GLOBAL BIOENERGY PARTNERSHIP
WORKING TOGETHER FOR SUSTAINABLE DEVELOPMENT

Working Group on Capacity Building

Activity Group 4 - Towards Sustainable Modern Wood Energy Development

Collection of examples:

Positive Relationships between Sustainable Wood Energy and Forest Landscape Restoration

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Images on cover page: Lourdes Gonzales Soria, UNA, 2018; Tiziana Pirelli, 2015; James Gitau, ICRAF; UNIUD, 2012; Kevin Standlee, 2019.

Contents

Introduction

The wood energy sector

In 2017, biomass accounted for 55.6 percent of the Total Primary Energy Supply (TPES) of renewables (IEA, 2019), of which the forestry sector is the largest contributor with 85 percent of all biomass for energy purposes coming from forestry products, such as charcoal, fuelwood, pellets and wood chips (WBA, 2019). The use of traditional woodfuel – i.e. the inefficient use of fuelwood and charcoal for cooking and heating – is a large contributor to the consumption of forest biomass. Indeed, traditional wood energy is still the primary source of energy for many households in some parts of the world, most notably in Africa and Asia. The situation is particularly prominent in Sub-Saharan Africa (SSA), where households primarily rely on traditional biomass to fulfil their energy needs. As well as the many other economic, social and environmental problems attributable to the unsustainable wood energy value chain for traditional wood energy production and use, deforestation and landscape degradation can occur as demand increases and the sustainable supply of fuelwood cannot keep up. This can have further consequences for biodiversity and soil health.

Forest landscape restoration

Forest landscape restoration (FLR) is the recovery of forest landscapes through the restoration of ecological functionality. As its name suggests, its focus is at the landscape level, taking into consideration the multiple ecological, social and economic functions of landscapes and the associated ecosystem goods and services. The concepts of FLR are applied all over the world and approaches are tailored to the local contexts.

SSA is a region of intense focus for FLR, due to the threat of desertification and the negative impacts on livelihoods brought about by degraded ecosystems and soils. Each year, around 6 MHa of productive land are lost to degradation. In this context, AFR100 is a pan-African, country-led initiative that seeks to address this by bringing 100 million hectares of degraded lands into restoration by 2030.

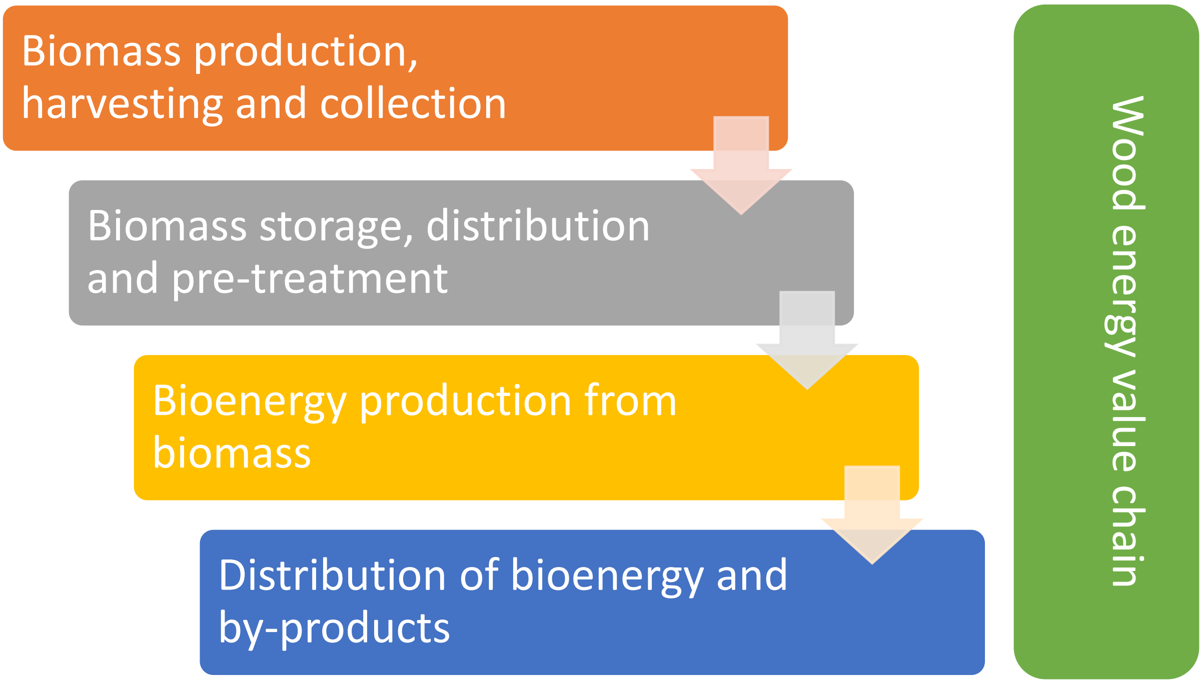
Improving the sustainability of wood energy value chains for FLR

The wood energy sector and FLR are inherently interlinked. Unregulated demand and markets for wood energy resulting in unsustainable wood use is one of the main drivers of degradation of forests and forested landscapes. Sustainability is therefore the major concern, and understanding the opportunities for sustainable wood energy production and use to contribute positively to FLR is key.

Indeed, there are many ways to improve the sustainability of the wood energy sector to ensure that it positively contributes to FLR, as well as other environmental, social and economic objectives.

Improving the sustainability of wood energy value chains can reduce pressures on natural forests through better management practices and improved technologies. Indeed, the sustainability of the wood energy can be improved across the value chain, from biomass production and transformation to the production and use of bioenergy and its by-products. Figure 1 shows the steps in a typical wood energy value chain.

Figure 1 Overview of the steps in a wood energy value chain



It is important to highlight that, as well as options to improve the sustainability of the wood energy value chain itself, there are also other options for bioenergy production from other sources that reduce the pressures on forest resources. These include: the use of other biomass sources such as waste and residues from agriculture, agro-industry or urban activities; and the use of other bioenergy production technologies such as anaerobic digestion. Although these approaches are extremely relevant, they are beyond the scope of this paper.

Across wood energy value chains, there are a multitude of opportunities:

Biomass production, harvesting and collection

For biomass production, sustainable forest management is an important first step, including the establishment of community forests, as well as the conservation of protected areas. Plantations are an opportunity to remove the pressures on natural forests whilst maintaining biomass supply. There is also the opportunity to produce biomass on currently degraded lands; these plantations could restore lands, provide employment, ecosystem services and carbon storage while also supplying modern bioenergy services (IRENA, 2017). Agroforestry is also an attractive option.

Biomass storage, distribution and pre-treatment

At the biomass transformation stage, improved feedstocks (such as wood pellets, chips or briquettes) could increase the efficiency of the value chain, thus reducing pressures on forests. These feedstocks could also be produced from wood 'wastes' such as those produced from the timber sawing industry, thus further improving the sustainability of the system.

Bioenergy production from biomass

The sustainability of the wood energy value chain can also be enhanced through the use of improved bioenergy technologies. For traditional bioenergy, this includes both the methods of charcoal production and the use of fuelwood in homes with improved cookstoves. However, woody biomass can also be used to provide modern energy services through e.g. the production of electricity in co-generation plants or the production of syngas through gasification technologies.

Distribution of bioenergy and by-products

Finally, the use of by-products can also enhance the sustainability of the system. For example, the biochar produced as a by-product of the gasification process can be used as a soil amendment to boost soil fertility, increase agricultural yields and therefore improve livelihoods.

Document structure

As a first step to highlight the important linkages between wood energy and FLR, this collection presents examples from around of the world of projects, policies and approaches that aim to improve the sustainability of wood energy for a positive contribution to FLR.

The collection includes country examples from Australia, Canada, Ghana, Lebanon, Kenya, Niger, Sri Lanka, Togo, USA and Zambia, as well as a regional example from SSA. These have been organised to follow the steps of the wood energy value chain outlined in Figure 1; examples that cover the entire value chain are presented first. A final concluding section draws together common lessons learned from these examples.

Wood energy value chains

The EverGreen Bioenergy Carbon Capture, Utilization and Storage (EBECCUS) approach – Shrub-based food-energy systems

Dennis Garrity, The Global EverGreening Alliance

Headline

The practice of integrated shrub-based food-energy systems using *Gliricidia sepium* shrubs by smallholder farmers in Sri Lanka has shown multiple benefits, including: enhancement of soil fertility and crop yields, production of biomass for energy, improvement in local livelihoods, enhancement of agrobiodiversity, carbon storage, and buffering the impacts of climate change, among others.

Overview

Geographic location:	**Type of example**:	**Status:**
Sri Lanka (various locations)	Practice	Ongoing since 1990s

Introduction

Shrub-based food-energy systems simultaneously provide electricity and bioenergy for power, while also providing bio-fertilizers for crop production and better-quality fodder for livestock production on the same land area. Such systems have the potential to transform livelihoods and food security, while enhancing economic development and conserving the environment in rural areas across the tropics.

These systems produce wood fuel from leguminous shrubs growing alongside the food crops in the same fields, and therefore no cropping area is sacrificed; rather, their presence enhances crop production. The regular coppicing of the shrubs (pruning to approximately 0.3 m height) allows optimal sunlight for the cereal crops, and it also provides the wood feedstock for power generation. The systems also: directly improve soil fertility and increase crop yields; provide enhanced high-quality livestock fodder; improve vegetative soil cover year-round; buffer crop production from drought and higher temperatures due to climate change; store more abundant carbon in the soil; and enhance agrobiodiversity. Such an integrated shrub-based food-energy system for rural electrification has already been commercially developed in Sri Lanka and it has been operating for many years. The system is based on the cultivation of nitrogen-fixing *Gliricidia sepium* shrubs by smallholder farmers. The trees are coppiced every 8 months, and the wood is used as feedstock for power generation by either steam turbine power plants or by gasification units (pyrolysis process). Farmers sell the wood to the power plant while retaining the leafy foliage for livestock feed and fertilizing their crops. These systems generate substantial rural employment while also regenerating the land.

Millions of farmers are establishing leguminous shrubs and trees in their crop fields in many countries throughout the tropics. Farmers can establish leguminous shrubs at densities of 1000 to 5000 plants per hectare throughout their crop fields and grazing lands (Garrity *et al*., 2010). The N-rich foliage dramatically increases crop yields and livestock production (Sileshi *et al*., 2008; Akinnifesi *et al*., 2010). These systems accumulate carbon above and below-ground in the range of 2-4 tC/ha/yr (Makumba *et al*., 2007; Kaonga and Bayliss-Smith, 2008). The shrub wood can be harvested at the end of the dry season for sale to local producers of electrical power, thus providing low-carbon energy with major co-benefits for poor rural populations of increased incomes and job creation. The potential for selling the surplus wood to local producers of electrical power provides an incentive to expand the cultivation of these valued agroforestry systems.

In 2009, Tokyo Power constructed and commissioned a 10 MW *Gliricidia sepium*-fueled plant in Trincomalee, Sri Lanka. Following its success, they commissioned a second plant of 5 MW capacity in Mahiyanganaya, Sri Lanka. There are now eight *Gliricidia*-based power plants built and operated by private sector companies in Sri Lanka, and it is reported that 10 or more plants are under construction or in the feasibility stage. Businesses have also been developing around the promotion of *Gliricidia* poduction among smallholder farmers, such as The Biomass Group. They purchase, aggregate, process and market the wood chips for use by energy companies and other industries.

This effort is strongly based on the merits of South–South cooperation and learning, to generate viable and successful development initiatives. It aims to facilitate the sharing of knowledge and experiences from Sri Lanka with interested parties across Eastern and Southern Africa, and to adapt the Sri Lankan experience to the African context.

The deployment of the EverGreen Bioenergy Carbon Capture, Utilization and Storage (BECCUS) solution can be done in phases:

- **1st phase: scaling-up of fertilizer shrub systems in croplands** across many countries in the tropics, and using the N-rich foliage for crop and livestock production, while using the wood for household fuelwood, local sale, charcoal-making, and briquette-making. The evergreen agriculture carbon capture benefits here are manifested in the build-up of soil organic carbon stocks, and the deflection of local deforestation, because wood fuel and timber needs are generated on the farm.
- **2nd phase: development of electrical power generation with rural power stations** to electrify rural communities. This will induce the expansion of shrub cultivation for wood fuel at a bigger scale, which is the phase in which Sri Lanka is now.
- **3rd phase: full evergreen (EBECCUS) with flue-driven CCUS.** Power stations capture the CO2 from the burning of the biomass. This is not fully practical yet, but the costs of deploying ambient air CO2 capture are declining rapidly (Keith *et al* 2018). The concentration of carbon dioxide in power station smokestacks is about 300 times greater than in the ambient air, making this form of carbon capture increasingly viable.

The full EBECCUS power plant solution is the ultimate state that is desired but the 'partial' EBECCUS solution of simply scaling-up evergreen agriculture systems is the practical first step toward building up the momentum. The 1st phase is applicable without the logistics and power plant investment challenges that occur in phase 2 and phase 3. Piloting power plants in many other countries besides Sri Lanka is the major next phase, to absorb the excess wood generated by the spread of these evergreen agriculture systems.

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

Gliricidia shrubs are the fourth most important tree crop in Sri Lanka. This source of bioenergy is already providing substantial electrical power generation in the country. There are now eight shrub-based power plants built and operated by private sector companies in the country, and 10 or more plants are under construction or in the feasibility stage. These electrical power generation systems are based on the cultivation of these nitrogen-fixing shrubs -- that capture atmospheric nitrogen for use as fertilizer by smallholder farmers in their crop fields. They also sell the wood that they have produced to the power plants for cash income. *Gliricidia* is an excellent fuelwood, producing 19.8 megajoules per kilogramme (MJ/kg), and it burns slowly with little smoke or sparks (IRENA 2017).

There are three project models of biomass energy generation and supply:

- **Local:** Small-scale 4kW and 9 kW gasifier systems operated by small holders and communities for their local power needs.
- **Industrial:** Medium-scale systems, such as the 1 MW plant in Walapane, Sri Lanka. Private sector investment would build and operate these plants to supply local communities and local industry.
- **National Grid:** Large-scale systems, such as the 5 or 10 MW Tokyo Power projects. Large-scale plants can be strategically placed to ensure feedstock and supply power to the national grid.

Positive impacts for forest landscape restoration:

Shrub-based food-energy systems accumulate carbon above and below-ground in the range of 2-4 tC/ha/yr. This rate of carbon capture in soils is extraordinary, and it has many positive effects on improving the quality of the land for crop or tree production. The shrubs improve vegetative soil cover year-round, and they increase soil moisture, soil fertility and crop yields. They also buffer crop production from the droughts and higher temperatures that are now occurring due to climate change, by providing a more favourable microclimate, improve soil erosion control, and by enhancing biodiversity.

Co-benefits:

<u>Climate change</u>

The EBECCUS approach has the opportunity to capture carbon not only from carbon sequestration in the soil (approximately 2-4 tonnes carbon/ha/y) but also from the capture of CO_2 in power plants.

<u>Benefits to Local Communities</u>

The EBECCUS approach has technical and social benefits compared to the conventional renewable energy sources now used, such as solar energy. It can ensure a continuous supply of power that can be increased or decreased when needed, avoiding involuntary power fluctuations. Beyond addressing the challenge of electrification for rural and remote cellular base stations, these systems also significantly contribute to local communities in ways that are not evident in other forms of renewable energy systems.

- **Social benefits** include: increased income and employment, empowerment of rural communities, better food and nutrition security, and increased participation in projects by women, the elderly and the disabled.
- **Economic benefits** include: improved agricultural productivity with greater food and livestock output, livelihood diversification for smallholder farmers, production of biofertiliser and biochar, increased rural business opportunities and job creation, foreign exchange savings from reduced use of fossil fuel, and development of rural infrastructure in off-grid and marginalised areas.
- **Environmental benefits** include: reduced GHG emissions with increased sequestration of atmospheric carbon, reduced land degradation with increased forest coverage, reduced soil erosion, enrichment of soil nutrients, and reduced use of chemical fertilisers (IRENA 2017).

