENERGY FEEDSTOCK AVAILABILITY

This section looks at how digital banking systems and new technologies extend the opportunities for rural communities to develop and access energy. Good practice examples include digital payments for contract farming of Jatropha curcas seed production for biodiesel fuel feedstock and the life-changing village kiosk monetary system in communities in Mozambique.

Concept

One of the largest constraints to living in rural sub-Saharan Africa is the limited accessibility to a formal banking system. Only one-third of adults have a bank account because the closest branch may be too distant to access. However, the alternative – keeping money in a rural house made of clay and bricks – is not safe either. Most of these homes do not have a locked safe, paper banknotes are easily eaten by insects and may get mouldy, and householders can be victimised by criminals. All of this makes it difficult for rural farmers to save money for future investments in a planned way.

More than one-half of the world's mobile money accounts are opened in Africa (GSMA, 2016). The rapidly growing popularity of the mobile money market strengthens its credibility and independence (Safaricom, n.d.). In Kenya, 60 % of the population, or 27 million people, use mobile phones to manage their money using mobile money accounts.

M-Pesa, one such mobile phone-based service, has a transaction value of more than half of the entire gross domestic product of Kenya. Initially, the M-Pesa system was used for electricity bill payments from solar photovoltaic projects in off-grid areas. In case of non-payment by the solar power user, the company could easily stop sending electricity remotely. Soon the system grew to encompass almost all financial activities, including receiving wages, purchasing food in supermarkets, borrowing money from friends and paying car park fees. Services like M-Pesa also enable urban workers to more conveniently transfer funds to family members living in rural areas or overseas. M-Pesa is now commonly used in ten African countries and is expanding into other continents.

Smartphone applications like M-Pesa are bringing about various innovations that have the potential to create dramatic change in sub-Saharan Africa. For example, Zimbabwe's e-agriculture system is expected to contribute to increasing biomass feedstock in the country. The Ministry of Land, Agriculture and Rural Settlement, with FAO support, has rolled out digital extension delivery and smallholder farm marketing through the Kurima Mari Mobile smartphone application (FAO, 2018). The app was developed by the Zimbabwe Livelihoods Food and Security Programme in 2016 with support from the UK Departement for International Development (DfID), FAO Zimbabwe, Palladium and Coffey International Development Ltd.

Traditional extension services have been conducted on-site, with face-to-face advice given by extension officers to farmers. However, the provision of extension services is often limited by an inadequate ratio of officers to farmers, as well as by distance and expense. Mobile phone apps like Kurima Mari have enabled smallholder farmers to access extension services, including advice to increase productivity.

Smartphone applications help to stimulate local bioenergy crop markets

In Mozambique, the Third Eye Project has introduced a drone (an unmanned aerial vehicle, or UAV) to be used for extension services for 2 800 farmers in 1 800 ha. A total of 14 extension service workers were trained to operate the UAVs to capture, analyse and present findings to farmers. As a result, a 41 % increase in production was achieved (African Union, 2018).

The establishment of a reliable marketing system is indispensable for rural agricultural development. In Zambia, the WFP started distributing an innovative mobile phone marketing system called Virtual Farmers' Market (VFM) in 2016 with the financial support of the German government (WFP, n.d.). The number of smartphone connections in Africa doubled between 2014 and 2016.

By installing the VFM application Maano on their smartphones, farmers can not only get information about which market will buy their agro-products, in what condition and at what price (WFP, n.d.), but they can also sell their products from home. This system helps smallholder farmers to increase their incomes efficiently. Also, it helps farmers increase production in accordance with market demands due to better predictive information.

Farmers have reported both satisfaction with the tangible benefits derived from the system and a stronger incentive to grow more agro-products. If the VFM helps to improve marketablility and boost agricultural production, then the supply of sustainable bioenergy feedstock supply can also be expected to increase in rural communities. The system will reduce food waste, and the higher incentives are expected to increase agro-products and biomass feedstock availability.

UAV Phantom2Vision
Photograph: Asia Air Survey

WFP's Virtual Farmers' Market
Photograph: WFP

RURAL BANKING DIGITALISATION AND BUSINESS MODELS IN MOZAMBIQUE

(Good practice example 3.1.1)

Organisations	Agro-Negócio para o desenvolvimento de Moçambique, Lda. (ADM), Nippon Biodiesel Fuel Co., Ltd. (NBF)
Type of organisation	Private company
Person in charge	Makoto Goda
Target area	Mozambique
Type of activity	Contract farming for a jatropha electric money system as village finance in off-grid areas
URL	http://nbf-web.com/
Co-operators	NEC, FAO

Summary

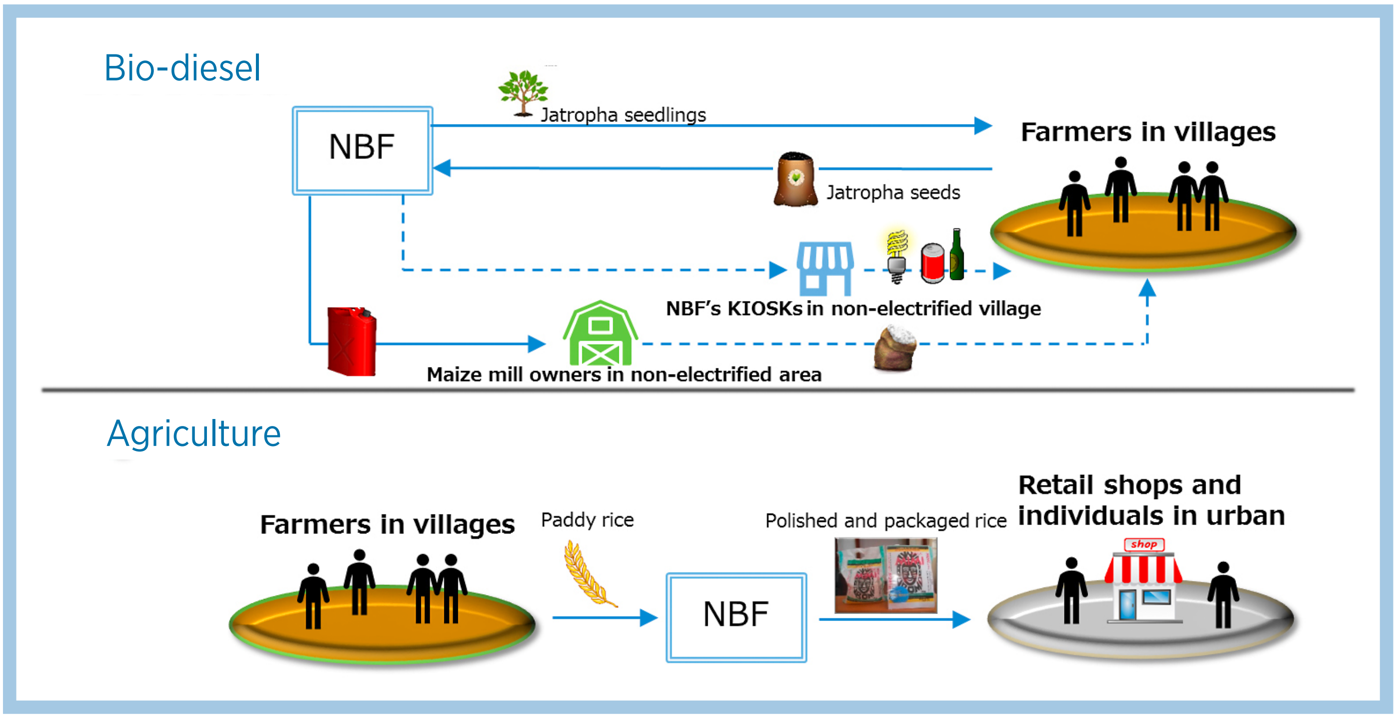
NBF/ADM (hereafter NBF) aims to contribute to the development of a viable post-peak-oil society. It strives to propose innovative solutions to eliminate the “poverty penalty” paid by less-privileged people in developing countries. Focusing on local production and consumption of energy, food and social overhead capital investment, NBF is pursuing the goal of local production and local consumption of biofuel made from the jatropha plant. Jatropha’s seeds contain oil usable as biodiesel fuel, and it grows well in sub-Saharan Africa’s semiarid climate. Jatropha is not edible, but it is suitable for energy use.

In off-grid areas of northern Mozambique, NBF has distributed 870 000 jatropha seedlings to 6 000 farmers who belong to farmers’ groups across four districts in Cabo Delgado. Farmers are allowed to plant and grow jatropha only as fencing on their farmland. They harvest the seeds when mature and sell them to NBF. However, NBF does not allow farmers to plant jatropha on their farms – only on the marginal part of the land as fences – in order not to disturb agriculture production for local food security. The increased income from the sale of jatropha seeds is considered to be an additional benefit for the farmers.

NBF purchases all the jatropha seeds sold by the farmers, no matter the amount. NBF then processes the jatropha seeds in an oil-milling factory and produces biofuel diesel. The biofuel is sold to customers who use it to run maize mills, to operate off-grid power generators to run the antenna of a mobile phone network and to drive tractors for ploughing. The fuel is used as an alternative to fossil diesel oil in ten districts across Cabo Delgado. Between 2013 and 2017, total sales of the biofuel reached 318 000 L for 2 366 clients. In addition, NBF provides a door-to-door delivery service of the jatropha fuel in remote areas to reduce transportation costs and to help small local agricultural enterprises to grow.

Since the establishment of its biofuel model, NBF has been strengthening relationships with local agricultural communities as producers and consumers. NBF has started several business diversification efforts to help develop the local economy. These include the production of organic fertiliser by using bagasse of jatropha, the production and commercialisation of rice and other local agro-products, and the purchase of agricultural crops from local farmers to sell at domestic markets.

Figure 51. NBF's jatropha and agricrop systems



Source: NBF

NBF built kiosks (local small retail shops) in unelectrified villages as platforms for buying agricultural products from farmers and selling consumer goods to farmers. Community members are employed to manage the kiosks. A feasibility study project ("the Creation of the Financial and Information Platform in Rural Mozambique through an Electronic Money System") was funded by JICA to study the financial services needs by using an electronic money system to eliminate errors in calculation of cash in NBF's rural kiosks.

NBF provided Integrated Circuit (IC) cards to local people in two off-grid, unelectrified villages as a pilot project. Clients charged money onto the IC cards (called near field communication [NFC] cards). The clients are able to purchase daily goods at the village kiosks with the electronic money. The charged money in the IC cards can also be withdrawn as cash. After the introduction of the service, some people started using the IC cards to deposit their money. In rural areas, due to a lack of commercial banks, people have not had access to financial infrastructures and services.

This new system has filled a need many rural people have: to reduce the risks associated with keeping money at home.

In the villages where the pilot project was carried out, there was no access to formal financial services such as branches of banks or ATMs. In the past there were only two ways to save money from earned income: keep it as cash or to convert it into livestock. Livestock is for fattening over time in order to pay house bills or to invest in family businesses in the future. The new electronic financial system is a simple and easy way for the users to manage their money. All users have to do is keep a card with money loaded on it. They can make purchases with the card without cash in-kind.

