Food and Agriculture Organization of the United Nations

UNHCR The UN Refugee Agency

Cost–benefit analysis of forestry interventions for supplying woodfuel in a refugee situation in the United Republic of Tanzania

Cover photo: A woman fetches woodfuel and water near the Nyarugusu refugee camp, United Republic of Tanzania ©FAO/Arturo Gianvenuti

Cost–benefit analysis of forestry interventions for supplying woodfuel in a refugee situation in the United Republic of Tanzania

By

Arturo Gianvenuti and Vincent Gerald Vyamana

Food and Agriculture Organization of the United Nations and
United Nations High Commissioner for Refugees
2018

Preferred citation

FAO & UNHCR. 2018. *Cost–benefit analysis of forestry interventions for supplying woodfuel in a refugee situation in the United Republic of Tanzania*, by A. Gianvenuti & V.G. Vyamana. Rome, Food and Agriculture Organization of the United Nations (FAO) and United Nations High Commissioner for Refugees (UNHCR).

ISBN 978-92-5-130742-7 (FAO)

Contents

Tables

Figures

Acknowledgements

Arturo Gianvenuti and Vincent Gerald Vyamana prepared this report. They thank the FAO and UNHCR offices in Dar es Salaam for their support of this joint initiative and for their excellent coordination of field work carried out in the Kigoma region; UNHCR field offices in Kibondo, Kasulu and Kigoma; local experts at the Kakonko, Kasulu and Kibondo district councils; field staff at the Community Environmental Management and Development Organization in Kasulu district and the Relief to Development Society in Kibondo district; refugees in the Mtendeli, Nduta and Nyarugusu camps; and local communities near the camps. The willingness of all these people to share their knowledge during field work made this study possible.

Rémi D'Annunzio, Naila Yasmin and Inge Jonckheere carried out the remote sensing analysis reported in Annex 1.

The report benefited considerably from the inputs of the following colleagues: Andrea Dekrout (UNHCR); and Xia Zuzhang, Mats Nordberg, Shukri Ahmed, Geofrey Bakanga, Dino Francescutti, Roble Sabrie, Mar Polo and Laura D'Aietti (FAO). Thanks to Alastair Sarre for editing the document and Roberto Cenciarelli for the graphic design.

This work was carried out thanks to a financial contribution from the UNHCR to FAO's Strategic Objective 5 ("Increase the resilience of livelihoods to threats and crises") within the framework of the FAO–UNHCR collaborative partnership. Those funds assisted in the cost-benefit analysis of forestry interventions in the Mtendeli, Nduta and Nyarugusu refugee camps in the United Republic of Tanzania and in the analysis of the extent of deforestation in this context, with the overall objective of contributing to building resilience to crisis among both the refugee and host communities and minimizing environmental degradation.

Acronyms and abbreviations

AOI	area(s) of interest
BFAST	Breaks for Additive Seasonal and Trend
CEMDO	Community Environmental Management and Development Organization
cm	centimetre(s)
CO_2	carbon dioxide
FAO	Food and Agriculture Organization of the United Nations
ha	hectare(s)
IRR	internal rate of return
m	metre(s)
MAI	mean annual increment
NAFORMA	National Forest Resources Monitoring and Assessment of Tanzania
NPV	net present value
NWFP	non-wood forest product
PFM	participatory forest management
REDESO	Relief to Development Society
TZS	Tanzanian shilling(s)
UN	United Nations
UNHCR	United Nations High Commissioner for Refugees
USD	United States dollar(s)
VLFR	village land forest reserve

Executive summary

This report presents a cost–benefit analysis of three forestry interventions aimed at producing a sustainable supply of woodfuel and reducing land degradation and deforestation in the vicinity of three refugee camps (Mtendeli, Nduta and Nyarugusu) in the Kigoma region, United Republic of Tanzania. The proposed forestry interventions are: forest rehabilitation; wood-energy plantations; and agroforestry.

Field activities were carried out between October and November 2017. Data collection comprised the review of various documents; focus-group discussions; field observations; and direct interviews with key informants in environmental non-governmental organizations, district councils, refugee camps and local communities. The cost–benefit analysis used a cash-flow model over a ten-year period, including investment and operational costs and the revenues to be earned from the various interventions.

The study showed that the wood-energy plantation and agroforestry interventions would both be financially viable in all three refugee camps in the Kigoma region. Given the key assumptions, values for net present value, benefit/cost ratio and internal rate of return were all highest for wood-energy plantations, followed by agroforestry. Forest rehabilitation was the least financially attractive option for woodfuel production, but the analysis did not take into account other benefits this option would provide, such as improved water quality. Sensitivity analyses for various parameters resulted in changes in the ranking of economic indicators but not in the overall findings. The lower returns obtained from forest rehabilitation can be attributed to relatively low annual wood increments, among other factors.

Recommendations arising from this study include the following:

- A forest management plan should be developed for existing forests and other woodlands for each refugee camp in the region.
- Land-use planning and forestry interventions should be integrated to ensure, among other things, that issues pertaining to land tenure are addressed.
- Awareness should be raised among stakeholders of the importance of sustainable forest management and the business potential of wood-energy plantations and agroforestry.
- The economic potential of the area's non-wood forest products should be assessed.
- Action should be taken to demarcate sites, assess land suitability and review existing land-use plans in preparation for forestry interventions.
- Refugee and host communities should be assisted to establish their own tree nurseries.

1 Introduction and background

1.1 Refugees in the study area

The Kigoma region, in the northwest of the United Republic of Tanzania, has been the recipient of refugees from Burundi, the Democratic Republic of the Congo and Rwanda since the 1990s. Almost 250 000 refugees have arrived in the country from Burundi since mid-April 2015 as a result of civil unrest there. These refugees were housed initially in the Nyarugusu refugee camp, established in November 1996, which had been accommodating about 65 000 refugees from the Democratic Republic of the Congo before the Burundian influx. More than 350 000 refugees were living in the United Republic of Tanzania in 2017, with new arrivals arriving daily (UNHCR, 2017). The refugee population in Nyarugusu was almost triple the camp's original planned capacity, making it one of the world's largest and most overcrowded camps. To ease congestion there and to provide accommodation for new arrivals from Burundi, two former refugee camps were reopened: Nduta, opened in October 2015, and Mtendeli, opened in January 2016.

The increasing demand for woodfuel due to the growing refugee population is one of the biggest environmental issues in the Kigoma region, where both refugees and host communities collect woodfuel as the main source of energy for cooking and to generate income from charcoal production. Competition for the same scarce resource has caused tensions and conflicts among refugees and host communities. A common approach to resolving these conflicts is the formation of committees comprising refugees, village leaders and representatives of the United Nations High Commissioner for Refugees (UNHCR), the Ministry of Home Affairs, and ward and district authorities. Formal law recognizes these reconciliation committees at the village and ward levels and they are constituted by well-respected members of both host communities and the refugees.

An urgent response is needed to sustainably meet the woodfuel demand in the refugee camps in the Kigoma region to ensure access to energy for cooking, promote food and nutrition security, and minimize environmental impacts. In addition to overharvesting to meet woodfuel demand, the growing need for food is leading to an increase in the clearing of forest for arable farming near refugee camps by both refugees and local communities. A better understanding is needed of the feasibility of interventions to improve the sustainability of existing traditional energy sources given the prevailing socio-economic and environmental conditions.

1.2 Political framework

The United Republic of Tanzania has an exemplary tradition of solidarity in supporting durable solutions for refugees in protracted situations. In 2014, the Tanzanian Government granted citizenship to more than 168 000 refugees who fled Burundi in 1972. Nevertheless, despite the political willingness to host refugees and help them meet their pressing needs, significant intertwined social and environmental challenges require attention.

The Kigoma Joint Programme in the United Republic of Tanzania is an area-based UN programme that cuts across sectors to improve development and human security in the Kigoma region; it involves 16 UN agencies and was developed in cooperation with regional and district authorities based on the development needs of Kigoma and the capacities of UN agencies in the United Republic of Tanzania.

The Kigoma Joint Programme promotes the following sectors: sustainable energy and environment; youth and women's economic empowerment; the mitigation of violence against women and children; education with a focus on youth and particularly adolescent girls; WASH ("Water, Sanitation and Hygiene"); and agriculture with a focus on developing local markets.

1.3 The environment and livelihoods in the study area

The average annual rainfall in the Kigoma region varies with altitude and location relative to Lake Tanganyika in the range of 600–1 500 mm. The mean daily temperature ranges from 25 °C in December and January to 28 °C in September. The target area lies within two agroecological zones, as follows:

1) The miombo zone occupies an altitude of 1 000–1 200 metres above sea level, with an average annual rainfall of 600–1 000 mm. Soils are red to sandy. The miombo woodland comprises mosaics of closed and open woodlands, bushy grasslands and swamps.

2) The intermediate zone occupies an altitude of 1 200–1 500 metres above sea level, with an average annual rainfall of 850–1 100 mm. The zone has dark-reddish clay-loam soils.

The climate in the region is tropical. There is a distinct long rainy season from late October to May (with a 2–3-week dry spell in January or February), and a prolonged dry season.

Refugee and host communities in the Kigoma region live within or near forests, with miombo woodlands the dominant vegetation type. Miombo woodlands are acknowledged for their resilience in the face of disturbances such as tree cutting for woodfuel, a characteristic that boosts the potential of the ecosystem to supply woodfuel over long periods if not converted to farmland (Malimbwi *et al.*, 2000). The expansion of farmlands into the woodlands, on the other hand, reduces this potential.

Forests can perform a safety-net function by providing resources such as woodfuel and non-wood forest products (NWFPs) that can be consumed directly or sold in local markets for quick cash. NWFPs can increase the diversity of household income and food. Thus, forests can help bridge the humanitarian and development divide and build a resilient livelihood base. For this reason, sustainable forest management is crucial in the Kigoma region.

1.4 The need for woodfuel and its impact

Woodfuel is the main source of energy for cooking in both the refugee and host communities, and it will continue to be an important source of energy for the foreseeable future. The three refugee camps in the region require large quantities of woodfuel, with an average daily consumption of 1.8 kg per person (Quigley, 2016).

