Rapid woodfuel assessment

2017 baseline for the Bidibidi settlement, Uganda

Woodfuel supply/demand and scenarios for improving access to energy and reducing environmental degradation

Cover photo: © East Africa Production House – Aerial photo of Bidibidi refugee settlement, Uganda

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Contents

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Acronyms

FAO	Food and Agriculture Organization of the United Nations
FGD	Focus group discussion
GDAL	Geospatial Data Abstraction Library
GIZ	German Agency for International Cooperation
IMAD	Iteratively Multivariate Alteration Detection
IRC	International Rescue Committee
LULC	Land use/land cover
NBS	National Biomass Study
NFA	National Forest Authority of Uganda
OFGT	Open Foris Geospatial Toolkit
REDD+	Reducing Emissions from Deforestation and Degradation
SAFE	Safe Access to Fuel and Energy
SEPAL	System for earth observations, data access, processing & analysis for land monitoring
UBOS	Uganda Bureau of Statistics
UNHCR	United Nations High Commissioner for Refugees
VHR	Very high resolution

Executive summary

Uganda is host to more than 1 million refugees who have fled famine, conflict and insecurity in the neighbouring countries of Burundi, the Democratic Republic of the Congo and South Sudan. The recent influx of refugees from South Sudan prompted one of Uganda's most severe humanitarian emergencies and led to the establishment of the Bidibidi settlement in Yumbe District in August 2016. The Bidibidi settlement is now the world's largest refugee-hosting area, with 272 206 refugees settled on a land area of approximately 250 km^2 in a total assigned area of 798 km^2. The Bidibidi refugee settlement constitutes more than half the population of the host district, Yumbe (484 822 people). It has increased pressure on the environment due to tree felling for settlement establishment and to meet ongoing household demand for woodfuel for cooking and heating.

FAO and UNHCR initiated a joint rapid woodfuel assessment in March 2017 to determine the supply and demand of woodfuel resources in the area. The assessment had three components: 1) an assessment of woodfuel demand; 2) an assessment of woodfuel supply; and 3) the identification of interlinkages, gaps, opportunities and alternative scenarios. Data and information were obtained through a desk review of existing documents, field surveys, and remote sensing analysis.

Main findings

- **Fuelwood consumption. Average fuelwood consumption for cooking/heating in the Bidibidi settlement is estimated at 20.5 kg of air-dried wood per household per day, or 3.5 kg per person per day**. For the purposes of the assessment, daily fuelwood consumption was assumed to remain constant over the year with no seasonal variations. Although only a minor share of fuelwood is used for heating, average daily fuelwood consumption of 3.5 kg per day is considered quite high in comparison with similar situations. For example, estimates in the literature of fuelwood consumption for cooking in displacement settings range from 0.7 kg to 3 kg per person per day.

  The rate of fuelwood consumption for the total population of 272 206 refugees is estimated at **about 952 tonnes per day, which amounts to approximately 347 480 tonnes of fuelwood per year**. Given that the settlement was opened a little more than seven months before the assessment, fuelwood consumption to March 2017 was estimated at 199 920 tonnes. The food rations of refugees include mainly maize and beans, with beans especially requiring a long cooking time. The household survey showed that few (3 percent) of the refugees use charcoal for cooking, and charcoal consumption between August 2016 and March 2017 was estimated at 672 tonnes, equivalent to 3 360 tonnes of fuelwood.

- **Mixed use of traditional and fuel-efficient stoves.** It was observed that many refugees use wet/green wood, which increases the volume of fuelwood consumed. Although more than half (56 percent) of **households use the traditional 3-stone fire for cooking**, the survey showed that the use of fuel-efficient stoves is not new to the Bidibidi refugees: **43 percent of refugee households use improved mud stoves and have knowledge of and skills in their**

construction. The adoption of fuel-efficient stoves appears to be lower in the host community than in the refugee community.

- **Heavy burden on women.** The burden of fuelwood collection in the Bidibidi settlement falls entirely on women. Women make an average of four trips per week to collect fuelwood, and they face a number of constraints and risks. They carry heavy loads of green wood, which they sometimes use before it dries. **Women and girls are exposed to multiple dangers as they walk long distances to fetch fuelwood**, including attack by wild animals and assault and rape by members of both the host and refugee communities. The shared use of natural resources overall has had an impact on social relations, causing tensions and conflicts between the host and refugee communities.

- **Woody biomass also sustains other uses.** Refugees have cut woody biomass to build shelters and other household structures. According to measurements obtained in the field, households used, on average, **approximately 0.9 m^3 of wood poles for construction**. The Office of the Prime Minister estimated the volume of woody biomass used for this purpose by the settlement's estimated 101 500 households in the area at 91 350 m^3, which equates to 63 945 tonnes (assuming an average wood density of 700 kg per m^3).

- **Biomass stock, growth and land use/land cover.** The total **aboveground biomass stock was estimated at 734 614 tonnes (air-dried) within the settlement boundary and at 1 617 953 tonnes when a buffer area within 5 km of the settlement boundary is included**. Most aboveground biomass is in open woodland, although closed woodland also contributes significant amounts despite their relatively small area. The combined use of field measurement, land-use descriptors and analysis of radar and optical data enabled the mapping of land-use/land-cover features in the Bidibidi settlement and provided estimates of biomass for each land-use/land-cover class.

  Within the Bidibidi settlement, closed woodland has the highest biomass density (191 130 tonnes of dry matter over an area of 3 356 hectares, representing 26 percent of the total woody biomass resource available in the settlement). The closed woodland resource is concentrated in a small area at the edge of the settlement in the northeast, exposing it to high pressure for use as woodfuel. The biomass in open woodland – the area of which is more than ten times larger (39 492 hectares) – constitutes about half (364 513 tonnes) the available total woody biomass and is identified as the main potential source of fuelwood in the Bidibidi settlement. Land assigned to agriculture ("cultivated land") in the settlement also contains significant biomass resources (18 percent of the total).

  Because of strong seasonality effects and agricultural practices (burning), land use and land cover change over the period between settlement establishment and the assessment did not reveal any change in woody biomass resources other than that caused by the establishment of the settlement itself. However, an estimated 203 280 tonnes of fuelwood (including charcoal expressed as fuelwood equivalent) was consumed in the seven months between the establishment of the settlement and the assessment, and this should be compared with the current estimated aboveground biomass of 734 614 tonnes and the annual estimated growth rate of 33 300 tonnes per year in the settlement area. If the 5-km buffer area around the settlement is taken into account, the estimated total aboveground biomass stock is

1 588 961 tonnes. Note, however, that the area outside the settlement boundaries is subject to woodfuel demand from the host community.

- **Scenarios.** By integrating the results of the woodfuel demand and supply assessments, the following future scenarios can be projected: 1) business as usual; 2) with improved cookstoves; and 3) with tree plantations and improved stoves.

    1. **Business as usual.** The woody biomass resources available in the Bidibidi settlement are scarce and under documented pressure. Given **annual fuelwood consumption of 347 480 tonnes**, these resources could meet demand in the settlement for up to three years, but at the cost of the full depletion of aboveground biomass in the area. Business as usual, therefore, would lead rapidly to severe fuelwood resource constraints, given that refugees already compete with local communities for scarce resources beyond the settlement area. Continuous monitoring of the resources is needed in coming months to guide decision-making on measures to mitigate resource pressure.
    2. **With improved cookstoves.** The use of improved and more energy-efficient cookstoves in place of traditional 3-stone fires could reduce fuelwood consumption by about 30 percent compared with business as usual. In this scenario, total fuelwood consumption in the Bidibidi settlement would be about 243 000 tonnes per year, compared with 347 480 tonnes under business as usual. In the improved cookstove scenario, women would spend less time collecting fuelwood and therefore would have more time for other activities. Given the current estimated annual growth rate of aboveground biomass of 33 300 tonnes, the annual deficit of woody biomass growth would be 209 700 tonnes. Under this scenario, therefore, **the woody biomass resources in the settlement area would meet demand in the settlement for up to four years**.
    3. **With tree plantations and improved cookstoves.** This scenario includes the establishment of tree plantations to increase the supply of woody biomass; it also assumes that all refugee households adopt improved mud stoves (as per scenario 2). Under this scenario, **it is estimated that 9 368–12 178 hectares – 12–15 percent of the total land area of the Bidibidi settlement – would need to be planted with fast-growing species to provide a sustainable fuelwood supply. Each household would need to dedicate a minimum woodlot area of 50 m x 50 m exclusively to growing wood for energy**.

1. Introduction

1.1 Background

The drivers and impacts of migration and displacement in acute and protracted crises are intimately linked to FAO's global goals of fighting hunger and achieving food security, reducing rural poverty and promoting the sustainable use of natural resources, including forests and woodlands. FAO is addressing its Strategic Objective 5 ("Increase the resilience of livelihoods to threats and crises") through, among other things, this study and its broader partnership with UNHCR. Collaboration between FAO and UNHCR is also a step in strengthening UN interagency support for displaced people and improving the management and sustainability of natural resources in the context of displacement.

FAO and UNHCR are working as partners in the Safe Access to Fuel and Energy (SAFE) framework to identify and implement appropriate solutions to the challenges faced by crisis-affected populations, including both the displaced and host communities. SAFE adopts a holistic approach that takes into account the mutually reinforcing linkages between energy access and associated challenges related to nutrition, forests, climate change, health, gender, protection and livelihoods.

Uganda hosts more than 1 million refugees from the neighbouring countries of Burundi, the Democratic Republic of the Congo and South Sudan, who seek protection from famine, conflict and insecurity. Of these people, refugees from South Sudan face the most severe humanitarian emergency. The recent influx of refugees from that country to Uganda led to the establishment of the Bidibidi settlement in Yumbe District in August 2016. Bidibidi is the world's largest refugee-hosting area, with 272 206 refugees (OPM, Level 1 Registration to 19 December 2016).

The Bidibidi settlement constitutes more than half the population of Yumbe District (484 822 people) (UBOS, 2014). Inevitably, it has caused an increase in tree-cutting for the establishment of the settlement and to supply refugee households with woodfuel. The refugee management policy in Uganda is characterized by a non-camp settlement approach, which is widely regarded as an example of best practice in the region. The 2006 Refugee Act and the 2010 Refugee Regulations grant *prima facie* refugee status to all South Sudanese and Congolese and facilitate the food-security and emergency agricultural livelihoods strategy, which allocates plots of land to refugees for agricultural use. The Uganda refugee management policy also promotes the integration of life-saving social services into national government systems. Specifically, refugee settlements are integrated into host communities, granting refugees:

- access to the same services (e.g. health facilities) as nationals;
- the right to livelihoods and to establish businesses;
- the right to go to school;
- freedom of movement; and
- access to allocated land for agricultural use.

These rights constitute a significant opportunity to protect refugees in the face of crises; ensure that suitable conditions exist for integrating emergency livelihoods in refugee-hosting areas and local government systems; and build self-reliance and resilience.

Woodfuel is the major source of energy in rural Uganda. The consumption and production of woodfuel in 2015 was estimated at around 42.4 million m^3 for fuelwood and 1.06 million tonnes for wood charcoal (FAO, 2015a); thus, about 95 percent of woodfuel in Uganda is consumed in the form of fuelwood. Uganda faces significant pressure on its forests and woodlands and suffers from a high rate of deforestation and land degradation; there have been drastic changes in forest cover in the past few decades. According to FAO (2015b), an estimated 2.6 million hectares of forest cover (approximately 13 percent of Uganda's total land area) was lost in the period from 1990 to 2015. The average annual loss of forest cover was 88 000 hectares between 1990 and 2000; 111 000 hectares between 2000 and 2010; and 185 000 hectares between 2010 and 2015.

Fuelwood is the primary source of energy for refugees in the Bidibidi settlement, although households use charcoal if they can afford it. The National Forest Authority of Uganda (NFA) has marked trees that should not be cut, but all other trees in the settlement are liable to be cut down due to the sudden increase in population in the area and the high demand for woodfuel for cooking. The cooking-energy needs of the large number of refugees in Uganda exacerbates the country's existing fuelwood overharvesting problem and increases the risk of rapid degradation of soils, forests and woodlands.

With the large number of people crossing the border from South Sudan to Uganda, there is an urgent need to develop strategies for supportive sustainable energy access and forest resource management targeting both the refugee population in the Bidibidi settlement and the host community.

1.2 Objectives of the assessment

The objectives of the rapid woodfuel assessment reported here were to:

1. assess the woodfuel demand (fuelwood and charcoal) for cooking and heating and challenges related to the collection and use of woodfuel by the refugee population in the Bidibidi settlement;
2. identify the cooking technologies and practices in use in the area of interest and the associated opportunities and challenges;
3. assess the potential woodfuel supply in the area of interest and the state of and changes in aboveground biomass stock, growth and land use/land cover; and
4. make recommendations for planning interventions to improve energy access, promote sustainable forest management and contribute to building resilience in the affected population in the Bidibidi settlement.