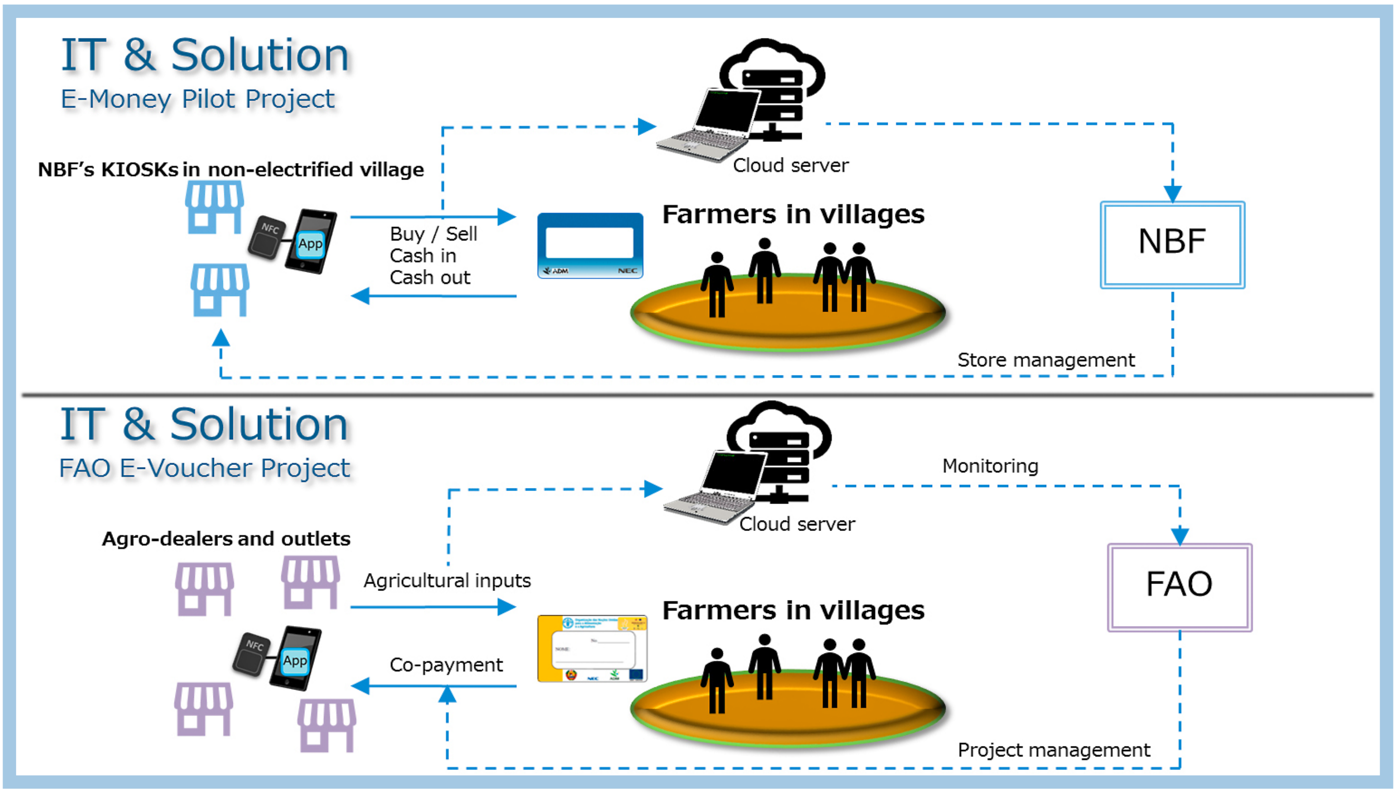
The IC card electronic money system is beneficial not only for the user but also for businesses, as it reduces the cost of financial management while enabling businesses to access marketing information such as the kinds of items purchased, the timing of purchases and the identity of buyers.

A kiosk in an off-grid village (left); a kiosk operator (centre); equipment charged by electricity (right)
Photographs: NBF

Scaling up

There is a need for financial services in rural areas; 88 % of 4.6 million adult farmers live in rural areas and 73 % of them are excluded from formal saving services in Mozambique (CENFRI, 2014). The NFC devices and tablet application have proven successful and are being used by people in rural areas. With the support of NBF, the technologies and the system that were used in the electronic money pilot project by NBF are being adopted by FAO as an electric voucher scheme in four provinces in Mozambique: Manica, Sofara, Zambezia and Nampula.

Figure 52. NBF/ADM's E-Money System (2014) and FAO's E-Voucher Scheme (2015–2017)



Source: NBF

Users have asked for some new functions to be added to the IC card, such as:

» money transfer, particularly for sending funds from urban to rural areas

» money deposit, to manage money in a secure way

» savings, to control and accumulate funds for future large expenditures (e.g., to start new businesses, to invest in education, to save for an agricultural intensification, to construct houses, to buy a car, etc.)

» instalment payment at kiosks.

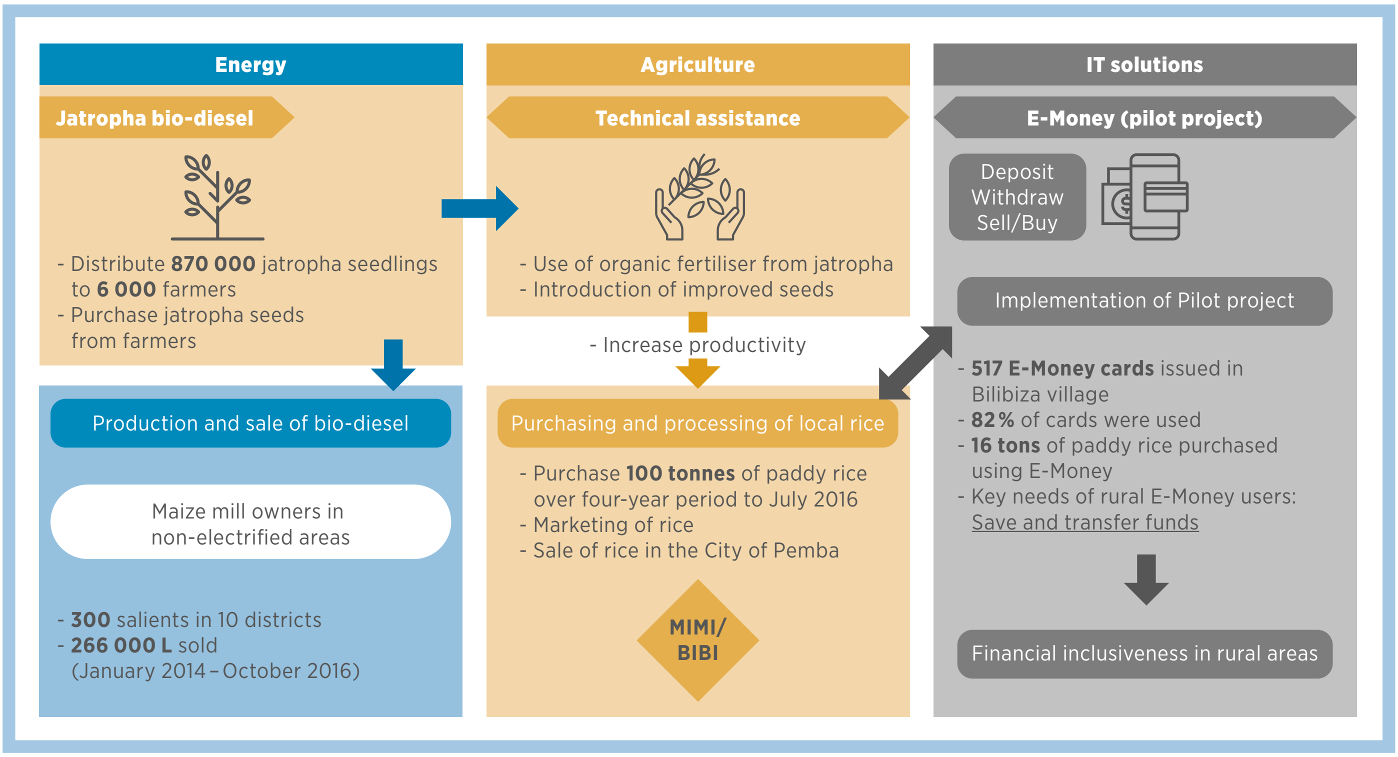
Throughout Mozambique, the financial situation is similar in most of its rural areas. The creation of the "information hub and village finance system" has the potential to solve various social problems and to create breakthrough growth on a community basis.

The electronic money system was piloted to sell and purchase agricultural products. The system expands farmers' marketing opportunities.

Screen capture of application for selling crops by electronic money pilot project

Image courtesy of NBF

Figure 53. Overview of NBF/ADM activities in Mozambique



Source: NBF (modified)

Presentation and summary provided by: Matsunaga (2018)

3.2. SMALL AND MEDIUM ENTREPRENEURSHIP SUPPORT OPPORTUNITIES

This section explores opportunities for youth or the youthful-minded in sub-Saharan Africa to engage, create solutions and bring about positive change by promoting sustainable, renewable-based energy and lifestyles in their communities. Good practice information centres on a "powering agriculture" project conducted by GIZ, USAID, Swedish International Development Co-operation Agency (SIDA), Duke Energy and the Overseas Private Investment Corporation (OPIC).

Concept

Africa's booming population and age structure are projected to present significant business opportunities in the coming decade. There is an abundance of needs, employee candidates, ideas, natural resources, opportunities and challenges across Africa. On the other hand, there are limited financial resources, infrastructure, reliable transportation systems, R&D and transfers, predictable regulatory environments, and vocational training opportunities, among others.

A study on self-perceptions about entrepreneurship showed that 43 % of the global population foresaw good opportunities for starting a business within the following six months. Participants in North America perceived the highest rate of opportunity (61.9 %), while those in Africa anticipated the lowest (37.2 %) (Global Entrepreneurship Research Association [GERA], 2018). This lower percentage of perceived opportunity is primarily rooted in a lack of confidence in financial availability and the existence of regional instabilities.

However, organisations do exist for willing entrepreneurs in Africa to step forward to respond to the need for improvements to the region's livelihood and welfare (see Annex 1). Entrepreneurship supports bring about various positive impacts on society, including employment opportunities, economic and social welfare, technical innovation, livelihood diversification, and change, among many others.

Another dimension stressed is the importance of R&D to bring about innovative solutions by entrepreneurship based on the needs of recipient communities. The Business Incubation Platform (BIP), an organisation under the International Institute of Tropical Agriculture (IITA), plays an incubation role by providing services to stimulate product development, expertise and training in commercial agriculture and farm management, and opportunities for market expansion.

One of the examples is using the innovative research outcome of the biogas production system. BIP develops a project to distribute the technology on the ground in communities in need with concrete feasibility studies and marketing strategies, which attract investment. IITA's BIP has a special youth empowerment programme, IITA Youth Agripreneurs, which enables young people to join workshops to learn business management in agriculture entrepreneurship (Features, 2015).

R. Diaz-Chavez and the Stockholm Environment Institute (SEI) have revealed that the fund for bioenergy R&D is quite limited compared to other renewable energy technologies, especially in Africa, despite the wide recognition of its importance. A budget increase is needed to create an enabling environment.

Figure 54. Interrelationship among needs, innovation and business

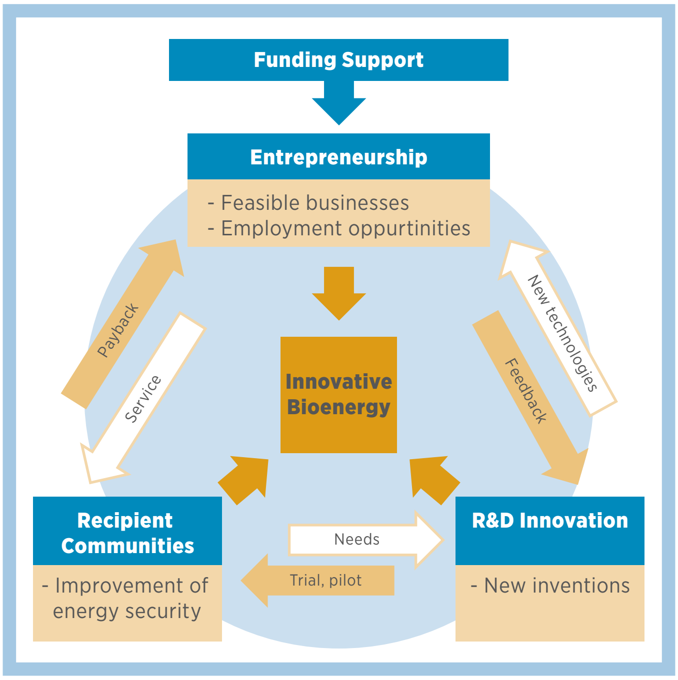
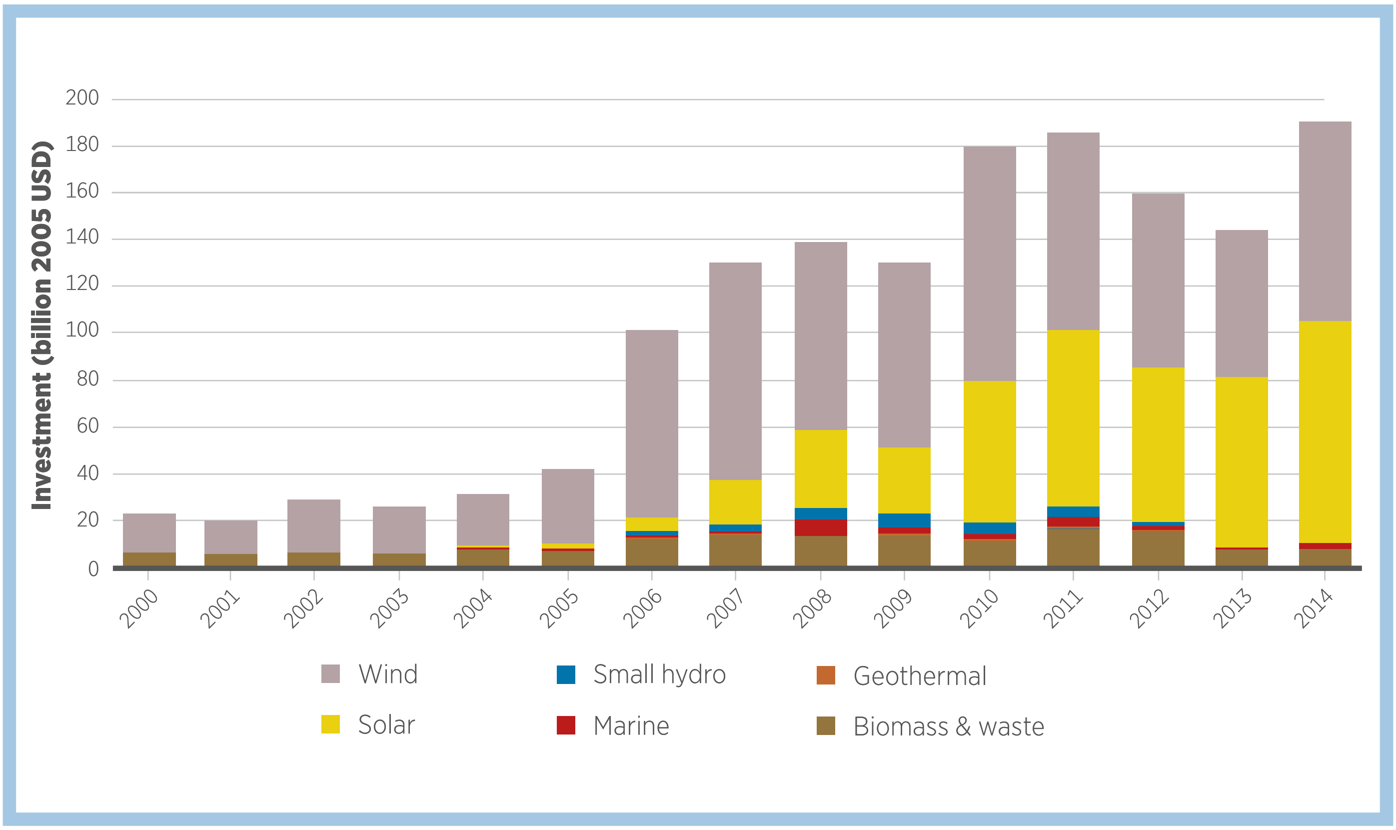


