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REGIONAL SUSTAINABLE LAND MANAGEMENT

Rapid Assessment of Natural Resources Degradation in Areas Impacted by the South Sudan Refugee Influx in Northern Uganda

TECHNICAL REPORT

October 2018

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ACKNOWLEDGMENTS

Between February and July 2018, the World Bank commissioned the Food and Agriculture Organization of the United Nations (FAO)[1] to undertake a 'Rapid Diagnostic Assessment of Land and Natural Resources Degradation in Areas Impacted by the South Sudan Refugee Influx in Uganda'. This work was undertaken in close collaboration with the Ugandan Ministry of Water and Environment (MWE). The aim of the assessment was to determine the environmental impacts of the refugee influx, with a focus on forest resources, and propose appropriate intervention options to mitigate pressure on the environment and support energy access to the refugee and host communities.

The World Bank task team comprised Ross Hughes (Task Team Leader), Matthew Owen (Senior Consultant), Lesya Verheijen (Senior Operations Officer), Christine Kasedde (Environmental Specialist), and Herbert Oule (Senior Environmental Specialist). This Technical Report summarizing the findings and recommendations of the assessment was prepared jointly by the following authors at FAO (listed alphabetically): John Begumana, Laura D'Aietti, Arturo Gianvenuti, Inge Jonckheere, Eva Kintu, Erik Lindquist, Rebecca Tavani, and Zuzhang Xia. The team would like to thank the staff of the World Bank, FAO and the United Nations High Commissioner for Refugees (UNHCR) in Kampala, the FAO Resilience Team for East Africa, and the National Forestry Authority of Uganda for their support and inputs, as well as the United Nations Institute for Training and Research (UNITAR) headquarters in Geneva for providing very high-resolution satellite imagery. The authors also wish to acknowledge and thank those in the West Nile region for their invaluable assistance with the field work: the FAO Office in Yumbe, the UNHCR Sub-Offices in Arua and Yumbe, the Office of the Prime Minister, and the District Local Governments of Adjumani, Arua, Moyo, and Yumbe.

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[1] World Bank Contractual Agreement no. 7185743; FAO Project Symbol: OSRO/GLO/801/WBK.

ACRONYMS

AGB	Above-ground Biomass
AOI	Area of Interest
BFAST	Breaks for Additive Season and Trend
CRRF	Comprehensive Refugee Response Framework
DBH	Diameter at Breast Height
DEM	Digital Elevation Model
DM	Dry Matter
DRDIP	Development Response to Displacement Impacts Project
FAO	Food and Agriculture Organization of the United Nations
GFC	Global Forest Change
GoU	Government of Uganda
IBEK	Improved Basic Earth Kiln
IDA	International Development Association (World Bank Group)
IPCC	Intergovernmental Panel on Climate Change
LULC	Land Use and Land Cover
MWE	Ministry of Water and Environment
NBS	National Biomass Study
NDMI	Normalized Difference Moisture Index
NFA	National Forestry Authority
NGO	Non-governmental Organization
NDP II	Second National Development Plan
OPM	Office of the Prime Minister
pppd	per person per day
ReHoPE	Refugee and Host Population Empowerment
RRP	Refugee Response Plan
SEPAL	System for Earth Observations, Data Access, Processing and Analysis for Land Monitoring
SPGS III	Sawlog Production Grant Scheme, Phase III
SRTM	Shuttle Radar Topography Mission
STA	Settlement Transformation Agenda
T	metric ton
THF	Tropical High Forest
UNHCR	United Nations High Commissioner for Refugees
UBOS	Uganda Bureau of Statistics
UN	United Nations
UNDP	United Nations Development Program
UNITAR	United Nations Institute for Training and Research
WG	Working Group

EXECUTIVE SUMMARY

The ongoing refugee crisis in South Sudan has led to the establishment of some of the world's largest refugee settlements over the border in northern Uganda. By March 2018, over a million South Sudanese refugees and asylum seekers had migrated to Uganda, more than 350,000 of them in 2017 alone. Uganda is also hosting refugees from Burundi, the Democratic Republic of Congo, and Somalia, making it the largest refugee host country in Africa (and second in the world), with a total of 1.4 million refugees and asylum-seekers.

The influx of refugees is reported to have exacerbated a range of ongoing environmental impacts and associated challenges, including land degradation and woodland loss, resulting in inadequate access to energy for cooking and competition with local people for water and other natural resources. Supporting more sustainable use of those resources, especially forests and other woodlands, could help address environmental degradation and improve energy access.

The World Bank commissioned the Food and Agriculture Organization of the United Nations (FAO) to undertake a rapid assessment of natural resource degradation around the refugee settlements in northern Uganda, with a focus on forest resources, and to identify possible interventions to mitigate pressure on the environment and support energy access for both the refugee and host communities.

This Technical Report summarizes the main findings and recommendations of the assessment. These are expected to guide World Bank support to the Government of Uganda (GoU)—including the Development Response to Displacement Impacts Project (DRDIP) and an IDA disbursement window for refugee-affected countries—as well as provide information of wider strategic value to other agencies concerned with the impacts of refugees on natural resources in Uganda.

Main findings

The assessment revealed the following key findings:

- The refugee influx from South Sudan has led to an **increase in the rate of degradation and tree loss, both inside the West Nile refugee settlements and around their boundaries**, with accelerated land cover changes in bushland and woodland. Deforestation and forest degradation are not new phenomena in Uganda, where the rate of forest loss is one of the highest in the world at 4 percent per year, but the refugee presence has added to the existing pressure on the environment, causing a high risk of degradation due to increased demand for wood as cooking fuel. Competition for available resources could become a source of tension between the refugees and host communities.