Across Africa and the tropics, trees are already widely integrated into agricultural systems, and they are increasingly the basis for sustainably boosting maize production in countries like Malawi, Zambia and Kenya. In Eastern Zambia, for instance, through a major extension program implemented by the social enterprise COMACO, over 80 000 smallholder farm families have recently planted a total of 41 million *Gliricidia* shrubs, on over 27 000 hectares of land (IRENA 2017).

Prospects

Key enabling factors:

In Sri Lanka, government policy and facilitation strongly encouraged the development of *Gliricidia* biomass power solutions. The social and economic factors described above were instrumental in attracting the interest of hundreds of thousands of small-scale farmers in growing the shrubs for cash income and to benefit their agricultural production.

Main challenges encountered:

The major challenges to be overcome in the scaling-up of this integrated food-energy system are the need to attract more investment in power plant development, scaling-up agroforestry extension to large numbers of smallholder producers, and in synchronizing the increase in wood feedstock produced on farms with the supply demands of the power plants.

Potential for scaling-up and replicability:

The potential appears enormous for such systems to be implemented in Sub Saharan Africa. Valuable lessons and experience can be sourced from the proven models in Sri Lanka, for application in the countries of eastern and southern Africa.

Gliricidia is already widely distributed in farming systems throughout Africa, having been introduced four centuries ago from Central America. Research during the past three decades by the World

Agroforestry (ICRAF) and its partners has demonstrated its value as an extremely fast-growing nitrogen-fixing fertilizer shrub. In Malawi, *Gliricidia* is a major species underpinning the scaling-up of fertilizer trees for dramatically increasing crop yields in maize-based systems through the National Agroforestry Food Security Program. It is also being massively scaled-up in eastern Zambia, where 41 million trees were planted by smallholders during 2017-8 alone. A massive scaling-up program for the species is also underway in Kenya. Thus, the development of food-energy electrification projects would be a natural extension of the evergreen agriculture shrub and crop production systems in these countries. The species has also been widely tested and is well-adapted for such food-energy systems in Tanzania, Ethiopia, Ghana, Mali, and many other countries across the African continent, showing the potential for massive scaling-up (IRENA, 2017).

The mission now is to undertake a range of technical, socio-economic, market, biomass supply sustainability and feasibility analyses for both small-scale and large-scale *Gliricidia*-fueled power plants, and to secure investment and private sector participation in implementing integrated food-energy projects in Sub Saharan Africa. The initiative will create broad awareness of the potential for these systems to be implemented in the region through publications, briefs, a web site, and dialogs with government and the private sector. It will expose interested parties to the Sri Lankan experience for *Gliricidia* systems, and it will create a facility for bringing investors, commercial power plant developers, governments and NGOs/civil society together in realizing new projects based on these successful models.

Additional information

The Global Evergreening Alliance (the Alliance) is an international non-government organisation (iNGO) that was established by its 35 member organizations to facilitate a collaborate approach to addressing the global challenges of food insecurity, rural poverty, climate change and land degradation, and to develop and implement long-term solutions on a globally significant scale. Its core members include World Agroforestry (ICRAF), World Resources Institute (WRI), World Vision, CRS, Oxfam, CARE International, Concern Worldwide, Conservation International, The Nature Conservancy, and Global Good. The Alliance's primary focus is on sustainable agricultural intensification and the restoration of degraded farmland, rangelands and forest lands. It does this through grassroots approaches to integrating and, where appropriate, regenerating trees into smallholder farming systems, pastoral systems and the community-led management of degraded forests. The Alliance's core activities relate to the collaborative development and implementation of massive-scale land restoration programs that will enhance food security and sustainable biomass energy.

Link: www.evergreening.org

Briquette production within the adaptive Forest Landscape Restoration plan in the Shouf Biosphere Reserve, Lebanon

Pedro Regato (Senior Technical Advisor), Marco Pagliani (Senior Technical Advisor) and Nizar Hani (Manager), Shouf Biosphere Reserve

Headline

Setup of a briquette production plant for local communities using the biomass from coppice woodland thinning and pruning of olive and vine in the framework of the adaptive forest landscape management (FLR) plan in the Shouf Biosphere Reserve (SBR). The briquette plant is producing cheap and clean energy that is becoming an increasingly valued alternative to firewood and diesel, the main energy source in most households, and at the same time significantly abating the risk of fires.

Outline

Geographic location:	**Type of example**:	**Status:**
Shouf Biosphere Reserve (SBR), Lebanon	Specific project within a broader FLR program	Ongoing since 2012

Introduction

The FLR plan designed for the SBR includes the management of abandoned coppice woodlands (mainly evergreen and broadleaf oak) with the objective of turning them into old-growth stand thereby increasing their ecological value. This action resulted in the production of considerable amounts of biomass from thinning. The setup of a briquette plant in the village of Kfarfakoud allowed to “close the circle” and make use of the biomass.

The action started with a survey in November 2013 to evaluate the amount of wood that the mountain forests in the area around Kfarfakoud could supply to the new briquette plant. The survey focused on areas with less than 30 percent slope, while steeper wooded areas were discarded to avoid erosion problems. Studies were conducted on the forest species distribution, size, crown closure and exploitation strategy, as well as on the agriculture land. The forest biomass available with sustainable harvesting is around 1 000 tonnes/year, which represents the biomass needed to reach the maximum capacity of the factory in 2021, according to the business plan. The availability of olive pomace (olive pressing residue) that is produced every year in the area, as well as the available wood resulting from the fruit tree pruning, are not a limiting factor. A greater quantity of both residues is produced each year than what the plant could absorb; part of this surplus is used to produce compost that is donated to involved farmers.

The production of the Kfarfakoud Briquettes Center and the sustainable management of the Dalboun Oak Forest to optimize its biomass production are helping prevent forest fires and pollution from agriculture waste, and mitigate the problems caused by the CO_2 emissions from fossil fuels and forest fires, while converting waste into an economic and rural development opportunity.

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

The briquettes produced in the plant can be used to provide modern bioenergy services, thus replacing less efficient firewood use. They are also highly competitive with the common alternatives currently used by most households in the village (i.e. firewood and diesel) both in terms of the Lower Calorific Value (LCV) and price. The LCV of the briquettes compared with other fuels is as follows:

Table 1 Comparison on LCV and price of briquettes with alternative fuels

Fuel	Price/weight (USD/tonne)	LCV/weight (kWh/tonne)	LCV/price (kWh/USD)
Briquettes	175-200	4 650	23.3-26.6
Olive wood	300	3 720	12.4
Oak wood	312	3 100	9.9
Diesel	-	-	9.3

As Table 1 shows, the same LCV costs 2.8 to 2.5 more times with diesel, 1.7 to 1.5 more times with olive wood and 1.8 to 1.56 more times with oak wood; this demonstrates the competitiveness of briquettes compared with other fuels.

Positive impacts for forest landscape restoration:

The FLR plan designed for the SBR includes the management of abandoned coppice woodlands (mainly evergreen and broadleaf oak) with the objective of turning them into old-growth stand, thereby increasing their ecological value. The thinning of the woodlands also increases the capacity of forests to adapt to climate change because of the reduced competition for the scarce water resources in the thinned forest stands.

The buffer zone of SBR is very prone to forest fires. These take place mainly in the fall, when farmers prune their crops (mainly olive and vines) and the biomass burned on the spot often start fires that spread through the landscape. The collection of this biomass and their use for briquette production – mixed with woodland pruning waste – has decreased the number of autumn fires in the Reserve with associated benefits. This represents an economically viable use of forest/agriculture waste whose burning increases forest fires that devastate large areas of Lebanon every year.

Co-benefits:

Climate change

The production of briquettes has the following ***climate change mitigation*** values:
- Reduction of CO_2 emissions from fossil energy consumption (e.g. diesel for house heating) and the burning of forests and agriculture waste.
- Increased CO_2 sequestration in forest lands due to reduced incidence of forest fires.

The thinning of the forests also enhances the ability of the forests to ***adapt to climate change***.

Employment and income

The briquette plant has increased local employment and business in the briquette value chain.

Approx. 100 daily-paid workers (USD 20/day) are involved in the gathering of biomass from October to April. Five workers (2 permanent, one a woman; 3 seasonal for a period of 8 months/year), with an average salary of USD 600/month, manage the factory. The plant produces approx. 6 000 briquettes per day, with the plan to increase production from 1 million briquettes in 2013 up to 5.6 million in 2021.

The total investment for establishing the factory was USD 200 000. The net profit is 25 percent of sales (profit of USD 50/tonne of briquettes with a sale price of USD 200/tonne), part of which reverts to the improvement of the management of the SBR and FLR implementation. At the early stages of the program, some of the briquettes were distributed free of charge to promote its use and gain acceptance by the local communities.

Table 2 Business plan for the production of briquettes

Business plan for the production of briquettes (2013-2021)							
Year	Briquettes t/yr (17% MC)	Briquettes N°/year	Forest woodchips (t/yr) (45% MC)	Fruit tree woodchips (t/yr) (45% MC)	Olive Pomace (t/ yr) (30% MC)	Total raw material (30%-45% MC)	Expected net benefit (USD 50/t)
2013	1,200	1,000,000	357	238	800	1,394	60,000
2014	1,489	1,241,000	443	295	993	1,731	74,450
2015	1,848	1,540,081	513	403	1,232	2,148	92,400
2016	2,293	1,911,241	591	546	1,529	2,666	133,300
2017	2,846	2,371,849	677	734	1,898	3,309	142,300
2018	3,532	2,943,465	771	981	2,354	4,106	176,600
2019	4,383	3,652,840	869	1,303	2,923	5,095	219,150
2020	5,440	4,533,175	971	1,726	3,627	6,323	272,000
2021	6,751	5,625,670	1,071	2,276	4,501	7,847	337,550

Reduction in energy cost

The cost of energy has been reduced by more than two thirds in comparison with the average of other fuels, with a positive effect on the consumption and savings of the local population.

Health

The burning of briquettes has also contributed to abate health problems due to the burning of diesel and firewood in the home.

Rural development

The same initiative has also supported livestock grazing as a complementary measure to the thinning and pruning management interventions in forest land. Local shepherds were involved in goat grazing interventions in the years following thinning operations as a way to prevent the regrowth of the cut stems and control the growth of the forest understory in high fire-risk areas, such as along the road network.

Prospects

Reasons or main drivers:

This action is framed within the broader FLR plan designed and implemented in the SBR since 2012, with the aim of preserving/restoring its mosaic landscapes of old growth forests, woodlands, rangelands and agriculture land (traditional stonewall terraces) while increasing the resilience of the landscape to climate change.

Key enabling factors:

- Strong team with national and international experts covering different fields joined to design a comprehensive and innovative FLR plan
- High reputation of SBR facilitated support by international donors (EU, international foundations, private sector)
- Excellent network of contacts and existing cooperation enabled strong by-in from local stakeholders (local authorities, farmers, civil society etc.)

Main challenges encountered:

- Overcome initial scepticism by local communities especially farmers, which were required to actively collaborate by taking the biomass waste from their fields to the collection point, instead of burning it on the spots. This was overcome by establishing broader agreements with farmers, whereby the farmers joining the initiative would get benefits in. return, i.e. free compost obtained by part of the biomass collected.
- Land tenure/policy issues: some forest land is owned by the State that has strict policies on the pruning and cutting of trees - especially pines. This was overcome by establish dialogue and showing the benefits of the practice on private lands.

Potential for scaling-up and replicability:

- The Kfarfakoud plan is no longer funded by SBR and it keeps working according to the rules established by the local market.

- The availability of biomass from forest and agriculture is much higher than what is required in the 10-year business plan of the factory.
- The experience is being disseminated and debated at the national level in Lebanon but also using existing networks within the Mediterranean region. A dissemination project funded by the MAVA Foundation (CH) is being implemented including a number of tools (publications, webinars, MOOC).

Additional information

The project is implemented by Al Shouf Cedar Society (ACS), the organisation set up in collaboration with the Lebanese Ministry of the Environment to manage the SBR. ACS is an interesting mix of public/private bodies, which largely depends on raising funds at national and international level to run its programme, but also gets part of its revenues from the entrance fees to the SBR.

Link: www.shoufcedar.org

Publication:

Shouf Biosphere Reserve, 2019. *Forest and Landscape Restoration Guidelines*. 263 pp. Available online: https://www.medforval.org/wp-content/uploads/2019/12/Forest-Landscape-Restoration-Guidelines_Shouf_2019.pdf

Forest landscape restoration through a sustainable wood energy value chain in Ghana

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Headline

Project to support communities in charcoal producing regions in Ghana for rehabilitating degraded land and improving the efficiency of the charcoal value chain, with a view to provide recommendations for energy- and climate-related strategies in Ghana, including the Ghanaian Nationally Determined Contribution (NDC).

Outline

Geographic location:	**Type of example**:	**Status:**
Ghana – 10 selected communities in the Bono East and Savanna Regions	Specific project	On-going (April 2019 – March 2023)

Introduction

The main aim of the "Forest Landscape Restoration through sustainable wood energy value chains" project is to support partner institutions in Ghana to work with small entrepreneurs and organized charcoal producer groups of several communities in charcoal producing regions to restore forest landscapes. Ten charcoal-producing communities in the Bono East and Savannah regions of Ghana have been identified by the project. Here, measures for afforestation for sustainable energy wood production on degraded land, rehabilitation of degraded forest landscapes, and improvement of the energy efficient use of energy wood and charcoal are implemented.

Since its commencement in 2019, the project has so far raised the following lessons:

- It is crucial to obtain the commitment from leaders and relevant stakeholders to create the enabling environment needed for effective sustainable measures in the wood energy value chain.
- It is important to have a wood fuel regulation regime because the absence of regulations makes it difficult to implement sustainable measures. For instance, it is very difficult to encourage the production of charcoal from woodlots when wood can easily be harvested from natural forests.
- The presence of incentives for a sustainable production of charcoal could encourage more actors to also establish woodlots and construct improved kilns for a sustainable production of charcoal.
- Additionally, awareness creation is also vital among all value chain actors and relevant stakeholders about the importance of sustainable charcoal production. Lastly, the capacities of actors should be built in the areas like improved sustainable wood sourcing, transportation,

financial access and managements, marketing, efficient kiln technologies and improved cooking stoves.

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

- A total of 300 hectares of degraded land are used in the 10 selected communities to produce wood energy through the planting of woodlots.
- The energy-efficient use of wood energy is improved in 4 selected communities through the improvement in the wood energy values chain and the introduction of improved kilns
- Recommendations for the improvement of the wood energy value chain are discussed in the Ghanaian process of modification/reformulation of energy- and climate-relevant strategies.
- The recommendations for improving the wood energy value chain are being integrated into the process of updating the Ghanaian Nationally Determine Contributions (NDC).

Positive impacts for forest landscape restoration:

- A total of 700 hectares of natural forests and agroforestry areas are rehabilitated in the 10 selected communities
- The Ghanaian approach to sustainable and efficient wood energy production in connection with the restoration of natural forests and agroforest areas is well-known in the West Africa region
- Biodiversity will be improved in the project area due to enrichment planting and farmer managed natural regeneration (FMNR)
- Community members will be trained in restoration techniques and management plans will be developed

Co-benefits:

- Improvement of wildfire management at the community level.
- Income for community member through restoration and sustainable wood energy activities.
- Expected carbon Sequestration is around 28 000 t CO_2 eq.

Prospects

Key enabling factors:

The project fulfils the great need to improve the sustainability of the charcoal value chain in Ghana, given the high and still increasing demand for wood fuel (both firewood and charcoal) in Ghana. The existing charcoal value chain causes high deforestation and degradation especially in Central and North-Ghana to satisfy this demand for wood fuel. Furthermore, charcoal is mainly produced with traditional earth mound kilns with a low efficiency and therefore with a high consumption on wood. The charcoal business provides a significant source income to charcoal value chain actors and is therefore an integral part of rural livelihoods in these areas.