Figure 55. tInvestment in renewable-power sources in OECD and G20 countries



Source: Diaz-Chavez (2018)

IRENA's supporting tools for entrepreneurship

Along with facilitating direct funding through the IRENA/ADFD Project Facility, IRENA offers several tools to support entrepreneurship and investments. These include:

» **Global Atlas for Renewable Energy (www.irena.org/globalatlas):** A GIS-based map platform that helps to identify the renewable energy potential in a specific location. A Bioenergy Simulator is also available.

» **Project Navigator (www.irena.org/navigator):** A guidance manual for investors/entrepreneurs to write bankable proposals. A Navigator on Solid Bioenergy is already available for bioenergy.

» **Renewables Readiness Assessment: (www.irena.org/rra):** A country's or region's readiness for renewable energy is examined and reported.

» **Sustainable Energy Marketplace (www.irena.org/marketplace):** A web platform to indicate which entrepreneurs are doing what business in which location to create partnerships.

Funds for entrepreneurship support

» **After School Africa (www.afterschoolafrica.com/9200/business-plan-competitions-and-awards-for-african-entrepreneurs/):** This is a compilation of various awards and prizes for young African entrepreneurs funded by private companies and organisations such as Coca-Cola Africa Foundation, Unilever, Google and USAID, among many others.

» **Agribusiness Africa Window (www.aecfafrica.org):** This fund is for private companies with challenging, innovative ideas related to agribusiness, financial services and value chains aimed at benefitting rural communities in sub-Saharan Africa.

» **Anzisha Prize (www.anzishaprize.org):** Africans between the ages of 15 and 22 who are founders of an existing venture business, invention or social project in any field or industry are eligible for this prize.

» **Ashden International Awards for Entrepreneurs in Developing Countries (www.ashden.org/awards/apply-for-an-international-award):** This fund's mission is to encourage the growth of sustainable energy to tackle climate change and bring social and economic benefits to millions. Since 2001, 205 people have been awarded funding support.

» **Centre for African Entrepreneurship (www.caentr.org/about-us):** This South Wales, UK organisation seeks to inspire, support and promote African entrepreneurship by funding social businesses, community investment and micro-business loans.

» **Eastern Africa Farmers Federation/IFAD Call for Rural Youth Agribusiness Entrepreneurs (www.opportunitiesforafricans.com/the-eastern-africa-farmers-federation-eaff-ifad-call-for-rural-youth-agribusiness-entrepreneurs):** This funds rural youth groups (35 years or younger) in fields related to agriculture and agribusiness in East Africa (Kenya, Uganda, Burundi and Rwanda). The aims include support for access to developing enterprise-ready investment proposals, agri-business incubation services, and membership and potential funder/investor partnership opportunities.

» **Entrepreneur's Organization Global Student Entrepreneur Awards for Innovative Student Entrepreneurs 2018 (www.eonetwork.org/eo-gsea):** A global competition for undergraduate students who run a business for at least for six months. Three finalists will receive a combination of funding and business services.

» **Global Alliance for Clean Cookstoves (http://cleancookstoves.org/funding-opportunities/):** The alliance provides a variety of grants, including those for research, capacity building, training, entrepreneur support, in-country alliances and other initiatives, that help advance and catalyse the clean cookstoves and fuels sector.

» **IRENA/ADFD Project Facility (www.irena.org/adfd):** The Abu Dhabi Fund for Development (ADFC) provides sovereign funding to projects in developing countries in the form of concessionary loans for 20 years with a fiveyear grace period to support national priorities and assist in achieving sustainable economic development. USD 50 million will be funded annually for selected projects of USD 5 million to USD 15 million each, and up to 50 % of project costs will be covered.

» **Innovation Prize for Africa (http://innovationprizeforafrica.org/news15-05-18.html):** Entrepreneurs, inventors or academics can apply for this fund for home-grown solutions. USD 150 000 is shared among three winners, and nominees receive vouchers worth USD 5 000.

» **Miss.Africa Seed Funding Tech Initiative for Women in Africa 2018: (http://dotconnectafrica.org/yes-campaign/miss-africa/miss-africa-2018-seed-funding/):** Grants will be awarded to African women 18 years and older who propose projects with high potential for tangible impact on women and girls in computer science, science, technology, engineering and mathematics.

» **Sasakawa Peace Foundation (www.spf.org/e/grants/):** There are five categories of support areas, including empowerment of women. The foundation provides annual funding for up to three years.

» **Tony Elumelu Foundation (www.tonyelumelu-foundation.org/):** Launched in 2015, this foundation aims to channel USD 100 million over ten years to identify and empower 10 000 young African entrepreneurs. It also aims to add USD 10 billion in revenue to Africa's economy.

» **Zayed Sustainability Prize (https://zayed-sustainabilityprize.com/en/):** The Zayed Sustainability Prize is a tribute to the legacy of the late founding father of the United Arab Emirates, Sheikh Zayed bin Sultan Al Nahyan. Prizes of USD 600 000 are awarded annually for each of five categories: health, food, energy, water and global high schools. The prize for the global high schools category is divided among six regions (the Americas, Europe and Central Asia, sub-Saharan Africa, East Asia and Pacific, South Asia, and the Middle East and North Africa); each global high schools project winner receives USD 100 000.

POWERING AGRICULTURE

(Good practice example 3.2.1)

Organisations	GIZ, USAID, SIDA, Duke Energy and OPIC
Type of organisation	International organisations
Person in charge	Katharina Meder, GIZ
Target area	Global, including Africa
Type of activity	Entrepreneurship support for renewable energy to develop agriculture worldwide
URL	https://poweringag.org/

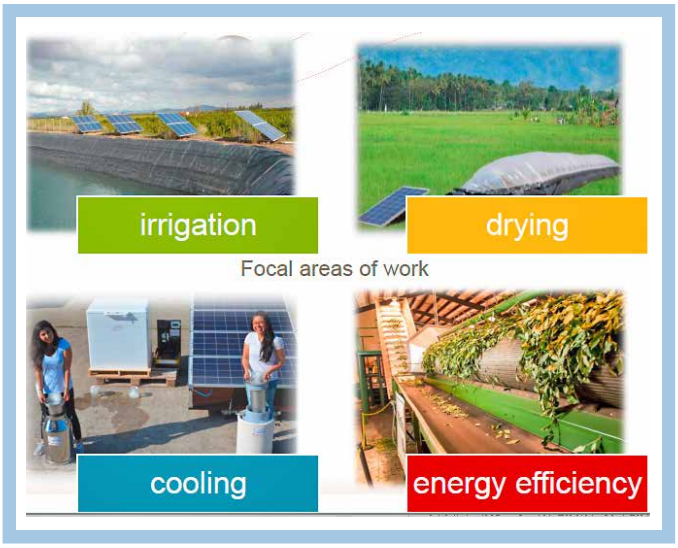
Summary

Powering Agriculture: An Energy Grand Challenge for Development (PAEGC) aims to help end extreme poverty and hunger by supporting the deployment of clean energy innovations. These innovations are intended to improve agricultural productivity and stimulate low-carbon economic growth in developing countries' agriculture sectors.

PAEGC is a joint global initiative involving GIZ on behalf of the German Federal Ministry for Economic Co-operation and Development (BMZ), the US Agency for International Development (USAID), the Swedish International Development Co-operation Agency (SIDA), the Overseas Private Investment Corporation (OPIC – a US government agency) and Duke Energy (a US-based energy company).

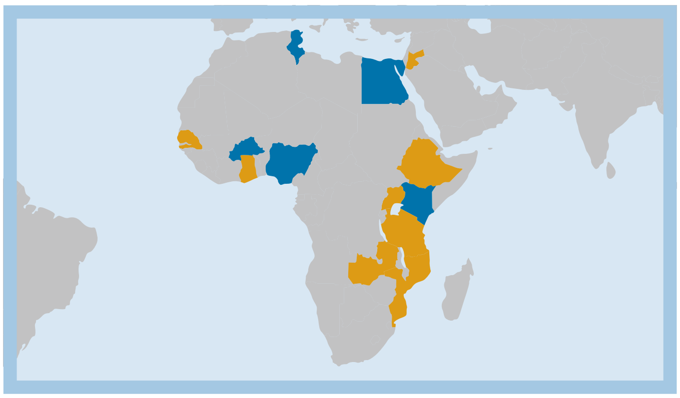
To date, the PAEGC initiative has taken a mainly competition-based approach. This approach aims to identify, upscale and support the development of market-based, clean energy innovations for agriculture in developing and emerging countries.

Figure 56. Powering agriculture: Focus areas for development



Source: Meder (2018)

Figure 57. Powering agriculture: Locations of funded organisations



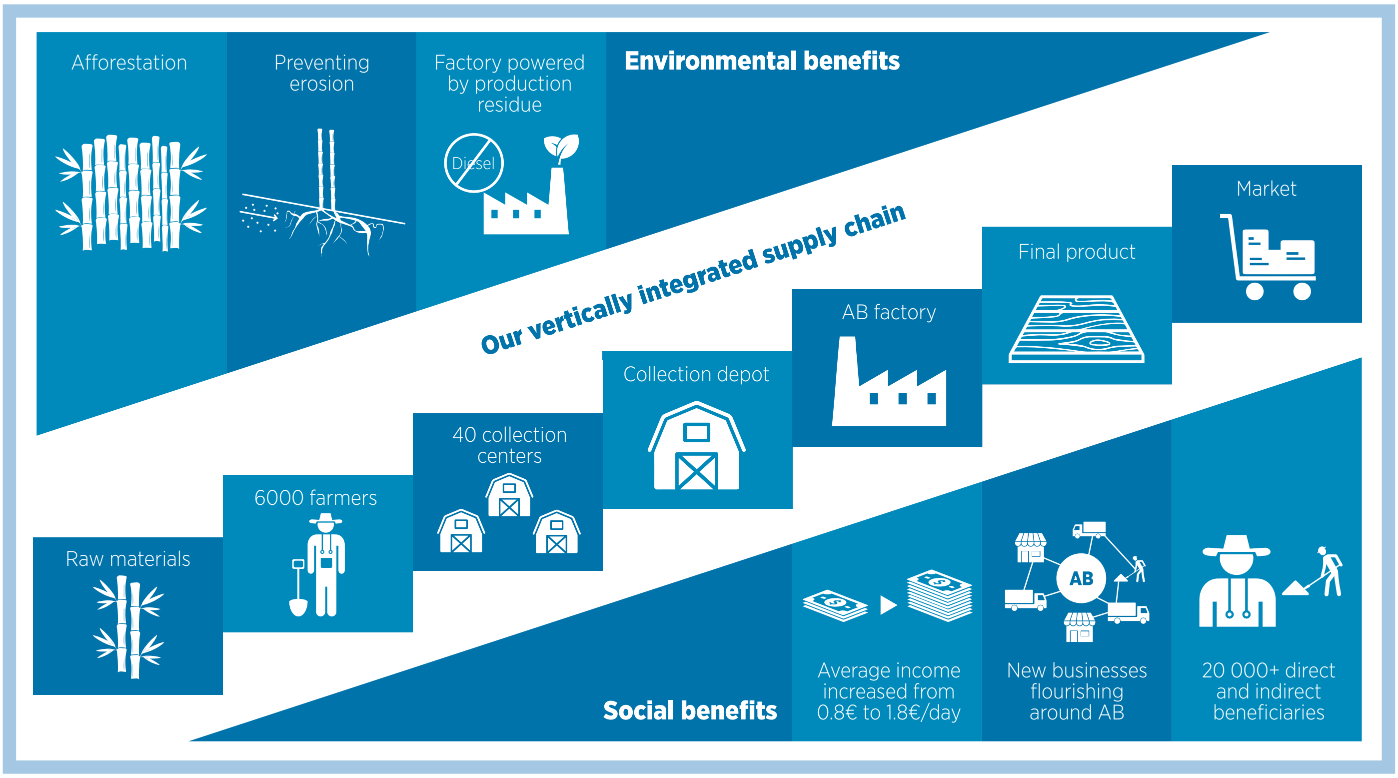
Source: Meder (2018)

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

So far, PAEGC has supported a few bioenergy entrepreneurships, including African Bamboo in Ethiopia. African Bamboo produces and sells bamboo products such as panels for flooring and decking to export markets of 850 000 m^2 annually (Worku, 2018). African Bamboo planned to use their processing residues to supply a combined heat and power plant, and they applied for PAEGC support for this.