The high woodfuel demand has led to deforestation and land degradation in areas surrounding the refugee camps, causing soil erosion as well as conflicts between refugees and host communities as they compete for the same resources. Moreover, women and girls face the risk of assault as they walk increasing distances away from the camps in search of woodfuel. The environmental impacts have been exacerbated by the recent influx of refugees, which has increased demand for food and energy.

During the field survey, it was observed that woodfuel collection and clearing for agriculture are the main causes of forest degradation and deforestation in the areas surrounding the refugee camps. This is also confirmed by the results of a rapid remote sensing analysis conducted within a 25-km radius of each refugee camp (see Annex 1) and other recent studies in the Kigoma region (Kessy *et al.*, 2016; Makunga and Misana, 2017). The key results of this remote sensing analysis are based on a temporal change analysis of high-resolution satellite imagery within a 25-km radius of the Mtendeli, Nduta and Nyarugusu refugee camps showing the extent of forest, non-forest and tree loss, estimated aboveground biomass, and land-cover change to agriculture, built-up areas, roads and "other" for the period 2015–2017. The reopening of the two former refugee camps – Nduta in October 2015 and Mtendeli in January 2016 – appears to have had a marked impact on the surrounding forest area, with 44 percent and 48 percent tree-cover loss, respectively; on the other hand, tree cover near Nyarugusu was relatively stable over the period, with a decline of only 8 percent (see Table 15 in Annex 1).

In the short term, the provision of woodfuel is the main priority, but there is also an urgent need for land restoration and sustainable forest use, which would provide considerable long-term benefits. Planning the sustainable provision of woodfuel is a priority for ensuring access to energy for cooking in the three target refugee camps, taking into account both immediate needs and the longer-term benefits resulting from specific forestry interventions. The current annual sustainable supply of woodfuel in the Kigoma region is less than the demand. Alternative energy sources for cooking (such as liquefied petroleum gas and briquettes from agricultural residues) have been introduced to refugees in Kigoma, but woodfuel remains the most affordable and accessible energy source for cooking. Addressing the scarcity of woodfuel and other forest products, therefore, is an urgent task for appropriate forestry interventions.

1.5 Objectives of the study

The overall objective of the study reported here was to support strategic planning processes by analysing the costs and benefits of forestry interventions for increasing access to energy, reducing environmental impacts and building resilience among the refugee and host communities in the Kigoma region. The specific objectives were to:

- determine possible forestry interventions;
- conduct a cost–benefit analysis of those forestry interventions; and
- map relevant actors and incentive mechanisms.

2 Methodology

2.1 Data collection

The study used both primary and secondary data. Primary data and information were collected through direct field observations and from key informant interviews and focus-group discussions with local experts from the Kakonko, Kasulu and Kibondo district councils, UNHCR staff, and two local non-governmental organizations (the Community Environmental Management and Development Organization – CEMDO – and the Relief to Development Society – REDESO); refugees in the Mtendeli, Nduta and Nyarugusu camps; and local communities near the camps. The aims of interviews and focus-group discussions were to identify possible forestry interventions for a sustainable woodfuel supply and to develop an accounting matrix of revenues and costs for each option. Information provided by individual key informants was validated in the group discussions, and vice versa. A checklist was used of the main aspects to be borne in mind in planning forest management in displacement settings (FAO and UNHCR, 2018). Secondary data and information were obtained from a comprehensive literature review.

2.2 Data analysis

The cost–benefit analysis conducted in the study used a cash-flow model over a ten-year period comprising all investment and operational costs and the revenues derived from the various forestry interventions. The economic indicators used to compare the cost-effectiveness of the forestry interventions were net present value (NPV), benefit/cost ratio (BCR) and internal rate of return (IRR). The NPV equation calculates the cumulative benefits and costs converted to their present value using a discount rate. The discounted costs are subtracted from the discounted benefits to estimate the discounted net benefits or NPV. If the NPV is greater than zero, the project is considered financially viable. The BCR is the ratio of the discounted benefits to the discounted costs. If the BCR is greater than 1, the discounted benefits exceed the costs and the project, therefore, is financially viable. The IRR is the theoretical discount rate at which the NPV equals zero (that is, the rate that equalizes the discounted costs and benefits). The IRR, therefore, is an indicator of the strength of a project. Table 1 shows the formulas used to calculate the three indicators.

Sensitivity analyses were performed to determine how changes in key parameters such as discount rate, price and sustainable wood yield would affect the profitability of the various options over a period of ten years.

Table 1. Economic indicators and their critical minimum values

Indicator	Equation	Critical minimum value
Net present value (NPV)	$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t}$ Where: r = discount rate *t* = individual years n= number of years over which the project is evaluated *B* = the sum of benefits in a given year *C* = the sum of costs in a given year	NPV > 0
Benefit/cost ratio (BCR)	$BCR = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}}$	BCR > 1
Internal rate of return (IRR)	$\sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t} = 0$	IRR > r

2.3 Assumptions and limitations

The following six assumptions and limitations applied to the study:

1. The study did not consider combinations of the three forestry interventions, which were each assessed separately (nevertheless, a combination of these interventions is likely to be a realistic way in which to simultaneously address energy needs and environmental impacts and provide livelihood opportunities).
2. The study used a cash-flow model over a ten-year period. A time horizon of 5–10 years is reasonable for a solution to energy access for cooking through sustainable forest management. History suggests that it is unlikely that the refugees will have vacated the camps within the next 5–10 years. Even if they were to do so, wood demand among local communities far exceeds current sustainable wood yields.
3. The population of the refugee camps and the woodfuel demand were considered to remain constant over the analysis period.
4. Prices and other inputs were considered to remain constant over the period, although sensitivity analyses were carried out.
5. The forestry interventions identified in this study start to supply woodfuel after a minimum of three years; meanwhile, the refugees will continue to collect woodfuel in the surrounding environment. The remote sensing analysis in Annex 1 provides indications of the available forest land and the existing wood biomass stock, although the analysis

was conducted on a buffer area of 25-km radius, which far exceeds the realistic woodfuel catchments of the camps.

6. The study considers only direct benefits (i.e. woodfuel production, carbon sequestration and agricultural production). Thus, indirect benefits such as the supply of NWFPs and the mitigation of climate change are not included.

Annex 2 provides details of the key assumptions and calculations for each of the three forestry interventions.

3 Findings

The study's findings are presented in the following order in accordance with the scope of work:

1. proposed forestry interventions;
2. cost–benefit analysis; and
3. actors and incentive mechanisms.

3.1 Proposed forestry interventions

The following three forestry interventions were identified that could help achieve the objectives of meeting woodfuel demand in the refugee camps and reducing environmental impacts in the remaining natural forests and woodlands:

1. Rehabilitation of degraded native forests – a combination of natural and artificial regeneration to restore degraded forest areas with scattered tree planting at an average of 400 trees per ha.
2. Wood-energy plantations – afforestation and reforestation with trees planted at a high density of 10 000 trees per ha.
3. Agroforestry – woodlots of trees planted at a density of 1 100 trees per ha with maize intercropping and a one-year fallow (no intercropping, but livestock grazing, for example, is allowed) before wood harvesting.

Each option is described in more detail below.

Rehabilitation of degraded native forests

In the context of the miombo woodlands in the vicinity of the refugee camps, "rehabilitation" means the sustainable management of native forest in which wood is harvested periodically based on growth characteristics. The objective is to restore forest productivity with a view to producing a sustainable supply of woodfuel and ecosystem services. The field survey determined that naturally growing seedlings and young trees, especially coppice shoots, are common in deforested areas. The approach considered in this intervention involves enrichment planting using nursery-grown seedlings of native (but fast-growing) species to accelerate the rehabilitation process. Species that have fast-growing characteristics, are adapted to the climate and topography, and have strong root systems are preferred. Maintenance is especially needed in the early years after outplanting to reduce the impact of weeds on the growth of tree seedlings and coppiced stems. The three most common indigenous tree species used for timber and woodfuel in the region are *Julbernadia globiflora*, *Pterocarpus rotundifolia* and *Brachystergia speciformis*.

The intervention would involve the outplanting of 400 seedlings per ha, and the area of intervention would be protected from use for the first four years to allow tree establishment and the restoration of forest productivity. Grasses would be slashed to enhance the growth of wildlings and planted seedlings in the first 2–3 years; firebreaks would be constructed and maintained to reduce the risk of fire. It is estimated that, after four years, the annual allowable cut would be 2.63 tonnes per ha (Kityo, 2004; Gerald, 2012).

An important approach in the United Republic of Tanzania to promote sustainable forest management is participatory forest management (PFM), which has been practised in the country since the 1990s. The key characteristic of PFM is that communities have the right to

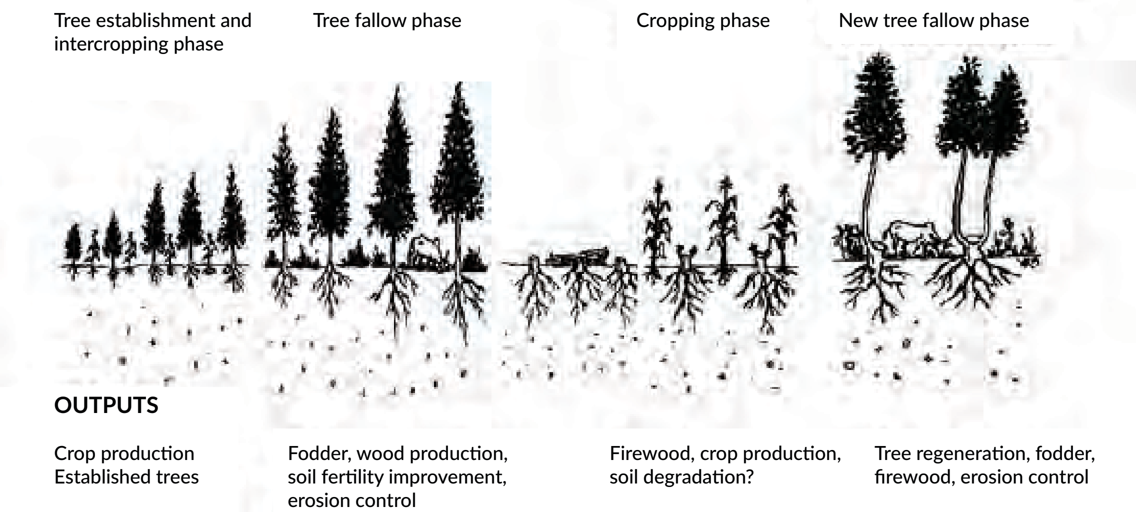

Figure 1. The three management phases of the rotational woodlot agroforestry system in the United Republic of Tanzania

Source: Nyadzi, 2004.

access government-owned forests, the right to harvest NWFPs, and the right to the controlled harvesting of woodfuel. PFM can be implemented in two ways: through community-based forest management, whereby local communities own and manage forest resources, and through joint forest management (JFM), whereby local communities or non-governmental organizations are involved in the management and conservation of government-owned forests and forest land, with certain user rights as an incentive. PFM can contribute significantly to the resilience of refugees and host communities by providing access to additional income, food and other household resources. It is important, therefore, that refugees and host communities are engaged in the rehabilitation of degraded forests through PFM to ensure the wise use of natural resources and to provide the communities with ongoing benefits (FAO, 2018).