- **Land cover change analysis shows an increase in tree cover loss and degradation both within and around the refugee settlements after the start of the refugee influx from South Sudan.** Within a 5 km buffer zone from the settlement boundaries, the total tree cover loss between 2010 and 2013 was about 1,919 ha, while degradation covered about 5,664 ha (in woodland and bushland, including the areas of the settlements themselves). Meanwhile from 2014 to 2018, there was 34,112 ha of loss and 29,604 ha of degradation. **Between the two periods, there is an average increase of around 14 percent of the rate of degradation and loss in woodland, bushland and cropland**

on the total areas within 5 km of the settlement boundaries, and additional loss and degradation in the extended 15 km buffer - though the latter suggests extensive ongoing degradation by host communities rather than refugee-related impacts.

- **Refugee and host households are highly dependent on forests and other woodlands** as primary sources of woodfuel for cooking and for income generation contributing to their livelihood resilience. The average **daily consumption of firewood by the refugees is 1.6 kg per person and among host communities is 2.1 kg, about 30 percent higher. Taking into account the additional use of charcoal**, average daily fuel consumption rises to **1.8 kg per person** in firewood equivalent among refugees and **2.2 kg** among households of host communities.

- **Total cooking fuel demand in the 14 targeted refugee settlements is about 500,000 metric tons of wood per year,** based on the December 2017 refugee population. This is about **five times the quantity of tree growth within the settlements and the 5 km buffer zone, which could result in an annual biomass loss of about 10 percent.** Only around the Maaji (I and II) settlements in Adjumani District is there an apparent surplus of woodfuel in excess of demand within the 5 km buffer zone. Based on the woodfuel demand and supply assessment, the refugee settlements with greatest pressure on the surrounding forests and other woodlands are Pagrinya, Nyumanzi, Imvepi, Palorinya, Bidibidi, and Ayilo (I).

- It is important to note, however, that woodfuel demand is based on refugee population data for December 2017. An ongoing verification exercise is likely to result in a reduced population figure. **With a verified refugee population reduced in the target area by 15 percent, 30 percent, and 45 percent, the annual biomass loss would decrease from an estimated 10 percent to 8 percent, 6 percent, and 4 percent, respectively.**

- **Refugee woodfuel consumption at Bidibidi settlement has significantly reduced,** to about half the amount recorded in a March 2017 survey, probably due to greater wood shortage, a more diverse diet with fresher food, drier firewood, and more efficient stoves and cooking practices. A further reduction of woodfuel demand combined with the probable drop in verified refugee numbers **may have important implications for the estimated impacts on biomass stocks.**

- Both refugees and locals have a tradition of building improved mud-stoves from locally available materials. **A higher proportion of refugee households use improved cookstoves than host communities,** and in Bidibidi there has been a marked increase in their use since the March 2017 survey. **Modern prefabricated cookstoves are also available in regional markets but are too expensive for most refugees and locals. Improved mud-stoves are likely to remain a practical cooking solution** and are already well-known and culturally acceptable. There would be value in confirming thermal efficiency, pollutant emissions, and safety of the adopted mud-stoves to identify areas of possible improvement.

- The majority of households have constructed semi-permanent structures and have improved their homes with latrines and kitchen shelters. A few have bathing shelters, animal sheds, and poultry/bird pens. **Households need additional wood to build and maintain these structures,** which was not measured under this study.

- Although natural resource depletion is a major concern for the GoU and partner organizations, there are **few organizations working in refugee-affected areas focusing on the issue of environment and energy.** Those organizations that do so are operating at a small scale on 12-month budget cycles. To ensure a more effective and harmonized approach with appropriate technical expertise and adequate resourcing, **there is a need for a joint action on a coherent set of interventions implemented on a multi-year basis through a multi-agency program.** This would effectively address environmental degradation associated with the presence of the refugees and ongoing local drivers.

The assessment recommends a range of costed interventions and additional measures to improve environmental management, ensure access to woodfuel resources for both refugee and host communities, and contribute to building livelihood resilience:

1) **Rehabilitation of degraded forests** using both natural and assisted regeneration. This intervention should target areas owned by host communities and individuals, protected areas managed by the Ugandan National Forestry Authority (NFA), and areas assigned to the refugees.
2) **Establishment of woodlots for energy and other purposes** such as building poles, fruits, and fodder. This intervention should target areas owned by host communities and individuals, protected areas managed by the NFA, and areas assigned to the refugees.
3) **Development of agroforestry systems** on household plots and farmland, where trees and woody perennials are interplanted along boundaries and with crops for energy, food, and fodder. This intervention should target the residential plots assigned to refugees and the cultivated fields of both host and refugee communities surrounding refugee settlements.
4) **Enhancement of energy efficiency,** to reduce demand for woodfuel through more efficient cooking practices and charcoal production techniques. This intervention should target both host and refugee populations.

Table 1 gives estimated costs for the implementation of the proposed interventions for 14 refugee settlements in northern Uganda.

Table 1. Summary of the indicative costs of the recommended interventions

Recommended intervention	Cost (US$)	% of total
Rehabilitation of degraded forests	15,007,000	13.6
Establishment of woodlots for energy and other purposes	26,632,000	24.2
Development of agroforestry systems	62,235,000	56.5
Enhancement of energy efficiency	6,247,000	5.7
Total	**110,121,000**	**100**

The recommended interventions should be coordinated under **an integrated energy and environment program that has the necessary institutional capacity and resources** to undertake more in-depth analysis at the site level; carry out monitoring and evaluation; support systematic efforts to promote the interventions across the associated host communities; and ensure sound learning, sharing, and interaction with other programs of a similar nature in Uganda and elsewhere. This will ensure that the measures do not take place in isolation or in a scattered, ineffectual, and short-term manner. Such an integrated energy and environment program could complement the community-driven approaches adopted under the DRDIP, which are likely to focus on the shorter-term development needs of host communities.

1. INTRODUCTION

1.1 Background

The refugee crisis in South Sudan has led to the establishment of some of the world's largest refugee settlements in northern Uganda. By March 2018, over a million South Sudanese refugees and asylum seekers had migrated to Uganda, over 350,000 of them in 2017 alone.[2] Uganda is also hosting refugees from Burundi, the Democratic Republic of Congo, and Somalia, making it the largest refugee host country in Africa (and second in the world), with a total of 1.4 million refugees and asylum seekers.