Because the feedstock factory wastes are "own resources", more sustainable and stable energy availability was expected without price fluctuations or power cuts. The combined heat and power plant will give African Bamboo 12 MW of thermal energy capacity and 1.2 MW of electric energy (Worku, 2018).

Figure 58. Supply chain for African bamboo



Source: Worku (2018)

Presentation and summary provided by: Meder (2018) and Worku (2018)

3.3. BIOENERGY SUSTAINABILITY ASSESSMENT TOOLS

This section introduces newly developed tools to ensure the sustainability of new bioenergy technology installations. Two tools to strengthen sustainability are considered: GIS in Cameroon and a stakeholder perspective assessment based on Global Bioenergy Partnership (GBEP) sustainability indicators in Nigeria.

Concept

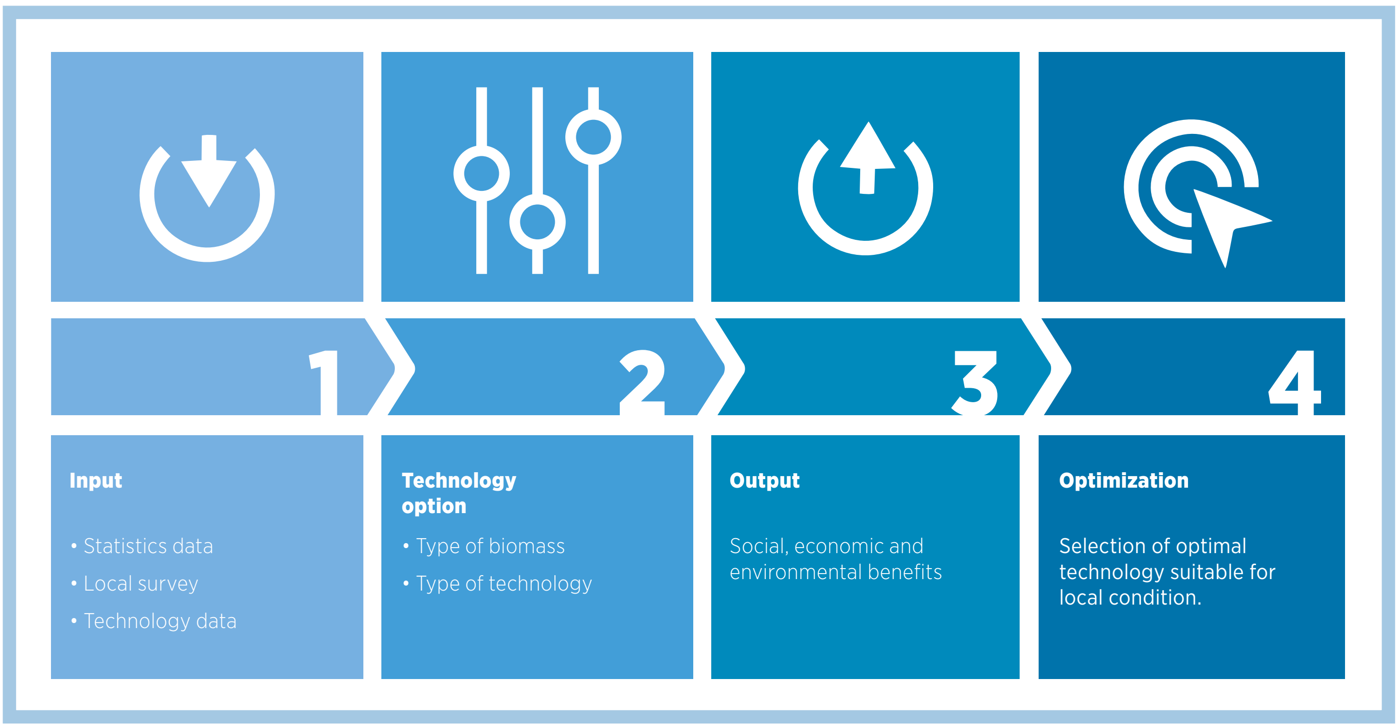
When there are plans to introduce new bioenergy production technology in a given area, the technology's sustainability should be assessed. A bioenergy project is considered to be sustainable if the bioenergy use continues without causing negative impacts over a long period of time. Figure 59 displays the steps to follow when selecting sustainable bioenergy options.

First, sustainable feedstock options and volume should be examined. Then the applicability of a bioenergy production option in a given area should be explored. The social, economic and environmental impacts in a target area must also be explored and analysed before starting bioenergy development planning. Based on the analysis, the best technologies for local conditions should be selected.

GIZ developed an assessment method for improved cookstove dissemination (GIZ, 2011). This method provides sustainability criteria and rates of penetration, usage, maintenance and replacement.

In 2005, the Paris Declaration on aid effectiveness was agreed by Organisation for Economic Co-operation and Development (OECD) countries and others to achieve sustainable development (OECD, 2005). The declaration outlines fundamental principles, including ownership, alignment, harmonisation, results, and mutual accountability and monitoring systems, to assess progress.

Figure 59. Selecting the optimal bioenergy technology



BIOENERGY SUPPLY-DEMAND POTENTIAL AND SPATIAL ANALYSIS OF AGRO-PROCESSING WASTES BY GEOGRAPHIC INFORMATION SYSTEM (GIS) IN CAMEROON

(Good practice example 3.3.1)

Organisations	IRENA, JIRCAS
Types of organisation	International organisation, international research organisation
Person in charge	Shunichi Nakada
Target areas	Ghana, Cameroon
Type of activity	GIS for bioenergy supply/potential area analysis
URL	www.irena.org, www.jircas.go.jp
Financial support	MAFF-Japan

Summary

As part of a framework to promote the valorisation of the use of biomass residues as an energy source, IRENA conducted a data collection pilot project in five countries in Africa, including Cameroon. The objectives of the project were to identify techno-economic pathways for different residue availabilities and to assess the potential on a national level for stakeholders to consider policy support measures. Information about residue amounts and current use was collected and analysed together with consideration of Cameroon's energy situation. This study provides background information for the first steps to introduce new bioenergy development policy measures.

Locality in distribution of agro-processor

Figure 60 shows the distribution of major agro-processing plants in Cameroon. A total of 40 agro-processors using nine different commodities were listed as medium- to large-scale plants. A strong locality was observed in the distribution of different kinds of agro-processors. Most of the timber processors are located in the country's east, while oil palm industries are in coastal areas of the Littoral and southwest regions. The Littoral Region also handles most of the country's major export products, including cocoa, coffee and oil palm. Those two factors – resource availability associated with natural environment and marketing opportunity – are major determination factors for the distribution of agro-processing plants.

High potential, uneven distribution

Bioenergy potential derived from agro-processing residue was estimated by multiplying the volume of production by the commodity-specific residue generation coefficient (0.2–3.6) and residue recovery fraction (0.75). The volume of residue is converted into energy value using commodity-specific heating value (10–18 gigajoules [GJ]/t). Overall, there are significant amounts of biomass from the agro-processing industry: 3 600 terajoules (TJ) (as primary energy). About 40 % of this is concentrated in the Littoral Region (1 539 TJ), followed by the Central Region (690 TJ) and East Region (590 TJ) (Figure 61).

In the Littoral Region, a palm oil processing plant contributes a significant portion of bioenergy potential. The largest contribution in the Central Region is sugarcane bagasse. In the East Region, all bioenergy potential is derived from the wood processing industry. No medium- to large-scale processor was identified in the Far North Region and, accordingly, its agro-processing-sector potential is estimated at almost zero.

Different areas produce bioenergy from palm oil, sugarcane or wood chips

Electricity demand distribution

After estimating each region's potential, energy demand was estimated by multiplying the regional population, the share (percentage) of the population without electricity access and national average home electricity consumption (43 kWh/person/year). High demand was observed in the Far North, Central, North and Northwest regions (Figure 62). The Central Region has high demand because of its large population, and the other three regions have high demand because of low electricity access (12 % for Far North, 16 % for North, and 30 % for Northwest). The difference between distribution of electricity demand and bioenergy supply potential is a supply-demand gap and is especially large in the Far North and North regions.

Processing residue has lower supply cost than harvesting residue

Electricity generation costs were calculated using an FAO-developed tool, BEFS Rapid Appraisal (FAO, n. d.4). Electricity is assumed to be generated in small-scale distributed systems (100 kWh). Generation costs were estimated as 0.25 kWh for processing residue and 3.61 kWh for harvesting residue. A large difference in cost comes from the cost of raw material (0 vs. 3.21). The cost of raw material was calculated based on the assumption that 120 person-hours are required to harvest maize stalk from a 1ha field.

These costs are still higher than conventional electricity prices in Cameroon (0.15 USD/kWh), but processing residue has better potential to fill the gap. Detailed transportation cost assessments and optimisation of power plant location were not conducted due to a lack of detailed information.

Potential to electrify 80 000 households using residues for power generation

Although the supply cost is still higher than the conventional electricity price, the potential of an electricity supply to electrify off-grid households was calculated using estimated electricity demand and supply potential. The result is shown in Figure 63. Nationwide, over 80 000 households could potentially be supplied with electricity from a biomass residue-based power generation system (Figure 63).

Scaling up

This study identified a high availability of biomass residue for potential use in electricity generation in Cameroon. Further study and analysis of GIS-based assessment for biomass logistics and the development of a technology selection support tool will enable comparative assessment of different technology pathways.