1.3 Methodology

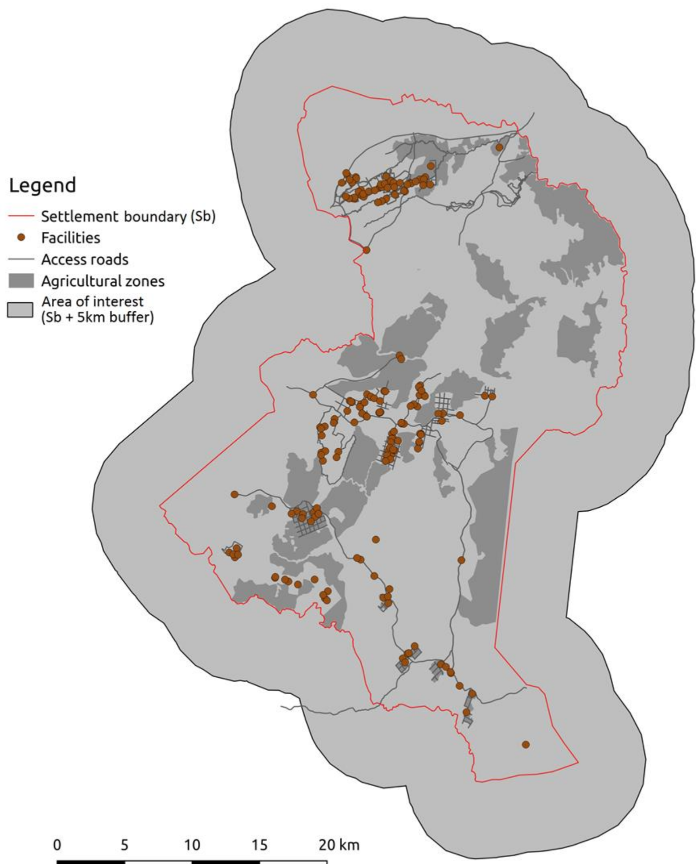
This rapid woodfuel assessment builds on the methodology developed in the joint FAO–UNHCR technical handbook, *Assessing Woodfuel Supply and Demand in Displacement Settings* (FAO and UNHCR, 2016). The methodology comprised three programmatic components: 1) an assessment of woodfuel (fuelwood and charcoal) demand since the establishment of the settlement (assuming woodfuel demand is equal to ongoing woodfuel consumption) and the associated challenges faced by refugees and the host community; 2) an assessment of the woodfuel supply, including the aboveground biomass stock, land-cover classification, and changes since settlement establishment; and 3) the identification of relevant interlinkages and gaps, and the development of possible future scenarios involving interventions to introduce improved cookstoves and afforestation initiatives.

The study involved a combination of a desk review of existing documents, field surveys, and an analysis of very high resolution (VHR) satellite imagery. Field surveys comprised assessments of woodfuel demand in the refugee settlement and of the biophysical parameters of forests and woodlands. Satellite imagery analysis was performed by combining semi-automatic land classification and change detection processes.

Area of interest

The area of interest (Figure 1) comprises the area within the settlement boundary and a buffer zone around the settlement, arbitrarily taken to be the area within 5 km of the settlement boundary (and viewed as a possible area for fuelwood collection outside the settlement). The settlement itself comprises an area of 798 km^2, within which five zones covering a total of 250 km^2 have been established. The area of the 5-km buffer zone brings the total area of interest to 1 617 km^2.

Figure 1. The area of interest defined by UNHCR and the 5-km buffer area around the settlement



Wood energy data collection and analysis

The woodfuel demand assessment was conducted using a household quantitative survey combined with qualitative interviews and focus group discussions (FGDs) in the refugee and host communities. The objective was to provide data and information on fuelwood and charcoal consumption, the average time spent by households collecting fuelwood, the types of cooking system used for cooking, and the main challenges. The process was participatory, with FAO and UNHCR staff holding several field discussions on the assessment with members of the communities. Key informant interviews were held with representatives of the Office of the Prime Minister, district officials and a team of community workers with the International Rescue Committee (IRC) to obtain a broader understanding of environmental and energy factors in the Bidibidi settlement. An FAO–UNHCR team supported by four IRC enumerators collected data on wood energy and sociocultural factors between 28 February and 3 March 2017. The sampling design for the household survey involved the selection of zones within the settlement to be surveyed; an estimate of the sample size according to the timeframe and resources available; and a random selection of sample households.

Four data collectors – community workers in the settlement – were given an orientation on the household survey, after which they tested the tools with an initial sample of households under the supervision of the FAO–UNHCR team. Households were then selected randomly in the different parts of the selected zones in the Bidibidi settlement. Respondents were mainly women – because they had knowledge of fuelwood collection and use in households – and heads of households. Data collection was carried out in three zones (1, 3 and 4); 72 households were interviewed to collect quantitative and qualitative data through questionnaires and direct interviews.

To quantify daily woodfuel (fuelwood and charcoal) consumption, the assessment team weighed the estimated amount of woodfuel for cooking and heating using a digital hanging scale; in the case of fuelwood, the team also took note of whether it was wet/green or dry based on visual inspection. Other observations were made and photographs taken of fuel-efficient cookstoves in use in households. These data were analysed to estimate average daily wood consumption per person in the settlement.

Focus group discussions were held in the Bidibidi settlement and in one village in the host community involving a mix of ages, social groups and genders. Key informant interviews were conducted in the settlement and with district-level authorities.

Data collectors undertook substantive checking in the settlement to verify assertions made in the household survey, interviews and focus group discussions. Data from the household survey were entered and analysed using Excel and compiled into tables and graphics. Data analysis was supported by the application of the SAFE tool, *Woodfuel Assessment in Displacement Settings*, to identify the baseline situation and to simulate scenarios in which improved cookstoves and tree plantations are introduced to increase energy efficiency in cooking, reduce energy consumption and increase woody biomass growth. The scenarios analysed were 1) business as usual; 2) improved cookstoves to reduce woodfuel demand; and 3) new tree plantations and improved cookstoves.

Biophysical field inventory

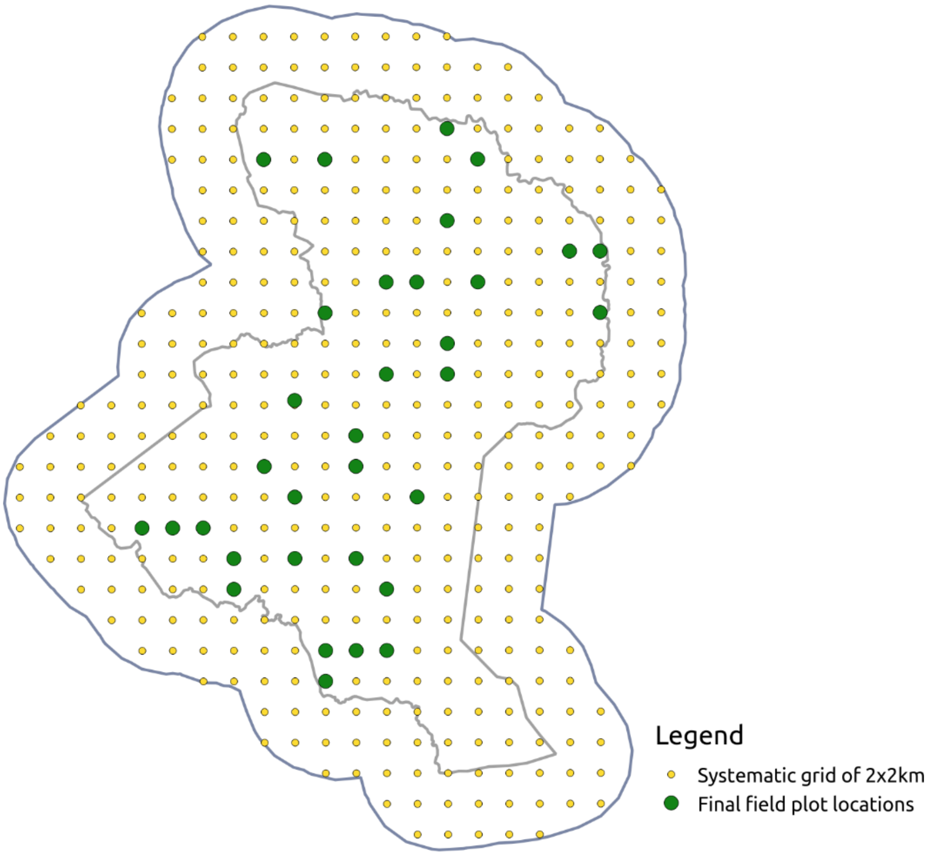
Biophysical field data was used to estimate fuelwood stocks for various land-use/land-cover (LULC) classes. The distribution of fuelwood resources was mapped using remote sensing, enabling an assessment of stock changes before and after the establishment of the Bidibidi settlement.

Sampling design

A systematic grid with a spacing of 2 km x 2 km was generated over the settlement area. A first visual interpretation of the grid points was performed to establish a preliminary stratification of land cover. This was based on a combination of Sentinel-2 imagery for the beginning of 2017 and freely available VHR imagery for the time before settlement establishment.

Data from Uganda's National Forest Inventory were used against the classes identified in the area of interest to determine the number of field plots needed to measure biomass by LULC class. Based on the stratification of relevant classes (see Chapter 3), 33 points in the settlement were selected randomly for measurement in the field (Figure 2).

Figure 2. Systematic grid with a spacing of 2 km x 2 km and the 33 randomly selected plot locations



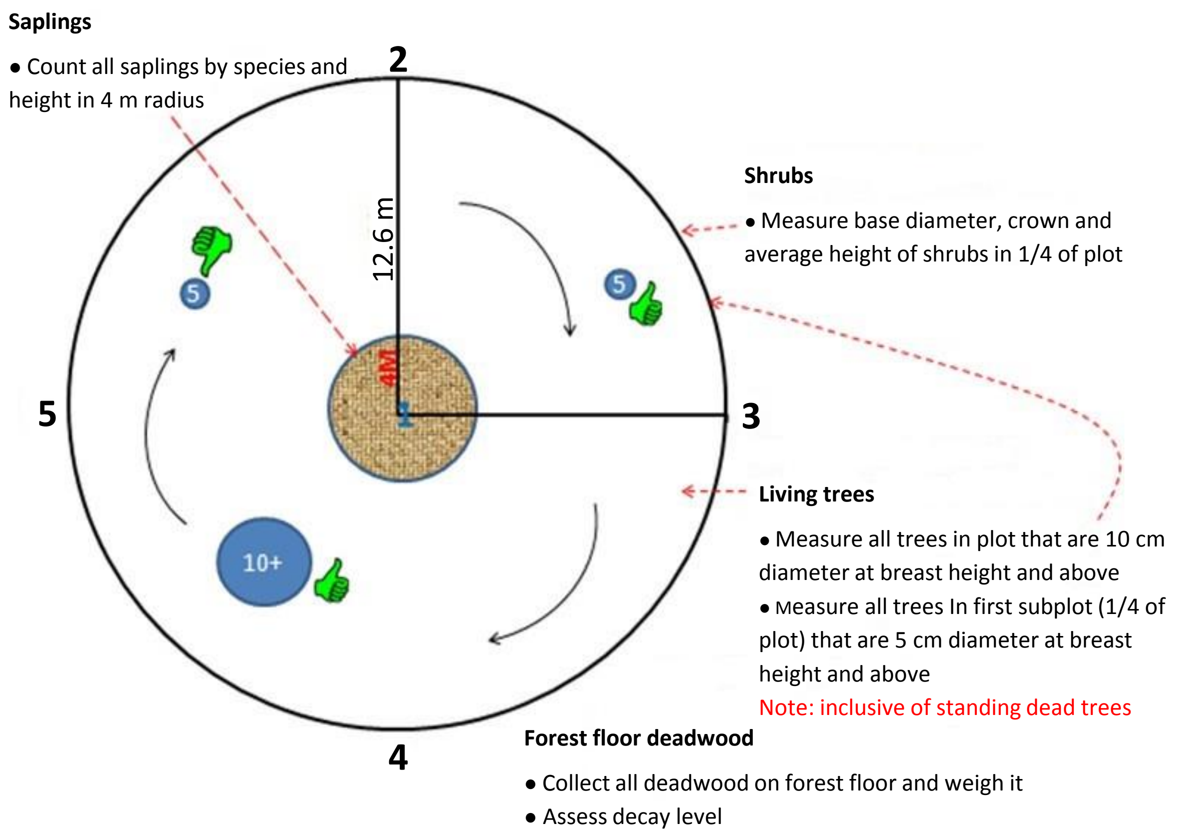
Plot design and field data collection

For each field point, a circular plot with a radius of 12.6 m and an area of approximately 500 m^2 was established. Several subplots were measured in each plot (Figure 3) so as to follow the methodology used in the National Forest Inventory.