The project is further supported by:

- Commitment and support from relevant government institutions i.e. Ministries of Land and Natural Resources, Ministry of Energy, Forestry Commission, Energy Commission, Environment Protection Agencies, etc.;
- Availability of favourable aligning national strategies and policies e.g. REDD+ Strategy, Ghana Forest Planation Strategy, Ghana Forest Development Master Plan, Ghana Bioenergy Strategy, Strategic National Energy Plan, commitment to the AFR 100 initiative, etc.;
- Strong interest and willingness from participating communities; and
- Close collaboration with Civil Society Organisations (CSOs).

Main challenges encountered:

After just one year since the project began, the following challenges have been identified:

- Lack of regulation in the wood fuel sector;
- Prevalence of wildfire; and
- Lack of incentives for community woodlot and plantation establishment.

Potential for scaling-up and replicability:

The Ghanaian charcoal value chain is a vibrant one and provides income for many actors (producers, aggregators/off-takers, retailers, transporters, etc.) along the chain. A study by Brobbey *et al*. (2019) on the economic importance of charcoal to rural livelihoods has shown that charcoal is the second primary source of income after crop production, and accounts for 17 percent of the total household income. The study also found charcoal production appears to be the most frequently mentioned coping strategy against shocks associated with crop failure, illness and cattle invasion.

In Accra, around 470 000 households consume charcoal, and in Kumasi about 443 000 households. It is expected that population growth, especially in the cities, and economic development will increase the demand for charcoal by 2050 to 2.8 million tons (Energy Commission of Ghana, 2017).

Thus, charcoal production will continue to play a vital role in the economic situation of charcoal producing communities and provide income for these actors for a very long time. Therefore, an improved and sustainable charcoal value chain is crucial to the sustainability of the livelihoods of the actors and the protection of natural forests which is what the project seeks to achieve.

The scalability and the replicability of the project is very feasible especially within Sub-Saharan Africa since charcoal is set to remain an important energy source throughout Sub-Saharan Africa in the foreseeable future (Schure *et al*., 2019). It is therefore very important that the sustainability of the value chain within Sub-Saharan Africa is guaranteed.

Additional information

The project is implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) of Germany through the International Climate Initiative (IKI). It is a EUR 4.5 million project that began in 2019.

Link: https://www.international-climate-initiative.com/en/details/project/forest-landscape-restoration-through-sustainable-wood-energy-value-chains-19_III_077-3028?cookieName=search_results&iki_lang=en&source=single&cHash=c512db9126f1df8f4294d72891fa4f5c

Biomass production, harvesting and collection

Potentials for bioenergy from Degraded Land in sub-Saharan Africa

Toshimasa Masuyama, International Renewable Energy Agency (IRENA)

Headline

75 million hectares of restoration pledged under the African Forest Landscape initiative (AFR100) in sub-Saharan Africa (SSA) could yield around six exajoules per year of primary bioenergy.

Overview

Geographic location:	**Type of example**:	**Status:**
Sub-Saharan Africa countries (with country-level analysis for Kenya and Rwanda)	Study	Finalised in 2017

Introduction

As of March 2017, 18 SSA countries had pledged a total of 75.36 million hectares under the African Forest Landscape initiative (AFR100). A study was conducted by IRENA in cooperation with Utrecht University to assess the sustainable potential of biomass for energy from the restoration of degraded land pledged to the AFR100 initiative.

This study aims to provide a methodology using ROAM (Restoration Opportunities Assessment Methodology) to estimate the yields of all Bonn Challenge pledges. During a ROAM assessment, different facets of the restoration opportunity are explored. The total magnitude of restoration opportunity in an area is calculated taking social, economic and ecological factors into consideration. The assessment ascertains the different types of restoration and specific sites in a particular country. The costs and benefits of different restoration strategies are evaluated. Finally, ROAM identifies the important stakeholders and the policy, financial and social incentives in place or required to support restoration efforts.

The study concluded that these 75 million hectares of restoration pledged under the AFR100 could yield around six exajoules per year of primary bioenergy, assuming that the entire amount of land pledged were dedicated to bioenergy crops, and these pledges were fulfilled on land with the highest potential yield.

After the analysis for Sub-Saharan Africa as a whole, a country level analysis was conducted for Kenya and Rwanda because the assessments based on the ROAM have been completed for these two countries.

The result of the assessment study was presented in a report entitled “Bioenergy from Degraded Land in Africa: Sustainable and technical potential under Bonn Challenge pledges” in 2017.

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

The analysis shows that around 6 EJ of primary energy per year could in theory be sustainably extracted from short rotation woody crops (SRWC) cultivated on land pledged for restoration under the AFR100. This proportion would account for 87 percent of total primary energy supply (TPES) projected in 2050 for the 18 countries studied. However, this assumes bioenergy crops will be planted on the entire pledged area and that the most productive land will be selected to plant such crops. If bioenergy crops were planted on just 63 percent of the area pledged (the average intention in the current country plans), and if the most degraded land were selected instead of the highest yielding, the amount of energy extracted would amount only to around 1.8 EJ per year – 25 percent of TPES.

Positive impacts for forest landscape restoration:

Growing bioenergy crops on degraded land – especially perennial crops – could significantly increase the productivity of the land and would have little negative impact on biodiversity and GHG balance.

Sustainable biomass production for energy could also stimulate the Bonn Challenge and could improve the economic sustainability of projects undertaken while mitigating more GHG by replacing fossil fuels. Furthermore, the extra financial incentive arising from bioenergy crop production could increase the likelihood that the Bonn Challenge succeeds.

Countries that make pledges to the Bonn Challenge usually do this by stating number of hectares to be restored without providing details on the location or type of restoration. Conducting a study using ROAM provides more insight into the possible restoration strategy.

The ROAM reports of Rwanda and Kenya show significant potential of restoration activity that could support bioenergy feedstock production. Kenya identifies 1.8 Mha for agroforestry under a conservative scenario, while another 0.4 Mha is eligible for commercial plantations. Rwanda identifies 1.1 Mha to be restored through agroforestry, while another 0.25 Mha consists of existing eucalyptus plantations with the potential to be improved.

The ROAM assessment conducted in **Rwanda** generated six restoration interventions consisting of 1) new agroforestry on steeply sloping land, 2) new agroforestry on flat and gently sloping land, 3) improved management of existing eucalyptus woodlots, 4) improved management of existing pine timber plantations, 5) protection and restoration of existing protected forest and 6) establishment or improvement of protected forests on sensitive sites. The assessment indicated the first three restoration options are relevant to feedstock production for bioenergy, summing up to 1.37 Mha out of a total restoration opportunity of 1.52 Mha.

The ROAM assessment was also carried out in **Kenya** which generated seven restoration interventions consisting of 1) reforestation and afforestation of natural forests, 2) rehabilitation of degraded natural forest, 3) agroforestry on cropland, 4) commercial plantations on marginal cropland and un-stocked plantation forests, 5) buffer zones along water bodies and wetlands, 6) buffer zones along roads and 7) restoration of degraded rangelands. The assessment found the third and fourth options to be appropriate for producing feedstock for bioenergy, amounting to 2.2 Mha out of a total restoration opportunity of 5.1 Mha.

Co-benefits:

Using land with zero or little previous productivity can contribute to social and economic development in rural regions. In Africa, additional bioenergy production could generate further benefits by lightening the burden of energy insecurity so typical of the region while generating employment and income, thereby reducing poverty.

Prospects

Reasons or main drivers:

Using degraded land to produce bioenergy may avoid problems related to land use change because this type of land is usually unsuited to and economically unattractive for food crops.

Key enabling factors:

SRWC is especially well suited to landscape restoration because it can grow on non-prime agricultural land and could provide different ecosystem services. SRWC could increase soil carbon sequestration, reduce soil degradation processes such as water and wind erosion and improve wildlife habitat.

Main challenges encountered:

Difficult growing conditions mean that establishing perennial energy crops on such land will require sustained effort over many years. Even then, the expected yields in these areas will be lower than on high-quality land. Furthermore, these degraded sites are often an essential resource for poor rural communities. Though degraded, land may still produce useful amounts of food and animal feed that could be displaced by wood crops, which are often considered an alternative. Restoration with wood crops should be planned in such a way that supplements rather than displaces more important uses with higher markets or other value.

In addition, prioritising the restoration of land with relatively low yield potential could divert attention from other action that could more effectively improve the overall efficiency of land use. Examples included increasing the yields on existing cropland and reducing the demand for land-intensive products.

Potential for scaling-up and replicability:

Studies investigating the potential for bioenergy in more detail at a national level should be conducted when ROAM assessments become available. However, more accurate and detailed input data on land degradation and availability are required as well in order to conduct meaningful country-level studies.

This will involve primary field research. Economic and social factors should be included as well as environmental sustainability. Involving local stakeholders in the process is important because land restoration should respect their rights and provide them with benefits. Incorporating bioenergy potential assessments into future ROAM studies is a possibility worth considering, since the ROAM studies engage with local stakeholders.

Additional information

IRENA is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy.

Publication:

IRENA, 2017. *Bioenergy from Degraded Land in Africa: Sustainable and technical potential under Bonn Challenge pledges*. IRENA, Abu Dhabi. ISBN 978-92-9260-050-1 Available at : https://www.irena.org/publications/2017/Dec/Bioenergy-from-degraded-land-in-Africa

Sustainable and productive private forest management in Southeast Queensland, Australia

Dr Michael Berry, Forest Research Institute, University of the Sunshine Coast, Australia

Headline

Integrated land management strategies that include biomass recovery for the wood energy market can increase biomass quality and supply, reduce owner risk, provide up to a six-fold increase in return and mitigate operational and fire hazards, thus promoting wider adoption of private native forest growing schemes in the region.

Overview

Geographic location:	**Type of example**:	**Status**:
Queensland, Australia	Research project	Ongoing – first phase to be completed by the end of 2020.

Introduction

Integrated land management strategies can increase biomass quality and supply, reduce owner risk, provide a return and mitigate operational and fire hazards.

Biomass harvesting can be an effective way to enable more sustainable and productive forest management silvicultural regimes. The viability of emerging biomass markets is highly dependent on establishment of appropriate and flexible operational and supply chain designs.

A diverse supply of biomass is required to sustain a resilient regional bioeconomy. Furthermore, the establishment of a sustainable regionally-oriented bioeconomy depends on cooperation and transparency from private land owners, contractors and industry.

Within the private native forest sector, however, there is currently little information related to resource availability. This research project focuses on evaluating the economic and operational feasibility of biomass recovery to enable the viability of silvicultural interventions prompting more productive forest management in the region. It evaluates the quality and quantity of material available for biomass markets allowing for more sustainable market planning. This project is exploratory in nature as it evaluates the potential for future integrated active forest management strategies.

Biomass production, harvesting and collection

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

The project will have positive impacts for sustainable wood energy as it will:

- Help enable material that was previously considered a logging waste by-product to be used as feedstock for the wood energy market, thus greatly increasing supply capability.
- Provide an assessment around the potential for different grades of biomass including low quality wood energy fuel as well as the potential for higher quality co-products.
- Support the burgeoning local bioeconomy, creating new local jobs in resource management and commercial product development using a previous waste material

Positive impacts for forest landscape restoration:

Biomass recovery in the private native resource would enable the economic viability of key silvicultural treatments, which would:

- Enable more effective management of the private native resource, potentially improving productivity and increasing sustainable yield (up to a six-fold increase in yield and returns for private landowners).
- Provide for more accessible grazing land, increasing the effective usage of silvi-pastoral systems.
- Promote wider adoption of private native forest growing schemes in the region, providing enhanced ecological and habitat benefits to native species.
- Potentially reduce the likelihood and severity of bushfires.

Co-benefits:

- Alleviate the anticipated shortfall in domestic hardwood supply by increasing timber availability, supporting the long-term viability of the regional timber industry.
- Promote local jobs, enable domestic hardwood industry resiliency, utilisation of a waste product, development of new local supply chains.
- Lower carbon emissions by the substitution of fossil fuels by renewable wood fuels
- Potential reduction in utility costs (and risk of future increases) for biomass consumers compared with high cost for electricity and heat generation by fossil fuels.

Prospects

Reasons or main drivers:

- Dynamic policy considerations surrounding private native forest resource availability and trends (namely a state-wide moratorium on public native forest harvesting planned in the next 5 years).
- Need for economic and operational sustainability of broader industry (existing hardwood markets).

- Current practices in private native forests involve periodic harvesting to remove the best trees, leaving a high proportion of trees that are of little productive value, which limits sustainable timber supply (only 5 percent currently actively managed).
- There exists interest from across the supply chain in the development of more effective management systems and the higher utilisation of waste materials.
- Emerging biomass markets are actively soliciting high quality wood feedstocks.

Key enabling factors:

- Regional interest from all aspects of the supply chain (growers, contractors, end users), and support from all sectors has greatly contributed to the likelihood of success.
- Key support from contractors willing to test and trial novel methods to enable better management of resource and biomass utilization.
- Magnitude of logical benefits from better management of resource (financial, regional economy, waste reduction, energy production, grazing, etc.).

Main challenges encountered:

- Broader state and federal policy considerations and trends promoting an element of planning uncertainty.
- Private land owners are generally an unconnected cohort of individuals generally disinterested in structural change to management practices.
- Transportation distances moving feedstock can prohibit economical utilization of material.
- Lack of forest management skills (due to focus on the grazing enterprise).
- Financial and time constraints limiting investment in thinning and silvicultural treatments.
- A lack of cost-neutral or cost-effective mechanical thinning regimes.
- Challenges related to the development of a new supply chain and connecting key partners.
- Conceptually viewing traditionally non-commercial material as a product within the value chain.

Potential for scaling-up and replicability:

Similar conditions exist for more effective resource management throughout Australia, especially in rural communities. Key enablers to replicability of biomass markets include access to locally derived consumers of feedstock for fuel and/or access to ports and critical infrastructure for efficient and cost-effective transportation of raw or processed feedstocks to end markets.

Replication of studies and connecting of supply chain players continues in Queensland, Victoria and New South Wales, Australia.

Additional information

This example is based on a research project led the University of the Sunshine Coast in collaboration with the Private Forest Service Queensland (PFSQ) and GMT Logging, with key funding coming from each collaborator and IEA Bioenergy.

Prosopis juliflora – a potential game changer in the charcoal sector in Kenya

Phosiso Sola, Mary Njenga, Grace Koech, Erick O. Wanjira, Moses Kirimi, Ignatius Siko and Mieke Bourne, World Agroforestry Centre (ICRAF)

Headline

The management and utilisation of the invasive species, *Prosopis juliflora*, along with the optimisation of charcoal production efficiency, can improve livelihoods and the environment.

Overview

Geographic location:	**Type of example**:	**Status**:
The intervention is being implemented in three sites in Marigat sub-county, Baringo County, Kenya.	Project	Ongoing – 2018 to 2021.

Introduction

Woodfuel remains the major energy source for cooking and heating for more than 60 percent of people in Kenya (MoE and CCAK, 2019). Though charcoal and firewood are renewable forms of energy, their unsustainable production and inefficient utilization pose environmental and health challenges (FAO, 2017a). For instance, in Kenya about 40 percent of the woodfuel is sourced unsustainably and over 90 percent of charcoal is produced using traditional kilns with low conversion rates ranging between 10 and 15 percent (Drigo *et al*., 2015: MoE and CCAK 2019). The carbon footprint of unsustainably produced charcoal along its whole life cycle is 6-9 kgCO_2eq, which has climate change consequences (FAO, 2017b). Thus, there is an urgent need to seek sustainable sourcing solutions, which include management and utilisation of invasive species like *Prosopis juliflora*.