Figure 60. Major agro-processors, Cameroon

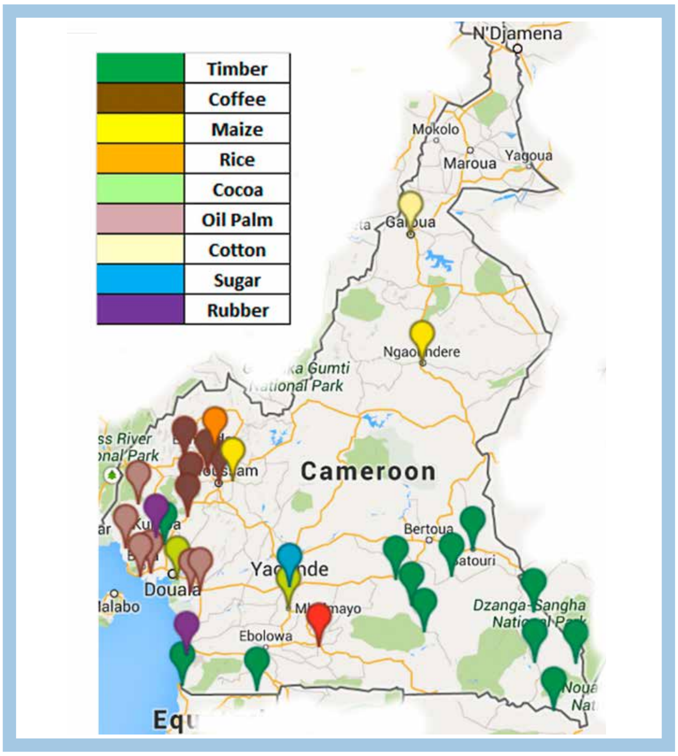


Figure 61. Agro-processing residue potential by region, Cameroon

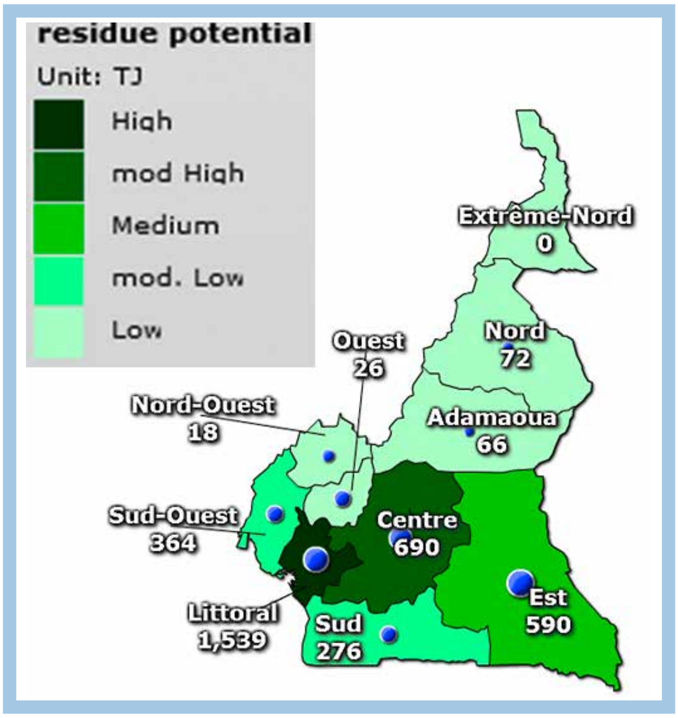


Figure 62. Electricity demand by region, Cameroon

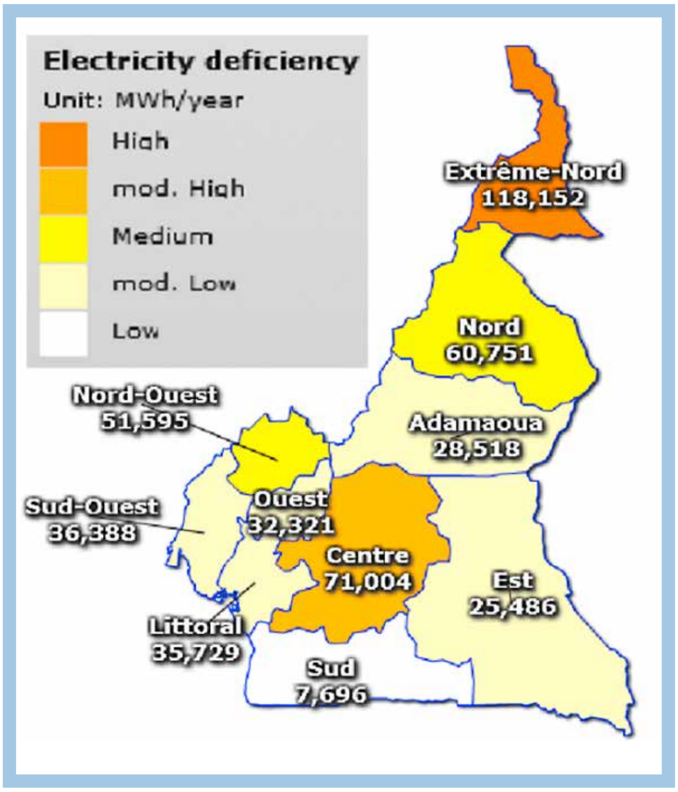
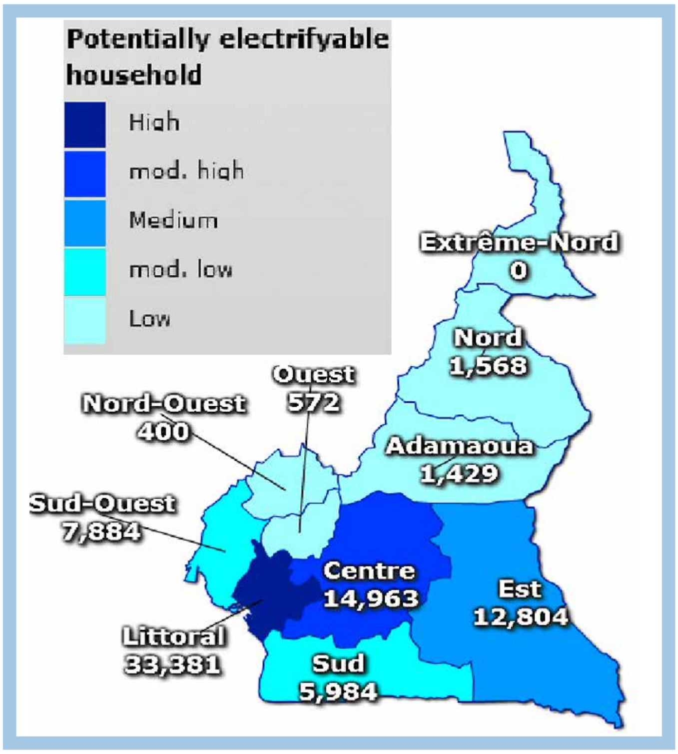


Figure 63. Number of potentially electrifiable households, Cameroon



SUSTAINABILITY ASSESSMENT TOOL ON BIOENERGY TECHNOLOGY (SATBT)

(Good practice example 3.3.2)

Organisations	PRIMAFF, JIRCAS/IRENA, University of Nigeria
Type of organisation	Research institutes
Persons in charge	Takashi Hayashi, Yasuko Inoue and James Ogbonna
Target area	Ghana, Nigeria
Type of activity	Bioenergy sustainability assessment by stakeholders for decision making
URL	www.maff.go.jp/primaff/e/index.html, www.jircas.go.jp/en
Financial support	MAFF-Japan

Summary

A tool to assess stakeholders' views on the Stakeholder Sustainability Assessment Tool on Bioenergy Technology (SATBT) has been developed to identify more sustainable options. SATBT is based on the GBEP's sustainability indicators for bioenergy (GSIs) from the perspectives of stakeholders on various combinations of technologies in given areas.

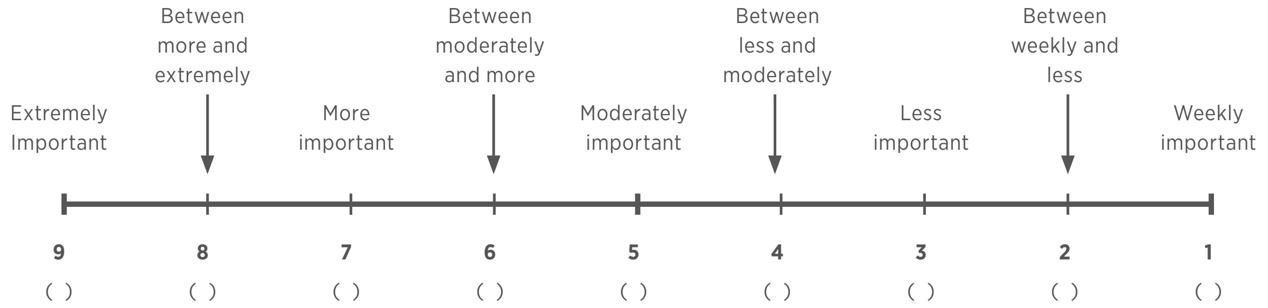
SATBT aims to comprehend, by conducting a questionnaire survey, which technology option is viewed as more sustainable by which stakeholder groups and from which indicators (including social, economic and environmental sustainability).

This tool provides background information for the introduction of new bioenergy development policy measures (Figure 64). The tool works in conjunction with the IRENA Project Navigator to provide guidance on developing bankable and sustainable bioenergy projects.

Figure 64. Examples from GBEP Sustainability Indicator questionnaire, parts 1 and 2

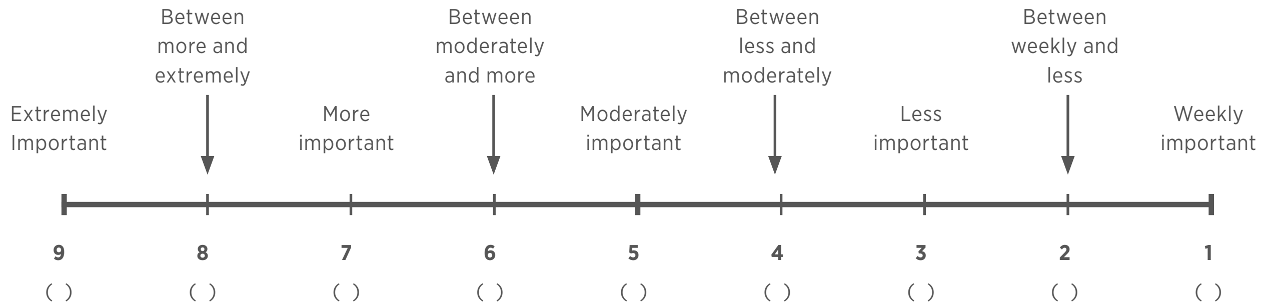
Part 1

Job oppurtinity



Part 2

5-1 From your point of **view, how significantly will Bioethanol** contribute to **water use efficiency** of the bioenergy sustaiability indicator?



Method

The first step is to identify the most important indicators from GSI, considering the features of the target locations. GSI has eight indicators in each of the three pillars: environment, social and economic (Table 14). A balanced number of indicators should be selected from each of the three pillars; for example, two indicators from each (six indicators altogether).

The second step is to select bioenergy conversion technology options relevant to the target area in consideration of the feedstock availability in a sustainable way. In this consideration, the opinion of local experts who are knowledgeable about central government policy, agricultural development and technology availability in the country – especially about the target areas – should be taken into consideration. Three to four technology options should be selected as having higher potentials.

Table 14. Three pillars of GBEB Sustainability Indicators: Environmental, social and economic

	INDICATORS	
ENVIRONMENTAL	**SOCIAL**	**ECONOMIC**
1. Lifecycle GHG emissions	9. Allocation and tenure of land for new bioenergy production	17. Productivity
2. Soil quality	10. Price and supply of a national food basket	18. Net energy balance
3. Harvest levels of wood resources	11. Change income	19. Gross value added
4. Emissions of non-GHG air polutants, including air toxics	12. Jobs in the bioenergy sector	20. Change in consumption of fossil fuels and traditional use of biomass
5. Water use and efficiency	13. Change in unpaid time spent by women and children collecting biomass	21. Training and requalification of the workforce
6. Water quality	14. Bioenergy used to expand access to modern energy services	22. Energy diversity
7. Biological diversity in the landscape	15. Change in mortality and burden of disease attributed to indoor smoke	23. Infrastructure and logistics for distribution of bioenergy
8. Land use and land-use change related to bioenergy feedstock production	16. Incidence of occupational injury, illness and fatalties	24. Capacity and flexibility of use of bioenergy

Source: FAO-GBEP (2014)

The third step is to conduct a questionnaire survey by conducting face-to-face interviews. The questionnaire consists of two parts: the level of importance of selected GSI indicators and the extent to which the technology option will contribute to each of the selected GSIs.

Target stakeholders for the questionnaire might include researchers/experts (energy, agriculture, forestry, etc.), national policy makers, local policy makers, plant owners/managers, investors/bankers, feedstock distributers/retailers, civil society organisations, feedstock suppliers (e.g., enterprises such as cassava starch factories) and farmers as feedstock suppliers.

Ensuring gender balance is important, as well as ensuring stakeholder involvement. For statistical efficiency, sufficient numbers of questionnaires should be conducted. Interview surveys may be conducted as group interviews.

In that case, different target groups should be interviewed separately; for example, female groups should be interviewed separately from male groups in rural communities, because in many cases women are not able to express their opinions in front of men, or vice-versa, depending on the cultures in the region. Likewise, the standard socio-economic study sampling method needs to be followed. To avoid biased results, selecting interviewees from a random sampling is also recommended (Bernard, 2000).

The fourth step is to calculate the comprehensive score of each bioenergy conversion technology from the answers to the questionnaire. By multiplying the extent of contribution to each indicator by the level of importance of a selected GSI, comprehensive scores that reflect both the contribution of each bioenergy technology and the importance of the indicators can be obtained (Figure 65).

Figure 65. Matrix multiplication

	Contribution to indicators					
	Ind. 1	Ind. 2	Ind. 3	Ind. 4	Ind. 5	Ind. 6
Tech. A	A_1	A_2	A_3	A_4	A_5	A_6
Tech. B	B_1	B_2	B_3	B_4	B_5	B_6
Tech. C	C_1	C_2	C_3	C_4	C_5	C_6
Tech. D	D_1	D_2	D_3	D_4	D_5	D_6

Questionnaire 1

×

Importance	
Ind. 1	M_1
Ind. 2	M_2
Ind. 3	M_3
Ind. 4	M_4
Ind. 5	M_5
Ind. 6	M_6

Questionnaire 2

=

Comp. Scores	
Tech. A	S_1
Tech. B	S_2
Tech. C	S_3
Tech. D	S_4

Multiplication result

Analysis

This tool was tested in Nigeria from October to December 2017. It examined cassava production areas by interviews with 244 stakeholders. Of the four bioenergy conversion technologies, the bioethanol option received the highest scores. The stakeholders, including both genders, viewed bioethanol as the technology that would contribute most to sustainability, according to the matrix multiplication analysis.