In the first quadrant of a given plot, the base diameter, crown and average height of all shrubs were measured. Height, diameter at breast height and species name were recorded for all standing trees (living and dead) with a diameter at breast height of 5 cm or more. Standing trees with a diameter at breast height of 10 cm and above were measured in the remaining subplots.

All saplings and deadwood within a radius of 4 m from the centre of the plot were measured. Deadwood was collected and weighed when possible. If deadwood was too heavy to be weighed, length and diameter were recorded.

Figure 3. Plot design for the field inventory



In addition to these dendrometric measurements, the following LULC descriptors were collected for each plot:

- slope, orientation, altitude and accessibility;

- major LULC types;
- proportions of each LULC type;
- fire evidence;
- grazing intensity; and
- undergrowth type.

Specialists from the NFA inventory team collected the biophysical data between 28 February and 11 March 2017. Data were recorded using Open Foris Collect Mobile,[1] an Android app that facilitates fast, intuitive, flexible data collection in field-based surveys (Figure 4).

Figure 4. Open Foris Collect Mobile is used for a field inventory exercise in Uganda

© Uganda National REDD+ Secretariat

Estimating biomass stocks and annual increment

In each plot, aboveground biomass was calculated from field data using the allometric equations of Chave *et al.* (2014), which were also used in Uganda's National Biomass Study (NBS). R scripts developed for REDD+[2] in the NBS were used to estimate stocks. For the final estimates, plot-level results were aggregated into LULC classes, as assigned to plots during the field inventory. Biomass estimates by LULC class were calculated as means (95 percent confidence intervals).

Average annual biomass increments were obtained from the NBS, which provides these for the various LULC classes in each of Uganda's agroecological zones (Forest Department, 2002). Yumbe District is in the semi-moist lowland zone.

[1] www.openforis.org/tools/collect-mobile.html
[2] REDD+ = Reducing Emissions from Deforestation and Forest Degradation.

Remote sensing analysis

The aim of the remote sensing analysis was to map LULC before and after the establishment of the settlement as a way of estimating biomass change over the period. LULC was mapped for the entire settlement and for the 5-km buffer zone.

Satellite imagery used

The assessment used freely available satellite imagery from the Sentinel series (Sentinel-1 and Sentinel-2) of the European Union's Copernicus programme, which combines radar and optical data. The combination of the two data sources has been shown to improve biomass estimates, especially in open woodlands such as those in northern Uganda (Joshi *et al*., 2016). The use of VHR commercial optical imagery was considered, but no adequate imagery was available covering the full settlement area for either the end of 2016 or the beginning of 2017.

Radar data

Sentinel-1 is a C-Band SAR satellite. Sentinel-1 data were selected for the period 1 January 2016 to 15 March 2017, considering both single and dual polarized data. Sixteen images for Track 102 were found and subsequently downloaded as a Level 1 GRD product from the Alaska Satellite Facility server using the Open Foris SAR toolkit interface on the SEPAL (System for earth observations, data access, processing & analysis for land monitoring) platform.[3] These data were used to create a time-series stack and for the subsequent application of a multitemporal speckle filter.

Two separate TimeScan products were developed at 10 m spatial resolution. Because vertical-horizontal (VH) polarized imagery were unavailable for all the dates of interest, only the vertical-vertical (VV) polarized bands were considered in this step.[4] The procedure itself consists of taking the time-series stack and creating descriptive statistics such as the minimum, maximum and average values as well as the standard deviation and coefficient of variation, calculated in the temporal domain. Dry-season images were chosen for the two TimeScan products (four images for the beginning of each of 2016 and 2017) because the SAR signal is sensitive not only to structural attributes but also to moisture effects. Because woody vegetation is characterized by low temporal variation and relatively high backscatter values, a correlation between the TimeScan products and biomass can be expected.

Optical data

Sentinel-2 is an optical sensor that captures spectral reflectance of the wavelengths characteristically useful for differentiating vegetation. Image mosaics (greenest wettest pixels closest to the target date) at a spatial resolution of 10 m were acquired through Google Earth Engine API for February 2016 and January 2017 – before and after the establishment of the settlement. February 2016 was chosen because of seasonal similarities with January 2017.

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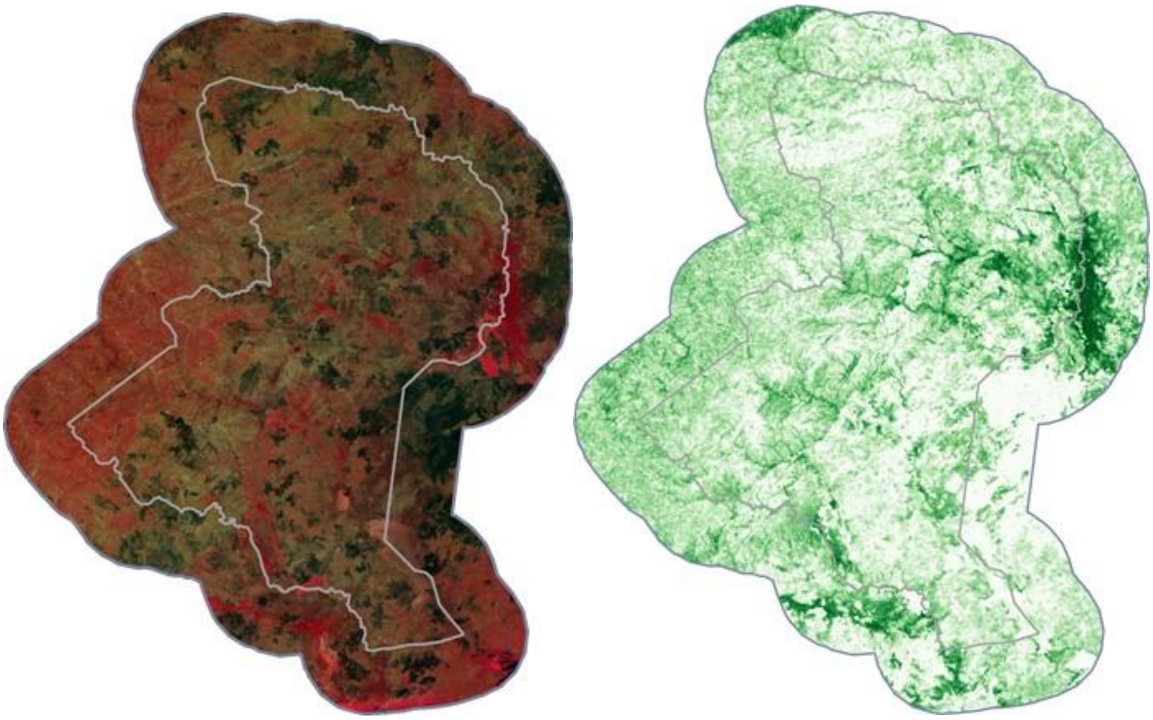
[3] https://sepal.io

Figure 5. Sentinel-2 (left) and Sentinel-1 data (right) for the area of interest, beginning of 2017



The left-hand image in Figure 5 shows a false colour composite of the Sentinel-2 mosaic for January 2017, including the boundaries of the settlement area and the 5-km buffer zone. Band 8 (near infrared) is displayed as red; band 4 (red light) is displayed as green; and band 3 (green light) is displayed as blue. Green vegetation shows as red in this image, grassland (dry at this time of year) shows as light green/brown, and dark areas correspond with burnt areas.

The right-hand image in Figure 5 is a pseudocolour image of Sentinel-1 Gamma0 VV minimum backscatter intensity TimeScan layer for January–February 2017. Dark green areas indicate high levels of woody biomass and white areas indicate no woody biomass.

Image processing for LULC classification and direct biomass estimates

Data from both Sentinel-1 and Sentinel-2 were processed to the same spatial extent and resolution (~10 m) and clipped to a 5-km buffer around the settlement boundary.

The following processing steps were undertaken for each time step:

- Processing of Sentinel-1 imagery to the same spatial extent and resolution (~10 m) as Sentinel-2 imagery.
- For 2017, use of bands 2, 3, 4 and 8 in Sentinel-2 imagery and all four available bands in Sentinel-1 multitemporal data (mean, minimum, maximum and standard deviation). For 2016, use of only bands 2, 3, 4 and 8 for Sentinel-2 because Sentinel-1 data contained artefacts that presented biased results.
- An unsupervised classification (50 clusters) run over the imagery for each time period (using the oft-kmeans tool of OFGT).
- Sieving of the clusters to a minimum size of 8 pixels (using the gdal_sieve.py tool of GDAL).

- Calculation of the mean spectral signature for each unique cluster (using the oft-stat tool of OFGT).
- RA supervised classification (R package randomForest) run for LULC classification.
- Computed statistics of resultant classification images for both settlement area only and the buffer area of 5 km around the settlement boundary.

The following training datasets were tested for the supervised LULC classification:

1. points visited during the field mission only;
2. a combination of points from field missions and manually added points; and
3. hand-drawn polygons.

Dataset 1 was insufficient to derive a sound classification. Dataset 2 provided very good classification results for January 2017, and dataset 3 was deemed most appropriate for February 2016.

Change detection

Independent change detection was performed using the IMAD [Iteratively Multivariate Alteration Detection] algorithm (using the oft-imad.py tool of OFGT) to determine any changes between the two periods covered by the Sentinel-2 imagery. This ensured that zones of change were properly detected, taking into account issues related to seasonality and the presence of clouds and shadows.

Tools and software

Field data were collected using Open Foris Collect Mobile, with the survey developed and database handled in Open Foris Collect.

Remote sensing data were processed using SEPAL, a cloud-based system developed by FAO that provides the user with easy access to satellite imagery and powerful processing capacities. Table 1 summarizes the software and tools used in the assessment.

Table 1. Software and tools used in the woodfuel assessment

Description	Software/tool used
Field data collection	Open Foris Collect Mobile
Field data database	Open Foris Collect
Sentinel-2 acquisition	Google Earth Engine API
Sentinel-1 acquisition	Open Foris SAR toolkit
Working environment SEPAL	Ubuntu 16.04
Processing code	Bash 4.3.46
Spatial data processing	Open Foris Geospatial Toolkit 1.26.6
Calculations	R 3.3.2
Visualization and spatial editing (on local machine)	QGIS 2.18.3

Definitions

LULC classes

Wood resources are distributed unevenly among LULC classes in the area of interest. The LULC classes used in the assessment are similar to those used in the Uganda NBS (Forest Department, 2002), the main ones being closed and open woodland, bushland, grassland, and cultivated land. Bare/open land, water and burnt areas were added for LULC mapping purposes. The field plots were distributed unevenly among LULC classes, with the number of sample plots per class ranging from 3 to 20 (Table 5).

The LULC classes are described as follows in the NBS (Forest Department, 2002, pp. 17–19):

- **Woodland.** "Wooded areas where trees and shrubs are predominant. There are wet and dry types. The wet type occurs as a zone along wetlands (riverine forest) and the dry type is found on grass-covered upland areas. To qualify as woodland the average height of the trees must exceed 4 m." Woodland can be categorized as closed or open woodland according to its canopy cover. Closed woodland has a canopy cover > 40 percent and open woodland has a canopy cover of 10–40 percent.
- **Bushland.** "Refers to vegetation dominated by bush, scrub and thicket growing together as an entity, but not exceeding an average height of 4 m."
- **Grassland.** "Rangelands, grazing grounds, improved pastures and natural savannah grassland. Various trees–bush/woody vegetation frequently occur on this land, but grass dominates the landscape."
- **Cultivated land/farmland area.** "Scattered trees are frequently found in the vicinity of the homesteads. Examples include fruit trees and various multipurpose trees integrated in the farming system (agroforestry). Farmland areas including smallholder subsistence farm units cover 50–90 percent of the land cover of Uganda. The cropping systems include mono- and mixed cropping."
- Bare/open land. Includes bare soil with no or very limited vegetation cover, as well as built-up areas and settlements without significant amounts of vegetation.

Wood resources

The focus of the assessment was on LULC classes with potential woodfuel resources. Both bushland and grassland were found to have very low aboveground biomass stocks and few sample plots and were therefore aggregated into one class.