Prosopis juliflora, locally known as 'mathenge', is a shrub or small tree that is native to Mexico, South America and the Caribbean, and is an invasive species in Kenya. In Kenya, *Prosopis juliflora* was introduced from 1973 through to the 1980s to arid and semi-arid areas to mitigate desertification and fuel wood shortages (Pimentel *et al*., 2000; Masakha & Wagulo, 2015). The species was preferred because of its resilience, drought tolerance and fast growth (Meyerhoff, 1991). However, it is aggressively invading about 500-1300 ha per year, causing land use and land cover change, and losses of grasslands, woodlands, croplands, grazing lands and settlements, especially in Turkana, Baringo, Garissa, Tana River and Taita Taveta Counties (Mbaabu *et al*., 2019; Eckert *et al*., 2020). By 2016, *Prosopis juliflora* had invaded 2 percent of Kenyan drylands, covering 18 792 hectares in Baringo County alone. In this County, *Prosopis juliflora* coverage is estimated to have increased by almost 4 percent or 640 ha per year since 2002 (Mbaabu *et al*., 2019). In Marigat Sub-County, Ng'ambo is the most highly invaded, whilst Ilchamus and Loboi are relatively less affected.

Thus, management and utilization of the current 18 792 ha of *Prosopis juliflora* in Baringo County for charcoal production using improved kilns and effective transportation and marketing presents potential for improving livelihoods and the environment (Mbaabu *et al*., 2019). Various technologies with high charcoal conversion efficiencies of about 30 percent have been adapted and/or developed by Kenya Forest Research Institute (KEFRI) and other institutions. However, studies have shown that uptake of these improved technologies has been very low due to several factors such as lack of information and skills, as well as high costs (Kitheka *et al.,* 2017).

Management by utilisation of the estimated 37 million ha of this invasive species spread across several counties in Kenya can provide timber, poles, firewood, charcoal and fodder, among other benefits.

Improving kiln efficiency will optimise use of *Prosopis juliflora* for charcoal, reduce pressure and retain trees on the landscape for climate change mitigation and other ecosystem services and products.

Formalised and legal production and trade in charcoal based on sustainable wood sourcing and improved charcoal production will maintain environmental health, increase incomes, and revenue as well as provide a reliable source of cooking and heating energy for the urban household.

Figure 2 Production of charcoal from Prosopis juliflora (KEFRI and World Agroforestry)

The project aims to pilot innovative options for wood sourcing and charcoal production to support sustainable charcoal value chains and inform the development of enabling governance systems. A participatory collaborative learning approach has been adopted to catalyse farmer to farmer extension, targeting charcoal producer associations. Farmer trainers were selected and engaged in learning about sustainable wood management and harvesting, efficient carbonization encompassing properly drying the wood, stacking/arranging wood in the kiln as well as use of chimneys and air breathers which result in increased recovery rates as reported in other countries (Njenga *et al*., 2019; Schure *et al*., 2019; Oduor *et al*., 2006). A quasi-experimental approach was also adopted in the monitoring of kiln efficiency and keeping input and output records. Drum kilns were also introduced to optimize wood utilization where small stems that would otherwise be left as residues or waste are carbonized, reducing wood wastage while supplying additional charcoal. This was targeted at charcoal producer associations (CPAs) with 150 members; 32 of them were trained and tasked with training fellow association members. At subnational level, the project aims to support the development of country level strategies/road maps for legalising and formalising *Prosopis juliflora* charcoal value chains, as its harvesting in Baringo County is exempt from the logging moratorium since 2018.

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

Sustainable sourcing of feedstock for charcoal production is a major challenge in the slow growing indigenous woodlands. Using fast growing trees with limited management inputs – like invasive species that are present in the landscape – will ensure a sustainable low-cost production system of charcoal compared to plantation woodlots. Coupled with enhancement of community skills through collaborative learning and extension, and increased access and adoption of appropriate technologies, this will result in production of sustainable charcoal at scale to meet the growing urban demand.

Positive impacts for forest landscape restoration:

The project seeks to promote management by utilisation of the invasive *Prosopis juliflora* to:

i. produce charcoal from improved and appropriate technologies to reduce pressure on indigenous woodlands; and
ii. open invaded areas for natural regeneration of indigenous woodlands, grazing lands and cultivation of food crops in agroforestry systems.

This will increase standing biomass, species diversity and build resilient livelihoods systems among the communities living in *Prosopis* invaded areas.

Co-benefits:

Charcoal production and trade is one of the major income sources for many in semi-arid areas like Baringo County in Kenya. However, it is repeatedly associated with deforestation and degradation as well as being riddled with illegality which makes the business ventures unpredictable and prone to bribery (Sola *et al*., 2017; Ndegwa *et al.*, 2020). This intervention seeks to reduce the contribution of charcoal production to these negative impacts. This is being done by promoting use of the invasive *Prosopis juliflora,* as well as adoption of improved harvesting and management techniques that ensure the trees are not completely cut but remain in the landscape to continue coppicing and maintain the carbon sink. In addition, use of improved carbonization technologies is expected to cut the GHGs emitted during the charcoal carbonization process and maintain carbon sinks saved through reduced wood consumption (FAO, 2017b; Iiyama, *et al*., 2014).

Furthermore, reduction of wastage and improvement of kiln efficiencies increases return on labour, ensuring higher incomes for charcoal producers as well as more time to invest in other productive activities. The support to the governance of charcoal value chains will make the business competitive for all value chain actors from producers to retailors. Furthermore, sustainable supply of charcoal ensures that the urban poor have access to cooking and heating energy sources at competitive prices. Health outcomes are also a major concern and promotion of improved cookstoves is expected to reduce negative impacts on charcoal users.

Prospects

Key enabling factors:

Although charcoal movement beyond county boundaries was banned under the National Government Gazette notice of 2018, trade is still ongoing. This is despite the reduced number of actors in the value chain, evidenced by almost empty collection points but more individual roadside sales to supply the thriving urban markets. Since the exemption of *Prosopis juliflora* from the Moratorium on Logging in Baringo County at the end of 2018, *Prosopis* charcoal stakeholders are in the process of reviewing the Charcoal Production Act and developing a road map with safeguards to guide the resumption of charcoal trade. This has provided the entry point for generating knowledge, piloting options and incorporating evidence on how charcoal production can be optimised.

Reasons or main drivers:

Dependence on woodfuel in Kenya has remained above 60 percent since 1990s (MoE, 2002) with recent studies showing that most of the traded charcoal (89 percent) comes from the drylands (Iiyama *et al.*, 2014; KFS, 2017). Even with the well-developed policies and legislative frameworks in Kenya, woodfuel production and distribution are inadequately guided, controlled and supported (Sola *et al*, 2019). Challenges documented in the literature include: ineffective institutional arrangements and support mechanisms; poor enforcement and compliance; and inadequate investment and financing (Sola *et al.*, 2019). In fact, lack of transparency and consistency in implementation and enforcement in Kenya make charcoal 'illegally legal'. It is legal to produce, illegal to transport, but perfectly legal to sell and use charcoal in cities. Notwithstanding, woodfuel value chains remain important in providing income and energy sources for many in Kenya and thus it was envisaged that the project will catalyse processes that would make the value chains more sustainable.

Main challenges encountered:

The logging moratorium on all types of forests made engagement in and implementation of the project by many stakeholders a great challenge, although for others it was an opportunity to reflect, strategize and generate evidence to inform the reopening of the subsector. This affected the roll out of the activities as most stakeholders were hesitant to engage in what was seemingly illegal. Even so, stakeholders remain hopeful and have high expectations that the project will inform policy and legislative processes and contribute to sustainable charcoal value chains.

Potential for scaling-up and replicability:

Prosopis Juliflora, which is found in more than five counties, presents an opportunity for sustainable charcoal value chains, as it covers 2 percent of land in Kenya, with millions of tonnes of utilizable biomass that would cater for the charcoal deficit faced in the country (Choge *et al*., 2011; MEWNR, 2013). Any increase in the spread of *P. juliflora* negatively impacts the livelihoods of local communities in the drylands (Mbaabu *et al*., 2019). This is because it leads to loss of croplands and grazing lands that are the major sources of livelihood for the agro-pastoralist communities. Taking advantage of the willingness and urgency to try all options to manage the invasive *Prosopis* is a huge opportunity for scaling up this initiative. Secondly, charcoal demand is insatiable, and the national and subnational governments are keen to find a solution for reducing pressure on the indigenous woodlands by implementing the Prosopis Exemption and thus this initiative will get political will and support. Finally, already many small-scale initiatives are being undertaken in various dryland and *Prosopis*-infested counties, seeking for practices to optimise production and marketing. Building on these initiatives, the intervention can be replicated in most of the communities within Baringo and across other counties.

Additional information

World Agroforestry (ICRAF) – (www.worldagroforestry.org) is one of the CG Centres. It is a centre of scientific excellence that harnesses the benefits of trees for people and the environment. Driven by our vision of a world where all people have viable livelihoods supported by healthy and productive landscapes. ICRAF's mission is to harness the multiple benefits trees provide for agriculture, livelihoods, resilience and the future of our planet, from farmers' fields through to continental scales. Headquartered in Nairobi, Kenya, ICRAF operates six regional programmes in Sub-Saharan Africa, Asia and Latin America and conducts research in 33 countries around the developing world. Bioenergy is one ICRAF's of the key programmatic areas.

This work is part of a four-country project entitled Governing Multifunctional Landscapes (GML) in sub-Saharan Africa: managing trade-offs between social and ecological impacts funded by the European Union (EU), implemented by CIFOR in partnership with ICRAF, FAO, and ADRA in Kenya (as well as other partners in Cameroon, DRC and Zambia). This component focuses on knowledge generation, piloting policy options and engagement for more sustainable woodfuel value chains.

Partners: Baringo County, Kenya Forest Research Institute (KEFRI), Adventist Development and Relief Agency, Kenya (ADRA), FAO Forest Farm Facility

Link: https://www.cifor.org/gml/sustainable-woodfuel/

Publication:

Njenga, M., Kirimi, M., Koech, G., Otieno, E., Sola, P., 2019. Training of Trainers (ToT) on Sustainable *Prosopis Juliflora* Woodfuel Production and Utilization in Baringo County, Kenya. Available online: https://www.researchgate.net/publication/337534857_Training_of_Trainers_ToT_on_Sustainable_Prosopis_Juliflora_Woodfuel_Production_and_Utilization_in_Baringo_County_Kenya

Integration of forest biomass procurement as a silvicultural tool for forest restoration in Quebec, Canada

Dr. Evelyne Thiffault, Research Centre on Renewable Materials, Department of Wood and Forest Sciences, Université Laval

Headline

Preliminary results from research into the consequences on seedling growth from the harvesting of low-quality wood for bioenergy suggest that forest biomass procurement increases the number of seedlings, suitable microsites and the exposure of minerals, and reduced the obstacles for establishment of regeneration and site preparation.

Overview

Geographic location:	**Type of example**:	**Status**:
The study area located in Québec, Canada.	Research project aiming at testing forest biomass procurement as a component of a forest management system.	Ongoing. Launched in late 2018 and to be completed in early 2021.

Introduction

Studies of the economics of using forest biomass for bioenergy often show that profitability is hard to achieve unless supported by policies and/or regulations. When considering the entire silvicultural system, recovery of forest biomass could play a positive role in contributing to silvicultural objectives and reducing the cost and effort to establish high-quality regeneration, especially in stagnant forest stands with an abundance of degraded or low-quality trees.

The example quantifies the quantity and quality of microsites and environmental conditions for seedling growth created by forest biomass recovery in the form of degraded/low-quality wood relative to reference systems.

Early results suggest that forest biomass procurement increased the number of seedlings and suitable microsites in the cutovers and the exposure of minerals, and reduced the obstacles for establishment of regeneration and site preparation. However, differences between treatments were not large and variability was high.

Further field work is to be conducted to increase the number of sites and the ecological/technical conditions sampled, which will allow a strong inference potential to the results.

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

Studies of the economics of using forest biomass for bioenergy often show that profitability is hard to achieve unless supported by policies and/or regulations, due to the often high costs of forest biomass procurement. This is a major obstacle to the large-scale deployment of forest bioenergy when competing with low-cost fossil options. However, when considering the entire forest silvicultural system, from harvest to a new growing stand of trees, there is an increasing recognition that the recovery of forest biomass (in the form of branches, tree tops, discarded log pieces and trees), can play a positive role in reducing the cost and effort to properly prepare harvested site for effective planting or re-establishment of natural regeneration. If forest biomass recovery is initiated and this influences the rate of re-establishment, survival, growth and yield of the regenerating stand relative to a reference silvicultural system without forest bioenergy, this in turn influences the net carbon balance of implementing bioenergy. For example, if biomass recovery is a silvicultural practice that leads to improved planting microsite availability and quality, higher tree growth and faster C sequestration, the net GHG effect of replacing the fossil fuel with forest biomass is improved. Moreover, if biomass procurement translates into less machinery operations overall to achieve suitable microsites for regeneration establishment, either naturally or through planting, this would further improve the net GHG outcome, and provide economic savings.

Positive impacts for forest landscape restoration:

Regeneration stocking and density are critical factors determining forest productivity. They directly depend upon successful tree regeneration following harvesting, which, in turn, is influenced by many factors including seed and propagules sources and down woody debris. Debris can indeed affect the soil microenvironment, which directly influences resource availability to regenerating trees (air and soil temperatures, nutrients, water and light). Studies conducted in Canada suggest that retention of high quantities of debris –that might otherwise be used as a bioenergy source– might have a negative effect on the survival of regeneration caused by the difficulty of planting and the reduction in the abundance of suitable microsites for the establishment of seedling, either naturally or through planting. This is especially true when stands contain a high proportion of low-quality, degraded or uncommercial trees that lead to a high amount discarded log pieces and trees during timber harvesting. Site preparation treatments must then be used to create a good environment for the establishment and growth of naturally established or planted regeneration, as well as to enable and facilitate reforestation work. An abundance of woody debris can cause an increase in site preparation costs in managed forests. The project contributes to forest landscape restoration by assessing how forest biomass procurement along with timber harvesting in stagnant stands with an abundance of low-quality, degraded trees influences the quantity and quality of suitable microsites for the establishment of high-quality regeneration.

Co-benefits:

The project allows a comparison of the costs of procurement of wood for timber and biomass for bioenergy, and the costs of site preparation. The analyses make it possible to assess whether biomass procurement provides benefits in terms of costs of regeneration after harvest, and also whether differences in regeneration patterns can translate into carbon sequestration differences.

Prospects

Reasons or main drivers:

In Quebec (Canada), among the possible sources of forest biomass, secondary residues from wood (e.g. chips, sawdust, shavings) are already largely used as raw material by the pulp and paper and board industries, or to meet the needs for internal heat and power plants. As a result, the main sources of forest biomass for bioenergy development are primary residues generated during roundwood harvesting, consisting of stems, sections of stems and other tree parts left on the cut blocks during forestry operations. These sources of biomass are at the interface of the harvesting activities focussing on conventional products, namely those for the production of pulp and timber.

Stands containing a high proportion of low-quality, damaged or uncommercial trees are often found across Quebec's forest landscapes, partly due to the occurrence of natural disturbances. During harvesting of these stands, forest operators need to leave large amounts of wood on site because it does not meet quality requirements for conventional wood products such as lumber, pulp and panel: wood is either too dry or too rotten, affected by fungi, cankers, cambial necrosis or trunk fissures, or is of a species that do not fit with current standards of wood-processing industries. Although this resource is unfit for conventional wood products, it can represent an attractive source of biomass for the production of bioenergy because it does not compete with fibre supply of other forest industries.

Key enabling factors:

By 2050, the global bioenergy potential from forest biomass could reach 110 EJ, which corresponds to about 15 X 10^9 m^3 of wood. Achieving such levels of deployment will require, however, significant efforts. This is especially true for countries like Canada, characterized by a vast forest resource, 49% of which is certified by third parties as meeting sustainable forest management criteria (the largest certified world landbase in the world). Levels of forest biomass mobilization for bioenergy production in Canada is well below levels observed in other countries of the boreal and temperate biomes. Facilitating access to forest biomass potential is of strategic importance for Canada, as part of its efforts to fight climate change and to accelerate the deployment of its bio-economy to ensure its competitiveness on the world markets.