Ensuring gender balance helps to gain a full picture

Table 15. Final results of Questionnaire 2 (Nigeria)

	Water	Land use	Food supply and price	Job opportunities	Productivity	Infrastructure and logistics
Bioethanol	0.272	0.271	0.267	0.264	0.262	0.255
Biogas	0.258	0.257	0.262	0.258	0.256	0.258
Improved cookstove	0.228	0.235	0.233	0.239	0.237	0.242
CHP	0.242	0.236	0.238	0.239	0.245	0.245

Male	Water	Land use	Food supply and price	Job opportunities	Productivity	Infrastructure and logistics
Bioethanol	0.273	0.273	0.269	0.266	0.263	0.256
Biogas	0.258	0.257	0.262	0.256	0.257	0.255
Improved cookstove	0.228	0.237	0.233	0.240	0.235	0.242
CHP	0.241	0.232	0.236	0.239	0.245	0.247

Female	Water	Land use	Food supply and price	Job opportunities	Productivity	Infrastructure and logistics
Bioethanol	0.269	0.268	0.265	0.261	0.258	0.253
Biogas	0.258	0.257	0.260	0.262	0.256	0.262
Improved cookstove	0.228	0.230	0.235	0.236	0.239	0.243
CHP	0.244	0.245	0.241	0.241	0.247	0.242

Note: CHP = Combined heat and power

Conclusion

The tool allows stakeholders' views on the sustainability of bioenergy technology options to be reflected in a clear and quantitative manner. This requires not only looking at the total results of the questionnaire, but also using the tool to uncover and analyse the differences in opinions and priorities of each stakeholder group. This can be achieved by taking into consideration stakeholders' job categories as well as stakeholders' attributes, such as gender or rural-urban. Special attention has to be devoted to less privileged people when considering different bioenergy development options in the region.

Scaling up

When selecting the GSI and bioenergy conversion technologies and conducting the questionnaire survey, local co-operators need to be familiar with local bioenergy conditions and have a human network to communicate with relevant stakeholders.

Presentation and summary provided by: Hayashi and Inoue (2018)

The questionnaire targets researchers, experts and practitioners in energy, agriculture and forestry

Interview with female farmers
Photograph: Ogbonna

3.4. REDD+ AS A MOTIVATOR TO PROMOTE SUSTAINABLE RURAL ENERGY SOLUTIONS

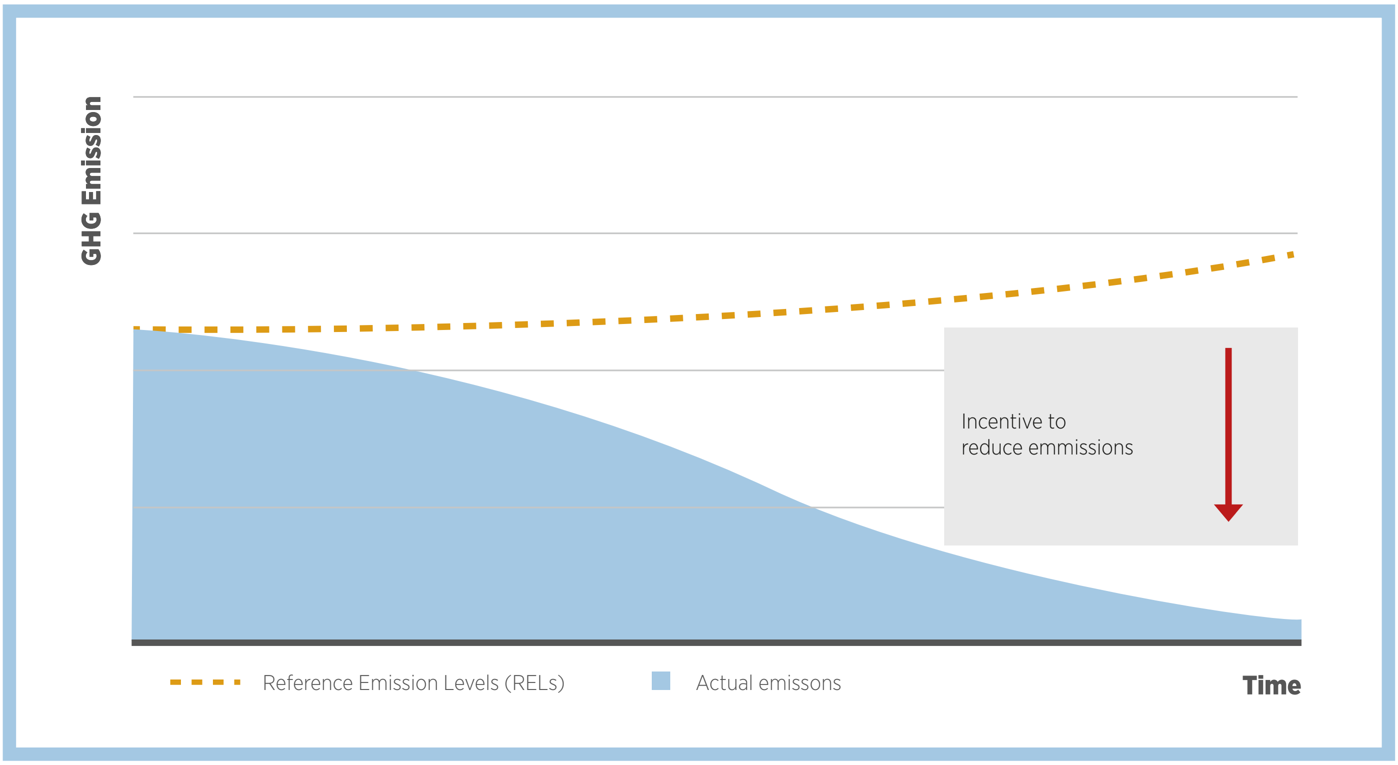
This section explores the possibility that sustainable bioenergy could be a solution for REDD+ (abbreviation for reducing emissions from deforestation and forest degradation, along with enhancing forest carbon stock in developing countries). The case study examines an agroforestry approach that can help to introduce sustainable energy and potentially reduce Mozambique's greenhouse-gas emissions.

Concept

Article 5 of the Paris Agreement states that each party should "take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases" and "implement and support … the existing framework" for "policy approaches and positive incentives for activities relating to reducing emissions from deforestation and forest degradation". Parties should also support "the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries" as well as alternative policy approaches. The shorthand for this undertaking has been assigned the acronym REDD+ (United Nations Framework Convention on Climate Change [UNFCCC], 2015).

Every country in sub-Saharan Africa that intends to incorporate REDD+ into its climate-change mitigation policies has to identify the drivers of deforestation and indicate these in its national action plan or strategy (UNFCCC, 2010). For the majority of sub-Saharan Africa's population, wood is a main source of energy: its use accounts for 92 % of total wood consumption in Africa. Wood as a source of energy contributes to GHG emissions, and it is a major cause of land use change (FAO, n. d.2); its use also drives deforestation and forest degradation.

Figure 66. FRELs for REDD+

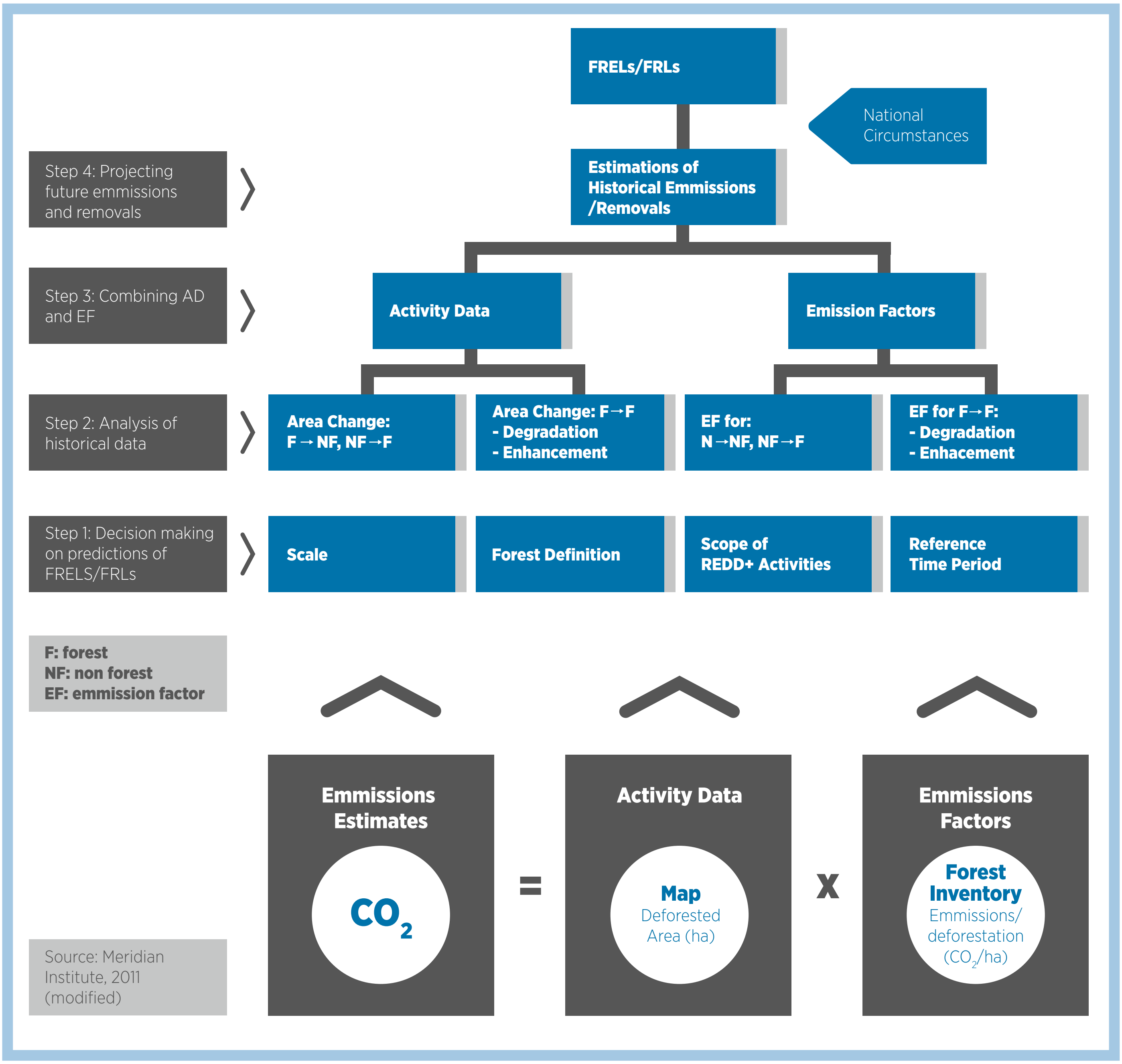


Source: UNFCCC 1/CP.16

Various policy initiatives are assigned for countries to take in preparation for REDD+. These include the establishment of national forest monitoring systems, the development of forest reference levels (FRLs) or forest reference emission levels (FRELs), and the formation of a system of information about safeguards. The Cancun Agreement spells out five REDD+ activities (UNFCCC, 2010). These are 1) reducing deforestation emissions; 2) reducing forest degradation emissions; 3) conserving forest carbon stocks; 4) managing forests sustainably; and 5) enhancing forest carbon stocks. Countries are encouraged to pursue these activities to ensure the receipt of adequate and predictable funding supports for result-based payment opportunities.