The field data captured three main sources of wood resources:

1. aboveground biomass (twigs, branches and stems) of shrubs and trees;
2. deadwood (both in standing trees and on the ground); and
3. saplings as a proxy for regeneration potential.

2. Woodfuel demand results

Woodfuel demand in the Bidibidi settlement is concentrated at the household level. There are schools in the settlement, but feeding programmes (which would require woodfuel for cooking) are not yet in place. Some fuelwood is used for cooking at the refugee reception centre, although in very small quantities compared with total consumption at the household level. Wood is also used as a building material; an estimate of woody biomass extraction for refugee housing, therefore, was also made.

2.1 Population and household information

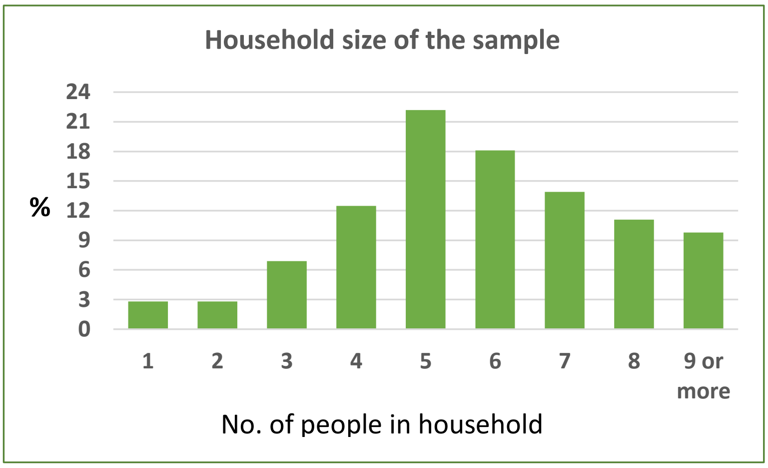
The population of Bidibidi settlement is estimated at 272 206 refugees (OPM Level 1 Registration to 19 December 2016). Bidibidi settlement dwellers come mainly from five ethnicities (i.e. Madi, Peri, Lotuko, Acholi and Dinka) in South Sudan; some (such as the Acholi and Madi) speak languages that are similar to those spoken in northern Uganda.

Seventy-two households were selected randomly and 68 females and four males were interviewed; 11 households were headed by males and 61 were headed by females. The majority (68 percent) of interviewees were female aged 25–40 years, of whom 53 percent were heads of household, 25 percent were spouses (wives), 2.8 percent were daughters and 19 percent were not specified.

Size of households

The majority of the 72 households involved in the interviews had 4–7 members (Figure 6), and the average number of members in a household was six.

Figure 6. Number of people in households as a percentage of all households surveyed



Livelihoods

It is estimated that more than 66 percent of households in the Bidibidi settlement had engaged in crop agriculture before the crisis. Only two of the 72 surveyed households had had two sources of income; 22 percent had been engaged in some business related to pastoralism, fishing, charcoal production, cooking food, masonry, poultry keeping or education; 5 percent had been agropastoral; and 3 percent had members who had worked as health workers.

Although none of the 72 surveyed households indicated the number of income/wage earners, a few stated that they now had occasional sources of income. Just over 26 percent reported selling food, and one household was involved in the sale of fuelwood. The majority of households reported having no sources of income.

Focus group discussions confirmed that people in the Bidibidi settlement generally do not have sources of income; the few who do are engaged in the petty trade of certain food items and necessities. Makeshift markets were observed in the Bidibidi settlement. A few refugees had been engaged by non-governmental organizations on a one-off contract to make fuel-efficient devices (FGD-F: 6; Zone 4). A few refugees own some livestock, which they sell for small amounts of money.

Income opportunities available to refugees include the making of mandazi (a type of local fried bread); cooking food (e.g. maize- and bean-based meals); and the petty trade of soap, salt and sugar. Developing such opportunities, however, requires cash for capital investment, which the refugees lack in the current circumstances.

The majority of households in the host community depend on natural resources for their main incomes, including agricultural production and the sale of fuelwood, charcoal and grass for brooms. Households in the host community have the perception that the number of trees has declined in recent times.

There is competition between the refugees and the host community for fuelwood and grass, the latter of which is used as fodder for livestock and to thatch houses. This competition is a potential source of conflict and tension.

2.2 Woodfuel consumption for cooking and heating

In the assessment, refugee households were asked about the type of fuel they used for cooking/heating and to estimate the average quantity of woodfuel they used for cooking and heating per day. According to information gathered from the household survey, a considerable amount of fuelwood is consumed in the preparation of beans, which require a long cooking time. Fuelwood is also used to heat water for children's baths and to provide heat on cold mornings and evenings. Fuelwood was weighed and recorded (Figure 7) to estimate daily fuelwood consumption for cooking/heating and for the specific task of cooking beans. The majority (97 percent) of surveyed refugee households use only fuelwood for cooking/heating, and 3 percent use charcoal (Table 2). The majority (96 percent) of households collect fuelwood directly from surrounding forests and woodlands; 4 percent purchase fuelwood from the market; and 2 percent obtain fuelwood from both forests and the market.

Table 2. Fuel type used in the Bidibidi settlement

Fuel type	No. of households	%
Fuelwood	70	97.2
Charcoal and fuelwood	2	2.8
Total	**72**	**100**

Households in the surrounding host community mostly use fuelwood for cooking and heating; they also use fuelwood for making bricks to be used as building materials – a practice not permitted in the Bidibidi settlement. Inside Bidibidi, households receive maize, red sorghum grain, beans and some other basic food items each month. Usually, each household cooks and lights a fire twice a day.

On average, households in the Bidibidi settlement consume 12 kg of fuelwood per day for cooking/heating other than cooking beans, which is equivalent to 2 kg of fuelwood per day per person. Although beans take a long time to cook, 83 percent of the surveyed households in the Bidibidi settlement cook beans at least four times per a week. Taking into account the quantity of fuelwood required to cook a portion of beans, an average of 1.5 kg of fuelwood is consumed per person per day to cook beans.

Thus, the overall average fuelwood consumption for cooking/heating is estimated at 20.5 kg per day per household, which amounts to an average of 3.5 kg of fuelwood per day per person. This quantity is considerably higher than in other similar situations: according to Gunning (2014), the literature indicates that fuelwood consumption for cooking in displacement settings is generally in the range of 0.7–3 kg per person per day. In the Bidibidi settlement, the long time required to cook beans is a driver of high fuelwood consumption. Moreover, it was observed during the survey that households occasionally use wet/green wood, which results in relatively low efficiency in burning fuelwood. More analysis of cooking technologies and practices in the Bidibidi settlement is needed to better understand the main drivers of fuelwood consumption there.

By scaling up the results obtained from the sample household survey to account for the 272 206 registered refugees in the Bidibidi settlement, the rate of fuelwood consumption is estimated at approximately 952 tonnes per day, which equates to a demand of over 347 480 tonnes of fuelwood per year. The total volume of fuelwood extracted in the seven months from the opening of the settlement in August 2016 to the assessment in March 2017 is estimated at 199 920 tonnes.

Figure 7. A survey team member in the Bidibidi settlement weighs a bundle of wood to estimate daily household wood consumption

Charcoal

Refugees are not permitted by local authorities to produce charcoal, although they are free to purchase and use it. During data collection, the impression gained was that many respondents did not feel free to disclose that they use charcoal out of fear that their charcoal use would be considered illegal. According to the household survey, very few interviewees (3 percent) use charcoal for cooking, with average household consumption of 2.7 kg per day (equating to 0.4 kg per person per day). Assuming that 3 percent of the total population in the Bidibidi settlement use this amount of charcoal per day, total charcoal consumption in the settlement is estimated at 3.2 tonnes per day and 1 170 tonnes per year. Assuming a conversion efficiency of fuelwood to charcoal of 20 percent, total fuelwood consumption is estimated at approximately 5 840 tonnes per year. Total charcoal consumption in the settlement in the seven months from August 2016 to March 2017 is estimated at 672 tonnes, equivalent to 3 360 tonnes of fuelwood.

Refugees are experiencing a fuelwood shortage and are devising ways of coping with scarcity:

> [...] sometimes exchange food for charcoal; before crisis, most refugees were using fuelwood, but now even smaller pieces of wood, twigs and maize cobs are used.” [FGD, F&M refugees]

Other uses of woody biomass

Refugees have cut down trees to build shelters and other household structures. According to field measurements, each household has used, on average, approximately 0.9 m^3 of wood poles for house construction. Therefore, the woody biomass used for this purpose in the 101 500 households registered by the OPM in the area is estimated at 91 350 m^3, which is equivalent to 63 945 tonnes (assuming an average wood density of 700 kg per m^3).

Results of woodfuel demand and other woody biomass uses

The total estimated quantity of woody biomass used for fuelwood, charcoal and building purposes in the seven months from August 2016 to March 2017 is 267 225 tonnes. Taking into account the energy needs of refugees for cooking and heating in the Bidibidi settlement, the estimated annual fuelwood demand is 353 320 tonnes (including charcoal on a fuelwood basis) (Table 3).

Table 3. Baseline wood consumption, Bidibidi settlement

	Baseline wood consumption		
	Total daily consumption (t)	Total annual consumption (t)	Total consumption in 7 months from establishment of Bidibidi settlement (t)
Fuelwood	952	347 480	199 920
Charcoal*	16	5 840	3 360
Building materials			63 945
Total	**968**	**353 320**	**267 225**

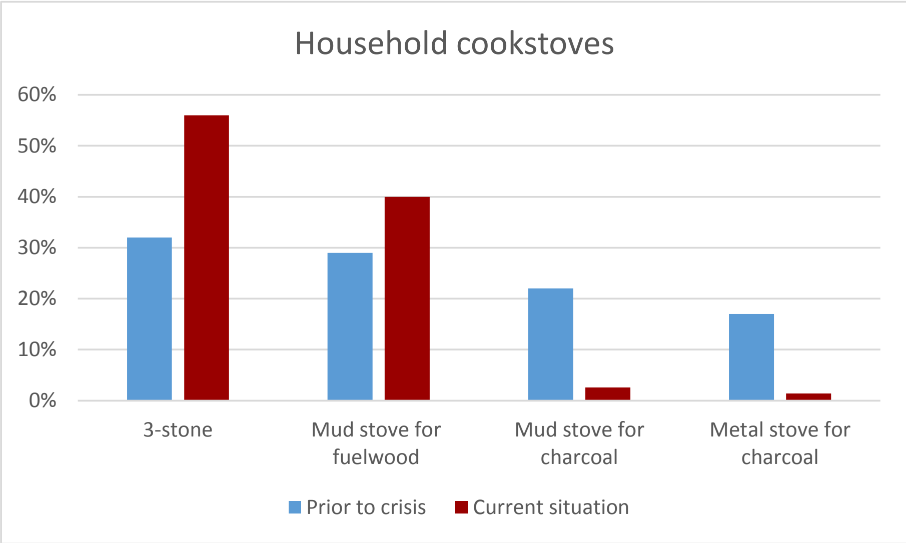
* Expressed as fuelwood, assuming a conversion efficiency of fuelwood to charcoal of 20%.

2.3 Cooking technologies and practices

The assessment team asked respondents about their experiences with cooking/heating devices and types and the problems they had experienced before fleeing to Uganda and in their present situation. The team also observed and photographed some of the cooking devices used in the settlement and the host community.

More households use the traditional 3-stone fire in the Bidibidi settlement than did before the crisis (56 percent compared with 32 percent). A considerable proportion (40 percent) of households now have improved mud stoves for fuelwood, but observations by the assessment team indicate that many households with mud stoves still use 3-stone fires. Three percent of households use mud stoves for charcoal (thus, 43 percent of households use mud stoves for either fuelwood or charcoal) and only 1.4 percent of households now use metal charcoal stoves, compared with 17 percent before the crisis (Figure 8).

Figure 8. Type of cookstoves used by Bidibidi residents before the crisis and at present



It was observed that the mud stoves for fuelwood used in the Bidibidi settlement are not standardized, meaning that stove energy efficiency might differ depending on the design used. The household survey showed no marked difference in fuelwood consumption between households of the same size using the 3-stone fire and the mud stove. In the focus group discussions, however, respondents indicated that there was a difference in the fuel consumed, with the mud stove requiring less. Further investigation is recommended to verify the energy efficiency of mud stoves.

Many households in the host community use the traditional 3-stone fire (Figure 9), and a few use more fuel-efficient devices (Figure 10 and Figure 11). However, this assessment did not investigate the different kinds of devices in use in the host community.