Wood-energy plantations

Woodfuel can be produced in dedicated plantations of fast-growing tree species designed to maximize biomass production and quickly meet woodfuel demand. The maximum production of biomass can be achieved with a high planting density, and a short-rotation coppice system can provide an ongoing supply of woodfuel for decades.

Dedicated woodfuel plantations can help prevent or minimize soil erosion on marginal and degraded lands, promote carbon sequestration (FAO and UNHCR, 2018) and reduce pressure on natural forests and woodlands.

Tree species selected for woodfuel plantations should have high growth rates and the ability to coppice, and they should be adapted to the climate. Moreover, where possible, they should be capable of improving soil fertility and hydrology.

Common tree species and shrubs planted for energy purposes in the United Republic of Tanzania and other countries in eastern Africa include *Acacia auriculiformis*, *Acacia crassicarpa*, *Acacia julifera*, *Acacia leptocarpa*, *Acacia mangium*, *Acacia nilotica*, *Acacia polyacantha*, *Albizia harveyi*, *Albizia lebbeck*, *Albizia versicolor*, *Calliandra calothyrsus*, *Glyricidia sepium*, *Leucaena leucocephala*, *Leucaena pallida*, *Markhamia lutea*, *Sapium ellipticum*, *Senna siamea* and *Sesbania sesban* (Gerald, 2012; Hoogwijk *et al*., 2005; Kimaro, 2009; Nyadzi, 2004; Otsyina, Minae and Cooper, 1996; Otsyina *et al*., 1997).

The tree density proposed in this study for the wood-energy plantation option is 10 000 trees per ha. Woodfuel production is estimated at 30 tonnes per ha per year, with the first harvest at year 3 and the coppice shoots of tree stumps harvested annually thereafter.[1] CEMDO and REDESO have already established woodfuel distribution centres to serve people with special needs. Woodfuel production from dedicated wood-energy plantations would benefit from this distribution system.

Agroforestry

Under current policies and laws, refugees are not allowed to cultivate land except in specific, very small backyard gardens. They are strictly prohibited from cultivating land outside the camps. Therefore, agroforestry is considered viable as an option on the assumption that appropriate mechanisms are put in place that would allow refugees to be supplied with woodfuel grown in agroforestry plots. The rotational woodlot agroforestry system assessed in this study consists of planting trees intercropped with maize. By definition, rotational woodlot agroforestry systems entail three distinct management phases symbolizing functional features of both sequential and simultaneous agroforestry systems (Figure 1): 1) initial tree establishment; 2) tree fallow; and 3) post fallow.

In this option, 1 100 seedlings per ha are planted. The land is ploughed for maize production, and tree seedlings are planted between the rows of maize. The plots are weeded twice per year, benefiting both the trees and the maize. Maize is cultivated only in years 1 and 2 (after which it is limited by shading from tree crowns). The land is left as a tree fallow in year 3. The trees are harvested in year 4, and the land is planted again with maize between tree stumps at the beginning of year 5. A tree fallow is observed again in year 6, and coppiced stems are harvested in year 7. The coppice–maize cycle continues in this way for ten years.

An annual allowable cut of 6.1 tonnes per ha per year is estimated for woodfuel production, based on studies conducted in the United Republic of Tanzania in areas with similar vegetation types and climatic conditions (Nyadzi, 2004; Kimaro, 2009; Gerald, 2012). The first wood harvest is at year 4, and subsequent coppice tree crops are harvested every two years.[2]

The key economic advantage of this system is in the efficient use of labour in land preparation, weeding and other tending operations during the intercropping phase, which contributes to the production of both trees and maize. The trees used in rotational woodlots also have ameliorative effects on soil fertility, thereby increasing crop yields relative to continuous cropping (i.e. the baseline scenario). Overall, there is a significant increase in the return on labour, as well as benefits for the sustainability of the land. The agroforestry rotational woodlot system is an appropriate practice for the western regions of the United Republic of Tanzania, including the Kigoma region (Kitalyi *et al*., 2010).

3.2 Cost–benefit analysis

A cost–benefit analysis of the proposed forestry interventions was undertaken to assess economic efficiency over a period of ten years, taking into account the estimated woodfuel demand of each refugee camp, potential wood yields, the land area needed, returns on production, and the projected cost streams associated with the interventions. Various components of costs and benefits were identified and valued based on production potential and prevailing market prices (Annex 2). Table 2 presents a summary of the costs and benefits used in the cost–benefit analysis for each of the three forestry interventions. All costs and benefits were discounted to the present at a rate of 9 percent.[3]

1 Because coppiced stems grow faster than trees grown from seedlings, it is assumed that the coppiced trees will produce the same quantity of wood annually as that produced in the first (three-year) rotation.

2 Because coppiced stems grow faster than trees grown from seedlings, it is assumed that the coppiced trees will produce the same quantity of wood every two years as the first rotation produced in four years.

3 This value is the real discount rate currently applied to commercial banks in the United Republic of Tanzania for loans from the Bank of Tanzania.

Table 2. Identification of the costs and direct benefits of three forestry interventions

Forestry intervention	Costs	Direct benefits
Rehabilitation of degraded native forests	• Demarcation • Site assessment and planning • Seedlings • Land preparation • Outplanting • Land (opportunity cost) • Weeding and fire protection • Harvesting • Supervision • Training and capacity building • Miscellaneous (tools, etc.)	• Woodfuel production • Carbon sequestration
Wood-energy plantations	• Demarcation • Site assessment and planning • Seedlings • Land preparation • Outplanting • Land (opportunity cost) • Weeding and fire protection • Harvesting • Supervision • Training and capacity building • Miscellaneous (tools, etc.)	• Woodfuel production • Carbon sequestration
Agroforestry	• Demarcation • Site assessment and planning • Seedlings • Land preparation • Outplanting • Land (opportunity cost) • Weeding and fire protection • Harvesting • Supervision • Training and capacity building • Miscellaneous (tools, etc.) • Crop inputs and other labour	• Woodfuel production • Carbon sequestration • Agricultural production

Assuming an average daily woodfuel consumption of 1.8 kg per person (Quigley, 2016), Table 3 shows the estimated quantities of wood needed and the land area required to meet demand for each of the three forestry interventions in the three refugee camps.

Table 3. Estimated woodfuel demand and the land area needed to meet demand, three refugee camps, by forestry intervention

Camp	Population		Estimated woodfuel demand (air-dry tonnes/year)	Land area needed to meet woodfuel demand (ha), by forestry intervention		
	Number of households	Number of people		Forest rehabilitation	Wood-energy plantations	Agroforestry
Nyarugusu	30 000	144 194	94 735	36 021	3 158	15 530
Nduta	49 364	125 546	82 484	31 363	2 749	13 522
Mtendeli	16 882	50 279	33 033	12 560	1 101	5 415
Total	**96 246**	**320 019**	**210 252**	**79 944**	**7 008**	**34 467**

Assessment of costs

The financial costs of the proposed interventions were calculated using preliminary estimates of investment and operational costs. Table 4 summarizes the total discounted costs (based on current costs) expected in each of the options for meeting woodfuel demand in the Mtendeli, Nduta and Nyarugusu refugee camps over a ten-year period.

Table 4. Total discounted costs over a ten-year period for three forestry intervention options in the area of interest of three refugee camps

	Forest rehabilitation		Wood-energy plantations		Agroforestry	
Camp	Total cost (USD million)	Cost per ha (USD 000)	Total cost (USD million)	Cost per ha (USD 000)	Total cost (USD million)	Cost per ha (USD 000)
Nyarugusu	28.1	0.8	20.2	6.4	32.9	2.1
Nduta	24.5		17.6		28.7	
Mtendeli	9.9		7.1		11.5	
Total	**62.5**		**44.9**		**73.1**	

Note: Discount rate = 9 percent.

The total discounted cost of the forest rehabilitation intervention in the Kigoma region over a ten-year management period is estimated at USD 62.5 million for an area of 12 560 ha at Mtendeli, 31 363 ha at Nduta and 36 021 ha at Nyarugusu. The total discounted cost of this intervention on a unit basis for the ten-year period is estimated at USD 782 per ha. The total area needed was calculated according to the estimated woodfuel demand in the three refugee camps (Table 3). Assuming that forest rehabilitation actions start in year 1, the allowable annual woodfuel harvest would be 2.6 tonnes per ha starting in year 4. The major economic cost of this intervention is the opportunity cost of the land (calculated using information on current prices collected from interviews with key informants in the refugee camps), accounting for about 45 percent of the total cost. The opportunity cost of labour for harvesting woodfuel (calculated according to the time required for collecting one head load in the surrounding forests and woodlands and applying an economic conversion factor of 0.7 for a conservative estimate of the opportunity cost of labour based on the minimum daily wage), constitutes about 36 percent of total costs, and nursery production, land preparation and outplanting account for 8 percent. Table 7 provides further details on the investment and operational costs of this intervention.

The total discounted cost of the wood-energy plantation intervention over a ten-year period was estimated at USD 44.9 million on an area of 1 101 ha at Mtendeli, 2 749 ha at Nduta and 3 158 ha at Nyarugusu (an overall discounted unit cost of USD 6 416 per ha). Assuming that actions to implement this option begin in year 1, the annual woodfuel harvest would be about 30 tonnes per ha, starting in year 4. The biggest costs are labour for woodfuel harvesting (34 percent of the total cost); equipment (such as machetes, axes and saws) for intensive manual harvesting (26 percent) (part of “miscellaneous” in Table 6); seedlings (22 percent); and land opportunity cost (about 6 percent). Table 8 provides further details on the investment and operational costs of this intervention.