The Canadian forest sector is built as an industrial ecosystem, in which different tree parts, trees and stands are used as feedstocks by the various industries within the sector, and in which by-products flow from one industry to the other. The profitability of each industry is highly reliant on the vitality of other stakeholders. Empirical evidence has shown that takers of low-quality fibre and residues are particularly important within that ecosystem. The best opportunities for unloved wood are therefore likely to be found in integrated forest product chains, where conventional forest products, such as lumber and pulp, and bioenergy streams are integrated to optimize the fibre flows and values. Modelling of the forest sector of Quebec suggests that the mobilization of low-quality wood for bioenergy contributes to unlock timber-quality wood volumes in currently stagnant, undermanaged landscapes.

Main challenges encountered:

Integration of forest biomass procurement as a silvicultural tool for forest restoration faces several challenges. First, the high variability in the characteristics of forest residues left on site following conventional harvesting operation represents a technological challenge in terms of logistical structures (collection, handling, transportation, transformation) and end-use markets. Uncertainty in terms of future policies, regulations and other governance policies also represent a challenge, as these are decisive in creating an attractive investment climate to invest in the establishment of forest biomass value chains that would include silviculture objectives. The trade of forest biomass, particularly as it relates to emerging sustainability legislation, criteria and requirements for supply chain custody, may also pose challenges in the integration of forest biomass procurement and silviculture. Another challenge resides in the access to nearby facilities that can process biomass composed of small or low-quality logs typical of the material usually left on site during harvesting operations. Under current market conditions, bioenergy sourced from this type of low-quality material is at risk of remaining unprofitable, unless a clear advantage could be demonstrated in regards of reducing overall silviculture costs as related to forest restoration. Finally, safeguarding environmental sustainability is an important challenge across forest biomass supply chains, including the one described in this example. Forest biomass procurement may conflict with biodiversity conservation and protection goals, as intensified forest management to meet increasing demand bioenergy and other bio-based products may affect ecosystem services negatively.

Potential for scaling-up and replicability:

This example draws from a large-scale research study with a network of experimental sites distributed in several contrasting forestry contexts throughout Québec. The study, and thus its immediate inference potential, include fir- and spruce-dominated stands of the northeastern boreal forest of Quebec affected by cyclic severe spruce budworm outbreaks, wet boreal fir stands of the Laurentian Highlands of central Quebec, hardwood dominated forests typical of southeastern Quebec, and two contrasting forest types of low quality conifer-dominated mixedwoods typical of the Gaspesie peninsula in eastern Quebec. These study installations also vary in terms of the nature and organisation of the regional industrial network, forest tenure (Crown lands, private lands), nature and abundance of available forest biomass material, silviculture system (clearcut, shelterwood, salvage cut), and machinery. Altogether, this network encompasses a large gradient of ecological, technical and financial conditions, which provides high potential for scaling-up the results and evaluate how the strategy tested here could apply to other contexts.

Additional information

This example is based on a research project jointly led by the Canadian Wood Fibre Centre of Natural Resources Canada (NRCan) and the Research Centre on Renewable Materials, of Université Laval. The Canadian Wood Fibre Centre is a governmental research organization which mandate focuses on the development and uptake of end-user relevant wood fibre research. The Research Centre on Renewable Materials is an academic research group which mission is to provide training and conduct research in the field of solid wood and wood/non-woody fibre-based renewable products to meet present and future environmental and economic challenges. The project also includes collaborations with private energy and forest companies, forestry contractors, the provincial government of Québec (Ministère des Forêts, de la Faune et des Parcs, MFFP), and NGOs.

The project is financially supported by NRCan, the Natural Sciences and Engineering Research Council of Canada and the Fonds de recherche du Québec – Nature et technologies. The project receives in-kind support from MFFP, Université Laval (Forêt Montmorency), Forêt communautaire Hereford, Société d'Exploitation des Ressources de la Vallée, Coopérative forestière de la Matapédia, the Coopérative forestière de St-Elzéar and Produits Forestiers Arbec.

Publication:

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The domestic energy strategy in Niger

Wata Issoufou (Project Coordinator RFP-GDT), FAO, Niamey

Headline

The Niger Domestic Energy Strategy aims to develop controlled local rural markets for wood energy to enhance rural development and increase forest cover.

Outline

Geographic location:	Type of example:	Status:
Niger	Policy	The experience of rural markets that began in the 1998s faded around 2005 with the end of the Natural Forest Management (FAFN) project.

Introduction

The Niger Domestic Energy Strategy (SED) derives its substance from a long reflection led by the country in the management of natural resources and rural development, with the support of its development partners. However, the reform, as it was designed and implemented, encompasses issues related to the sustained supply of wood energy and wood substitutes (oil, gas, etc.) by encouraging practices that are concerned with preservation of the environment.

The implementation, in the 1970s and 1980s, of two major forestry projects in Niger (Project Use of Forests and Soils, PUSF, funded by USAID; and *Projet Forestier du Niger*, jointly funded by the World Bank and Agence Française de Développement), helped to fuel internal thinking in the Environment Department and to draw several lessons in terms of forest resource management.

The content of the SED was supported by principles favouring a decentralization of the control of the forest exploitation which concretizes the transfer of the responsibilities of management for the benefit of the rural populations compared to the resources of their soils on the one hand and on the other hand the need to change the role of the forest agent, and therefore of the State if we want real participation by grassroots communities

Wood energy, it should be remembered, was (and remains) the basic household fuel and a basic necessity for fast growing urban populations. Dynamics of exploitation of forest resources in the absence of a sustainable management system proves to be very detrimental to these resources

The approach consisted in setting up rural wood markets with the involvement of local communities which have a monopoly on the exploitation and marketing of wood energy.

Furthermore, the SED also incorporated the refinement of the wood energy forest taxation, with:

- A decreasing differential taxation between uncontrolled exploitation (taxed at level 3) and exploitation by rural markets (classified into two types, namely oriented rural markets taxed at level 1.5 and controlled rural markets taxed at level 1);
- Within rural markets, a device for collecting the tax from the rural market which allows better visibility of the tax and optimal development of the resource; and
- Production of coupons justifying payment of the tax.

Thus, alongside the rural markets known as uncontrolled essentially based on the exclusive and industrialized collection of dead wood, we are timidly witnessing the establishment of controlled rural markets where the management of forest areas is underpinned beforehand by management plans accompanied by plot plans of rotary exploitation with cutting quotas.

Unfortunately, this latter approach to the different massifs is not systematised, and the absence of monitoring will lead to abuses harmful to the sustainable management of resources.

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

An evaluation of the strategy in Niger is noted in Bertrand and Montagne (2009):

- Increase in the incomes of rural populations;
- Increase in effective contribution of wood energy to the incomes of the populations and to local development; and
- A normally constituted and functional local management structure in all rural markets.

Positive impacts for forest landscape restoration:

An increase in forest cover in villages where management rules and quotas are strictly respected.

Co-benefits:

Although the setting up of rural markets is expensive (see challenges below), there are many co-benefits:

- Impacts on local rural development;
- Reduction of seasonal or long-term rural exodus and increased income of rural populations;
- Significant reduction in the number and intensity of conflicts; and
- Improved social image and status of loggers.

Prospects

Reasons or main drivers:

The development of the SED was driven by the following factors:

- Exploitation of resources is carried out in an uncontrolled manner and according to a logic resulting in the over-exploitation of the most accessible areas;
- The exclusion of the communities at the base of the logging system and the marketing of wood; and
- The risk of compromising the needs of the populations for forest resources, particularly wood, and the already weakened balance with the natural environment.

Key enabling factors:

- The development of a planning tool intended to guide the levies of the spatial point of view and possibilities of forest formations.
- The empowerment of rural populations for the management and control of the exploitation of the resources of their land, with the cutting system under management and the issuing of cutting permits to operators foreign to the abstraction areas.
- Improving the capacity of public authorities in terms of orientation and coordination in the field of domestic energy.
- The promotion of alternative fuels to wood, in order to reduce the pressure on the natural environment, particularly the peri-urban one.

Main challenges encountered:

The cost of setting up and maintaining rural markets is very high. The cost and duration are estimated in Table 3.

Table 3 Cost of setting up a rural market

Type of rural market	Number people per day	Duration (days)	Total cost (F CFA)
Oriented	26	55	1 000 000
Controlled	33	97	2 250 000

Source: Bachir, 2005, p. 24

Further challenges are:

- The necessary involvement of all social groups;
- The establishment of management structures for all the forest areas before the creation of the rural market (and the transformation of rural markets from oriented to controlled form); and
- The need for capacity building for forestry agents and local management structures.

Additional Information

Publications:

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Bertrand, A. and Montagne, P., 2009. Domestic energy strategies and sustainable management of forest resources in Niger and Mali: management, public property regime, forest taxation and forestry assessment. *Bois et Forêts des Tropiques*, (301), pp.83-97.

Positive trends in key fibre source forest landscapes of the US South

Richard Peberdy (Head of Sustainable Forests) and Andy Dugan (Senior Forest Industry Specialist), Drax Group

Headline

Monitoring reports of forests used for biomass procurement for pellets suggest an increase in forest area, growth and surplus, and a consequent increase in forest carbon stock, whilst there was no evidence of abnormal fluctuations in prices for forest products. Differences in geographical locations show the need for diligent monitoring in every catchment area to ensure sustainable procurement.

Outline

Geographic location:	Type of example:	Status:
US South – Mississippi, Louisiana, Arkansas, North Carolina and Virginia	Private sector sustainability monitoring reports	Active since 2013

Introduction

Drax Group sources and uses 7 million tonnes of wood pellets p.a. at its power station in N Yorkshire, UK. Drax also has 3 of its own pellet production facilities in the US South, in Louisiana and Mississippi, which produce c1.5 million tonnes p.a. Third party suppliers (predominantly in the US, Canada and the Baltics) provide the balance. Integral to the sustainable use of wood pellets is extensive due diligence prior to procurement, and then ongoing monitoring of supply areas to ensure positive forest and climate outcomes. Over the last 12 months Drax has been working on a pilot project to better understand the impacts of wood pellet demand on forest resources, markets and management trends in the catchment areas around industrial pellet mills. This paper summarises 3 monitoring reports (Catchment Area Analyses) from the US South. The first stage of this research is complete, and the results are available in the public domain.

The US South provided 4.6 million tonnes of pellets to Drax in 2019 (65 percent of total supply). The first phase of this analysis looked at 5 mills in the US South that provided almost 30 percent of total fuel supply in 2019. These mills are located in 3 catchment areas: Chesapeake in North Carolina and Virginia with a cluster of 3 pellet mills owned and operated by Enviva (Hood Consulting, 2020); Morehouse in Louisiana (which also sources into Arkansas) owned and operated by Drax (Forisk Consulting, 2019), and Amite in Mississippi, also owned by Drax (Hood Consulting, 2019).

Pellet plants commonly use a mix of feedstocks (see Drax (2020a) for detailed reports of all Drax feedstocks). These mills have used varying proportions of both primary feedstocks (thinnings, low grade roundwood, tops and branches) and secondary feedstocks (sawdust, shavings and chips from sawmills). The feedstock mix is affected by market conditions, and over the past few years the trend has moved towards more sawmill residuals as the sawmilling sector recovered after the 2008

Recession. Research has shown that, in terms of carbon outcomes for forest biomass, feedstocks are not universally good or universally bad. Using the same feedstock (e.g. low grade roundwood, or sawmill chips) can lead to different outcomes in different scenarios and geographies. The aim of this analysis and monitoring process is to identify trends – whether positive or negative - in forest area, inventory, growth and market dynamics by using publicly available data sources and targeted analysis.

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for forest landscape restoration:

Sustainable biomass demand is a significant contributor to multiple positive outcomes for forest landscape restoration, these include:

- Ensuring that forests stay as forests; that owners have positive incentives to manage their land, retain forest areas and invest in better management. Sustainable biomass demand achieves this through the provision of markets for low-grade by-products (thinnings, low-grade pulpwood, harvesting residues and sawmill residuals). These markets increase revenue generation for owners, incentivise the increased production of saw-timber (through thinning and markets for mill residuals), help re-establishment of future forests (utilising harvesting residues), and improve the profitability of forest management and ownership compared to other land uses.
- Ensuring that the growth, productivity and health of the forest landscape is maintained or improved; encouraging the production of a higher proportion of structural timber for long-life wood products. The additional market demand and revenue is one of the ways in which biomass contributes to this outcome, but responsible and sustainable biomass markets also contribute in other ways. For example, adopting stringent biomass sourcing policies that include requirements to sustain forest productivity and health (Drax, 2020b). The criteria in this type of policy is a step beyond the traditional forest industry. Actively monitoring and analysing the trends and impacts in catchment areas and supply chains for biomass procurement, and transparently reporting this data, is also a positive step beyond conventional wood product sourcing. If these trends and impacts are identified and managed responsibly, with appropriate remedial action when required, then the outcome for the forest landscape is positive.
- The biomass sector is a significant contributor to the development of best management practice and improved forest level certification and auditing, far in excess of its scale. The Sustainable Biomass Program – a dedicated and robust independent certification body – has been developed to audit and drive improvement in sustainable performance in the biomass sector.

Increase in forestland

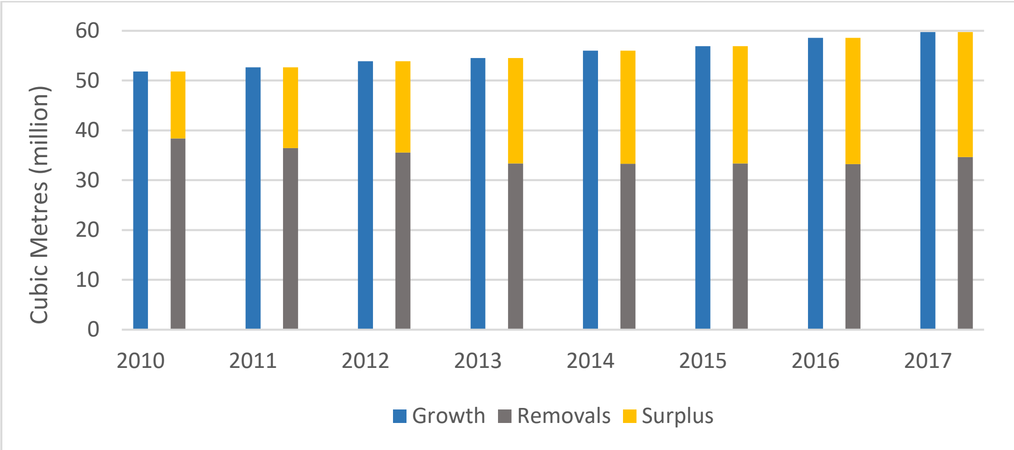
All of these catchment areas are heavily forested (63% of the land cover is forestland), with the majority of this forest area classified as productive 'Timberland' (97%). The analysis shows that the forest area has increased in each catchment area between 2010 and 2017 and by a total of 285 000 ha. The 3 Chesapeake mills began operation in 2012 and the Amite and Morehouse mills in 2014. Forest

Inventory and Analysis (FIA) data shows no evidence of deforestation or a reduction in forest area since these mills began operation. All 3 areas have a significant upward trend in total forestland.

An increase in growth and surplus

The average annual surplus of growth compared to removals in these 3 studies was 20.7 million m^3 for 2010-17. In 2019 Drax sourced 2.1 million tonnes of pellets from these catchment areas, the equivalent of approximately 4.5 million m^3 of wood raw material. This wood fibre represented just 0.4% of the average growing stock volume and 8% of the average annual growth (2010-17) (see Figure 3).