Figure 9. A resident of the Bidibidi settlement cooks beans in her home using a traditional 3-stone fire

Direct interviews conducted with households in the settlement revealed that many refugees have the knowledge and skill to make and use fuel-efficient mud stoves of various designs. Some people have received training on the construction and value of fuel-efficient stoves; others have received no training but have copied mud-stove designs from neighbours or relatives:

> My 16-year-old daughter constructed the fuel-efficient stove after seeing it at the neighbours. [FGD-mixed refugees, F: 3; M: 2; Block 11]

> I saw already one mud stove and I thought I could make it myself and that's how I have and use one; I first made the bricks and then prepared mud after bricks had dried. [FGD-F: 6; Zone 4]

> Only three households in the village are using the fuel-efficient stove; they now have time to attend to other household chores and making craft for income. [Luzira village focus group discussion, host community]

Respondents stated that mud stoves protect fire from the wind, require less wood than 3-stone fires, and cut down on the number of fuelwood collection trips, thereby saving time for other productive work.

Figure 10. An improved mud stove used by a refugee household

Figure 11. A woman cooks posho (maize meal) on an improved mud stove (two-pot rocket lorena)

Problems experienced by households with different cooking methods

The most common problems experienced by refugee households using 3-stone fires is high fuelwood consumption and smoke inhalation. Some households have experienced high fuelwood costs and undercooked food.

The host community is also experiencing problems of smoke inhalation and high fuelwood consumption – but not undercooked food, except when they have purchased beans from refugees. This suggests that the beans provided to refugees are old and therefore require more cooking compared with beans produced locally.

> [...] sometimes food is undercooked if beans are purchased from refugees; lots of fuelwood used. [Luzira village focus group discussion, host community]

Forty-two percent of the households interviewed use mud stoves for cooking. They mostly mentioned the same problems of high fuelwood consumption and smoke inhalation. Moreover, fixed mud stoves are not moveable in the rainy season and can break within one week when affected by rain.

Residents in the host community who have been trained through GIZ and UNHCR programmes on the construction of portable mud stoves (Figure 12) pointed out several disadvantages during the focus group discussion. Mud stoves need to be protected from rain but are heavy to move; cut off heat and therefore you are unable to warm yourself in the cold; can be stolen; need skills to construct; and require constant maintenance.

Figure 12. Refugees and host community members work on a project to produce energy-saving cookstoves

Compared with the refugee community, the adoption of improved fuel-efficient devices is still low in the host community. Of the more than 30 women and men who participated in the focus group discussion, only three households were using fuel-efficient stoves for cooking.

Field observations indicate that many households in the Bidibidi settlement have the skills to make fuel-efficient stoves from locally available materials. Some household members were provided with training and a one-off paying contract under a programme by UNHCR, non-governmental organizations and local authorities for the construction of portable improved mud stoves.

A number of people in both the refugee and host communities have received training on fuelwood-saving techniques. Some refugee women participated in a one-day training course, and members of the host community recently participated in a one-week training exercise for community groups.

Trained people can help in sharing knowledge on the construction and use of improved stoves and promoting awareness with the aim of ensuring that every household has a fuel-efficient stove.

Food preparation methods

The majority (74 percent) of households in the Bidibidi settlement do not soak or process their beans in any way before cooking. Twenty-five percent stated that they soak beans, but key informants explained that “soaking” is typically for 15 minutes, followed by grinding (breaking the beans into smaller pieces) before cooking (Table 4).

Table 4. Surveyed households that soak/do not soak beans, Bidibidi settlement

Preparation of beans	No. of households	% of total
Households that soak beans	18	25.0
Households that don't soak beans	53	73.6
Missing value	1	1.4
Total	**72**	**100**

According to information gathered in the household survey, beans are a main food in all refugee households; according to respondents, however, beans have the longest cooking time and require the highest fuel consumption for preparation compared with any other type of food consumed in the settlement. From the household interviews it was determined that 83 percent of refugee households cook beans at least 4–5 times in a week.

Soaking beans overnight greatly reduces cooking time and fuelwood consumption, and it has the additional benefit of increasing the nutritional benefits and enabling the greater absorption of nutrients by the body.[5] Soaking beans overnight would have an impact on fuelwood consumption, but many interviewees reported that they don't like soaking beans because soaked beans are not palatable or they smell bad, and interviewees would rather cook beans for longer than soak them.

2.4 Challenges and risks in accessing woodfuel

Social and economic vulnerabilities identified in the survey as challenges associated with the collection and use of fuelwood include: carrying heavy loads; walking long distances; wild animals; assault/rape; lack of tools; fuel costs (for some); and the burden of household chores. Some of these, and other issues, are discussed below.

Fuel collection distance. The responsibility for fuelwood collection falls entirely on women and girls above 15 years of age; they go either with others or on their own. Fuelwood collection involves walking to the site, cutting the wood and transporting it home. Most women walk 2–3 km to collect fuelwood, but some walk up to 5 km and some go into host community areas. Respondents indicated that the distance has increased steadily in the past months as the availability of wood close to the settlement has diminished. Moreover, given the low availability of woody biomass, people are increasing their use of green or wet wood; the time required to cut and dry fuel is a barrier to more efficient cooking practices.

> Women collect fuelwood almost every day; taking 2-3 hours; it is taxing and tiring. [FGD-mixed refugees, F: 3; M: 2; Block 11]

> [...] when we came to Bidibidi there were many trees around the settlement. Now we have to walk longer distances: for round trip it takes 2–3 hours. [FGD-F: 6; Zone 4]

Wild animal threats. A number of women talked of a risk of attack by wild animals during fuelwood collection.

[5] www.fao.org/3/a-i5388e.pdf

Assault/rape. Refugee women face the risk of assault by members of the host community in the form of physical beating, verbal abuse and even rape.

> Yesterday, two girls were chased by host community members complaining that they should not collect fuelwood from here. [FGD-mixed refugees, F: 3; M: 2]

> Sometimes people in the host community prevent refugees from collecting fuelwood and producing charcoal. [FGD-F: 6]

Instances of rape have been reported that have been perpetrated by members of the host community and also within the Bidibidi settlement.

Lack of tools. According to a key informant and focus group discussions, refugees lack tools such as axes for collecting fuelwood.

> Lack of axes, the machetes are not able to cut, they have broken handles, not easy to use or mend (lack materials to mend the handles). [FGD-mixed refugees, F: 3; M: 2; Block 11]

However, this might be an indication that the number of small trees has decreased and individuals are targeting bigger trees, which require better tools.

Poor dietary practices. Before the crisis, refugees cooked a variety of foods, including cassava, millet, sorghum, maize, sweet potatoes, yams, pumpkins, greens, cabbage, meat and cowpeas. The only foods mentioned as being consumed in the Bidibidi settlement today were posho/maize and beans, with a few interviewees reporting eating daga fish. Nutritional and dietary needs are compromised, with many households eating only posho and beans; 51 percent of households consume fewer than three meals a day and 47 percent of households consume three meals in a day. A typical refugee household in Bidibidi will have porridge for breakfast and posho/maize and beans for lunch. Many households have reduced the number of meals per day to two because of uncertainty about the continued availability of food rations. Sometimes, refugees cope by exchanging food for fuelwood or cooking only once a day – that is, cooking enough food for lunch and the evening meal.

> Currently, most households cook beans, posho, porridge, which has been suspended because the rations have not yet been received. [FGD-mixed refugees, F: 3; M: 2; Block 11]

Conflict and tension. A number of issues arose during focus group discussions that indicate tensions in the refugee and host communities over competition for natural resources, unfulfilled agreements, shared services and miscommunication. As natural resources diminish, tensions are growing between the host and refugee communities, particularly because the host community can no longer access resources in the Bidibidi settlement area. The designation of Bidibidi as a refugee settlement has increased competition for local natural resources such as wood for energy and construction and grass for thatching and grazing; it has also cost the host community part of its grazing lands and sources of thatching material. Both the host and refugee communities have complained that the other community burns the grass or takes their cut fuelwood.

Misunderstandings on the use of land and water have also arisen that have caused tension between the refugee and host communities. The refugee community, for example, believes that the land on which they are settled has been purchased and paid for, but the host community lent the land in exchange for services agreed with the local authorities.

Land and tree tenure. In establishing woodlots or tree plantations, challenges may arise associated with the land-tenure system in Yumbe. The majority of land in Uganda is under customary tenure; although farmers on customary land are protected by the law and enjoy secure tenure, there is a need to discuss issues pertaining to the tenure of land and trees that may be planted under the various land-tenure systems existing within Yumbe District. Such issues need to be agreed on, with a gender perspective, and represented in a formal document. The practice of involving end users in both the host and refugee communities in the selection of multipurpose trees to be planted – already encouraged by UNHCR in reforestation programmes[6] – could help alleviate tensions, particularly if benefits in addition to fuelwood can be obtained (e.g. in the provision of food, fodder and shelter) and if reforestation helps meet both subsistence and income needs.

[6] www.unhcr.org/protect/PROTECTION/438724c42.pdf

3. Woodfuel supply results

3.1 Results from field measurements

Only aboveground biomass and deadwood were targeted in the assessment as primary sources of woodfuel; these are the only woodfuel resources that can be directly inferred from available satellite imagery.

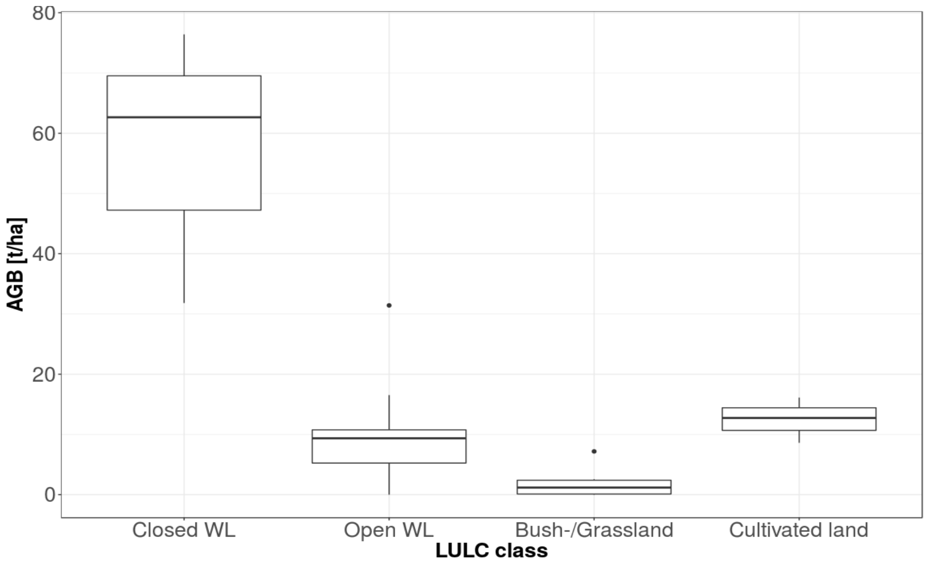
The potential woody biomass (in terms of aboveground biomass, deadwood and number of saplings) available as fuel differs significantly by LULC class (Table 5 and Figure 13). The finding of similar average aboveground biomass on cultivated land and in open woodland is in line with findings by the NBS and other field inventory data for Uganda.

Table 5. Woodfuel potential by LULC class, including 95% confidence intervals

LULC class	No. of plots surveyed	No. of trees per ha	Aboveground biomass (t/ha)	Deadwood (t/ha)	No. of saplings per ha
Closed woodland	3	1 209 ± 2 101	56.96 ± 44.75	1.62 ± 5.46	265 ± 900
Open woodland	20	647 ± 1 310	9.23 ± 13.57	17.58 ± 144.73	368 ± 1090
Bushland and grassland	6	394 ± 1 095	2.02 ± 5.37	0.64 ± 1.56	133 ± 472
Cultivated land	3	367 ± 1 112	12.49 ± 7.38	0.56 ± 1.89	66 ± 225

Forty-three tree species were recorded in the field (see Annex for a list of tree and shrub species). The dominant tree species are *Acacia hockii* (102 trees), *Combretum collinum* (67 trees), *Grewia mollis* (42 trees) and *Combretum fragrans* (28 trees). Four shrub species were recorded (Annex); some shrub species could not be identified, however, mainly due to burning.

Figure 13. Aboveground biomass distribution between LULC classes



Note: The boxplot depicts the median, first and third quartiles and largest and lowest values.

Estimating growth rates (in terms of mean annual increment) requires repeated measurements over time, and such measurements were unavailable for the Bidibidi settlement. The NBS provides estimated growth rates as national averages and for agroecological zones (Yumbe District is in the semi-moist lowland zone) (Forest Department, 2002). Growth rates vary widely between LULC classes (Table 6).