To find out how much emission reduction from REDD+ is achieved as a result of the REDD+ activities, FRLs/FRELs are produced as a baseline of the current emission status (Figure 67). The figure below shows the steps necessary to calculate FRLs/FRELs (Meridian Institute, 2011). Activity data are expressed in hectares per year for each

Figure 67. REDD+ emission calculation method

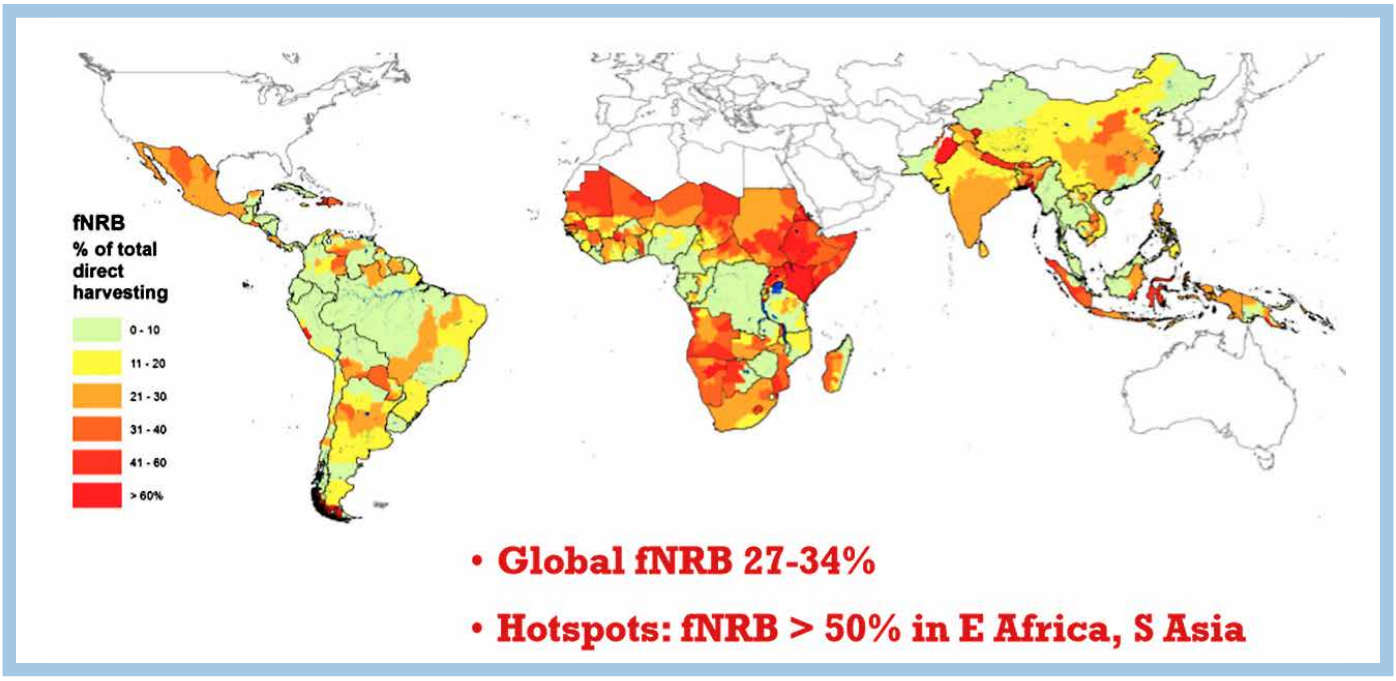


Source: DINAF-JICA (2018), based on Meridian Institute (2011) emission/removal category such as deforestation, forest degradation, afforestation/reforestation and forest carbon stock enhancement. REDD+ effects are expressed in gross changes based on remote sensing interpretation. Emission factor is GHG emissions and/or removals per unit area (hectare) expressed in tonnes of carbon dioxide (CO_2) from either the difference in carbon stock of land use change, or the difference between the gain and loss of carbon; for example, loss from timber exploitation and gain from regrowth of pre- and post- conversion land category.

This section explores a case study from Mozambique.

Sustainable bioenergy can be introduced as REDD+ activities. Policy makers can promote climate-change mitigation policies and their contribution in land use sectors under Nationally Determined Contributions (NDCs) with concrete figures of CO_2 equivalent values, which can be reported as a part of global efforts under the Paris Agreement. With these impacts, reasonable financial support proposals can be drawn up.

Figure 68. Non-renewable biomass use globally



Source: DINAF-JICA (2018), based on Meridian Institute (2011)

Note: fNRB = Fraction of non-renewable biomass

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

POTENTIAL REDD+ BIOENERGY SOLUTIONS IN MOZAMBIQUE

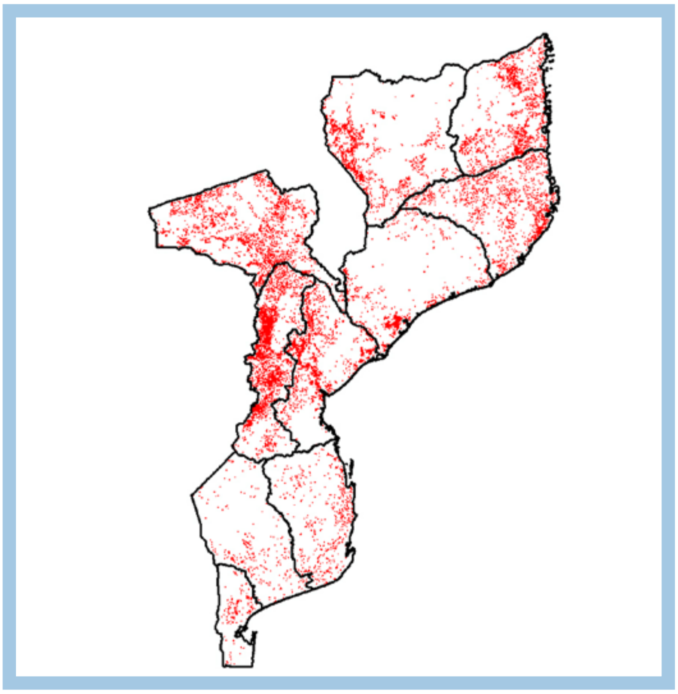
(Good practice example 3.4.1)

Organisations	National Directorate of Forestry, Ministry of Land, Environment and Rural Development, Mozambique (DINAF); University of Amsterdam; IRENA
Types of organisation	Research institute, national organisation, international organisation
Persons in charge	Joaquim Armando Macuacua and Yasuko Inoue
Target area	Mozambique
Type of activity	GIS analysis of renewable energy potential as REDD+ activities
URL	www.dinaf.gov.mz/pirf_mreddplus/index.php/en/
Co-operating organisations	Japan International Co-operation Agency (JICA), Japan Overseas Forestry Consultants Association (JOFCA), Kokusai Kogyo Ltd.

Summary

Currently in Mozambique, one of the major drivers of deforestation and forest degradation is wood used for energy. Environmental deterioration caused by deforestation is increasingly resulting in life-threatening damage to local communities, and this has been exacerbated by more frequent and less-predictable natural disasters such as floods and droughts brought on by climate change. To protect forest and land is to protect the lives of the people who are living on them. Transitional and renewable energy use must therefore be promoted at scale. To contribute to Article 5 of the Paris Agreement, many countries are now considering the adoption of alternative or renewable energy policy approaches as a REDD+ activity, incorporating these approaches into their NDCs as their mitigation as well as adaptation strategies.

Figure 69. Deforestation across Mozambique, 2008–2010



Source: DINAF-JICA (2018)

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

Charcoal production site in Zambezia Province in 2010
Photograph: Inoue

Demand analysis

Falcão (2013) estimated the average annual per capita consumption of firewood and charcoal in urban areas and rural areas, respectively. In urban areas, the annual per capita consumption of wood for energy was 263 kg of firewood and 179 kg of charcoal, while that in rural areas was 670 kg of firewood (Table 16).

A REDD+ option to introduce agroforestry: Farm fence tree planting and fuel-efficient stove use

Various alternative and sustainable bioenergy solutions are available to reduce deforestation and forest degradation due to fuelwood use. One option is the planting of trees that have strong regeneration capacity such as Moringa oleifera. Moringa trees can be planted and grown around family farms in rural areas without disturbing the growth of other crops.

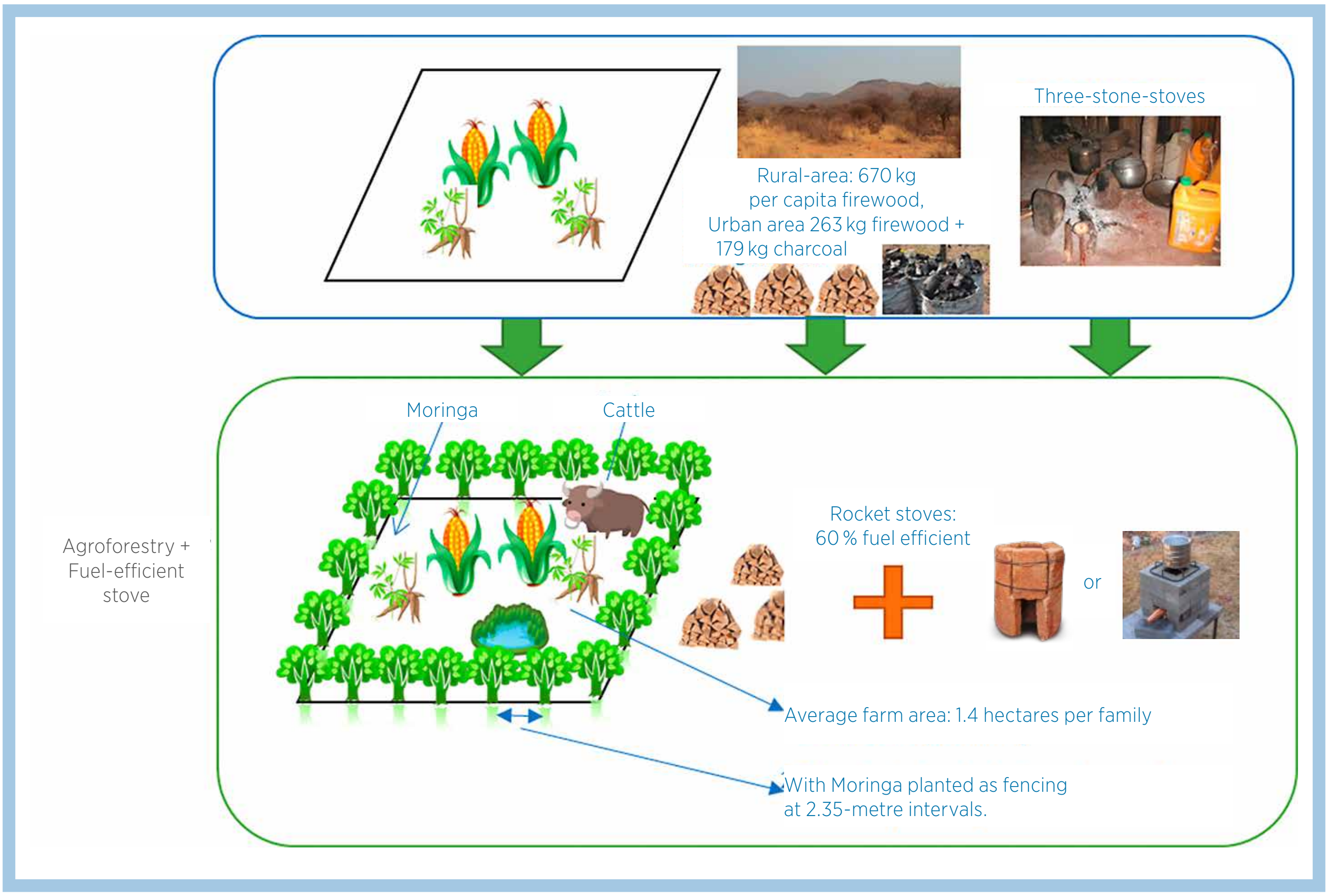
Moringa branches can be used to fulfil the energy needs of both rural and urban areas with the distribution of fuel-efficient stoves. Moringa trees have a high tolerance for dry areas, and their nutritious leaves are favourable for both human and domestic animals (see good practice example 1.2.3).

Table 16. Per capita consumption of fuelwood and charcoal in urban and rural areas of Mozambique

	Fire wood	Charcoal
Urban area	0.263	0.179
Rural area	0.670	--

Source: Falcão (2013)

Figure 70. Potential impact of introducing agroforestry and fuel-efficient stoves



The average farm area in Mozambique is 1.4 ha per family (FAO, 2007). If Moringa trees were planted at 2.35 m intervals as fencing, 200 trees per family farm would be planted. According to Yambe (2018), 12.76 kg of branch pruning per tree is harvested annually in Nampula Province, northern Mozambique. (This figure may vary by area depending on soil fertility.) Taking Yambe's case as a model, the 200-tree fence planting would create 2 552 kg of branch waste annually from pruning.

Total wood biomass demand is estimated by calculating per capita consumption of fuelwood in rural areas and fuelwood and charcoal in urban areas (Table 17). Per capita fuelwood and charcoal use is based on the figure in Table 16 (Falcão, 2013). Wood consumption for charcoal has been estimated at 19.5 % is based on assumptions cited in a Falcão study (Falcão, n. d.). Total wood consumption for energy has been calculated at about 20 million tonnes.