Figure 3 Change in growth, removals and surplus between 2010 and 2017 in the 3 catchment areas

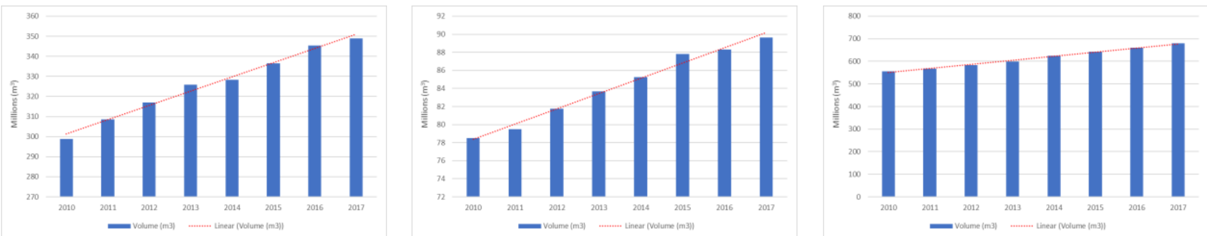


Co-benefits:

Forest carbon sequestration

The amount of carbon stored in the forest has also increased substantially. The growing stock of standing volume in the aggregate catchment area increased by 184 million m^3 between 2010 and 2017. This represented an increase in each assessed region of 17%, 22% and 14% in Morehouse, Chesapeake and Amite respectively (see Figure 4). The average annual increase across all 3 catchment areas was a 2.6% total increase in inventory each year.

Figure 4 Changes in standing volume (in m^3) between 2010 and 2017 in Morehouse, Amite and Chesapeake, respectively

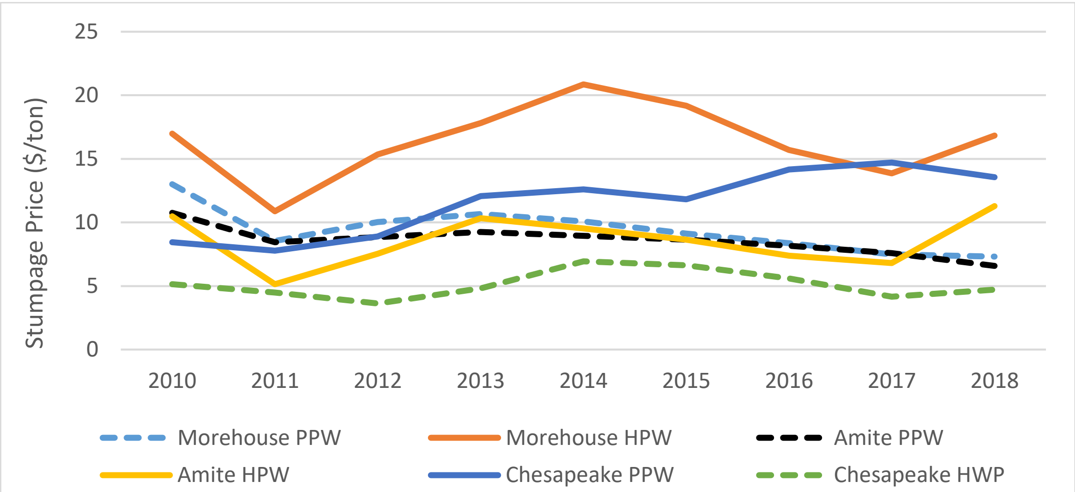


The average annual growth rate across the forest landscape also increased by 7.9 million m^3 p.a. from 2010 to 2017. This increase can be a function of the age class, but it is also a reflection of improved management (better quality planting, fertilisation, weeding and thinning all leading to improved growth and more saw-timber production). Whilst improvement in management has been in evidence for several decades, markets and the revenue from them are required to maintain and continue this process. Over the same period, harvesting removals declined 3.7 million m^3 p.a. despite an increase in wood pellet demand for Drax of around 4.5 million m^3 p.a. (based on 2019 supply data). This decrease reflects a downturn in traditional markets for wood products, in particular the pulp and paper sector in these localities. Wood pellet demand has played a substantial role in compensating for this loss of traditional demand. In the absence of the wood pellet market, forest owners would have fewer opportunities to thin their mid-rotation stands, producing less saw-timber and less revenue at the end of the rotation. There would also be limited markets for harvesting residues and low-grade pulpwood, reducing total revenue and increasing the costs and difficulty of establishment for the next generation of forest stands. In some cases, owners would convert their land to non-forest use if viable local markets do not exist.

<u>No abnormal deviation in price</u>

There are many factors that affect the stumpage price that an owner may receive: weather patterns and extreme events, fluctuations in end-product demand (e.g. demand for structural timber for housing construction or demand for paper products.), localised competition for fibre and proximity to markets and operational and transport costs. Annual and quarterly variations are normal in the US South and the trends shown in Figure 5 reflect the long-term normal fluctuations.

Figure 5 Changes in stumpage price between 2010 and 2018



(NOTE: Morehouse and Amite source PPW and Chesapeake predominately utilises HWP)

Each individual catchment area report provides a detailed analysis of price trends and possible consequential impacts associated with biomass demand. There is no evidence that biomass markets have compromised or negatively impacted other wood users, largely due to the substantial surplus of available wood fibre (the primary reason for locating pellet mills in this region), and also to the low paying capability of the pellet sector which does not allow competition with any other markets. The pellet mill is at the lowest end of the spectrum in the market for wood products.

Prospects

Reasons or main drivers:

The Drax Group purpose is to enable a zero-carbon, lower cost energy future. To do this, Drax need to fully understand the carbon consequences of our demand in the forest landscapes from which Drax source. The most up to date science tells us that good carbon outcomes come from avoided deforestation, sustained capacity to store and sequester carbon, and avoidance of diversion of woody fibre from long term carbon stores such as sawn timber. Our 'Catchment Area Analysis' program is designed to monitor these aspects and will cover all our sourcing geographies when completed in the next 18 to 24 months.

Key enabling factors:

The availability of robust data, including forest area, inventory, type and levels of demand and price is critical to the monitoring process and understanding clearly the impact of wood pellet demand. The US South has robust forest data through the publicly funded FIA programme, and there is also good information regarding demand and prices over the required timescales.

Considering the forest response to the demand, the particular circumstances of the US South are important. This heavily wooded landscape is capable of abundant growth – average productivity measured as yield per ha has more than doubled over the past 50 years. Growth significantly outpaces demand – there is a substantial surplus of wood growth compared to removals and an increasing inventory of carbon stored in the forest. There has also been a significant increase in harvesting and production of solid wood products. This has been one of the key drivers of increased investment in forests, and the active management that has led to improved carbon sequestration and storage. Though it seems counter-intuitive, the data clearly shows that active forest management increases growth and carbon storage (Forest2Market, 2017).

The well-established system of private ownership in the US South means that both private and corporate owners are able to benefit from investment in forests. There is a large cohort of academics and professionals who have studied and understood how US forests grow, and well-established and effective out-reach mechanisms to share knowledge with forest owners.

Main challenges encountered:

The two biggest challenges are: defining the catchment area around each mill and the availability of up to date reliable data. Forest markets are micro-regional and vary considerably even within the same country or region. The concentration of forest resources, distribution, size and competitiveness of established markets and the viability of transport logistics all influence the size and shape of a mill's catchment area. This may also change over time as markets fluctuate, forests mature, or the feedstock mix changes. Establishing a credible and realistic catchment area for current and future monitoring is a key aspect of this process. Whilst adverse impacts have yet to be detected, because landscapes are sources for many users, it may be challenging to ascribe adverse outcomes to one or more specific operators.

Potential for scaling-up and replicability:

On the collection of forest information, different geographies will have varying sets of information available, however, Drax expects it to be possible to conduct meaningful analysis in all supply regions.

Not all geographies have forest landscapes with biological, structural or cultural capacity to respond to increased demand in the same way as the US South, though many do. Nations such as Finland, Sweden and others have demonstrated that as demand increased over time, so has the amount of carbon stored in forests. A common factor in these examples is the connection between the use and sale of wood for energy as part of the provision of a range of wood products, and positive forest owner responses (keeping forest as forest, sustaining storage and sequestration capacity, no adverse market displacement).

The analysis summarised here is focussed on carbon outcomes. However, impacts on biodiversity, and on the communities that live and work in these forests, is of equal importance. Drax is committed to monitoring these as well. Over the coming 12 to 24 months Drax will report on these aspects too.

Additional information

Drax are working with the Earthworm Foundation to collate and publish data through a programme called 'Healthy Forest Landscapes'. This project will seek to incorporate remote sensing data, and 'big data' - both technologies of increasing interest in this sector.

Link: https://www.drax.com/

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Bioenergy production from biomass

Initiative for the production and distribution of sustainable charcoal and feedstock in Togo

Koffi Elom Towodjo Dzotsi, Mouvement Togolais pour le Salut des Peuples (MTSP)

Headline

The production and use of bio-charcoal, made from waste from the agricultural and forestry sectors, as well as bush straw, preserves the forest, revalorizes a generally wasted raw material, and can have a positive impact on the purchasing power of the citizens and on the environment.

Overview

Geographic location:	**Type of example:**	**Status:**
Plateaux region Atakpamé capital Population 1 425 199 (est. 2006) Density 84 ppl/km^2 Area 16 975 km^2	Project	2016 – 2017 (pre-study)

Introduction

Charcoal is the basic energy resource for the majority of Africans. In Togo, the share of energy biomass (firewood, charcoal, plant waste) amounts to 75 percent of national total final consumption, compared to 19 percent for petroleum products and 6 percent for electricity (DGE, 2018), produced largely from rural traditional production, they come from unmanaged forests. The resulting deforestation is massive, bringing with it climate change and an inexorable rise in the cost of charcoal. To fight the problem of traditional charcoal production is to fight the problem of deforestation at its origin.

The project is located in Togo, in the plateaux region, more precisely in the prefecture of KLOTO Kpalimé, in the village of Gadjagan (15 km South West of Kpalimé). The region is characterized by its mild climate and lush vegetation. Kpalimé is one of the most important cities in the region and is located in the South West, approximately 120 kilometres from Lomé, and is at the centre of the coffee and cocoa region. The area surrounding the city is lush and fertile, surrounded by thick wooded hills, deep valleys and small peasant villages. The landscape remains green even during the dry season. Despite intense agricultural development, the Kpalimé region still retains some of the most beautiful forests in Togo, where mahogany, Wawa and Iroquos abound.

The “Bio Charcoal” project started in January 2017 with one idea in mind: to make a new sustainable and economical charcoal to limit the ecological disaster caused by the consumption of charcoal and the uncontrolled cutting of wood resources. ‘Bio charcoal’ (sometimes called ‘green charcoal’) refers to the charcoal produced from renewable raw materials. For this project, these raw materials are waste from the agricultural and forestry sectors, as well as bush straw that is usually burnt. Compared to traditional charcoal, bio charcoal is:

- An ecological alternative: it preserves the forest.
- A sustainable alternative: The revalorization of a generally wasted raw material.
- A competitive alternative: On an industrial scale, Bio Charcoal can be more competitive than traditional charcoal, and have a positive impact on the purchasing power of the citizens and on the environment.

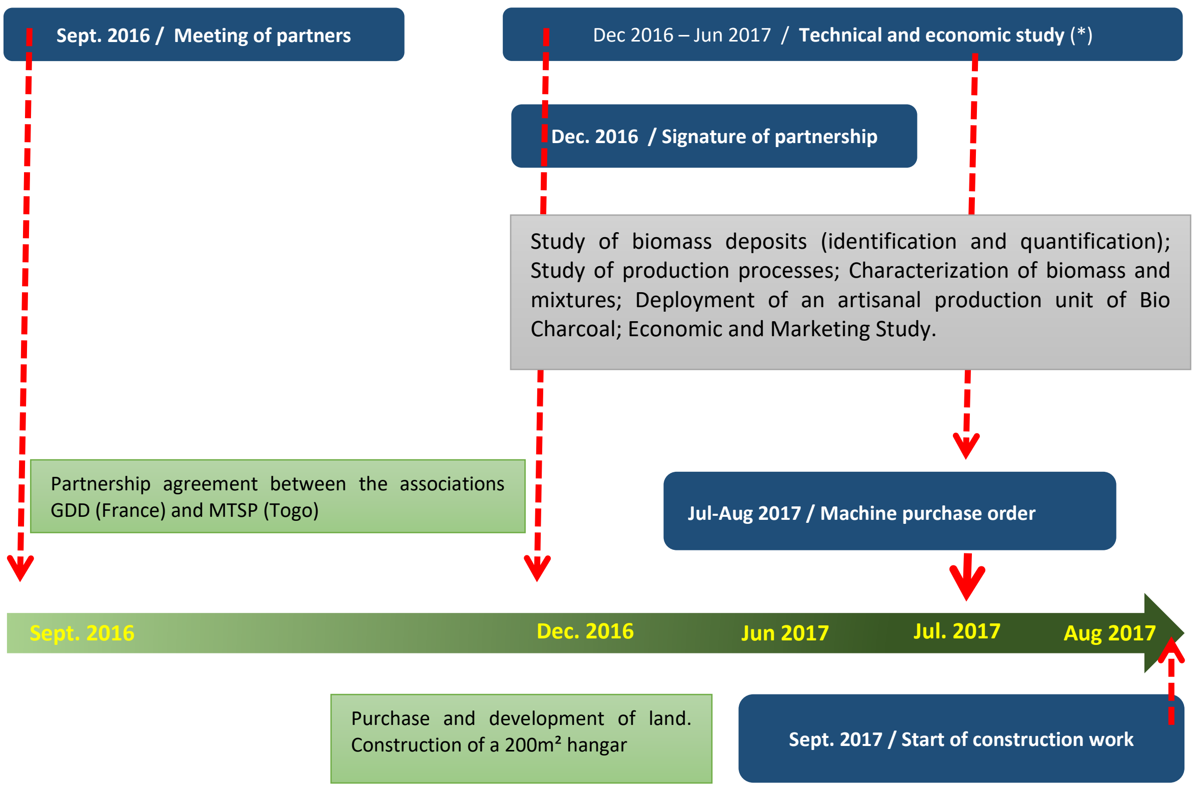
The project is the result of a preliminary study carried out by the Togolese association '*Mouvement Togolais pour le Salut des Peuples'* (Togolese Movement for the Salvation of Peoples – MTSP), with technical and financial assistance of the French association '*Graine de Développement*' (GDD).

It began with an analysis of the charcoal and wood-energy sector in Togo. This led to the discovery of a solution to the problems of deforestation through a first experimental phase in which a "prototype" of charcoal made from agricultural biomass – bio charcoal – was obtained.

This laid the foundations for a semi-industrial production which started in late 2017. Construction started in 2018 and ended in 2019. Today, the association is embarking on the search for funds for the construction of the first industrial production unit in the country which should ultimately allow the production of more than 1 tonne per day of bio charcoal. The final objective being in a few years to set up profitable industrial production.

Bioenergy production from biomass

Chronogram of the project:



The pre-study carried out between December 2016 and June 2017 made it possible to study the technical viability of the production of Bio Coal, to verify the biomass deposits, and to verify the economic viability of the project. During this study, technical and human resources were used:

Construction of a traditional dryer, purchase of a briquetting press, construction of a grinder

Construction of a press and craft ovens

Construction of a technical room

<u>*Human Resources*</u> :

- 1 chemical engineer (4 months); 1 engineering and arts student (6 months)
- 1 senior renewable energy consultant (9 months); 1 local renewable energy entrepreneur (9 months)
- Several technicians (production, harvest)

It should be noted that this pre-study was set up as a prelude to the pilot project. The pre-study was successfully completed, and the pilot project also started successfully (see chronogram above).

Sustainable Wood Energy and Forest Landscape Restoration Relationships

The degradation of forest resources is a major environmental problem that Togo must face. The causes are slash and burn agriculture and unsustainable logging of wood energy. According to FAO (Food and Agriculture Organization), Togo loses 4.5 percent of its forests each year, one of the highest rates of deforestation in the world. The wood energy sector alone accounts for a third of these losses.

Only three sources of energy are used as main energy by Togolese households: charcoal has been used as main energy source by 56 percent of households, firewood by 35 percent of households and butane gas by 8 percent of households. Other sources of cooking energy such as petroleum, electricity and agricultural residues are rarely used as the main cooking energy by households.

Bio Charcoal was chosen for this project to solve this problem and produce positive effects on the sustainability of the wood energy value chain and the Restoration of Forest Landscapes.

Solutions exist to produce charcoal not from trees but from unused agricultural biomass: rice husks, bush reed, teak branch, palm fronds, peanut bark, bamboo, corn stalk etc (Figure 6). Any woody material can easily be used to make Bio Charcoal.