Table 6. Annual increment (air-dry matter) from the 2002 National Biomass Study as national averages and for moist lowlands

LULC class	National mean annual increment (t/ha)	Semi-moist lowland mean annual increment (t/ha)
Woodland	5.0	4.2
Bushland	1.0	0.3
Grassland	1.0	1.2
Subsistence farmland	1.0	1.7

Source: Forest Department (2002).

3.2 Mapping the distribution of land use and land cover

In addition to the four LULC classes identified in the field data, three other classes were mapped: open/bare land, water, and burnt areas. It was necessary to map burnt areas separately because the optical Sentinel-2 imagery was from the dry season, when areas are burned regularly in that part of the country. Open/bare land and water were not represented in the field data because they have no aboveground woody biomass.

Figure 14 shows the spatial distribution of LULC classes inside the settlement and within 5 km of the boundary in 2017. Table 7 shows the areas calculated for each LULC class.

Figure 14. Land use and land cover in 2017 in the Bidibidi settlement and within 5 km of the settlement boundary

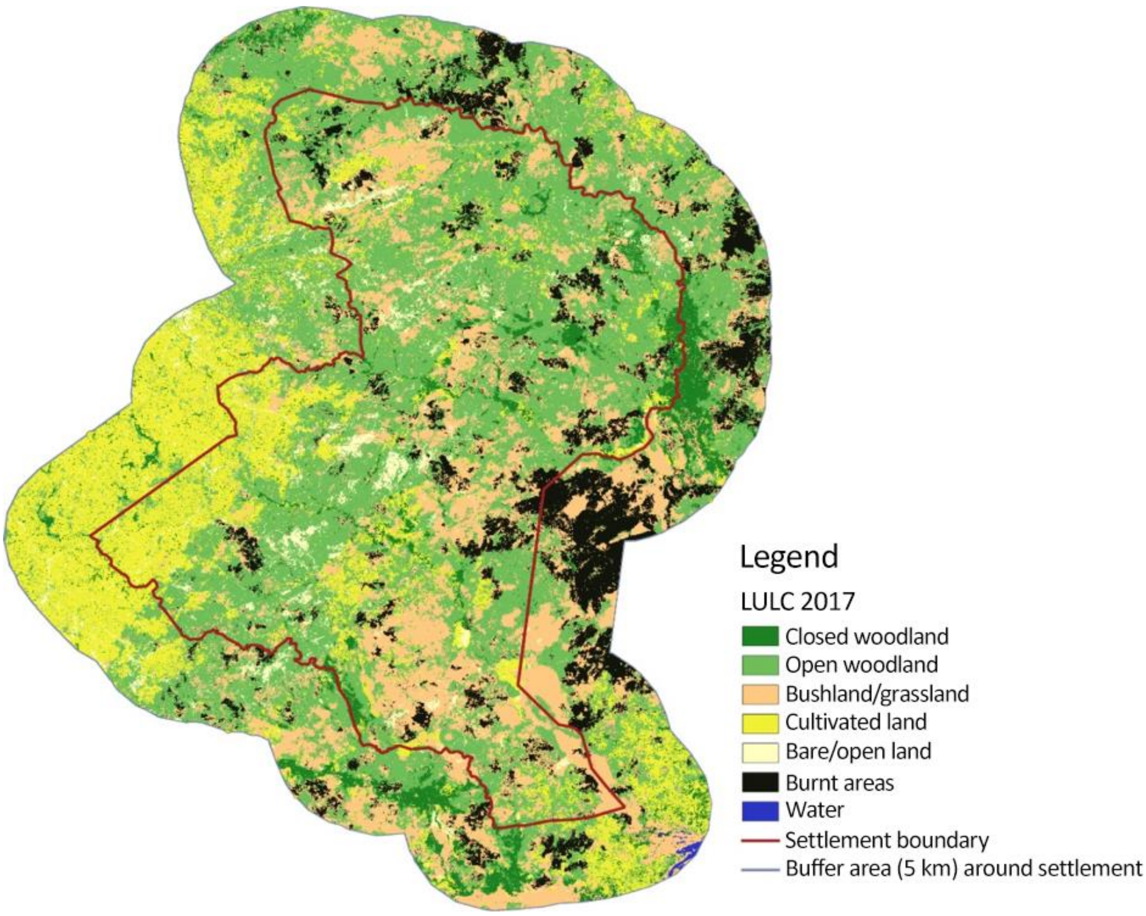


Table 7. Area of each land-use/land-cover class in the Bidibidi settlement and within 5 km of the settlement boundary

LULC class	Area within Bidibidi settlement boundary (ha)	Total area, including 5-km buffer (ha)
Closed woodland	3 356	8 935
Open woodland	39 492	69 164
Bushland and grassland	18 166	34 185
Cultivated land	10 598	29 829
Bare/open land	3 249	5 101
Burnt area	4 905	14 352
Water	1	126
Total	79 765	161 693

3.3 Mapping changes in land use and land cover

Detecting changes in land use and land cover using satellite imagery over the short time frame involved (i.e. 11 months from February 2016 to January 2017) is difficult because any longer-term changes are masked by changes due to natural (seasonality) and anthropogenic (agricultural burning practices) factors that are larger in magnitude (in terms of area) and spatially spread across complex landscapes. Only changes inside the zones, mainly related to the construction of roads, and seasonal differences in burnt areas, could be detected using IMAD change detection.

To map changes in LULC, all areas within the settlement boundary greater than five pixels (~500 m^2) in size assessed as bare/open land in 2017 but as other LULC in 2016 were assumed to be changes associated with setting up the settlement. Thus, it was estimated that a total area of 2 295 hectares was converted from other LULC to bare/open land due to settlement establishment. This area mainly comprised open woodlands (1 166 hectares) (Table 8).

Table 8. Area converted to bare/open land in 2017 due to settlement establishment, by land-use/land-cover class

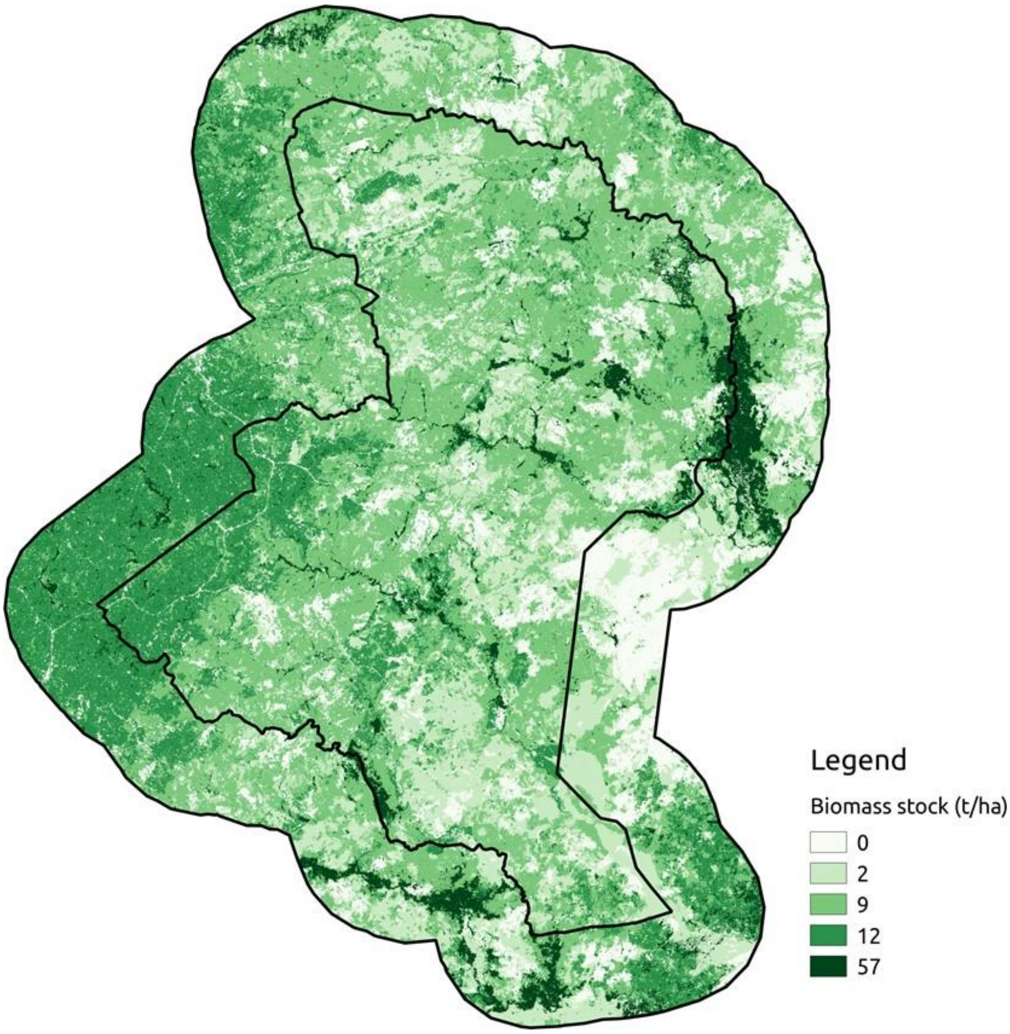
LULC class 2016	Area (ha)
Closed woodland	8
Open woodland	1 166
Bushland and grassland	680
Cultivated land	119
Burnt areas	322
Total	2 295

3.4 Biomass mapping

To estimate and map the wood resources available for woodfuel, the mean aboveground biomass was applied to each LULC class. Burnt areas, which were not assessed in the biophysical field inventory, were assumed to have the same aboveground biomass stock as bushland and grassland because those LULC types usually burn.

Table 9 shows, for each LULC class, the area inside the settlement boundary and within the 5-km buffer and the mean aboveground biomass. These two parameters were multiplied to derive the total available aboveground biomass. Figure 15 shows the spatial distribution of the biomass stock.

Figure 15. Distribution of wood biomass stock in the Bidibidi settlement (including a 5-km buffer) in January 2017



The total aboveground biomass stock in January 2017 is estimated at 734 614 tonnes in the settlement area and at 1 617 953 tonnes if the 5-km buffer area is included. Most of the aboveground biomass is in open woodland, but closed woodland also contributes a significant volume despite its relatively small area.

Table 9. Area, mean aboveground biomass and total aboveground biomass in January 2017, by land-use/land-cover class

LULC class	Area within settlement boundary (ha)	Total area including 5-km buffer (ha)	Mean aboveground biomass (t/ha)	Aboveground biomass stock within settlement (t)	Aboveground biomass stock within settlement and 5-km buffer (t)
Closed woodland	3 356	8 935	56.96	191 130	508 965
Open woodland	39 492	69 164	9.23	364 513	638 380
Bushland and grassland	18 166	34 185	2.02	36 695	69 054
Cultivated land	10 598	29 829	12.49	132 369	372 562
Bare/open land	3 249	5 101	0	0	0
Burnt area	4 905	14 352	2.02	9 908	28 992
Water	1	126	0	0	0
Total	79 765	161 693	NA	734 614	1 617 953

The establishment of the Bidibidi settlement had a detectable impact on 2 295 hectares; the total estimated aboveground biomass stock lost on that land is 14 725 tonnes (Table 10).

Table 10. Area and aboveground biomass (in 2016) converted to bare/open land by 2017 due to the establishment of the Bidibidi settlement, by land-use/land-cover class

LULC class	Area (ha)	Total aboveground biomass lost (t)
Closed woodland	8	450
Open woodland	1 166	10 763
Bushland and grassland	680	1 373
Cultivated land	119	1 488
Burnt areas	322	651
Total	**2 295**	**14 725**

4. Scenarios and recommendations

4.1 Scenarios

Several possible interventions have the potential to improve energy access in the Bidibidi settlement, minimize environmental impacts and bring additional benefits (e.g. the creation of livelihood opportunities; multipurpose tree-planting; and a reduction in the time required to collect fuelwood). Based on the woodfuel demand and supply assessment, the following future scenarios have been developed: 1) business as usual; 2) improved cookstoves; and 3) tree plantations and improved cookstoves. These are discussed below.

1. **Business as usual.** The rate of fuelwood consumption in the Bidibidi settlement is estimated at 952 tonnes per day, which equates to 347 480 tonnes per year. The total aboveground biomass stock in the settlement area is estimated at 734 614 tonnes, and aboveground biomass growth is estimated at 33 300 tonnes per year. Considering only the settlement area, the annual deficit of woody biomass growth in the target area is 314 180 tonnes. In a hypothetical worst-case scenario, the estimated total existing aboveground biomass stock and growth from trees and shrubs in the settlement could supply fuelwood to the current settlement population for up to three years (Table 11), at the cost of the full depletion of aboveground biomass in the settlement area. Such depletion under business as usual is an issue that urgently needs to be addressed because refugees are already competing with local communities for scarce resources beyond the settlement boundary.