The agroforestry intervention would have a total discounted cost of USD 73.1 million over an area of 5 415 ha in Mtendeli, 13 522 ha in Nduta and 15 530 ha in Nyarugusu. The discounted unit cost of this intervention over the ten-year period is USD 2 124 per ha. These estimates are based on the assumption that the intervention would produce an allowable annual woodfuel harvest of 6.1 tonnes per ha. The major costs are woodfuel harvesting (32 percent of the total cost), maize cultivation inputs and labour (29 percent), land opportunity cost (17 percent) and seedlings (7 percent). Table 9 provides further details on the investment and operational costs of this intervention.

Assessment of benefits

The assessed benefits of the proposed forestry interventions are: production of woodfuel to improve access to energy for cooking in the refugee camps; carbon sequestration; and, for the agroforestry intervention, crop production. Table 5 summarizes the discounted benefits derived from each forestry intervention in each camp, including on a per unit area basis. Table 6 shows the discounted net benefit (i.e. after the deduction of costs) for each option based on current market prices for inputs, labour and outputs. Further details on the benefits of the forest rehabilitation, wood-energy plantation and agroforestry interventions are shown in the Table 7, Table 8 and Table 9, respectively.

Table 5. Total discounted benefit over a ten-year period for three forestry interventions in the area of interest of three refugee camps

	Forest rehabilitation		Wood-energy plantations		Agroforestry	
Camp	Total benefit (USD million)	Benefit per ha (USD 000)	Total benefit (USD million)	Benefit per ha (USD 000)	Total benefit (USD million)	Benefit per ha (USD 000)
Nyarugusu	24.5	0.7	24.5	7.8	43.2	2.8
Nduta	21.3		21.3		37.6	
Mtendeli	8.5		8.5		15.1	
Total	**54.3**		**54.3**		**95.9**	

Note: Discount rate = 9 percent.

Table 6. Discounted net benefit over a ten-year period for three forestry interventions in the area of interest of three refugee camps

	Forest rehabilitation for energy		Wood-energy plantations		Agroforestry	
Camp	Total net benefit (USD million)	Net benefit per ha (USD 000)	Total net benefit (USD million)	Net benefit per ha (USD 000)	Total net benefit (USD million)	Net benefit per ha (USD 000)
Nyarugusu	-3.6	-0.1	4.3	1.3	10.3	0.68
Nduta	-3.1		3.7		8.9	
Mtendeli	-1.3		1.5		3.5	
Total	**-8.0**		**9.5**		**22.7**	

Note: Discount rate = 9 percent.

Table 7. Financial analysis of the forest rehabilitation option, per hectare basis

Year	0	1	2	3	4	5	6	7	8	9	10
BENEFITS											
Harvestable woodfuel (tonnes)					2.6	2.6	2.6	2.6	2.6	2.6	2.6
Woodfuel value (USD)*					173.6	173.6	173.6	173.6	173.6	173.6	173.6
Carbon sequestration (tonnes CO_2eq; belowground biomass)		0.4	0.4	0.4							
CO_2eq sequestration value (USD)		2.2	2.2	2.2							
Total benefit (USD)	**0.0**	**2.2**	**2.2**	**2.2**	**173.6**	**173.6**	**173.6**	**173.6**	**173.6**	**173.6**	**173.6**
COSTS (USD)											
Investment costs											
Demarcation and site planning	0.2										
Seedlings	80.8										
Land preparation	10.8										
Outplanting	14.4										
Operational costs											
Land opportunity cost		55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5
Capacity building and training		0.3	0.3	0.3	-	-	-	-	-	-	-
Fire protection and weeding		14.4	14.4	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Harvesting		0.0	0.0	0.0	90.9	90.9	90.9	90.9	90.9	90.9	90.9
Supervision		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Miscellaneous		0.3	0.3	0.3	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Total cost	**106.1**	**70.7**	**70.7**	**59.9**	**130.0**	**130.0**	**130.0**	**130.0**	**130.0**	**130.0**	**130.0**
Net benefit (benefits minus costs)	**-106.1**	**-68.5**	**-68.5**	**-57.7**	**43.7**	**43.7**	**43.7**	**43.7**	**43.7**	**43.7**	**43.7**
DISCOUNTED BENEFIT AND COST											
Discounted benefit	0.0	2.0	1.9	1.7	123.0	112.8	103.5	95.0	87.1	79.9	73.3
Discounted cost	106.1	64.9	59.5	46.3	92.1	84.5	77.5	71.1	65.2	59.8	54.9
Net discounted benefit	-106.1	-62.9	-57.7	-44.6	30.9	28.4	26.0	23.9	21.9	20.1	18.4
ECONOMIC INDICATORS											
Net present value (USD/ha)	-102										
Benefit/cost ratio	0.87										
Internal rate of return (%)	0.3										

Notes: * Woodfuel value is based on the local price of firewood (in FAO's terminology, "firewood" is equivalent to "fuelwood" – that is, woodfuel where the original composition of the wood is preserved). Discount rate = 9 percent.

Table 8. Financial analysis of the wood-energy plantation option, per hectare basis

Year	0	1	2	3	4	5	6	7	8	9	10
BENEFITS											
Harvestable woodfuel (tonnes)					30	30	30	30	30	30	30
Woodfuel value (USD)*					1 980.4	1 980.4	1 980.4	1 980.4	1 980.4	1 980.4	1 980.4
Carbon sequestration (tonnes CO_2eq; (belowground biomass)		4.8	4.8	4.8							
CO_2eq sequestration value (USD)		25.1	25.1	25.1							
Total benefit (USD)	0.0	25.1	25.1	25.1	1 980.4	1 980.4	1 980.4	1 980.4	1 980.4	1 980.4	1 980.4
COSTS (USD)											
Investment costs											
Demarcation and site planning	1.3										
Seedlings	2 020.8										
Land preparation	251.5										
Outplanting	296.4										
Operational costs											
Land opportunity cost		55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5
Capacity building and training		3.7	3.7	3.7							
Fire protection and weeding		46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7
Harvesting					462.5	462.5	462.5	462.5	462.5	462.5	462.5
Supervision		3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Miscellaneous					350.3	350.3	350.3	350.3	350.3	350.3	350.3
Total cost	2 570.1	109.3	109.3	109.3	918.4	918.4	918.4	918.4	918.4	918.4	918.4
Net benefit (benefits minus costs)	-2 570.1	-84.2	-84.2	-84.2	1 062.1	1 062.1	1 062.1	1 062.1	1 062.1	1 062.1	1 062.1
DISCOUNTED BENEFIT AND COST											
Discounted benefit	0.0	23.0	21.1	19.4	1 403.0	1 287.1	1 180.9	1 083.4	993.9	911.8	836.6
Discounted cost	2 570.1	100.2	92.0	84.4	650.6	596.9	547.6	502.4	460.9	422.8	387.9
Net discounted benefit	-2 570.1	-77.2	-70.8	-65.0	752.4	690.3	633.3	581.0	533.0	489.0	448.6
ECONOMIC INDICATORS											
Net present value (USD)	**1 344**										
Benefit/cost ratio	**1.21**										
Internal rate of return (%)	**16**										

Note: * Woodfuel value is based on the local price of firewood (in FAO's terminology, "firewood" is equivalent to "fuelwood" – that is, woodfuel where the original composition of the wood is preserved). Discount rate = 9 percent.

Table 9. Financial analysis of the agroforestry option, per hectare basis

Year	0	1	2	3	4	5	6	7	8	9	10
BENEFITS											
Harvestable woodfuel (tonnes)					6.1			18.3			18.3
Woodfuel value (USD)*					402.7			1 208.1			1 208.1
Carbon sequestration (tonnes CO_2eq; belowground biomass)		1.0	1.0	1.0							
CO_2eq sequestration value (USD)		5.1	5.1	5.1							
Maize production (tonnes)		1.2	1.5			1.5			1.5		
Maize production value (USD)		374.1	486.3			486.3			486.3		
Total benefit (USD)		379.2	491.4	5.1	402.7	486.3	-	1 208.1	486.3	-	1 208.1
COSTS (USD)											
Investment costs											
Demarcation and site planning	0.3										
Seedlings	222.3										
Land preparation	28.7										
Outplanting	40.9										
Operational costs											
Land opportunity cost		55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5
Capacity building and training		0.8	0.8	0.8							
Fire protection and weeding		37.7	37.7	37.7	37.7	37.7	37.7	37.7	37.7	37.7	37.7
Harvesting woodfuel					147.5			442.5			442.5
Supervision		0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Miscellaneous					14.1			14.1			14.1
Maize seeds		28.1	28.1			28.1			28.1		
Maize land preparation		44.9	44.9			44.9			44.9		
Maize planting		9	9			9			9		
Maize field operations		80.8	80.8			80.8			80.8		
Maize harvesting		25.7	33.3			33.3			33.3		
Maize post-harvesting		12.8	16.7			16.7			16.7		
Other		20.1	21.3			21.3			21.3		
Total cost	292.2	316.2	328.9	94.8	255.6	328.1	94.0	550.6	328.1	94.0	550.6
Net benefit (benefits minus costs)	-292.2	63.0	162.6	-89.7	147.1	158.2	-94.0	657.5	158.2	-94.0	657.5
DISCOUNTED BENEFIT AND COST											
Discounted benefit	0.0	347.9	413.6	3.9	285.3	316.1	0.0	660.9	244.1	0.0	510.3
Discounted cost	292.2	290.1	276.8	73.2	181.0	213.2	56.1	301.2	164.7	43.3	232.6
Net discounted benefit	-292.2	57.8	136.8	-69.2	104.2	102.8	-56.1	359.7	79.4	-43.3	277.7
ECONOMIC INDICATORS											
Net present value (USD)	**658**										
Benefit/cost ratio	**1.31**										
Internal rate of return (%)	**34**										

Note: * Woodfuel value is based on the local price of firewood (in FAO's terminology, "firewood" is equivalent to "fuelwood" – that is, woodfuel where the original composition of the wood is preserved). Discount rate = 9 percent.

Comparing costs and benefits

NPV, BCR and IRR were calculated for each intervention using the estimated discounted costs and benefits (Table 10).