Figure 6 Agricultural biomass for charcoal production: Reed, Rice husk, Teak branch, palm nuts, Palm fronds and Coffee rind

Positive impacts for sustainable wood energy and forest landscape restoration:

Given the quantity, availability and diversity of the existing biomass, charcoal produced on an industrial scale would be very competitive (given its calorific value) and very accessible to the population. This would persuade the population to switch to this new type of charcoal which would allow the natural flora to grow according to its normal cycle, thus allowing the restoration of the forest landscape and having a positive effect on the wood energy value chain.

Co-benefits:

Through the transition to Bio Charcoal, change in behaviour at the level of the base population could be achieved, which would produce environmental benefits (timely cutting of trees, regrowth of forests, clean environment, stable rainfall, etc.). Many socioeconomic advantages would emerge from these positive effects on the environment, namely: increase in the volumes of agricultural production, new trade due to the sale of Bio Charcoal, trade in biomass which before was burnt, and many others.

Prospects

Reasons or main drivers and key enabling factors:

The reason for the implementation of this project focuses mainly on the following issues:

- Recycling of unused agricultural biomass;
- Fight against deforestation and environmental deterioration;
- Political will of those responsible for the environment; and
- Energy to put an end to the anarchic exploitation of wood fuels.

Main challenges encountered:

Technology is not a problem in such a project, it has existed for several years and continues to evolve in the right direction, it is enough to have the necessary funding to buy them. However, the main problems arise on several other levels, namely at the human level due to tenacious habits but also from the point of view of production with high production costs and a non-existent market for agricultural residues:

- At a first glance, it is difficult to make the Bio Charcoal sector profitable as transport and electricity costs are high in a country like Togo. (Solutions are possible thanks to the installation of solar panels or by reducing the volume of raw material transported by grinding it directly in the fields rather than in the factory.)
- Rarity of the rains leading to mediocre productions.
- The bio charcoal sector being non-existent, it is difficult to succeed in fixing a price on the raw material, namely a biomass thrown away for decades and which nobody suspects it of any market value.
- One of the project's problems, and probably no less important, consists in raising awareness among farmers, organizing collection points, setting a price for the raw material to bring them additional income. It is an ant's work given the high number of small producers and to achieve this work a possible axis is to address directly to the farmers' groups which are already present in the villages, they are privileged intermediaries to achieve this.
- For decades, Togolese have known how to recognize quality charcoal at first glance. In addition, old habits die hard in this country of traditions. Therefore, acceptance of this new product, even if it is environmentally friendly, is difficult. One possible solution is the price, if a product of similar quality is offered at a lower price then everything suggests that it will be strongly accepted despite stubborn habits. However, in order for the product to be cheaper than traditional coal, it requires a subsidy until it becomes profitable.
- Now the biggest and most serious problem is the financing and the tax exemption of the company. (The factory is profitable only on an industrial level, but at this level the large machines are expensive when not bought on the Chinese market.)

Potential for scaling-up and replicability:

- Unlike many bio charcoal projects around the world, this approach is designed to be a scalable model which allows it to be replicated in several places across the country and even in neighbouring countries.
- The semi-industrial pilot project is a "test" factory, which must be thought of from the start as a profitable enterprise which will function without subsidies in the long run. Produced industrially, bio charcoal can be very profitable, but must have industry funding in its infancy.
- The only condition for the dissemination and replication of this model is availability of funds. The project was a pilot project which studied all the possibilities of production in all regions of Togo, the biomass available in all regions and the positive impact that this could have on the environment, especially in areas near the Sahel where deforestation is very pronounced.

Additional information

MTSP is a Non-profit organisation (receipt N ° 0921 / MATDCL-SG-DLPAP-DOCA) that has been operating since 2011. It has 21 Members and relies on private investment funding.

Support for the promotion of the "Casamance improved kiln" in Togo

Dr. Jérémie Kokou Fontodji, Forest Research Laboratory, University of Lomé

Headline

The proliferation of the Casamance improved kiln for charcoal production, which increases efficiency compared with traditional charcoal kilns by over 16 percentage points, could save 2.2 million tonnes of wood per year in Togo. This would reduce deforestation, increase revenue for charcoal producers, and reduce GHG emissions in the forestry sector.

Overview

Geographic location:	**Type of example**:	**Status**:
The project is carried out in the 5 economic regions of Togo (West Africa)	Project	2019-2021 (36 months)

Introduction

The use of traditional kilns in Togo is highly inefficient, with the consequential negative impacts on forest resources, GHG emissions and livelihoods of rural populations. The casamance improved kiln is a type of modified earth kiln with greater efficiency than its traditional counterparts thanks to a central chimney.

This project, a part of the ProDRA program in Togo, aim to diffuse the Casamance improved kiln technology to overcome these problems. It is currently training 1 500 charcoal producers on the using of the Casamance improved kiln and is raising their awareness of reforestation with a wood-energy vocation with pilot reforestation. The mains objectives are to:

- Reduce deforestation and increase carbon sinks;
- Increase revenue for charcoal makers; and
- Reduce GHG emissions in the forestry sector.

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

The Casamance improved kiln increases the efficiency of carbonization up to more than 26 percent while the traditional kiln has a yield of only 10 percent; which means that the demand for wood energy can be satisfied with fewer resources. The project on the Casamance improved kiln makes it possible to sensitize charcoal producers on energy efficiency and to strengthen their capacity to use this technology.

Positive impacts for forest landscape restoration:

If the Casamance improved kiln became widespread in Togo, this would make it possible to save 2.2 million tonnes of wood per year, which would constitute increased carbon sinks and retain the other benefits of the forest (Fontodji, 2015).

Co-benefits:

The widespread of the Casamance improved kiln in Togo would make it possible to avoid 800 000 tonnes of CO_2 per year (Fontodji, 2015). This is a real mitigation tool that is directly linked to the NDC and REDD+ in Togo.

From an economic point of view, the Casamance improved kiln generates added value for the charcoal producers. With the traditional charcoal kiln, the charcoal producing activity is a huge loss but the charcoal makers do not realize it because they often do not have an operating account and do not take into account the cost of wood and labour. An example comes from the community forest of Alibi 1 (put under management in 2018 with the support of GIZ) in the Central region of Togo; if the Casamance kiln is used for the exploitation of wood energy in the first annual cutting of the forest, the net operating profit is 1,770,850 CFA francs versus –592,250 CFA francs for the traditional charcoal kiln (Table 4). Given the huge improvement in profits from net negative to net positive balance, the Casamance improved kiln could be a leverage for rural development.

Table 4 Comparison of the net benefits from the exploitation of wood energy using traditional and Casamance kilns in the community forest of Alibi 1

	Units	***Traditional***	***Casamance improved kiln***
Total revenues	*F CFA*	*2 175 000*	*4 945 000*
Total costs	*F CFA*	*2 767 250*	*3 174 150*
Net profits	*F CFA*	***- 592 250***	***1 770 850***

Source: GIZ-Togo, 2019.

Prospects

Reasons or main drivers and key enabling factors:

Wood energy represented 75 percent of the national energy balance in 2018 and constitutes the main source of domestic energy for more than 90 percent of Togolese households. The techniques of carbonization of wood energy are very inefficient with yields on the order of 10 percent. The current demand for woody biomass for energy in the country is 2.5 times higher than the actual sustainable offer and this is a source of huge losses of forest resources[1].

In recent years, the Togolese government has become aware of the importance of wood energy and its impact on forest resources and the climate. This led to the design and implementation of the ProDRA program with the support of GIZ. Component 3 of ProDRA concerned the modernization of the wood-energy sector. Between 2013 and 2016, the implementation of ProDRA component 3 made it possible to carry out pilot reforestation with a wood-energy vocation, and to demonstrate the effectiveness of the Casamance improved kiln to fight against deforestation. Since the results of ProDRA component 3 have been very satisfactory, the AMCC+/PALCC project funded by the European Union has integrated the scaling up of ProDRA component 3 achievements. This is why, at present, a component of the AMCC+ project is devoted to the promotion of the Casamance improved kiln in the 5 regions of Togo. This project is currently training 1 500 charcoal producers on the using of the Casamance improved kiln and is raising their awareness of reforestation with a wood-energy vocation with pilot reforestation.

Main challenges encountered:

The main difficulty is the insufficient funding to extend the use of the Casamance improved kiln to the majority of charcoal producers and facilitate their access to the equipment of the Casamance improved kiln.

Another difficulty is that the charcoal producers show the will to carry out reforestation with a wood-energy vocation, but they do not have capacity to carry out the reforestation techniques.

Potential for scaling-up and replicability:

The Casamance improved kiln is economically very viable. As seen above in the example of the community forest of Alibi 1, the improved technology makes the charcoal production activity profitable.

The Casamance improved kiln is very easily managed by the charcoal producers and easy to replicate. Charcoal producers trained on this technology by different projects in Togo easily replicate it after the training. The Togolese government's perspective is to scale-up this technology throughout the country as part of the AMCC+ project.

[1] Data from Ministry of the Environment and Forest Resources (MERF), Togo (2017)

Additional information

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Sustainable charcoal production in Choma, Zambia

Svea Senesie and Vincent Ziba, Forest and Farm Facility (FFF), FAO

Headline

The formation of associations of charcoal producers can improve dialogues on important issues – such as policy, pricing, harvesting and manufacturing methods – thus helping to improve the charcoal value chain.

Overview

Geographical location:	Type of example:	Status:
Choma district, Zambia	Project	Ongoing

Introduction

Zambia is a land locked country surrounded by other countries such as Democratic Republic of the Congo in the northern part, Malawi on the eastern, on the southeast by Mozambique; on the south by Zimbabwe, Botswana, and the Caprivi Strip of Namibia; and on the west by Angola. It is about is 752 614 sq km in size and the capital city is Lusaka.

Zambia has approximately 60 percent of its land area forested. However, the rate of deforestation is one of the highest in Africa between 250 000 to 300 000 hectares of land per year. Charcoal production is one of the many drivers of deforestation. However, access to electricity in rural and urban areas is estimated at 3.2 and 49.3 percent, respectively, and Zambia relies on wood fuel (including charcoal) as the main source of energy for over 75 percent of energy needs (NJP 2010). An estimated 700 000 tonnes of charcoal is consumed annually and 85 percent urban households are reported to use it (AFREC, 2011).

The Forest and Farm Facility (FFF) is working in Choma district of southern province about 300 kilometres away from the capital city Lusaka. The project is among other objectives supporting sustainable charcoal production and other wood fuel value chains. The FFF believes in organised producers as major drivers of change. The project in Choma has mobilised 600 producers into 40 groups working to improve the charcoal value chain.

The FFF has facilitated the formation of an association with the 600 producers to enable the producers/traders in the charcoal value chain to come up with a discussion platform and opportunities for meaningful dialogue and come up with the way forward on contentious issues like, policy, pricing, harvesting and manufacturing methods.

As part of this project, improved charcoal production technologies are also promoted, such as the drum kiln shown in Figure 7 (left).

Figure 7 Improved methods (left) and traditional methods (right) for charcoal production

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

The organisation of Charcoal producers/traders into an association is expected to benefit the wood energy value chain through the adoption of sustainable means of harvest and production and a reduction in the illegal trade in charcoal.

The associations also enhance the relationship between the producers/traders and government forest department (FD) through dialogue, which will lead to increased regulation efficiency by FD through the association. The associations also provide improved contact time between FD and the producers for training in sustainable methods.

Positive impacts for forest landscape restoration:

The traditional methods of charcoal production currently have a recovery rate of around 10 percent. Improved methods being promoted currently using a drum kiln, which has over 20 percent recovery rate.

Currently a participatory Grantee system is being promoted to allow traceability of sustainably produced charcoal.

Given these improvements in the sustainable harvest and production of wood fuel and the reduction in illegal trade in charcoal, the outputs of the project are also expected to reduce deforestation rate in Choma and surrounding areas.

Co-benefits:

The FFF is empowering charcoal producers with improved technologies of production and harvesting, which will improve efficiency in charcoal production. This will have benefits by reducing net GHG emissions, as well as reducing illnesses caused by the production and utilisation of charcoal due to carbon monoxide through improved technologies.

Improved charcoal production would require the following additional cost to the producers: cost of improved kilns, packaging and labelling with a green certified logo (approximately USD 10 per bag). However, improved revenues would be realised from premium prices of certified sustainable charcoal and through improved efficiency of production from below 10 percent to about 20 percent conversion ratio of biomass into charcoal. This will increase revenues for producers by approximately 30 percent.

Additionally, the FFF has tried to build capacity among the charcoal producers and communities to attain improved business practices and participation in policy engagement. Participation by women was encouraged and facilitated in all capacity development activities, including business training for producer organizations using the FFF Market Analysis and Development approach with at least 50 percent female participation.

Prospects

Reasons or main drivers and key enabling factors:

The traditional methods for charcoal production currently have a recovery rate of at most 10 percent of the biomass, with over 90 percent of the primary resources being lost or wasted. Therefore, there is a great opportunity to improve the methods for charcoal production, with the consequential environmental, social and economic benefits.

Main challenges encountered:

The main challenges encountered are the following:

- Need for a charcoal regulation to promote sustainable charcoal production.
- Inadequate awareness among charcoal producers and other stakeholders on current forest regulations and sustainable charcoal practices.

Inadequate finance and technical support to the public forest administration for effective implementation of the 2014 national policy that encourages sustainable forestry resource management.

Additional information

The Forest and Farm Facility provides direct financial support and technical assistance to strengthen forest and farm producer organizations representing smallholders, rural women's groups, local communities and indigenous peoples' institutions. A partnership between FAO, IIED, IUCN and Agricord, the Forest and Farm Facility is funded by the EU through the FAO-EU FLEGT programme, Finland, Germany, IKEA, Sweden, the Netherlands, and the United States of America.

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Biochar producing gasifier cooking system for enhanced fuelwood efficiency, women's wellbeing and sustainable agroecosystems in Kenya

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Dr. Cecilia Sundberg: Associate Professor, Swedish University of Agricultural Sciences (SLU) and KTH Royal Institute of Technology.
Dr. Ruth Mendum, Associate Director of Gender Initiatives, Office of International Programs, College of Agricultural Sciences, and Assistant Professor of Research, Penn State University.

Headline

Research project that supplied biochar-producing gasifier stoves and training on the use of these cookstoves and biochar to rural farmers in Kwale County, Kenya.

Overview

Geographic location:	**Type of example:**	**Status:**
Kwale County, Kenya. Subsequently replicated in Siaya and Embu counties (selected for representation of diverse landscapes).	Research project	2015-2019

Introduction

Gasifier cookstoves produce heat for cooking through gasification of dry biomass at high temperature and produce charcoal as a by-product, which is used for further cooking or as biochar for soil amendment. Compared to conventional cooking practices, the gasifier is a cleaner cooking option that improves efficiency, and reduces exposure to smoke and need for firewood collection, a tiring and time-consuming exercise. The cookstove is suitable for fuelling with small pieces of wood, such as prunings from agroforestry trees reducing need for collection of forest residues allowing their accumulation into soil organic matter consequently enhancing biodiversity. When applied to soil, biochar helps to improve the crop yields and when used as fuel, households save money on the purchase of alternative fuels. Users, however, have faced challenges with fuel preparation, lighting and reloading fuel, especially when the fuel chars before the food is ready.

This pilot project was under the Biochar-Bioenergy project which ran from 2015 to 2019, working with 150 smallholder farmers in the highlands, lowlands and Coastal regions in Kenya. The project aimed to improve biomass use efficiency and crop yields through adoption of biochar producing gasifier stoves and application of biochar for soil improvement. The first phase of the project involved the piloting of a galvanized Top Lit UpDraft (TLUD) gasifier with 20 farmers in Embu Country. This prototype was found to be unstable and posed burn risks (Njenga *et al.*, 2016), therefore, the second phase of the project responded to these recommendations with the use of an updated TLUD gasifier branded as GASTOV from Kenya Industrial and Research Development Institute (KIRDI).