Uganda already faces significant pressure on its forests and woodlands and suffers from a high rate of deforestation and land degradation. According to the Food and Agriculture Organization of the United Nations (FAO) Global Forest Resources Assessment 2015 (FRA 2015), the net loss of Uganda's forests from 2000 to 2015 was estimated at 1.8 million ha. During this period, the annual forest loss was 120,000 ha, equivalent to an average annual loss of 4 percent—one of the highest in the world. In 2000, forests covered 19.4 percent of the land area. By 2015 this was only 10.4 percent.

Woodfuels[3] are the primary source of energy for cooking for both the refugee and host communities in northern Uganda. The energy needs of a large number of refugees are increasingly difficult to meet in a situation of declining tree cover and agricultural expansion, and extraction of wood for fuel may contribute to degradation of soils, forests, and woodlands. Given the large number of people who have crossed into Uganda, there is a pressing need to develop strategies for sustainable energy access and forest resource management targeting both refugees and hosts. The refugee influx has reportedly had a range of environmental impacts and associated challenges, including land degradation and woodland loss, resulting in inadequate access to energy for cooking and competition for natural resources. Insufficient arable land

2 UNHCR Monthly Snapshot, March 2018. https://ugandarefugees.org/wp-content/uploads/Uganda-Snapshot-March-2018.pdf.
3 In FAO's terminology, 'woodfuels' are a category of biofuels where the original composition of the wood is preserved. For this study, only firewood and charcoal are considered. 'Firewood' is equivalent to 'fuelwood'.

continues to impair the ability of refugees to grow their own food (UNHCR 2018), despite the allocation of plots for agricultural and residential purposes ranging in size from 30 x 30m to 100 x 100m per household.

A joint assessment conducted by FAO and the United Nations High Commissioner for Refugees (UNHCR) in one settlement (Bidibidi) in March 2017[4] concluded that the aboveground biomass (AGB) stock within the settlement area could meet the needs of the population for only three years, in the absence of any intervention. Measures were proposed to reduce demand for wood (for example, fuel-efficient stoves) and increase supply (for example, woodlots and multipurpose tree planting), to build resilience and create opportunities for sustainable development.

Uganda is benefiting from a new IDA18 sub-window for refugees and host communities.[5] The country's progressive refugee policies enhance its prospects for support under this window. Uganda is also benefitting from ongoing support to refugee-hosting areas under an ongoing IDA investment project—the Development Response to Displacement Impacts Project (DRDIP, P152822). The World Bank commissioned FAO to undertake a 'Rapid Diagnostic Assessment of Land and Natural Resources Degradation in Areas Impacted by South Sudan Refugee Influx in Kenya and Uganda'.[6] The assessment was expected to provide a clear profile of the scope of the environmental impacts of the refugee influx, with a focus on forest resources, management challenges, assessment of possible intervention strategies, and practical proposals for interventions for potential inclusion in financing packages submitted to the IDA18 sub-window for refugees, and to inform ongoing World Bank support under the DRDIP.

1.2 Objectives of the assessment

The purpose of the assessment was to conduct a rapid diagnostic assessment of land and forest resources degradation around the 14 refugee settlements in northern Uganda to identify potential intervention options to mitigate pressure on the environment, ensure access to energy for cooking, and contribute to building the resilience of displaced and host communities.

The study involved a combination of a desk review, field survey, and remote sensing analysis. The field survey comprised a socioeconomic assessment of woodfuel consumption and associated challenges in two refugee settlements and in selected villages in the local area, as well as a study on biophysical parameters of woodlands and bushlands in preselected hotspots in Adjumani, Arua, Moyo, and Yumbe Districts.

The assessment builds on the methodology developed in the joint FAO-UNHCR technical handbook, Assessing Woodfuel Supply and Demand in Displacement Settings (FAO & UNHCR, 2016).[7] The methodology comprised three components: (1) assessment of woodfuel demand and associated challenges; (2) assessment of woodfuel supply, including AGB stock, land cover classification, and changes; and (3) identification of interventions to address issues related to energy access, natural resource degradation, and livelihoods.

The methodology for the socioeconomic analysis, biophysical field inventory, and remote sensing analysis is described in detail in the annex (section 6).

4 FAO and UNHCR. 2017. http://www.fao.org/3/a-i7849e.pdf.
5 The refugee sub-window was created under the 18th replenishment of IDA.
6 World Bank Contractual Agreement no. 7185743; FAO Project Symbol: OSRO/GLO/801/WBK.
7 http://www.fao.org/3/a-i5762e.pdf.

1.3 Area of interest

Table 2 lists the 14 refugee settlements in northern Uganda, with districts and establishment dates.