Table 17. Total wood energy biomass feedstock demand, Mozambique

Year 2013	Mozambique Population	Fuel wood Consumption (ton)	Charcoal Consumption (ton)	Wood consumption from charcoal (ton)	Total Wood Biomass Demand (ton)
Urban	7 749 628	2 038 152	1 387 183	7 113 761	9 151 913
Rural	15 588 634	10 444 385	--	--	10 444 385
Total	23 338 262	12 482 573	1 387 183	7 113 761	19 596 298

Table 18. Potential reduction of wood volume using rocket stoves, Mozambique

Total Wood Biomass Demand (Table 2.)	Total energy wood demand if using rocket stove (60 % efficient, ton)
19 596 298	7 838 519

Table 19. Estimation of energy supply potential from Moringa agroforestry

Number of rural households (five/ family)	Area of farm (1.4ha/family farm)	Number of Moringa trees to plant as fencing (200 trees/farm)	Supply potential volume of annual fuelwood from moringa (ton) 12.76 kg/tree (Conversion to PJ is by multiplication)
3 117 727	4 364 818	592 368 092	7 956 439 [149.9 PJ]

Rocket stoves save wood feedstock use by 54–66 %; for example, the rocket stoves promoted by Aid Africa can reduce fuelwood use to almost a third (Aid Africa, 2018b) (see good practice example 2.2.3). If every household could reduce wood feedstock use by 60 %, then total consumption (currently about 20 million tonnes) could be cut to less than 8 million tonnes using rocket stoves (Table 18).

If enough trees are planted to meet wood energy demand sustainably, both the depletion of forest resources and the workload of collecting fuelwood or making charcoal will be diminished. According to the FAO, the average farm area of a family farming in Mozambique is 1.4 ha (FAO, 2007).

The length of a 1.4 ha farm fence is 473.2 m, and the number of Moringa trees to be planted on the fence in 2.35 m intervals is approximately 200. The average number of people in a family is five, and the number of families in rural areas is calculated at 3 117 727. Assuming that Moringa trees were to be planted as fencing for the all the family farms in rural areas of Mozambique, the number of Moringa trees to be planted would be 592 368 092. The volume that could be harvested annually from the total number of Moringa trees is nearly 8 million tonnes, roughly equivalent to the estimated wood energy demand given the widespread use of rocket stoves (Table 18).

Case study in Cabo Delgado Province and Gaza Province

Table 20. Population of Cabo Delgado and Gaza provinces

Province	Population (projected*)	Pop. urban 2013	Pop. rural 2013	Urban %	Rural %
C. Delgado	1 758 313	433 487	1 324 826	24.70 %	75.30 %
Gaza	1 299 651	358 750	940 901	27.60 %	72.40 %

*Falcão (2013)

Note: Convert the consumption value in tonnes and PJ; the conversion rate of fuelwood is 13.8 MJ/tonne and charcoal is 30.8 MJ/tonnes (FAO, n. d.)

Table 21. Annual total bioenergy consumption in Cabo Delgado and Gaza provinces

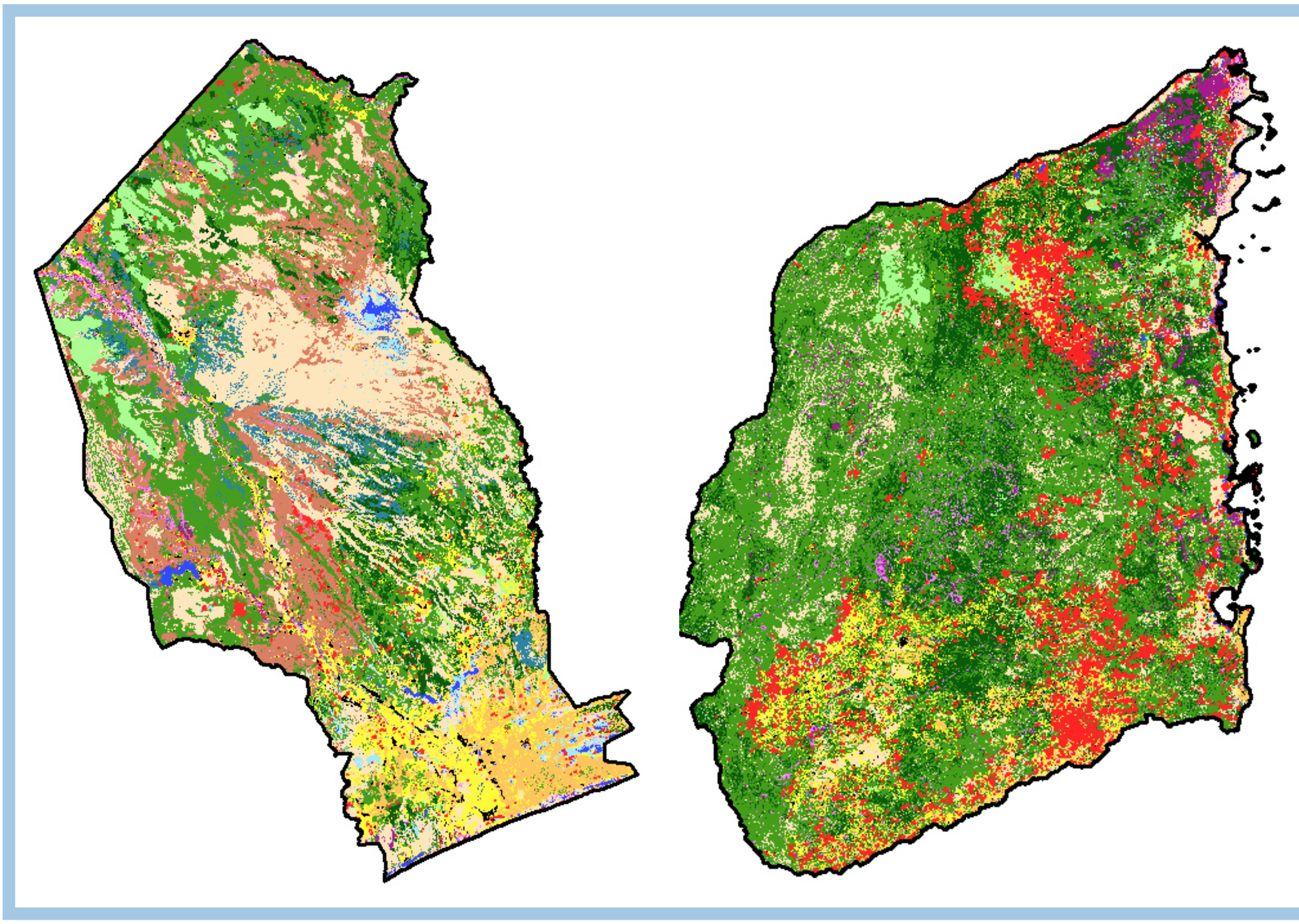
Province	Urban fuelwood (tonnes)	Urban charcoal (tonnes)	Fuelwood (PJ)	Charcoal (PJ)	Total urban (PJ)	Rural fuelwood	Fuelwood (PJ)	Total (PJ)
			0.0000138	0.0000308			0.0000138	
C. Delgado	114 007	314 738	1.6	3.5	5.1	887 633	12.2	17.3
Gaza	94 351	232 638	1.3	2.9	4.2	630 404	8.7	12.9

A tonne of carbon is approximately equivalent to a half tonne of wood. The CO_2 tonne (B) is calculated from wood carbon (A) by the equation: (A) tonne-C × 0.5 × (44/12) = (B) tonne-CO_2. Charcoal production efficiency varies depending on the type of charcoal, method of making charcoal and species of wood. Using the above equation, CO_2 emissions from charcoal and fuel consumption in Cabo Delgado and Gaza provinces are as shown in Table 22.

Table 22. Annual carbon dioxide emissions in Cabo Delgado and Gaza provinces based on wood use

Province	(a) Urban fuelwood (tonnes)	Wood use for urban charcoal		(c) Rural fuelwood (tonnes)	Wood use	Estimated annual emissions
		Urban charcoal use (tonnes)	(b) Wood equivalent (tonnes) based on 19.5 % yield		(a) + (b) + (c) = Total	
C. Delgado	114 007	77 594	397 919	887 633	1 399 599	2 565 859
Gaza	94 351	64 261	329 314	630 404	1 054 069	1 932 460

Figure 71. Deforested areas in Gaza Province (left) and Cabo Delgado Province (right) (2008–2010)



Source: DINAF-JICA (2018)

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

Table 23. Fuelwood volume from Moringa compared to demand with fuel-efficient stoves

Province	Total energy wood demand if using rocket stove (60 % efficient, tonne)	Number of rural households (five/family)	Area of farm	Number of moringa trees (200 trees/farm)	Supply potential volume of annual fuelwood from moringa (ton) 12.76 kg/tree [PJ]
C. Delgado	559 824	351 663	492 328	70 332 520	897 443 (12.38 PJ)
Gaza	421 628	259 930	363 902	51 986 040	663 342 (9.15 PJ)

Table 24. Enhancement of forest carbon stocks (removals) in Cabo Delgado and Gaza provinces

Province	Number of Moringa trees	Area of forest increase (m_2)	In ha	Above-ground biomass (3.96 tonnes CO_2/ha)	Below-ground biomass (11.03 tonnes CO_2/ha)	Total carbon stock increase (CO_2 tonnes)
C. Delgado	70 332 520	304 902 903	30 490	120 742	336 308	457 049
Gaza	51 986 040	225 367 931	22 537	89 246	248 581	337 827

Regarding the REDD+ effects, the increase of wood carbon stock by Moringa tree planting when the planted trees are matured can be estimated as follows. It may be assumed that each tree will be grown to a circle-shaped crown cover whose diameter is 2.35 m. Above-ground biomass and below-ground biomass are derived from wall-to-wall inventory from 2013–18 (DINAF-JICA, 2018). Carbon stock increase (removal) in each province by increased biomass stock by Moringa tree planting is estimated as 475 049 CO_2 tonnes and 337 827 CO_2 tonnes, respectively.

Conclusion

The analysis indicates it may be possible to fulfil the demand for fuelwood consumption by introducing fence planting on family farms as well as using fuel-efficient stoves. This can be achieved by using the pruned wood from fence plantings along with the introduction and adoption of rocket stoves nationwide. Furthermore, these practices have the potential to enhance forest carbon stocks, because significant removal volumes can be counted as carbon stock increases. This counts as a potential REDD+ activity.

Scaling up

Moringa trees were used in this analysis. Although Moringa trees are relatively strong in arid environments, the seedlings' overall survival rate may be as low as 40–50 %. Supplementary planting should therefore be planned when agroforestry projects are begun because of more frequent droughts and floods in sub-Saharan Africa (Inoue and Macuacua, 2014; Inoue and Nakanishi, 2015).

In addition to Moringa trees, legume species such as Faidherbia albida can also be considered for these uses. These species fertilise soil and can be used as firewood and to feed animals, especially in the dry season. Planting a variety of tree species is recommended to build up resilience against changing weather and diseases. Biogas is another energy option, but water availability must be considered in this instance (see Chapter 2, Section 4).

Presentation and summary provided by: Macuacua (2018) and Inoue and Macuacua (2014)

Overall findings

In this collection, good practice solutions to deploy bioenergy sustainably across sub-Saharan Africa, as well as solutions from other regions that are applicable in sub-Saharan Africa, are grouped according to three main themes: sustainable rural biomass supply; biomass-to-energy innovations; and tools for enhanced bioenergy sustainability.

These summaries, based experiences gained in projects around the diverse region, are intended to provide insights and guidance for policy makers, field practitioners, investors and researchers aiming to scale up sustainable bioenergy. While the focus here has been on sub-Saharan Africa, the good practices highlighted could be adopted, or adapted, wherever they are found to be applicable.

1. Sustainable rural biomass supply

Sustainable bioenergy feedstock supply examples include those with a focus on gender, agro-ecology, soil- and water-resource awareness, varietal improvement, community and participation, and humanitarian supportive practices. A special focus is the strengthening of ownership of the most vulnerable segment of rural societies, including different genders.

2. Biomass-to-energy innovations

Innovative bioenergy production technologies and systems such as briquettes, innovative cookstoves, bioethanol, biogas and small-scale power generation are introduced. Using these, fuelwood usage can be reduced and the heavy workload of collecting firewood is also decreased. GHG emissions can also be cut, thereby reducing respiratory diseases. The necessary technologies are less costly, available locally and easy to maintain.

3. Tools for enhanced bioenergy sustainability

New tools that help to enhance sustainable deployment of bioenergy are introduced. These include a tool that uses GIS analysis to comprehend supply and demand potential based on local biomass availability, a tool to enhance financial sustainability and inclusive participation, digital financing systems, and entrepreneurship supports that are viable in rural areas.

This collection should be seen as a first attempt to compile local knowledge and resources about sustainable bioenergy practices in sub-Saharan Africa. Further collection and exchange of good practices should be continued, in order to resolve energy issues for people in need.

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