Table 10. Summary of financial results on a per-hectare basis for three forestry interventions to meet the woodfuel demand of refugees in the Kigoma region

Indicator	Forest rehabilitation	Wood-energy plantations	Agroforestry
Net present value (USD/ha)	-102	1 344	658
Benefit/cost ratio	0.87	1.21	1.31
Internal rate of return (%)	0	16	34

The NPVs and IRRs produced in this analysis indicate that wood-energy plantations and agroforestry are more cost-effective for woodfuel production than the forest rehabilitation option. In the rehabilitation option, the main factors resulting in the negative NPV are the low wood yield, the land opportunity cost, and the cost of labour for harvesting. It should be noted, however, that the additional benefits deriving from rehabilitated miombo woodlands, such as the increased availability of NWFPs and improvements in water quality, soil fertility and biodiversity, are not accounted for in the study.

The IRR is higher for the agroforestry intervention (34 percent) than for wood-energy plantations (16 percent). This is attributable to the benefits of agroforestry associated with maize production and the increased yields due to the soil amelioration benefits of trees. Nevertheless, the wood-energy plantation option has the higher NPV.

Sensitivity analysis

A sensitivity analysis was conducted to determine how changes in key parameters would affect the viability of interventions. Each option was tested for sensitivity to higher and lower discount rates and woodfuel and maize market prices, and for reductions in woodfuel yields of 15 and 30 percent.

Discount rate. Reducing the discount rate from 9 percent to 3 percent, and increasing it to 15 percent, does not affect the IRR rankings of the three options, with agroforestry attaining the highest, followed by wood-energy plantations. Wood-energy plantations have the highest NPV for a discount rate of 3 and 9 percent, but agroforestry achieves higher values for NPV and BCR at a discount rate of 15 percent (Table 11).

Table 11. Sensitivity analysis of discount rate for three forestry interventions

Discount rate (%)	Net present value (USD/ha)	Benefit/cost ratio	Internal rate of return (%)
Forest rehabilitation			
3	-41	0.96	
9	-102	0.87	0
15	-136	0.78	
Wood-energy plantations			
3	3 247	1.40	
9	1 344	1.21	16
15	143	1.03	
Agroforestry			
3	1105	1.40	
9	658	1.31	34
15	383	1.23	

Effects of changes in price of woodfuel. Table 12 shows that changes in the price of woodfuel do not change the profitability rankings of the three forestry interventions. Wood-energy plantations and agroforestry are profitable for the two higher woodfuel prices, although the NPV is negative at the lower price for the wood-energy plantation option. The NPV for the forest rehabilitation option is positive (and therefore the option is financially viable) only at the highest tested woodfuel price.

Table 12. Sensitivity analysis of woodfuel price for three forestry interventions

Woodfuel market price (USD/tonne)	Net present value (USD/ha)	Benefit/cost ratio	Internal rate of return (%)
Forest rehabilitation			
45	-317	0.59	-
66*	-102	0.87	0
90	142	1.18	18
Wood-energy plantations			
45	-1 116	0.83	1
66*	1 344	1.21	16
90	4 119	1.64	26
Agroforestry			
45	192	1.12	20
66*	658	1.31	34
90	1 183	1.56	44

Note: * The price of USD 66 per tonne equates to TZS 147 per kg, which is the baseline price in local markets.

Effect of reduction in woodfuel yields. The effect of a 15 percent and 30 percent reduction in woodfuel yield was tested for each forestry intervention. Table 13 shows that the NPV remains positive for the agroforestry intervention, even with a 30 percent yield reduction; for the wood-energy plantation, the NPV becomes negative with a reduction in yield of 30 percent.

Table 13. Sensitivity analysis of reductions in wood yield for three forestry interventions

Woodfuel yield reduction (%)	Net present value (USD/ha)	Benefit/cost ratio	Internal rate of return (%)
Forest rehabilitation			
15	-167	0.78	-7
30	-232	0.67	-20
Wood-energy plantations			
15	180	1.03	10
30	-984	0.85	2
Agroforestry			
15	517	1.25	31
30	377	1.19	27

Changes in price of maize. Table 14 shows the impacts of changes in the price of maize on the agroforestry intervention. The NPV is positive for all three prices tested; at the highest price, the IRR is a very high 45 percent.

Table 14. Sensitivity analysis of maize price for the proposed agroforestry intervention

Maize market price (USD/tonne)	Net present value (USD/ha)	Benefit/cost ratio	Internal rate of return (%)
269	470	1.22	25
314*	658	1.31	34
359	845	1.40	45

Note: * The price of USD 314 per tonne equates to TZS 700 000 per tonne, which is the baseline price in local markets.

3.3 Actors and incentive mechanisms

For any of the canvassed forestry interventions to succeed, various stakeholders at the international, national and local levels need to work in close collaboration. At one end of the scale, the international community needs to provide financial resources and appropriate technical support. At the other end, local host communities and authorities are the producers and custodians of forest resources. The local communities are the ultimate landowners, given prevailing land policies and laws. The key limitation on them is a lack of technical know-how regarding land and forest management. This gap needs to be filled through the actions of national- and international-level stakeholders in collaboration with district councils.

In all cases, the role of the central government is to provide enabling policies, strategies and regulatory mechanisms. District councils are mandated to provide extension services in the form of technical advice and support for local communities. The national forest and land policies envisage decentralized forest and land management. With the overall technical support of district councils, communities have the mandate to own and manage their forests and lands.

Under the national policy, refugees have no direct roles in forestry except as informers for local communities and district councils when they observe illegal forest activities. Nevertheless, they are a potential key supplier of labour for land preparation, seedling production and other tasks and also the consumers of woodfuel produced in the interventions. A national review of refugee policies and laws now underway may allow refugees to play more active roles.

The Village Land Act (1999), the Local Government Act (1982) and the Forest Act (2002) provide the legal basis for villages to own and manage forest resources on village land in ecologically and economically sustainable ways. Host communities have the right to establish "village land forest reserves" (VLFRs) on village land, especially in large areas of unprotected miombo woodlands such as those in the Kigoma region. Incentives for the participation of host communities in natural regeneration and forest rehabilitation interventions include the following:

- **Waiving state royalties on forest produce:** when formal VLFRs have been established, host communities are not bound by government timber royalty rates (which are lower than market prices) and can sell their produce at prevailing market rates.
- **Retaining 100 percent of revenue from sale of forest products:** host communities have the right to retain 100 percent of the income derived from the sale of forest produce harvested in VLFRs. At their own discretion, villagers normally decide to share 10–15 percent of the forest revenue with district councils in return for services such as extension, advice and technical support.

District councils have two key incentives for participating in natural regeneration and forest rehabilitation:

1. **Revenue collection:** district councils have a mandate to establish and manage "local authority forest reserves" and to retain income from the sustainable harvesting of forest products (typically timber and woodfuel) in such reserves and from fees charged on forest products harvested in VLFRs in accordance with nationally prescribed rates.
2. **Local tax collection:** district councils may charge a "cess" or local tax on the transport of all forest products licensed at the local-government level.

4 Conclusions and recommendations

4.1 Conclusions

Based on the results of this study, the following conclusions can be drawn:

- Forestry investments to produce woodfuel for refugees in the Kigoma region and to reduce environmental impacts can be cost-effective for wood-energy plantations and agroforestry.
- The rehabilitation of degraded miombo woodlands for woodfuel production is less financially attractive under the conditions considered in this analysis. Given the potential for externalities associated with the rehabilitation of degraded forests that could not be evaluated due to limited information, it may be necessary to implement the forest rehabilitation option in concert with one or both of the other two interventions.
- Wood-energy plantations and agroforestry have great potential to support the wood-energy needs of both the refugee and host populations through the production of woodfuel with dedicated tree planting for this purpose.
- For both wood-energy plantations and agroforestry, estimated NPVs are positive for various (but not all) tested discount rates, woodfuel prices and woodfuel yields.
- Overall, the financial feasibility of the forestry interventions analysed in this study for the sustainable supply of woodfuel is most sensitive to changes in woodfuel yield.

4.2 Recommendations

- To create a system for the sustainable supply of woodfuel and other forest products, a forest management plan for existing forests and other woodlands should be developed urgently for each refugee camp in the Kigoma region. Among other things, this will require a forest inventory and more accurate estimates of woodfuel supply and demand. The assessment could be extended to include NWFPs for the development of alternative livelihood options based on those resources.
- Land-use planning should be an integral component for the implementation of forestry interventions because it provides avenues for securing land tenure under the prevailing land policy and laws, which mandate village governments to oversee land tenure once land-use plans are in place. Secure land tenure is a prerequisite for the broader engagement of refugee and hosting communities, local authorities and the private sector in sustainable forest management.
- Awareness should be raised about the importance of sustainable forest management and about the business potential of wood-energy plantations and agroforestry to ensure full understanding and support among the refugee and host communities and other stakeholders.
- The abundance and the characteristics of NWFPs (e.g. mushrooms, wild fruits and vegetables), and options for livelihoods based on specific NWFPs (e.g. honey), should be assessed.

- The following steps should be taken to move towards the implementation of one or more of the forestry interventions proposed in this study: the demarcation of sites, land suitability assessment, and the review of existing land-use plans or, where these do not exist, the formulation of new land-use plans. The official recognition of local land-use arrangements is also needed to avoid tensions and conflicts over land resources. After site demarcation, field assessments should be carried out to determine the most effective silvicultural practices, land preparation techniques, sites for the nurseries, species, and other important aspects of plantation design, establishment and management.
- Both the refugee and host communities should be assisted to establish their own tree nurseries, including by providing them with appropriate high-quality seeds and seedlings (the species of which should be selected in consultation with men and women from the communities) and with incentives for the implementation of sustainable forest management.
- Efforts should be made to build capacity among local authorities and partners (e.g. REDESO and CEMDO) to increase the availability of the technical and managerial skills needed for the rehabilitation of miombo woodlands and the management of wood-energy plantations.
- Trials should be established to test the suitability of a range of species (and species' mixes) for high planting densities to maximize woodfuel yields on specific sites.
- Techniques should be developed for the cost-effective harvesting of woody biomass in high-density wood-energy plantations using combinations of manual and mechanical means and specialized equipment.
- The establishment of local associations or cooperatives should be explored as a way of boosting the economic benefits of specific forestry interventions, with arrangements that provide equal opportunities for participation by both the refugee and host communities.
- An incentive mechanism should be created to integrate and support farmers from host communities to become entrepreneurs capable of providing forest-related services and thereby assisting in the implementation of forestry interventions and benefiting directly from them.
- The national forest policy and existing laws encourage decentralized forest governance through PFM. Thus, PFM should be promoted as a way of conserving and sustainably managing nearby forests and woodlands with the participation of both refugees and host communities.