Table 2: Refugee settlements included in study

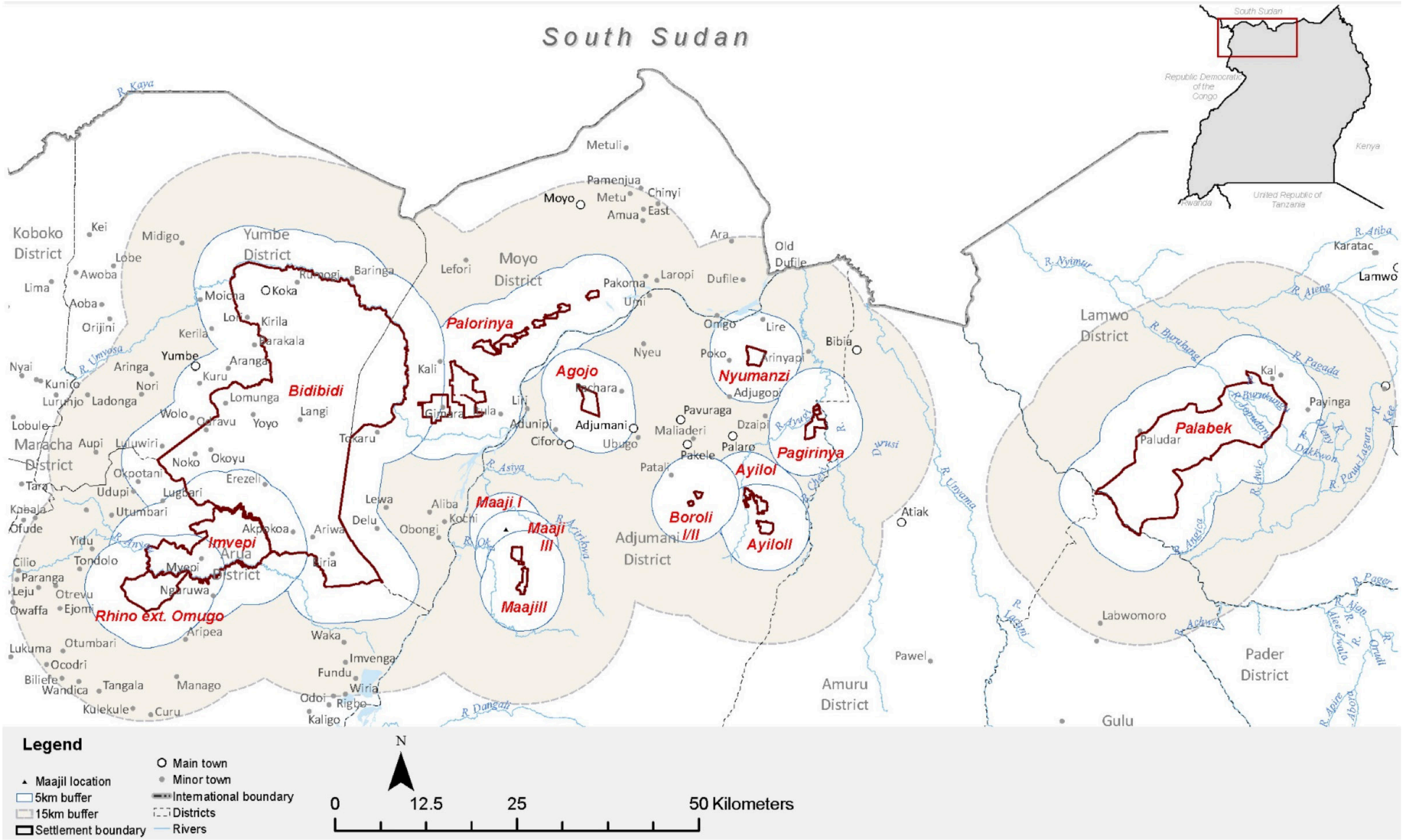
No.	Settlement name	District	Establishment date
1	Bidibidi	Yumbe	August 2016
2	Imvepi	Arua	February 2017
3	Rhino extension - Omugo	Arua	January 2017
4	Agojo	Adjumani	January 2016
5	Ayilo I	Adjumani	January 2015
6	Ayilo II	Adjumani	July 2014
7	Boroli I/II	Adjumani	January 2014
8	Maaji Ia	Adjumani	January 1997
9	Maaji IIa	Adjumani	January 1997
10	Maaji IIIa	Adjumani	January 1997
11	Nyumanzi	Adjumani	January 2014
12	Pagirinya	Adjumani	January 2016
13	Palorinya	Moyo	December 2016
14	Palabek	Lamwo	April 2017

Note: a. Settlements established in 1997 and reopened in 2015.

The area of interest (AOI) for this assessment was the ‘buffer zone’[8] up to 5 km of the boundaries of the 14 refugee settlements, this being the assumed limit for routine firewood collection. A wider AOI up to 15 km away was also assessed to understand trends and dynamics within host communities (Figure 1).

8 https://www.supermap.com/en/online/deskprodotnet/Features/Analyst/Vector/bufferanalyst/HowBufferWork.htm.

Figure 1. AOI: 5 and 15 km buffer zones around target refugee settlements, northern Uganda



Source: UNHCR - Settlements extents, administrative data.

Note: The boundary of Maaji I settlement was not available, so the settlement center point was used to create the buffer. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations (UN).

2. SOCIOECONOMIC FINDINGS

2.1 Refugee and host community political framework

Coordination of the refugee protection and response system in Uganda is led by the Office of the Prime Minister (OPM), while operational response is co-led by the OPM and UNHCR, supported by UN agencies and partners.

Uganda's policy toward refugees is unique in Africa. In accordance with the **Refugee Act** (2006) and **Refugee Regulations** (2010), the Government of Uganda (GoU) has developed national frameworks with an inclusive approach, granting refugees freedom of movement and the right to work, establish business, and access public services such as education, on a par with nationals. The **Second National Development Plan (NDP II)** (2015/16–2019/20) provides for refugee management and protection as a priority in development planning and implementation by the OPM of the **Settlement Transformation Agenda (STA)** to promote socioeconomic development in refugee-hosting areas. The allocation of plots of land where refugees can live and farm is a practice that has significant implications for the planning of community-based environmental interventions and for intervening to address environmental degradation. Host districts are required to develop Integrated District Development Plans that incorporate the development needs of host communities and refugees.

Refugee and Host Population Empowerment (ReHoPE) is a policy framework launched in 2017 by the GoU in collaboration with UN agencies and the World Bank. ReHoPE seeks to foster a multiyear, multisectoral program to bridge humanitarian and development approaches. It provides guidance for a comprehensive response to address refugees' and host communities' needs and to build the capacity of hosting districts in planning and providing services to refugee and host communities. ReHoPE supports the GoU to address environmental degradation in refugee-hosting areas through improved natural resource management and energy access.