Table 11. Woodfuel supply and demand in scenario 1 (business as usual)

Year	Total fuelwood consumption (t/yr)	Total aboveground biomass stock (t)	Annual aboveground biomass growth (t/yr)	Annual aboveground biomass loss (t/yr)
1	347 480	734 614	33 300	-314 180
2	347 480	420 434	19 058	-328 422
3	347 480	92 012	4 171	-343 309
4	347 480	---	---	---

2. **Scenario with improved cookstoves.** In this scenario, woodfuel demand is reduced through the use of fuel-efficient cookstoves. Fifty-six percent of households are using 3-stone fires for cooking and heating and 43 percent are using improved mud stoves. This scenario assumes that 100 percent of households shift to improved mud stoves with 20 percent thermal efficiency. Therefore, assuming that the efficiency of 3-stone fires is 10 percent, the adoption of improved stoves by the 56 percent of households now using 3-stone fires could achieve fuelwood savings of approximately 30 percent compared with the business-as-usual scenario, reducing total fuelwood demand in the Bidibidi settlement to an estimated 243 000 tonnes per year. Under this scenario, women would spend less time collecting fuelwood and therefore would have more time available for other activities. Given that estimated annual aboveground biomass growth in the settlement area is about 33 300 tonnes per year, the annual deficit of woody biomass growth in this scenario would be 209 700 tonnes (in year 1). In this scenario, the total existing aboveground biomass stock and growth from trees and

shrubs in the settlement could supply fuelwood to the current population in the settlement for up to four years (Table 12), at the cost of the full depletion of the aboveground biomass in the Bidibidi settlement. Thus, the full adoption of improved mud stoves in the settlement would delay by one year the full deforestation of the settlement area compared with the business-as-usual scenario.

Table 12. Woodfuel supply and demand in scenario 2 with improved cookstoves

Year	Total fuelwood consumption (t/yr)	Total aboveground biomass stock (t)	Annual aboveground biomass growth (t/yr)	Annual aboveground biomass loss (t/yr)
1	243 000	734 614	33 300	-209 700
2	243 000	524 914	23 794	-219 206
3	243 000	305 708	13 858	-229 142
4	243 000	76 566	3 471	-239 529
5	243 000	---	---	---

3. **Scenario with tree plantations and improved cookstoves.** In scenario 3, woody biomass production would be increased by tree-planting combined with the full adoption of improved cookstoves (scenario 2). Productive woodlots in Uganda commonly achieve mean annual increments of 20–26 m^3 per hectare; assuming an average wood density of 600 kg per m^3 and a biomass expansion factor of 1.5 (to include bark and branches in the mean annual increment), the total aboveground biomass increment achievable with tree plantations would be 18–23.4 tonnes per hectare per year. To compensate fully for the annual loss of biomass in the Bidibidi settlement of 219 206 tonnes (after two years) and assuming that the tree plantation becomes productive in its third year after planting, 9 368–12 178 hectares would need to be planted with fast-growing species, which is 12–15 percent of the total land area of the Bidibidi settlement (798 km^2) (Table 13). Each household would need to dedicate a minimum area of 50 m x 50 m to growing wood for energy. Such a tree plantation would provide a sustainable source of fuelwood for the existing population in the settlement, but it would involve considerable costs and require that, among other things, land ownership is addressed, suitable expertise is available, and sustainable forest management is adopted. Forest management would focus on maximizing biomass production in the shortest possible time, and tree density should ensure optimum growth rates per unit surface area. Short-rotation coppice management has been shown to produce regular volumes of fuelwood over long periods.

Table 13. Woodfuel supply and demand in scenario 3 involving tree plantations and improved cookstoves

Year	Total fuelwood consumption (t/yr)	Total aboveground biomass from existing resources (t)	Annual aboveground biomass growth from existing resources (t/yr)	Minimum tree plantation area (ha)	Annual aboveground biomass growth from new tree plantation (t/yr)	Annual aboveground biomass loss (t/yr)
1	243 000	734 614	33 300	9 368	0	209 700
2	243 000	524 914	23 794	9 368	0	219 206
3	243 000	305 708	13 858	9 368	219 206	0
4	243 000	286 277	12 977	9 368	219 206	0
5	243 000	265 965	12 056	9 368	219 206	0

Experience in reforestation programmes elsewhere suggests that, for this scenario to be sustainable and attractive to end users, tree species must be selected according to the needs of those users; moreover, multipurpose trees that might fulfil additional needs (e.g. for food, animal fodder and shade) should be integrated into this option.[7]

It is likely that a combination of interventions will be needed, effective immediately, to reduce the high woodfuel demand in the Bidibidi settlement and ensure a sustainable woodfuel supply. Such interventions include the adoption of fuel-efficient stoves and energy-saving cooking practices at the household level; establishing multipurpose tree-planting programmes; developing forest management plans; and promoting woodfuel alternatives (e.g. agricultural residues and liquefied petroleum gas). Such interventions would have the added benefit of contributing to the mitigation of climate change through carbon sequestration and a reduction of carbon dioxide emissions, and they could attract payments for carbon credits.

4.2 Recommendations

Fuel-efficient cookstoves and energy-saving measures

Fuel-efficient cookstoves should be promoted to reduce fuelwood demand, with the potential to achieve savings of about 30 percent compared with business as usual. It will be important to improve the effectiveness of programmes to increase the use of fuel-efficient stoves and the adoption of energy-efficient cooking practices by engaging relevant expertise to design community awareness and engagement programmes. A participatory approach should be promoted for planning and monitoring these activities in both the refugee and host communities.

The selection of appropriate fuel-efficient cookstoves must consider a range of factors, such as safety, the availability of local fuel resources, funding, cooking habits and user acceptability.[8] An in-depth assessment is needed of existing cooking technologies in the Bidibidi settlement and the potential to improve the

[7] www.unhcr.org/protect/PROTECTION/438724c42.pdf
[8] http://pdf.usaid.gov/pdf_docs/Pnadt959.pdf

design of mud stoves, requiring the engagement of specific expertise. Existing knowledge and skills in the communities in the construction and use of improved mud stoves should be nurtured, and awareness should be raised to ensure that all households in the settlement adopt fuel-efficient stoves.

The following energy-saving measures should be promoted to further reduce fuelwood consumption for cooking:

- the use and production of heat retention boxes and bags using locally available materials, which can reduce fuel consumption by more than 40 percent;
- the use of suitable lids for all cooking tasks to help contain heat so that food cooks faster;
- the soaking of beans and grinding or cutting of food into smaller pieces. For example, beans should be soaked overnight for 8–14 hours and cooked the next day. Soaking makes beans soft so they will cook in a shorter time, thereby using less fuelwood;
- drying fuel before use and processing into smaller pieces. Using dry wood would increase cooking energy efficiency, thereby reducing the quantity required for cooking and with the side benefit of reducing harmful smoke emissions;
- sharing cooking facilities among families; and
- using traditional clay cooking pots – although more delicate, these absorb and retain heat longer than metal pots and, when hot, they require less fuel than metal pots to continue the cooking process.

Tree-planting and improved forest management

There is a clear risk of high levels of deforestation and land degradation due to the increased woodfuel demand caused by the sudden influx of refugees to the Bidibidi settlement. It should be a priority to improve the management of existing forests and other woodlands and to plant trees to increase the production of woody biomass in the settlement and on the lands of the host community. In consultation with local and national authorities and the host and refugee communities, a forest management plan urgently needs to be developed, implemented and monitored. Forestry and environmental expertise should be engaged to guide the planning and implementation process and to build the capacity and knowledge needed to ensure the long-term success of the project.

The Bidibidi settlement's forest management plan should aim to support the energy needs of the refugee and host communities and reduce the environmental and social impacts caused by the overexploitation of natural resources and by deforestation and forest degradation.

Fast-growing tree species and short-rotation coppice management should be adopted to enable early harvesting for fuelwood. In addition, however, the use of multipurpose species can increase the motivation of people to manage trees effectively because of the provision of other socio-economic benefits, materials such as posts for fencing, non-wood forest products such as fruits and fodder, and ecosystem services such as soil conservation and soil fertility.

Afforestation, reforestation and ecosystem restoration/rehabilitation interventions should be carried out in a participatory manner involving community leaders, giving particular attention to the interlinkages between environmental and socio-cultural aspects. The establishment of tree plantations for either fuelwood production or land restoration/rehabilitation requires the development of detailed forest management plans, addressing elements such as the selection of tree species; planting materials; planting schedules and timeframes; tree nursery management; suitable land; the costs of all stages of the programme; tenure and legal issues; water supply; soil fertility; human resources; site protection; planting; tending; harvesting operations; and coordination with local governments and other actors engaged in similar programmes in the region.

"Fuelwood-for-work" programmes – similar to the World Food Programme's "food-for-work" programmes – could be linked to ongoing UNHCR "cash-for-work" programmes. FAO has decades of experience in forest and tree resource assessment, sustainable energy systems and the enhancement of ecosystem services. In particular, afforestation, reforestation, ecosystem restoration, agroforestry and improved energy efficiency can help address environmental degradation, deliver integrated solutions and enhance resilience and adaptation.

To compensate for the annual loss of biomass due to woodfuel demand in the Bidibidi settlement, 9 368–12 178 hectares would need to be planted with fast-growing species, which is 12–15 percent of the total land area of the Bidibidi settlement (see scenario 3 above). Focus group discussions revealed that the refugee and host communities would both be interested in planting trees if technical and financial support was provided. Refugees showed interest in tree-planting even through a fuelwood-for-work approach to planting and monitoring trees. They had concerns about planting trees for other purposes, citing constraints associated with termites, livestock destruction, lack of land, poor soils and water stress. "Fuelwood for work" seems to be a welcome and feasible idea for district authorities, UNHCR staff and the refugees themselves.

Gender equity

As in the host community, clear gender norms and inequities exist in the Bidibidi settlement that disproportionately affect women. Programmes need to take a gender-sensitive approach to address existing inequities and to minimize the potential for negative impacts. Women should be involved in tree-planting programmes, including the selection of tree species based on their specific needs. Such involvement could be coupled with training in alternative livelihood strategies.

Conflict sensitivity, resolution and peace building

Conflict sensitivity should be integrated into all programmes implemented by government and humanitarian agencies and in community structures. Conflict-resolution and peace-building activities should be promoted in the refugee and host communities. The peaceful co-existence of the refugee and host communities and a reduction in tension over natural resources are prerequisites if the two communities are to receive and appreciate the full benefits of humanitarian programmes. Working together and with the Office of the Prime Minister, all involved agencies should ensure that their planning, implementation and monitoring fully address peace building and conflict sensitivity, and data could be reported at regular meetings.

Monitoring

The methodology developed for this assessment can be used for monitoring woodfuel supply and demand in the Bidibidi settlement and in other refugee-hosting areas. Changes in biomass stock can be monitored continuously using free, publicly available satellite imagery and open-source software accessible through the SEPAL platform. The methodology should be used to regularly update the findings of this report.

5. Conclusions

The refugees in the Bidibidi settlement are living in a state of acute emergency and have a wide range of vulnerabilities. With their livelihoods disrupted, refugees have no source of income and lack secure access to fuel and energy for cooking, compromising their nutrition, food security, health and personal safety. Meanwhile, the host community is affected by tensions and conflicts and will ultimately be faced with irreversible environmental degradation and climate change. Practical measures need to be taken to urgently reduce some of these impacts through careful, participatory planning, implementation and monitoring.

The resources in the area are scarce and under obvious pressure; under a hypothetical worst-case scenario, there is sufficient supply for the refugees for only three years, at the cost of the full depletion of aboveground biomass in the area – an issue that urgently needs to be addressed. Continuous monitoring of these resources will be needed in coming months to assist decision-making on the measures to be taken to mitigate the pressure.

A combination of interventions will likely be needed, effective immediately, to reduce the high woodfuel demand of the refugees in the Bidibidi settlement and to support a sustainable woodfuel supply. These include:

- introducing fuel-efficient cookstoves and promoting other energy-saving measures at the household level;
- establishing multipurpose tree-planting programmes to build resilience and create opportunities for sustainable livelihoods;
- developing community-based forest resource management plans; and
- promoting woodfuel alternatives, such as agricultural residues and liquefied petroleum gas.

Such interventions would have the added value of contributing to climate-change mitigation. The carbon sequestered by forest plantations and the emission reductions achieved by the adoption of fuel-efficient cookstoves could also provide benefits through carbon credits.