Annex 1. Land-cover change and tree-loss detection in the refugee camps of the Kigoma region, United Republic of Tanzania

By Rémi D'Annunzio, Naila Yasmin and Inge Jonckheere (FAO)

Objectives of the remote sensing analysis

The objectives of the remote sensing component of this study were to:

1. assess the extent of deforestation (since the beginning of 2015) in a target area ("area of interest" – AOI) comprising a 25-km radius around each of the Mtendeli, Nduta and Nyarugusu refugee camps in the United Republic of Tanzania using temporal-change analysis of free, publicly available high-resolution satellite imagery, in combination with existing field datasets (e.g. the National Forest Resources Monitoring and Assessment of Tanzania – NAFORMA – and national maps of biomass and forest change); and
2. detect land-cover change and aboveground biomass in the AOI of the three refugee camps.

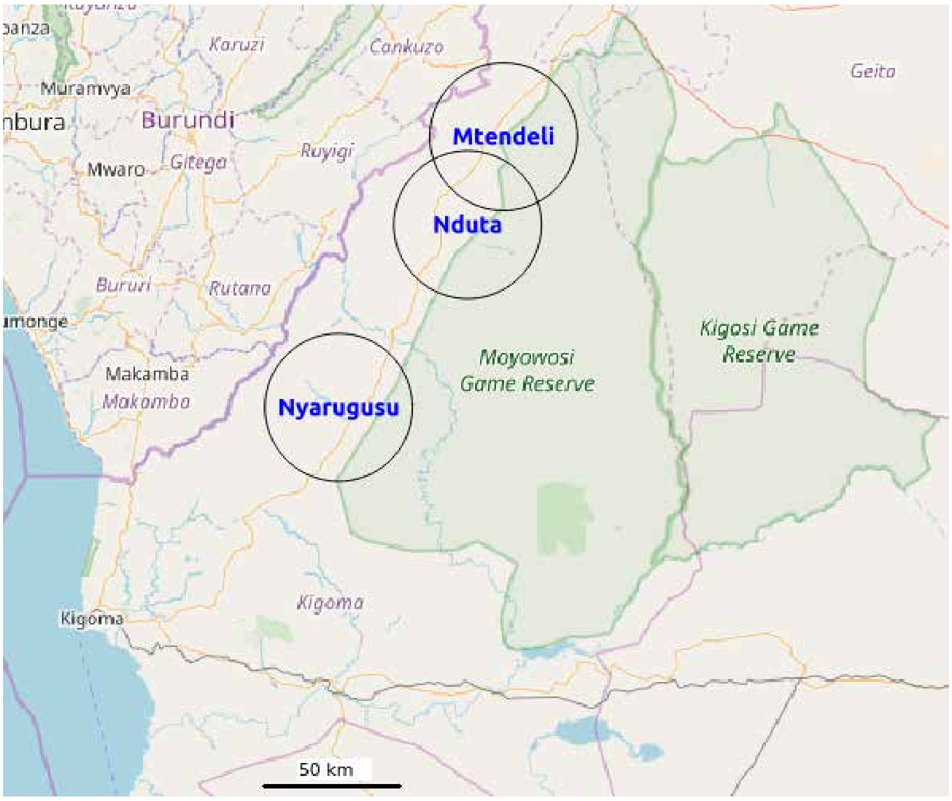

Figure 2. The location of the three refugee camps and the 25-km area of interest around each camp

Source: Google Maps.

Methodology

Area of interest

The AOI was defined as a 25-km radius around each of three refugee camps in the Kigoma region. The zones around the Mtendeli and Nduta camps overlap (Figure 2), but the estimates in the study do not take this into account and, rather, consider each camp separately.

Tree-cover loss

The global forest-change dataset for 2000–2016 (Hansen *et al*., 2013) was downloaded and clipped for the three AOI.[4] Each AOI was further divided into cells 2 km in size and the sum of the areas of detected tree-cover loss over the period (2000–2016) was computed (Figure 3). The temporal coverage of the global forest-change dataset does not completely encompass the period of interest (i.e. refugee influxes from 2015 to 2017), and the Breaks for Additive Seasonal and Trend (BFAST) method[5] was used to estimate tree-cover change over the period.

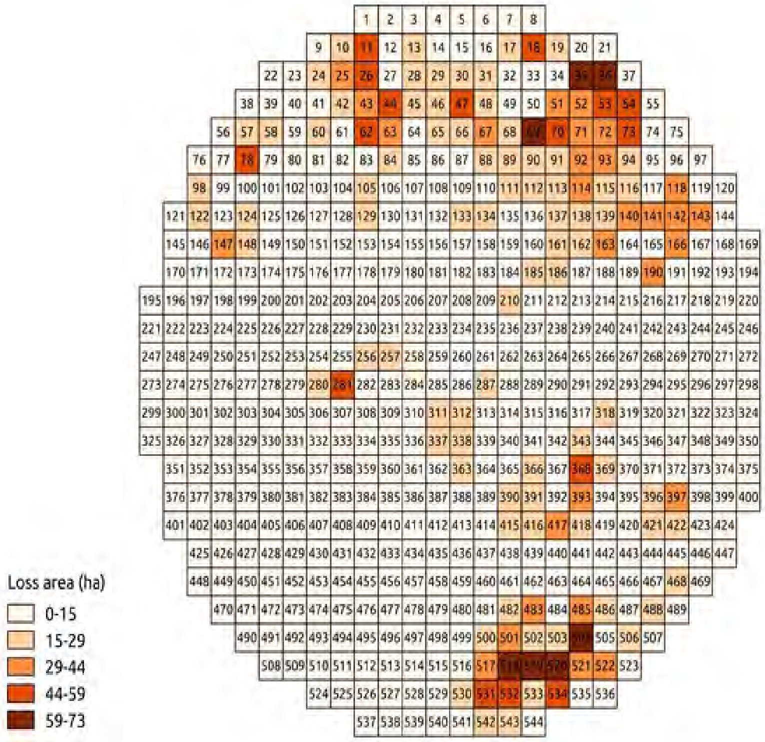

Figure 3. Global forest-change data for 2000–2016, Nyarugusu camp

BFAST approach

The BFAST method enables the analysis of the dynamics of satellite dense time series, overcoming the major challenge of distinguishing land-cover change from seasonal phenological variations. Verbesselt *et al.* (2010), Dutrieux *et al.* (2015) and DeVries *et al.* (2015) used this approach to demonstrate that time series can be decomposed into trend, seasonal, and remainder components and that the time and number of changes can be detected at high temporal resolution (i.e. 16 days), enabling the detection of tree-cover change and separation from the phenology signal. The same authors developed the bfastSpatial package[6] (R language),

4 https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.4.html

5 www.loicdutrieux.net/bfastSpatial

6 https://cran.r-project.org/web/packages/bfast/index.html

which provides utilities for performing change-detection analysis on time series of spatial gridded data, such as Landsat satellite imagery, which cover the study's period of interest.

The package was tested in the early versions of the cloud-based platform of SEPAL (System for Earth Observations, Data Access, Processing & Analysis for Land Monitoring) developed by FAO for the parallel processing of remote sensing data.[7] It has been adapted recently into a functional processing chain[8] that uses Google Earth Engine for the preparation of the time series and SEPAL for processing the algorithm itself.

The tools were used and applied directly to the AOI to detect tree-cover change.

Pre-processing of dense time series

The download and preparation of the time series was performed in Google Earth Engine.[9]

The parameters used for this analysis were as follows:

- Beginning of historical period: 1 January 2010
- Beginning of monitoring period: 1 January 2015
- End of monitoring period: 31 December 2017
- Accepted cloud-cover threshold: 50 percent.

Seventy-four, 159 and 208 scenes from Landsat 7 and 8 were downloaded and preprocessed for the Nyarugusu, Nduta and Mtendeli camps, respectively.

Tree-cover loss detection for 2015–2017

Several parameters were tested for the execution of the BFAST algorithm, and a first-order approach using the harmonized trend with Reverse Order Cumulated Sum criteria was chosen for the historical period.

The results of the processing chain consist of a three-band raster dataset covering the AOI, for which the date of break and the magnitude of detected change are recorded for each pixel. Only the breaks detected between 2015 and 2017 were selected to establish the tree-cover-loss map.

Woody biomass estimation

The tree-cover layer of year 2015 was obtained by subtracting tree-cover loss of 2000-2015 to the 2000 tree cover layer, with a threshold of 30 percent. All losses < 0.5 ha were filtered out in the final product.

This tree-cover layer was further assimilated with the "woodland" class of the NAFORMA (2011) classification. Plots from NAFORMA (2011) falling in the AOI were used to derive an average biomass expansion factor. The allometric equation developed by Chave *et al*. (2005) was used. The GlobAllomeTree database (Henry *et al*., 2013) for the United Republic of Tanzania was used to compute the average wood density of existing tree genera in the AOI.

The biomass expansion factor was applied to the tree/non-tree cover masks to obtain the biomass stock estimations.

Tools

All tools and datasets used in this rapid assessment are free, public and open-source.[10]

---

7 https://sepal.io

8 https://github.com/yfinegold/runBFAST

9 https://code.earthengine.google.com/575413198a5d8e919916adea6ed2e8ac

10 The process described here can be reproduced by accessing the scripts available at https://github.com/lecrabe/tzn_bfast_2017.git

Results

The information extracted from the NAFORMA dataset for the AOI consisted of 106 plots distributed in 16 clusters (Figure 4), in the "woodland" class only. In these plots, height and diameter at breast height were measured for a total of 199 trees (Figure 5).

The average wood density of species in the plots was 0.705 g per cm^3. Figure 6 shows the wood-density distribution for the species occurring in the AOI.

The average biomass stock was estimated at 9 068 kg per ha, reflecting the low density of trees in the plots.