Uganda's **Comprehensive Refugee Response Framework (CRRF)** was launched by the OPM and UNHCR in March 2017. It has five pillars: 1. admission and rights, 2. emergency response and ongoing needs, 3. resilience and self-reliance of refugees, 4. expansion of solutions through resettlement and complementary pathways, and 5. voluntary repatriation. In October 2017, a high-level, government-led Steering Group, facilitated by the UNHCR, was established to bring together humanitarian and development actors, local government, and the private sector, to engage and provide guidance on refugee matters. The CRRF Steering Group also documents lessons from the Uganda refugee experience to inform relevant global, regional, and national initiatives, as well as the development of the Global Compact on Refugees. The Steering Group has established a secretariat to support the application of the CRRF. The secretariat serves as a knowledge hub and platform for strategic discussions, building on initiatives already in place to manage and find solutions for refugees.

The **Working Group on Energy and Environment** operates under the umbrella of the CRRF to coordinate the country-wide energy and environment response for ReHoPE, in line with NDP II, the STA, and the Uganda Refugee Response Plans (RRPs).[9] The working group is chaired by the OPM and cochaired by the UNHCR and the United Nations Development Programme (UNDP), and its mandate is anchored in existing strategies including ReHoPE (Objective 4), the STA (Pillars 1, 2, 4, and 5), and the RRP (Strategic Priority 6, Objective 3). The working group has been constituted specifically to support refugee-affected districts and has a representation of relevant actors in the environment sector (government, nongovernmental organizations [NGOs], UN agencies). The working group will take the lead on Objective 4 of ReHoPE and validate and enhance the results and indicators in the next revision of the ReHoPE strategy.

2.2 Population and household characteristics

Household size and gender

The socioeconomic survey covered 174 households in the refugee settlements of Bidibidi (Yumbe District) and Maaji (Adjumani District), as well as 168 host community households in Ciforo (Adjumani) and Okangali (Yumbe) subcounties. The majority of respondents were female in both the refugee and host communities, where they constituted 91 percent and 83 percent of respondents, respectively. The average refugee household was found to be larger than the average host household (7.9 versus 6.4 persons).

Table 3 shows the gender of household heads. Among the refugee respondents, 75.9 percent and 62.1 percent were female headed in Maaji (Adjumani District) and Bidibidi (Yumbe District), respectively, while in the host communities in Ciforo and Okangali, only 32.5 percent and 24.7 percent, respectively, were female headed. These figures are aligned with the UNHCR's socioeconomic assessment report 2017, which indicates that 63.8 percent of refugee households in Uganda are female headed, but only 30.5 percent of host community households are female headed (UNHCR 2017a).

9 https://ugandarefugees.org/wp-content/uploads/Uganda-I-RRP-2018pdf.pdf.

Table 3. Gender of household head

	Refugee communities		Host communities	
	Female (%)	Male (%)	Female (%)	Male (%)
Adjumani District	75.9	24.1	32.5	67.5
Yumbe District	62.1	37.9	24.7	75.3

Livelihoods

The majority of refugee and host households engage in agriculture-based livelihoods, usually subsistence farming. A small proportion of refugee households have other income (for example, cash transfers, brewing, selling woodfuel, tailoring, teaching, transporting items, selling cooking oil, blacksmithing, selling dried fish or casual work in local food outlets). Host community households are also engaged with other income-earning activities such as engaging in casual labor, selling woodfuel and non-wood forest products, exchanging food, and cooking and selling food. Table 4 shows the proportions of refugee and host community households with and without a source of income.

Table 4. Household income

	Refugee communities		Host communities	
	HH with no income (%)	HH with income (%)	HH with no income (%)	HH with income (%)
Adjumani District	26.4	73.6	14.1	85.9
Yumbe District	18.4	81.6	4.2	95.8

Note: HH = household.

As expected, there are more households in refugee communities without an income. It is also important to note that among refugee settlements, 30 percent of those households with income earners had more than one person earning an income. Since the assessment conducted by FAO and the UNHCR in Bidibidi in March 2017, the proportion of refugee households with members earning an income has risen from 26 percent to 81.6 percent. This could be a sign that the population is transitioning from an emergency situation to a more stable way of life.

It was observed that the land allocated to refugees in the Maaji settlements (Adjumani District) has greater arable potential than the land allocated to refugees in Bidibidi settlement (Yumbe District). Refugees in Maaji were more likely to be engaged in commercial scale farming on their plots and renting additional land to grow more crops. In addition to the good soils, this can be explained by the establishment of Maaji settlements dating back to 1997.

Figure 2. A makeshift market in Bidibidi settlement

©FAO/Eva Kintu

2.3 Woodfuel consumption

An average of 97 percent of households across the refugee and host communities use firewood for cooking (Table 5). Refugee households are more likely to use charcoal than host communities (16.7 percent versus 6 percent) and a few of them use both charcoal and firewood. A number of households also burn crop residues such as cassava stalks and maize cobs and stalks (when available).

Per capita woodfuel consumption

The household survey reveals that the average firewood consumption of a refugee household in both districts is a little lower than that of a host household (Table 5). The figures provided in Table 5 are average of woodfuel consumption expressed as kilogram per person per day (pppd) by the users.

Table 5. Refugee and host woodfuel consumption, kg pppd

	Population using firewood (%)	Firewood consumption (kg pppd)	Population using charcoal (%)	Charcoal consumption (kg pppd wood equivalent)[a]
Refugees - Adjumani	94.3	1.73	25.3	1.25
Refugees - Yumbe	98.9	1.57	8.0	1.40
Refugees - total	**96.6**	**1.65**	**16.7**	**1.30**
Hosts - Adjumani	98.8	2.14	7.2	1.35
Hosts - Yumbe	96.5	2.13	4.7	1.25
Hosts - total	**97.6**	**2.13**	**6.0**	**1.30**

Note: a. Expressed in firewood equivalent, assuming 20 percent conversion of firewood to charcoal by weight. Kilogram of firewood pppd is expressed on an air-dry basis.