The GASTOV gasifier

Figure 8 Parts of the 'GASTOV'

(a) An insulated casing with a 5.5 cm x 4.5 cm air inlet with a door (damper) at the bottom that can be regulated at half or full height, (b) a 19 cm high fuel canister in the middle, (c) a charcoal cover (snuffer) used to cool the charcoal by cutting off oxygen, (d) a 6 cm high gas combustion chamber on top as the main burner, fitted with a skirting (e) to hold the pot in position and protect flames from wind and (f) a canister holder.

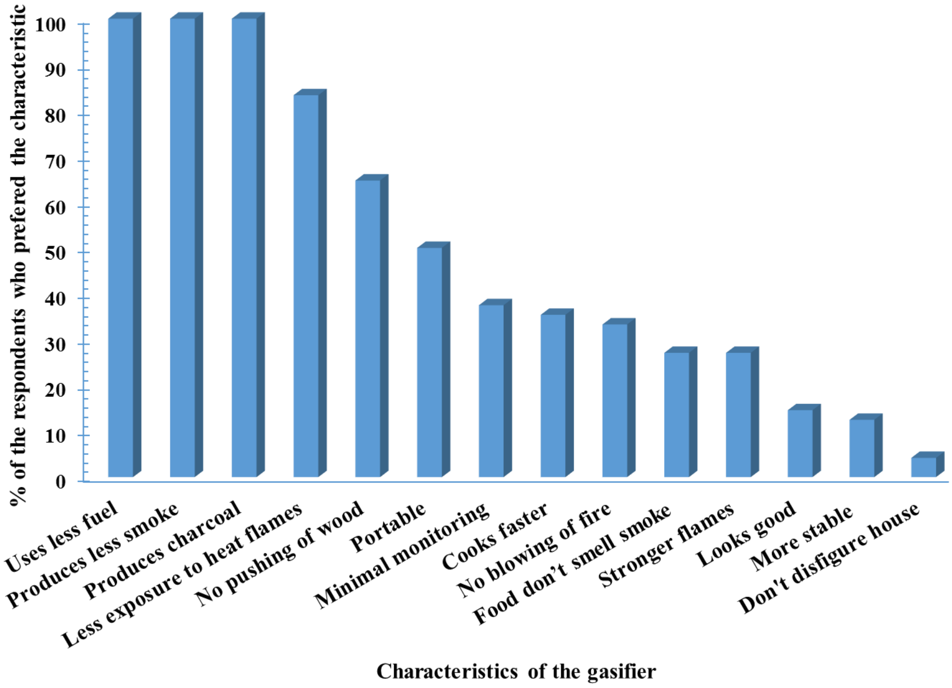
Chopped firewood is tightly stacked in a canister (Figure 8.b) and lit at the top using small pieces of wood and a match stick while outside the kitchen to reduce smoke. The well-lit fuel-filled canister is then held with a holder (Figure 8.f), moved into the kitchen and fitted into the insulated casing (Figure 8.a). The combustion chamber (Figure 8.e) is then fixed at the top and the biomass burns under limited air supply producing energy-rich gases which burn at 700˚C to 1000˚C generating heat which is used to cook. When the flame from the burning biomass goes off, the biomass has converted into char which can be harvested by covering the canister with a snuffer (Figure 8.c) to cut off oxygen and allow it cool down or left to burn to provide heat for continued cooking.

Beneficiary households were issued with a gasifier for free after being trained on its use. After three months of gasifier use, a household survey showed that 96 percent of the Kwale households were still using the stove (Gitau *et al*., 2019a). Most households stacked the gasifier with other stoves. The gasifier was appreciated by the users for the various benefits they observed when using it (Figure 9).

Participatory cooking tests were thereafter conducted with 25 randomly selected households in each of the sites, with 5 households repeating the test with a three-stone open fire for comparison. The tests aimed at determining energy use efficiency, the concentrations of indoor air pollutants in the cooking area during the cooking exercise and biochar production rates.

Since the end of the project in 2019, the farmers are continuing with the biochar production and use on their own.

Figure 9 Characteristics of the gasifier appreciated by Kwale households



Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

Compared to a three-stone open fire, the gasifier cookstove uses 32 percent less fuel when produced char is considered as fuel and 18 percent when char is used in soil amendment at Kwale (Gitau *et al*., 2019b). The char produced was also reported as suitable for cooking (Njenga *et al*., 2017) and hence frequent use of the gasifier could reduce the need to cut down trees for charcoal production.

Positive impacts for forest landscape restoration:

The gasifier uses less fuel reducing the need for firewood collection. As a result, the forest residues are left in the forest where they decompose and nutrients are recycled back into the forest soil enhancing forest regeneration thereby increasing the standing biomass. Furthermore, there is also no need to cut down trees for firewood as the gasifier works well with prunings from on-farm trees and other agricultural residues available.

Co-benefits:

<u>Health benefits</u>

The biochar-producing gasifier cookstoves produce less smoke, thus reducing the negative environmental impacts associated with these emissions, and potentially reducing the health effects from indoor air pollution.

Improved livelihoods

Biochar application to soil increases crop yields by holding nutrients and moisture in the soil hence making them available to the crops for a longer period (Figure 10). For instance, the average maize yield increased from 0.9 Mg/ha in the control plot to 4.4 Mg/ha in the first season of 2017 which was reported as a low rainfall year (Sundberg *et al*., 2020). The increased crop yields consequently means reduced need to buy food hence reduced household expenditure on food. The excess produce, and the produced char, could be sold to raise income.

Figure 10 A woman at her maize plots in Embu, Kenya. Biochar was applied in the plot to the right.

Climate change mitigation

Char production from the gasifier has reduced GHG emissions compared with the production of charcoal in traditional kilns, since the gases produced during carbonisation (e.g. carbon monoxide and other products of incomplete combustion) are burned to generate heat used to cook instead of being released into the environment. Specifically, gasifier use reduces the concentrations of carbon dioxide, carbon monoxide and fine particulate by 41, 57 and 79 percent respectively (Gitau *et al*., 2019b).

Biochar application to the soil sequesters carbon which mitigates climate change. Furthermore, biochar improves the growth of above-ground biomass which are carbon sinks and, if residues are left in the farms, they enhance soil organic matter (Sundberg *et al*., 2020).

Prospects

Reason or main drivers:

The majority of the households in rural Kenya inefficiently use biomass for cooking, leading to high fuel use and high concentration of household indoor air pollutants. The livelihoods of these rural households also primarily depend on farming and with the poor soils, the yields are low hence not benefiting these households. As a result, this project was developed to help improve the fuel use efficiency, reduce collection of forest residues and enhance women's wellbeing. It also aimed to mitigate health risks and climate change through reduction of smoke in the kitchen. Use of biochar for soil improvement was considered as a climate smart agricultural practice for improving farm yields, agroecosystem and landscapes.

Key enabling factors:

Some of the factors that enabled implementation of the project were the: issuing of the cookstove for free, continued training and willingness of the farmers to participate in the project. The witnessing of the fuel saving, reduced smoke, production of char by the stove and improved yields from use of biochar also contributed to the continued use of the technology hence success of the project.

Main challenges encountered:

Some of the main challenges were the functionality challenges experienced with the use of the new stove such as increased labour for cutting firewood into small pieces and need for refuelling when fuel charred before food was ready. In some instances, the male heads (who were not the household cooks) attended the training sessions and failed to pass on the information to the cooks when they went back home and this resulted in stove not being used. The low amount of rainfall received in Kwale during the long rain period of 2017 generally resulted in poor yields, although more maize was harvested from plots where biochar was applied.

Potential for scaling-up and replicability:

This project was carried out as a research project. The concept can be sustainable only if the household owning the cookstove continuously uses it and harvests the biochar. The functionality challenges experienced with use of the stove should be addressed for increased use of this novel cooking system. For scaling-up, the stoves also need to be more affordable for rural households. This can be achieved through training of the local artisans on how to fabricate the stoves at the local level while maintaining the standards. Continuous training and demonstrations to raise awareness on the benefits of biochar producing cookstoves is necessary.

Additional information

This project was implemented by a transdisciplinary team of scientists from various organizations and institutions, which include: World Agroforestry (ICRAF), KTH Royal Institute of Technology; The Swedish University of Agricultural Sciences; Lund University; International Institute of Tropical Agriculture (IITA); Wangari Maathai Institute for Peace and Environmental Studies; University of Nairobi; Office of International Programs, College of Agricultural Sciences, The Pennsylvania State University.

The work was supported by: Swedish Research Councils VR and FORMAS, ICRAF, CGIAR programme on Water Land and Ecosystems (WLE)-Sustaining rural urban linkages and Office of International Programs, College of Agricultural Sciences, The Pennsylvania State University.

Project website: www.biochar.abe.kth.se

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Distribution of bioenergy and by-products

Deployment of biochar technology for efficient production of cooking energy and biochar in Ghana

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Headline

The 'biochar system' includes production of pellets, use of improved cookstoves, and production and use of biochar. It represents a technical solution to address drivers of deforestation whilst increasing bioenergy access.

Overview

Geographic location:	Type of example:	Status:
Central Region of Ghana – Cape Coast.	Project followed by ongoing practice.	Ongoing. Began as a project from 2009 to 2017, from which time it became an activity implemented by ASA Initiative.

Introduction

This project looks to deploy biochar technology in Ghana. This includes the production of pellets from forestry/agricultural residues, improved stoves/kilns for efficient production of cooking energy, and production and use of biochar, a by-product that can improve soil fertility, crop yield and to restore toxic and degraded forestry and/or agricultural soil.

The project develops and promotes slow pyrolysis, low-temperature cooking stoves that use woody and agricultural solid residues (e.g. palm oil kernel shells) or pellets, locally produced from forestry/agricultural residues, thus avoiding the use of wood fuel and saving forests. The process also produces biochar, a carbon-rich by-product; the value chain is therefore called the "biochar system". The system represents a technical solution to address drivers of deforestation hence contributing to FLR whilst increasing bioenergy access.

Biochar systems are scalable and flexible, because they can use various types of solid biomass as feedstock. The technologies are characterized by a high efficiency; a small-scale burner (diameter of 6 inches) can allow for 2 hours of cooking with 1.5 kg of pellets or kernel shells. Stoves produce 70 percent gas and 30 percent biochar.

The biochar itself has multiple benefits, namely:

- Biochar can be buried into the soil as an amendment and fertilizer to improve soil fertility, crop yield and forest growth. Furthermore, due to its high carbon content, it serves as a means for carbon capture and storage (CCS).

- Biochar increases the soil capacity to hold nutrients and water over a long period of time and makes them available to the plants thus allowing for increased yield.
- Biochar is a porous material. Its holes enable air circulation in the soil to improve soil fertility.
- Biochar provides a platform for micro-organisms to grow in the soil.
- Biochar buried in toxic and degraded forest soil has been proven as a successful means to support seed germination, and plant and forest growth, thus bringing forest landscapes back to life.

Figure 11 Degraded land through small scale mining, Biochar treatment of degraded and toxic soil, and Field results after biochar treatment

Sustainable Wood Energy and Forest Landscape Restoration Relationships

Positive impacts for sustainable wood energy:

The biochar system includes technology for converting forestry and agro-waste into pellets as an alternative to wood fuel as a source of energy for cooking. This reduces pressure on forest resources through the use of waste streams, whilst also improving the efficiency of use of biomass. The system also includes the use of a micro-gasifier for burning the feedstock in an efficient way. The syngas produced during the gasification is 100 percent burnt and used as cooking energy, whilst the biochar is buried into the soil to enhance soil quality and fertility and as a means for CCS.

Positive impacts for forest landscape restoration:

The biochar system represents a valuable alternative to the use of wood fuel (charcoal and firewood), thus allowing for a reduced pressure on forest resources. Micro-gasification increases the efficiency of feedstock use compared to traditional stoves or kilns, thus, even if alternative feedstock is not available, the amount of wood needed for cooking is still reduced (wood must first be chipped). Biochar can be used as component of soilless substrates, thus serving in nurseries to grow forest seedlings: tests show that it leads to faster seed germination and forest seedlings' growth. Furthermore, when buried in the soil, biochar has been proven to: be an efficient means for restoring soil polluted by heavy-metals; increase soil water holding capacity; and increase the availability of plant mineral nutrients (e.g. Ca, P, K).

Co-benefits:

The biochar system represents an efficient strategy towards the achievement of the objectives defined under the Paris Agreement. It has dual climate benefits: 1-reducing carbon emission and 2- creating carbon sinks.

Biochar is a highly stable C-rich product; thus it is an efficient means for CCS for a long period of time and can contribute to climate change mitigation. Biochar systems also allow for significant GHG emission reduction compared to the traditional stoves or ways of making fire (e.g. three stone fire).

Prospects

Reasons or main drivers:

Self-motivation coupled with effectiveness of biochar technology and good field results from biochar field trials.

Key enabling factors:

Local availability of residues and/or waste biomass and/or ability to produce waste biomass and biochar system technology.

Main challenges encountered:

- Slow fund raising process for activity implementation
- Inconsistency of rainfall

Potential for scaling-up and replicability:

The practice has potential for replication and scale-up. There is the potential for many businesses for the production of pellets, stoves, and the sale of biochar in agriculture value chains for livelihood improvements.

The biochar technology is simple to replicate under the following conditions:

- Availability of waste biomass;
- Existence of artisanal skills; and
- Willingness and commitment of the local people.

However, financial resources are needed to establish the value chain and allow for market uptake of the technology.

Additional information

ASA Initiative is a non -governmental organization (NGO) that is implementing biochar systems in Ghana since 2009. It is a private Institution with a scale of medium size in nature that depends on grant for her project implementation.

The biochar systems have been developed and tested under the course of two ACP S&T financed projects, namely "Bebi – Benefits from Biochar" project and "Biochar Plus". Several other activities have been conducted from 2009 up to date.

Link: Biochar Plus Project website: https://sites.google.com/site/biocharplusproject/home

Publication:

FAO, 2018. *Lessons learned on the Sustainability and Replicability of Integrated Food-Energy Systems in Ghana and Mozambique*. FAO, Rome. ISBN 978-92-5-130350-4. Available at: http://www.fao.org/3/i8627en/I8627EN.pdf

Conclusion

From such a varied set of examples, from various geographic and development settings, and covering the whole wood energy value chain, it is difficult to draw common conclusions. This itself leads us to conclude that the solutions for sustainable wood energy to contribute to FLR are manifold and diverse. However, there are some common features that emerge from the examples presented above that it is worth highlighting.

Holistic approach

Many of the successful examples demonstrate a holistic approach, in that they take in to consideration all aspects of the system. For interventions that seek to enhance forestlands, recognising and managing the socioeconomic aspects is key to success. Indeed, these socioeconomic factors are invariably the drivers behind the degradation of forests, and so solutions to reduce these drivers through integrated and comprehensive policy reform are needed (Chazdon, 2018). Therefore, inclusion of all stakeholders in project development and implementation is integral.

Awareness and capacity

Lack of awareness of alternatives to traditional bioenergy use, including the benefits that can be drawn, was identified as a main challenge in many cases. Indeed, in most cases, the magnitude of logical benefits to better management of forest resources is overwhelming and raising awareness of these benefits stimulates adoption of new practices. This is important where local communities require ownership of practices to secure long-term sustainability beyond the boundaries of short project cycles. Moreover, capacity building of both practitioners and policy-makers is needed in some cases; projects typically provide training, equipment and other specialized support to facilitate this.

Enabling environment

In many of the examples presented above, a conducive enabling environment was important. In some cases, it was strong policies that enabled the success of the project (e.g. revision of the logging moratorium in Kenya to exempt invasive species) and in other cases, it was lack of regulation that caused major challenges (e.g. lack of adequate charcoal regulation in Togo). Policy certainty and secure land tenure are key, not only to secure investments, but to ensure support from local communities. Commitment from relevant institutions at all levels supports the development of a positive enabling environment. This can be further facilitated by alignment with relevant initiatives, such as AFR100, REDD+, SDGs, NDCs, etc.

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