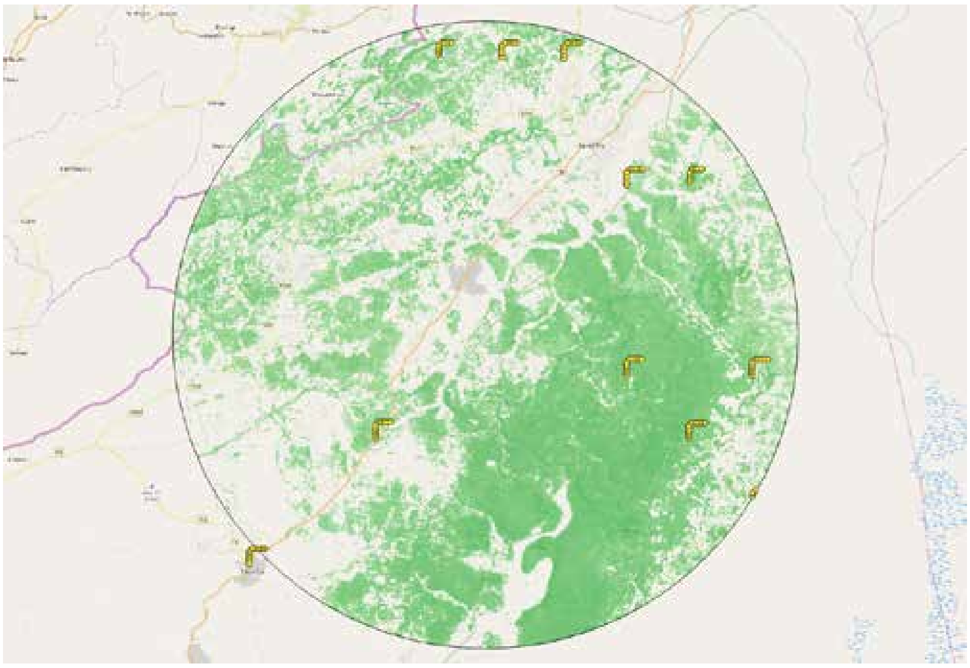

Figure 4. Location of the NAFORMA plots in the Mtendeli camp target zone with 11 plots of 16 over the entire area of interest

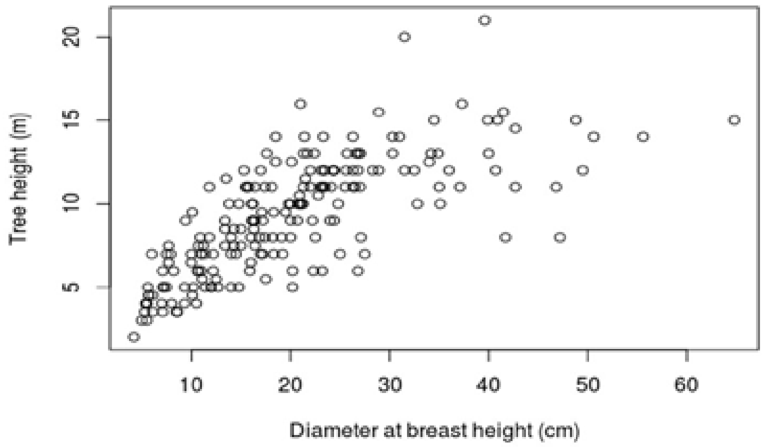

Figure 5. Tree height/diameter relationship for measured plots in the three areas of interest

Table 15 shows the estimated areas of tree cover and tree-cover losses between 2015 and 2017 (Figure 7) in a buffer radius of 25 km around the Nyarugusu, Nduta and Mtendeli refugee camps using temporal-change analysis of free public high-resolution satellite imagery. These results were obtained by assessing the accuracy of the tree-cover change product using a stratified random sampling of 80 points per camp (240 points assessed in total) visually assessed against Google Earth imagery and time series of Landsat and Sentinel-2 Data.

The final results include the estimated aboveground biomass and the change to agriculture, built-up, roads and others.

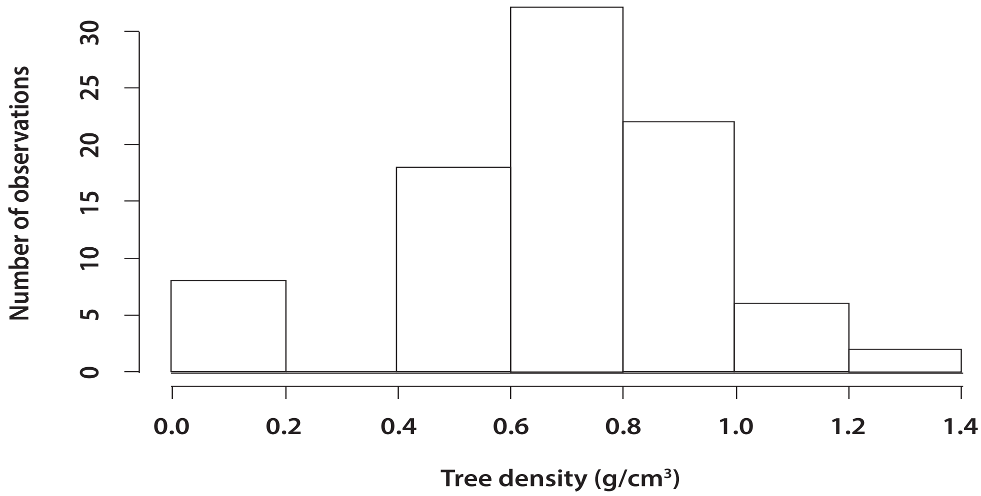

Figure 6. Wood-density distribution for the species occurring in the areas of interest

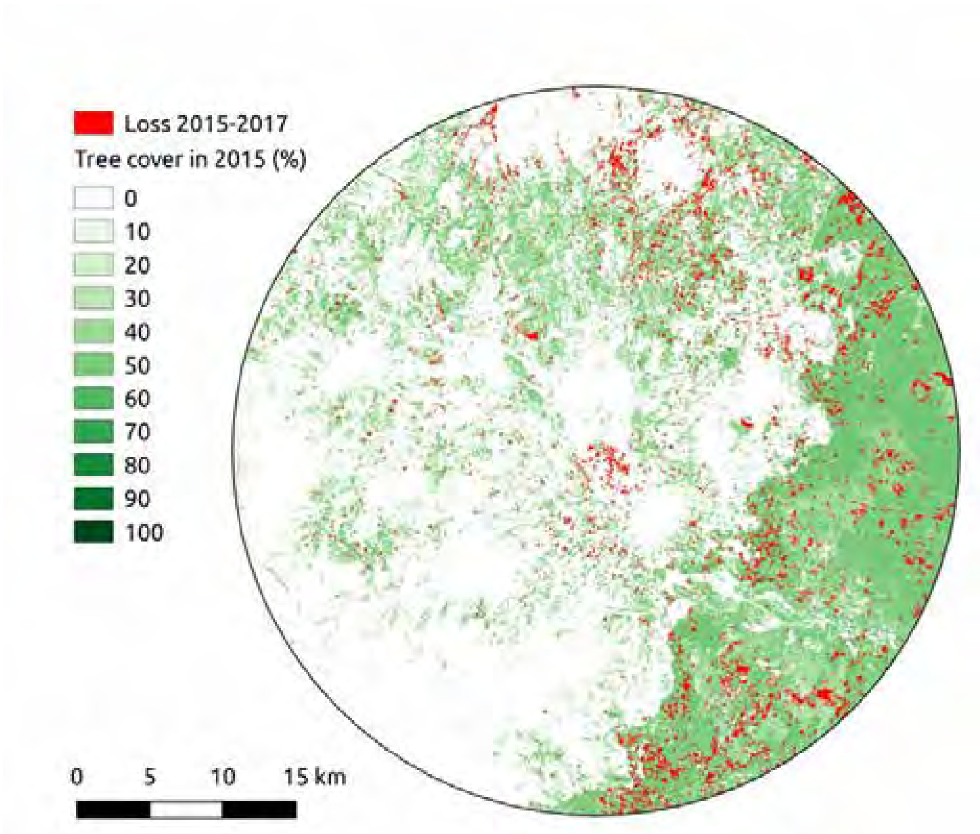

Figure 7. BFAST-detected tree-canopy losses between 1 January 2015 and 1 November 2017, Nyarugusu camp

The AOI of the Nyarugusu camp, for example, had an estimated tree cover of 54 010 ha in 2017 and the following non-tree cover: 58 138 ha (42 percent) of agricultural land; 725 ha of built-up; 4 085 ha of roads; and 74 335 ha of “other”. The main driver of tree-cover loss was agricultural expansion (3 747 ha, 84 percent), followed by conversion to roads and “other” (726 ha).

Tree-cover loss varied strongly between camps in 2017: it was 8 percent in the Nyarugusu AOI, 44 percent in the Nduta AOI and 48 percent in the Mtendeli AOI.

Table 15. Estimated area of forest and non-forest, tree-cover loss, aboveground biomass and land-use change in 2015–2017 in the three refugee camps of Nyarugusu, Nduta and Mtendeli

		2017			Change (2015–2017)				
		Area (ha)	Confidence interval	Aboveground biomass (tonnes)	Agriculture (ha)	%	Built-up (ha)	Roads (ha)	Others (ha)
NYARUGUSU	Tree cover	54 010	21 764	489 763	-	-	-	-	-
	Non-tree cover	137 284	22 302	-	58 138	42	725	4 085	74 335
	Tree-cover loss	4 472	6 068	-	3 747	84	0	363	363
	Tree-cover loss	8%	-	-	-	-	-	-	-
NDUTA	Tree cover	32 390	19 221	293 713	-	-	-	-	-
	Non-tree cover	138 000	20 830	-	59 054	43	201	0	78 746
	Tree-cover loss	25 378	16 603	-	463	2	0	0	24 915
	Tree-cover loss	44%		-	-	-	-	-	-
MTENDELI	Tree cover	34 565	18 061	313 435	-	-	-	-	-
	Non-tree cover	129 416	21 616	-	35 829	28	0	4 067	89 520
	Tree-cover loss	31 787	17 368	-	6 009	19	0	0	25 778
	Tree-cover loss	48%	-	-	-	-	-	-	-

Notes: “Agriculture” comprises all croplands; “built-up” comprise all areas with infrastructure other than roads; “roads” include primary and secondary roads; and “other” consists of all land uses not included in “agriculture”, “built-up” or “roads”, such as bare land and water bodies.