Notably, the daily firewood consumption of refugee households in Bidibidi settlement has declined significantly from 3.5 to 1.6 kg pppd since March 2017. A possible reason is a move from dry beans to a more diverse diet with more fresh food that cooks faster. It was also observed that refugees were using drier wood in 2018 than in 2017 when green wood was often collected and burned. A slight increase in charcoal consumption and a greater use of improved stoves were also observed in 2018.

A few refugee households use firewood for commercial purposes (Maaji: 2.4 percent; Bidibidi: 1.4 percent). This is more common in host communities, for commercial activities such as charcoal production, brewing alcohol, curing tobacco, and brick making.

Figure 3. Traditional charcoal kiln near Bidibidi settlement

©FAO/Rebecca Tavani

Total refugee woodfuel consumption

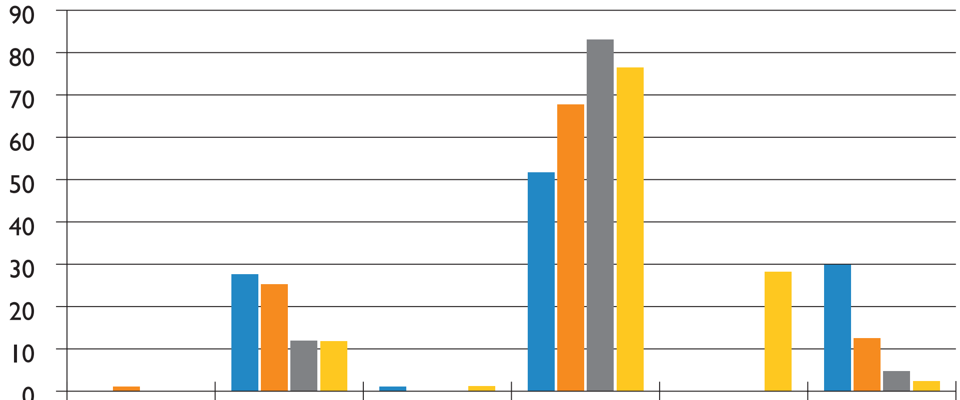
Table 6 indicates the total woodfuel consumption for all refugee settlements in northern Uganda. The figures for each settlement are based on weighted averages extrapolated from the proportions of woodfuel users (Table 5) drawn from the household surveys conducted in Bidibidi and Maaji. Total woodfuel consumption takes into account both firewood (expressed on an air-dry basis) and charcoal (expressed in firewood equivalent, assuming a conversion efficiency of 20 percent). The December 2017 population data suggest total woodfuel consumption of 528,000 tons per year in firewood equivalent.

Table 6. Estimated total woodfuel consumption in the target refugee settlements

Settlement	Population (December 2017)	Total woodfuel consumption (tons per year firewood equivalent)
Bidibidi	287,087	189,769
Imvepi	127,926	84,561
Rhino extension - Omugo	20,411	13,492
Agojo	3,026	2,000
Ayilo I	23,210	15,342
Ayilo II	11,260	7,443
Boroli I/II	12,415	8,207
Maaji I	695	459
Maaji II	17,434	11,524
Maaji III	16,235	10,732
Nyumanzi	43,508	28,759
Pagrinya	32,055	21,189
Palorinya	165,587	109,455
Palabek	37,650	24,887
Total	**798,499**	**527,819**

Woodfuel source. The dominant source of firewood for both refugee and host community households is bushland, followed by woodland. Host communities also source wood from cropland (Figure 4).

Figure 4. Fuelwood sources for households



	NGO	Woodland	Woodlot	Bushland	Cropland	Market
Refugees-Adjumani	0	27.6	1.1	51.7	0	29.9
Refugees-Yumbe	1.1	25.3	0	67.8	0	12.6
Hosts-Adjumani	0	12	0	83.1	0	4.8
Hosts-Yumbe	0	11.8	1.2	76.5	28.2	2.4

2.4 Access to woodfuel

Around 60 percent of both refugee and host households (refugee households - Adjumani: 59 percent; Yumbe: 73 percent; host households - Adjumani: 59 percent; Yumbe: 65 percent) collect more than three headloads of firewood per week. In refugee households, 84 percent of respondents spend two or more hours per trip collecting firewood (Adjumani: 78 percent; Yumbe: 89 percent), while in host communities, about 69 percent spend two or more hours, with a higher proportion in Adjumani (82 percent) compared to Yumbe (56.7 percent).

The most commonly mentioned challenge for refugees in firewood collection is its scarcity, which results in women walking long distances (exposing themselves to more risks and challenges). Refugee respondents also reported a fear of being attacked/beaten by host communities and a risk of encountering wild animals during firewood collection. Other challenges mentioned include fear of arrest by game rangers, assault/rape, inadequate or insufficient tools for collecting firewood, and flooded streams leading to inaccessibility in the rainy season. Some refugees also reported issues indirectly related to firewood collection, such as children missing school, lack of food or cash to exchange for firewood, lack of transport, and a language barrier to communication with the host community.

Host communities mentioned similar challenges in firewood collection, with the most common being its scarcity and fear of encountering hazards such as snakes and scorpions. Other challenges mentioned include lack of tools, rain interference, conflicts and tensions with landlords, and lack of transport.

2.5 Cooking stoves and practices

The majority of refugee and local households have constructed improved cookstoves, with hosts in Adjumani having the highest proportion and those in Yumbe having the lowest.