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7. Annex

Table A1. Tree species list and number of recordings from the field inventory per LULC class

Tree species	Closed woodland	Open woodland	Bushland and grassland	Cultivated land	Total	Common uses[9]	Remarks
Acacia hockii	40	51	11	0	102	Firewood, charcoal, medicine (roots), ropes (bark), fencing (dry branches).	The root is used to treat cough.
Acacia polyacantha	1	2	0	0	3	Firewood, timber (roofing, tables, matches, boxes, carving, musical instruments), live fence.	
Acacia sieberiana	1	5	0	0	6	Firewood, charcoal, timber, fodder (leaves), tool handles, N-fixation, gum, fences.	The foliage and fruit are good fodder and particularly important in the dry areas of northern Uganda. Often left in fields for shade.
Antiaris toxicaria	1	0	0	0	1	Timber (veneer, beer canoes), medicine (leaves, roots), bark cloth.	The root or leaves are used to treat mental illnesses. Plant individual trees for shade, as avenue trees or as a pure stand.
Balanites aegyptiaca	0	1	0	0	1	Firewood, charcoal, poles, timber (furniture), utensils, tool handles, food (fruit, leaves), medicine (roots, bark, fruit), mulch, shade, windbreak, gum, fencing (branches), oil (fruit), fish poison.	An important species for dry areas as it produces fruit in very dry seasons. Improved varieties exist in India. The wood is termite resistant. The edible fruits are rich in saturated fatty acids which are used as cooking oil. The leaves are eaten by populations in Adjumani and parts of Teso.[10]

[9] http://www.worldagroforestry.org/products/switchboard/index.php/name_like/Acacia/

[10] https://www.researchgate.net/publication/259921775_Balanites_Aegyptiaca_L_A_Multipurpose_Fruit_Tree_in_Savanna_Zone_Of_Western_Sudan

Borassus aethiopum	0	0	0	1	1	Firewood, charcoal, poles, timber (roofing, door frames, etc.), tool handles, bee hives, food (fruit, seeds, young seedlings), palm wine (sap of flower shoots), medicine (roots, flowers, oil), fodder (fruit, young leaves), thatch, fibre (leaves), baskets, mats (leaf stalks, leaves), oil (fruit, pulp), brooms, drums.	Elephants eat the fruits, thus distributing the tree. The wood is hard and resistant to termites and fungi. Populations in the Acholi area eat the first root shoot from the seed. The fruit is also edible, tasting like peach.
Borassus egyptian	0	2	0	0	2		
Bridelia scleroneura	0	7	0	0	7		Medicinal, the wood makes excellent fuel, termite resistant.
Butyrospermum paradoxum	0	1	0	0	1	Firewood, charcoal, timber, food (seed), fodder, oil (cooking, soap, candles), shade, ornamental.	The shea – a vital source of cooking and "smearing oil" (from the kernel) across northern Uganda, although more in the Acholi/Langi areas than West Nile. The fruit is also edible. Tree survives annual fires and the wood is hard and termite resistant and much sought after for making charcoal.
Celtis africana	2	0	0	0	2	Firewood, charcoal, timber (local construction, farm tools), tool handles, fodder (leaves), shade.	The timber rots and splits easily, but it is very strong and with proper seasoning useful for tool handles and building. Leaves are browsed by animals, including cattle, and the leaves and fruits are important in the diet of black and white colobus monkeys. Does not compete with crops since it has a light shade. It is a tree quite suitable for parks and avenues.
Combretum collinum	20	29	9	9	67	Firewood, charcoal, medicine (leaves, roots), bee forage, fencing (cut branches), firebreaks.	Roots are used to treat diarrhoea and vomiting. Makes very good charcoal. Flowers produce good nectar for honey. Suitable for savannah firebreaks. The hard, durable wood burns well but the living tree is tolerant of grass fires.
Combretum fragrans	1	20	7	0	28		
Combretum molle	3	10	3	0	16	Firewood, charcoal, poles, posts, timber (construction), tool handles, medicine (roots, leaves, bark), bee forage, mulch.	There are three East African varieties. The hard yellow wood is useful for tools and burns well giving intense heat. The wood is moderately

							termite resistant. Medicine from the roots has been used for treating hookworm, snake bite, stomach pains, fever, dysentery and leprosy. The charcoal from this species is highly appreciated in Uganda and its planting should be encouraged.
Combretum sp.	0	2	3	0	5		
Dichrostachys sp.	1	2	0	0	3	Firewood, charcoal, poles, posts, tool handles, medicine (leaves, roots), fodder (leaves, pods), bee forage, nitrogen fixation, soil conservation, fibre (bark), live fence, dry fence.	The tree is not planted near houses because it is very thorny. It can be an aggressive weed, has vigorous root suckers and can form a dense thicket. The timber is very heavy and hard but of quite small size. Pounded roots and leaves are used to treat epilepsy. Suitable for planting on degraded soils. It can be an indicator of overgrazing in low rainfall areas.
Ficus natalensis	1	0	0	0	1	Medicine (leaves), shade, live fence, barkcloth.	Barkcloth used to be made from this tree throughout Uganda. The leaves are used to treat dysentery and sore throats. The tree is also grown as a live fence around homes and at a wide spacing for shade in coffee, cocoa and banana plantations. It is emerging as fodder for zero-grazed cows.
Flueggea virosa	1	0	0	0	1		In parts of Africa, the slender branches are used to make fish traps. The small fruit is sweet and eaten by people, animals and birds when ripe. The roots and fruits are believed to be an effective snakebite remedy. Roots of this plant are also used in some African communities as contraceptives and for the treatment of syphilis, gonorrhoea, rheumatism, sterility, rashes, and an infusion of the root is taken to relieve malaria. The bark is believed to provide a treatment for diarrhoea and pneumonia.[11]
Gardenia sp.	0	1	0	0	1		
Grewia bicolor	5	0	0	0	5	Firewood, charcoal, timber, tool handles, carving (clubs, javelins,	Twigs from the tree are used by water diviners to locate underground water. The fruit is edible,

[11] http://pza.sanbi.org/flueggea-virosa

						walking sticks), medicine (roots, bark), fodder (leaves, fruit).	sweet and remarkably high in iron. It is especially important for pregnant woman.
Grewia mollis	1	33	0	8	42	Firewood, charcoal, timber, walking sticks, fodder (leaves and fruits), fibre (strings from bark).	Fibres under the bark are made into string for general use and in constructing granaries. The heartwood makes excellent walking sticks and the Acholi use the wood to make spears.
Harrisonia abysinica	4	0	0	0	4		
Hymenocardia acida	0	1	0	0	1	Firewood, charcoal, poles, medicine (bark, leaves), bee forage, ornamental, fibre (inner bark), oil (flowers, seed), soap (roots), brooms (from saplings).	A beautiful flowering tree with potential as an ornamental in parks and gardens. The wood is pale yellow and has been used for bows. The fibres have been used for fish nets, bead strings and thread to sew barkcloth. The roots contain ethylsalicylate and a saponin making them highly poisonous. An antidote for snakebite and a cough mixture are prepared from leaves, an abortifacient from powdered bark and a root infusion relieves toothache. But great care must be taken when using these medicinal substances.
Khaya senegalensis (Mahogany)	0	3	0	0	3	Firewood, charcoal, timber (heavy construction), soil conservation and improvement.	*Khaya senegalensis* is a hardier species than other Khaya. It can grow in open savannah as well as in forests and is suitable for northern and north western regions. The timber, which is harder and heavier than that of the other Khaya, can be used for construction such as bridges and for railway sleepers. It is also more termite resistant.
Lannea barteri	0	6	1	0	7	Firewood, charcoal, utensils (durable mortars), live fence.	A species that should be encouraged to improve fuelwood supplies. All Lannea are very fire resistant and coppice easily.
Lannea schweinfurthii	1	0	0	0	1	Firewood, charcoal, timber (stools, chairs, mortars), food (fruit), medicine (leaves, bark, roots), fodder (leaves).	The species is resistant to fire. The fibrous roots, like red-brown wool, have been used for stuffing pillows. Young branches are very flexible and the white wood is soft and light.
Lannea sp.	0	1	0	0	1	Firewood, charcoal, utensils (durable mortars), live fence.	A species that should be encouraged to improve fuelwood supplies. All Lannea are very fire resistant and coppice easily.

Lonchocarpus laxiflorus	0	2	0	0	2		
Maytenus ovata	1	13	0	0	14		
Maytenus sp.	0	0	0	0	0	Firewood, charcoal, timber (local construction), farm tools, medicine (roots), live fence, ornamental.	The wood is red and heavy. The trees grow easily from seed. Raise as a pure stand.
Piliostigma thonningii	0	0	0	1	1	Firewood, charcoal, poles, timber (houses), food (pods), drink (leaves, pods), fodder (pods, shoots), bee forage, medicine (leaves, bark, roots, pods), mulch, soil conservation, ornamental, N-fixation, tannin, dye (pods, seeds, bark, roots), rope (bark, root fibres).	A good tree that can be grown mixed with *Annona spp.*, *Grewia spp.*, and *Combretum spp*. Competes very little with maize if left in fields and pollarded to reduce shade. The pulp surrounding the seeds is edible and under famine conditions leaves, crushed green pods and seeds have been eaten. Pods and seeds give a blue dye and roasted seeds a black dye.
Pseudocedrela kotschyi	0	5	0	0	5	Firewood, charcoal, timber (joinery), utensils (mortars, etc.), poles, shade, ornamental.	An easy-to-grow species for the semi-arid savannahs. The timber is attractive, resembling mahogany but harder and heavier, and is suitable for high-class joinery. Mortars are made from the trunks. Can be grown in pure stands, for shade, as an avenue tree or interplanted with mangoes, *Cassia spp*. and cashew nut.
Rhus natalensis	4	1	0	0	5	Firewood, timber (utensils), tool handles, food (fruit), medicine (roots, bark, leaves), fodder, oil (seed), live fence.	A useful tree for semi-arid areas as it is drought resistant. The wood is heavy, hard and very durable. The seed contains up to 60% of a non-drying oil suitable for soap and lubrication. It has also been used as body and hair oil and for softening leather.
Senna sp.	0	0	0	2	2		
Sterculia setigera	0	5	0	0	5	Fibre (bark), bee hives (coppice shoots).	Once the bark is removed, the stem dies. The bark is used to make baskets.
Strychnos spinosa	2	1	0	0	3	Firewood, charcoal, timber (furniture, boxes), fodder (leaves), food (fruit), medicine (fruit, leaves, bark, roots), musical instruments (dry fruit shell).	Although the fruit is edible, seeds are toxic and unripe fruit may be also. The fruit are often eaten by wild animals. The wood is straight- grained and planes well but has not been much used for carpentry in Uganda.

Tamarindus indica	7	0	0	0	7	Firewood, charcoal, poles, timber (furniture, boats, general purposes), food (pulp for drink, fruit, spice), fodder (leaves, fruit), medicine (bark, leaves, roots, fruit), mulch, N- fixation, shade, ornamental, windbreak, tannin (bark).	The dark brown heartwood is hard and heavy, well grained and easy to polish. The pulp is rich in vitamin C. It is recommended for homestead planting and along river banks.
Terminalia glaucescens	0	0	0	1	1	Firewood, charcoal, bee hives.	Produces excellent charcoal. The timber is yellow-brown, hard, durable and tough and works well.
Unknown	5	0	0	0	5		
Unknown Lannea	1	0	0	0	1	Firewood, charcoal, utensils (durable mortars), live fence.	A species that should be encouraged to improve fuelwood supplies. All Lannea are very fire resistant and coppice easily.
Ximenia americana	0	3	0	0	3	Firewood, timber (utensils), tool handles, food (fruit), medicine (roots, bark, leaves), fodder, oil (seed), live fence.	A useful tree for semi-arid areas as it is drought resistant. The wood is heavy, hard and very durable. The seed contains up to 60% of a non-drying oil suitable for soap and lubrication. It has also been used as body and hair oil and for softening leather.
Ziziphus abyssinica	7	0	0	0	7	Firewood, charcoal, timber (furniture, interior work, carving), poles, food (fruit pulp and seed), live fence, bee forage, dye (bark).	The spiny branches make this plant useful as a protective live fence. Leaves and fruit are used elsewhere as fodder. The bark yields a cinnamon-coloured dye. The timber is heavy, hard and resistant to termites and borers.

Table A2. Shrub species list and number of recordings from the field inventory per LULC class

Shrub species	Closed woodland	Open woodland	Bushland and grassland	Cultivated land	Total
Alchornea laxiflora	0	0	0	1	1
Flueggea virosa	9	1	0	5	15
Harrisonia abyssinica	6	0	0	0	6
Rhus natalensis	3	0	0	0	3
Unknown	4	10	2	0	16
Total	22	11	2	6	41

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