Annex 2. Key assumptions for the cost–benefit analysis

Parameter	Data	Unit	Source of information
Discount rate	9	%	www.tanzaniainvest.com/finance/banking/bot-cut-discount-rate
Exchange rate (USD/TZS)	2 226.79	USD/TZS	(As of 9 December 2017)
Woodfuel market price (retail)	147	TZS/kg	Field data collection
Maize market price	700 000	TZS/tonne	Field data collection
Land opportunity cost	123 553	TZS/ha	Field data collection
Cost of seedling production	450	TZS/seedling	Field data collection
Carbon credit price	11 579	TZS/tonne CO2eq	Hamrick and Goldstein (2016)
Labour (wage of unskilled rural labour)	4 000	TZS/day	Field data collection
Seedling transportation with trailer (average)	100 000	TZS/tractor trailer trip	Field data collection
Woodfuel transportation with trailer (average)	100 000	TZS/tractor trailer trip	Field data collection
Capacity of tractor for transportation of tree seedlings	2 000	seedlings/trip	Field data collection
One head load of air-dry woodfuel	26	kg	
Time spent in collection of one head load of woodfuel	4	hours	
Estimated cost of woodfuel collection	52.85	TZS/kg	Field data collection
Population, by camp			UNHCR (2017)
Nyarugusu	144 194	people	
Nduta	125 546	people	
Mtendeli	50 279	people	
Daily woodfuel consumption (air-dry matter)			Quigley (2016)
Low estimate	1.20	kg/person/day	
High estimate	2.40		
Average	1.80		
Number of seedlings outplanted			
• Forest rehabilitation	400	seedlings/ha	

Parameter	Data	Unit	Source of information
• Wood-energy plantations	10 000	seedlings/ha	
• Agroforestry	1 100	seedlings/ha	
Wood yields (dry matter)			
• Forest rehabilitation	2.63	tonnes/ha/year	Kityo (2004); Gerald (2012)
• Wood-energy plantations	30	tonnes/ha/year	
• Agroforestry	6.10	tonnes/ha/year	Nyadzi (2004); Kimaro *et al.* (2008)
Average wood basic density	0.625	tonnes/m^3	Holmes (1995); United Republic of Tanzania (2015)
Year 0	1.19	tonnes/ha Relative to baseline continuous cropping	Baseline maize yield in Kigoma (Amin *et al.*, 2017)
Year 1	1.19		
Year 2	1.55		
Year 3	0		
Year 4	1.55		
Year 5	1.55		
Year 6	0		
Year 7	1.55		
Year 8	1.55		
Year 9	0		
Year 10	1.55		

References

Amin, A., Quétier, F., Munishi, P. *et al.* 2017. *Study on economic valuation of natural resources and ecosystem services in NRM4LED project landscapes*. Biotope report to Belgium Technical Cooperation, Natural Resources Management for Local Economic Development in Kigoma Region project. Dar es Salaam, Ministry of Natural Resources and Tourism.

Chave J., Andalo, C., Brown, S., Cairns, M.A., Chambers, J.Q., Eamus, D., Fölster, H. *et al.* 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, 145(1): 87–99. DOI 10.1007/s00442-005-0100-x

DeVries, B., Verbesselt, J., Kooistra, L. & Herold, M. 2015. Robust monitoring of small-scale forest disturbances in a tropical montane forest using Landsat time series. *Remote Sensing of Environment*, 161: 107–121. DOI:10.1016/j.rse.2015.02.012

Dutrieux, L.P., Verbesselt, J., Kooistra, L. & Herold, M. 2015. Monitoring forest cover loss using multiple data streams: a case study of a tropical dry forest in Bolivia. *ISPRS Journal of Photogrammetry and Remote Sensing*, 107: 112–125. doi:10.1016/j.isprsjprs.2015.03.015

FAO. 2018. *Training manual on community forest management and diversification*, by G. C. Kajembe. Rome.

FAO & UNHCR. 2018. *Managing forests in displacement settings: guidance on the use of planted and natural forests to supply forest products and build resilience in displaced and host communities*, by A. Gianvenuti, A. Guéret & C. Sabogal. Rome.

Gerald, V.V.K. 2012. *Coppicing of two indigenous* Albizia *tree species under different land tenure and use systems and their interaction with maize*. Thesis for award of PhD degree at Sokoine University of Agriculture, Morogoro, United Republic of Tanzania. 188 pp.

Hamrick, K. & Goldstein, A. 2016. *Raising Ambition: State of the Voluntary Carbon Markets 2016.* Washington, DC, Ecosystem Marketplace.

Hansen, M.C.P.V. 2013. High-resolution global maps of 21st-century forest cover change. *Science*, 850–853.

Henry, M., Bombelli, A., Trotta, C., Alessandrini, A., Birigazzi, L., Sola, G., Vieilledent, G. *et al.* 2013. GlobAllomeTree: international platform for tree allometric equations to support volume, biomass and carbon assessment. *iForest*. DOI: 10.3832/ifor0901-00

Holmes, J. 1995. *Forest ecology and management*. Natural forest handbook for Tanzania. Volume 1. Faculty of Forestry, Sokoine University of Agriculture.

Hoogwijk, M., Faaij, A.X.E., Eickhout, B., de Vries, B. & Turkenburg, W. 2005. Potential of biomass energy out to 2100, for four IPCC SRES land-use scenarios. *Biomass and Wood Energy*, 29(4): 225–257.

Kessy, J.F., Nsokko, E., Kaswamila, A. & Kimaro, F. 2016. Analysis of drivers and agents of deforestation and forest degradation in masito forests, Kigoma, Tanzania. *International Journal of Asian Social Science*, 6(2): 93–107.

Kimaro, A.A. 2009. *Sequential agroforestry systems for improving fuelwood supply and crop yield in semi-arid Tanzania*. Thesis for award of PhD degree at the University of Toronto, Canada.

Kimaro, A.A. Timmer, V.R., Chamshama, S.A.O., Mugasha, A.G. & Kimaro, D.A. 2008. Differential response to tree fallows in rotational woodlot systems: post-fallow maize yield, nutrient uptake, and soil nutrients. *Agriculture, Ecosystems and Environment*, 125(1–4): 73–83.

Kitalyi, A., Nyadzi, G.I., Lutkamu, M., Swai, R. & Gama, B. 2010. New climate, new agriculture: how agroforestry contributes to meeting the challenges of agricultural development in Tanzania. *Tanzania Journal of Agricultural Sciences*, 10(1): 1–7.

Kityo, P. 2004. *Productivity and utilization of natural fuel wood resources: an evaluation of the current situation in some parts of Gaza Province, Mozambique.* Dissertation for award of MSc degree, International Institute of Geo-information Science and Earth Observation, Enschede, the Netherlands.

Makunga, J.E. & Misana, S.B. 2017. The extent and drivers of deforestation and forest degradation in masito-ugalla ecosystem, Kigoma Region, Tanzania. *Open Journal of Forestry*, 7: 285–305.

Malimbwi, R.E., Zahabu, E., Kajumbe, G.C. & Luoga, E.J. 2000. *Contribution of charcoal extraction to deforestation: experience from CHAPOSA research project*. Morogoro, United Republic of Tanzania, Faculty of Forestry and Nature Conservation, Sokoine University of Agriculture (available at www.tfcg.org/pdf/Malimbwi%20CHAPOSA%20project%20lessons%20learned.pdf).

NAFORMA. 2011. *Field manual biophysical survey*. Compiled by L. Vesa, R.E. Malimbwi, E. Tomppo, E. Zahabu, S. Maliondo, N. Chamuya, E. *et al*. Dar el Salaam, United Republic of Tanzania, National Forestry Resources Monitoring and Assessment of Tanzania (NAFORMA).

Nyadzi, G.I. 2004. *Nutrient and water dynamics in rotational woodlots. A case study in western Tanzania*. PhD thesis. Wageningen, the Netherlands, Wageningen University and Research Centr.

Nyadzi, G.I., Janssen, B.H. & Oenema, O. 2006. Analysis of the effects of rotational woodlots on the nutrition and yield of maize following trees in western Tanzania. *Agriculture, Ecosystems and Environment*, 116: 93–103.

Otsyina, R., Minae, S. & Cooper, P. 1996. A never-ending story: rotational woodlots for soil conservation, wood and fodder. *Agroforestry Today*, 8(2): 8–10.

Otsyina, R., Msangi, R., Gama, B., Ramadhani, T., Nyadzi, G. & Shirima, D. 1997. *SADC/ICRAF Agroforestry Project Tumbi, Tabora, Tanzania. Annual Progress Report No. 114*. Nairobi, International Centre for Research on Agroforestry.

Quigley, P. 2016. *Providing energy for cooking: an analysis of fuel options in refugee camps in Tanzania.* Geneva, Switzerland, United Nations High Commissioner for Refugees (UNHCR).

UNHCR. 2017. *Tanzania refugee situation statistical report*. 31 October 2017. United Nations High Commissioner for Refugees (UNHCR) (available at https://data2.unhcr.org/en/documents/download/60875).

United Republic of Tanzania. 2015. *National forest resources monitoring and assessment of Tanzania mainland.* Ministry of Natural Resources and Tourism, Government of Finland & FAO.

Verbesselt, J., Hyndman, R., Newnham, G. & Culvenor, D. 2010. Detecting trend and seasonal changes in satellite image time series. *Remote Sensing of Environment*, 114(1): 106–115.

This report presents a cost–benefit analysis of three possible forestry interventions aimed at producing a sustainable supply of woodfuel and reducing land degradation and deforestation in the vicinity of three refugee camps in the Kigoma region, United Republic of Tanzania. The proposed forestry interventions are: forest rehabilitation; wood-energy plantations; and agroforestry. The analysis uses field data collected in 2017, including focus-group discussions, field observations and direct interviews.

The report shows that wood-energy plantations and agroforestry both have great potential to support wood-energy needs in both the refugee and host populations in the Kigoma region. Forest rehabilitation is less financially attractive, although the analysis did not take into account other benefits this option would provide, such as improved water quality. The report suggests that an incentive mechanism could be created to assist farmers in host communities to implement forestry interventions and to benefit directly from them.

ISBN 978-92-5-130742-7

9 789251 307427

CA0164EN/1/06.18