The most common improved cookstove used by refugee households is the mud-stove for firewood, sometimes represented by the Lorena stove (with two pot holes, one fireplace, and a chimney or smoke vent). It is common practice for households that have the mud-stove for firewood to construct another mud-stove for charcoal, as well as to use a 3-stone fire—a trend for multiple hearths previously noted in the 2017 FAO-UNHCR assessment in Bidibidi. The survey found that among refugee communities, 62.1 percent use an improved mud-stove with firewood and 23 percent with charcoal (Figure 5). A large proportion of refugee households (45 percent) use the 3-stone fire (38 percent in Maaji and 53 percent in Bidibidi), sometimes in combination with an improved stove (16 percent in Maaji and 33 percent in Bidibidi). In the host communities, 52 percent use a mud-stove with firewood and 6 percent with charcoal. The 3-stone fire is used by an average of 52 percent of host community respondents in Adjumani and Yumbe (respectively 19 percent and 85 percent), of which 11 percent (Adjumani) and 32 percent (Yumbe) use it in combination with an improved stove.

Figure 5. Types of household cookstoves

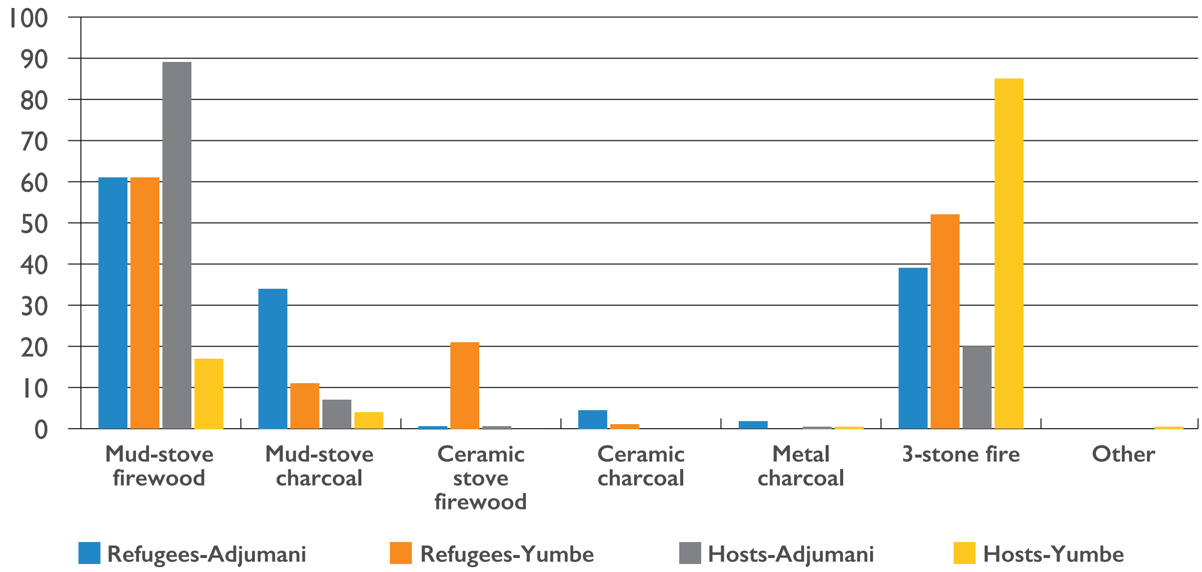


Figure 6. Typical outdoor kitchen setting: a Lorena stove and pile of firewood (refugee household - Bidibidi)

©UNHCR/Ranya Sherif

Cookstoves are set up both in dedicated indoor kitchens and in outdoor settings. Indoor cooking is more common during the rainy season, while outdoor cooking might reduce smoke inhalation and is cooler during the hot season. Indoor kitchens are often poorly ventilated.

Typical 2-pot mud-stove (host kitchen - Adjumani)

Type of mud-stove constructed in the veranda (host household - Yumbe)

Typical 1-pot mud-stove (refugee kitchen - Bidibidi)

Mud-stove used alongside 3-stone fire (refugee household - Maaji)

Woman heating water in indoor kitchen

Young woman lighting wire-mesh-like charcoal stove (Bidibidi)

Source of cookstoves

Over 91 percent of refugee households with improved cookstoves constructed or sourced the stoves themselves (Maaji: 97 percent; Bidibidi: 86 percent). A smaller proportion said they received them from an NGO (18 percent—Maaji: 7.8 percent; Bidibidi: 27 percent) while some were supported by relatives (1.5 percent—Maaji: 3.1 percent: Bidibidi: 0 percent) and others purchased from the market (0.8 percent—Maaji: 0 percent; Bidibidi: 1.5 percent).

Diet and food preparation

Although the refugee diet in Bidibidi is more varied than in 2017, maize and beans are still the dominant food, with beans especially requiring a long cooking time. The household survey showed an average of 69 percent (Maaji: 64 percent; Bidibidi: 74 percent) of households in the refugee communities cook beans on five or more days per week, compared to 42 percent (Adjumani: 27 percent; Yumbe: 57 percent) in the host communities that cook beans five or more days in a week. This is understandable considering that households in host communities are able to grow a range of crops, whereas refugee households have land constraints.

It was observed that both the refugee and host households often place the beans in water, add ash solution to soften them, and reduce time for cooking by pre-boiling them for about 15 minutes, skinning them through a grinding action, and putting them back on the fire to cook. There is therefore good evidence of energy-saving cooking practices being applied.

Another food prepared by most refugee households (84 percent—Maaji: 82 percent; Bidibidi: 86 percent) and host households (79 percent—Adjumani: 78 percent; Yumbe: 80 percent) on a daily basis is ugali, a dough made from maize, sorghum, or cassava flour that is boiled in water for 15–20 minutes.

The survey also sought to establish the most common foods prepared by the interviewed households, and a more varied diet for refugee communities in Bidibidi was observed compared to the 2017 survey. The refugees prepare vegetables, fish, and other food such as fresh roots (cassava, sweet potatoes, yams), groundnut or sesame paste, varieties of peas, and other foods cooked in different proportions: chapati, chicken, cassava leaves, rice, eggs, milk, and soya.

3. WOODY BIOMASS RESOURCES FINDINGS

3.1 Biophysical field measurements

Table 7 illustrates the main results of the biophysical field assessment and gives an indication of the potential woody biomass available in each land use and land cover (LULC) category. Only 67 sample plots were surveyed out of the planned 95, due to problems experienced with accessing the intact areas.

Table 7. Biomass stock by LULC category

LULC (main land use)	Source	No. of plots	No. of trees per ha	AGB (tons per ha)	Deadwood (tons per ha)
Intact woodland	NBS	15	567 ± 103	38.0 ± 7.0	No data
Intact bushland	NBS	10	708 ± 257	27.8 ± 5.0	No data
Cropland	This survey	21	391 ± 270	9.14 ± 5.23	4.61 ± 7.2
Degraded woodland	This survey	7	880 ± 923	25.3 ± 18.5	0.30 ± 0.25
Degraded bushland	This survey	14	120 ± 76	3.94 ± 3.95	0.25 ± 0.24

Note: NBS = National Biomass Study.

A total of 70 tree species were recorded in the field, of which *Acacia hockii, Combretum collinum, Combretum fragrans,* and *Lannea fruticose* were dominant.

As the table shows, AGB in degraded bushlands is approximately 4 tons per ha and was derived by analyzing data in the grassland category, as there were no field observations for the strata.

Woodland plots with the greatest indicators of degradation were analyzed and yielded total AGB of 25.3 tons per ha. This estimate, however, has the greatest uncertainty, with a confidence interval of ±18.5 due to the wide variability found in this class.

Woody biomass in cropland is estimated at 9.1 tons per ha, which is approximately the national average. This average includes plots that were measured in areas described as 'young fallow', which are commonly found where crop cultivation has recently advanced into woodlands. Much of the cropland is located in areas that were former woodlands and riverine forests. The riverine forests appear to be the most attractive areas for cultivation; however, there is no evidence that these areas are cultivated by refugees. Field observations show that sometimes trees are cleared and converted to charcoal as part of land preparation for crop establishment.

Analysis of intact woodland sites using the NBS dataset for 15 plots resulted in an average AGB of about 38 tons per ha. Analysis of intact bushland yielded 10 plots containing an average AGB of approximately 28 tons per ha.

The NBS provides estimated growth rates as national averages, and for agroecological zones (Forest Department 2002), the target settlements are all in the semi-moist lowland zone (Table 8).

Table 8. Annual increment (air-dry matter), as national averages and for semi-moist lowlands

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

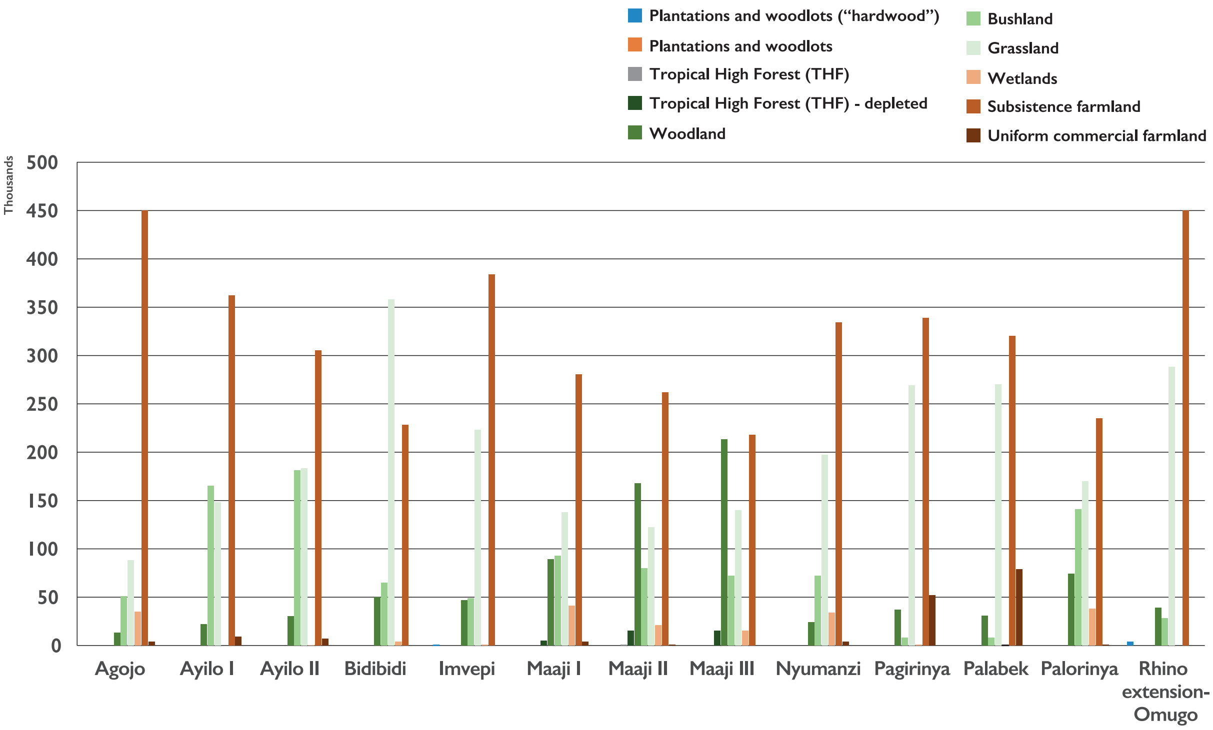
Source: Forest Department 2002.

3.2 LULC mapping and change detection

The aim of the remote sensing analysis was to map degradation and loss before and after the establishment of the refugee settlements, as a means of estimating land cover and biomass changes over time for the AOI, and to validate the consumption data generated by the surveys within the settlements and host communities.

The LULC map is part of Uganda's national mapping system and was used in this study to gain a better understanding of the dominant LULC classes. As shown in Figure 7, the AOI is characterized by relatively homogeneous distribution of the main land cover types (bushland, grassland, and subsistence farmland). The Maaji settlements in Adjumani District seem to be the richest in vegetation, particularly tree cover. Details on the methodology and datasets used in the remote sensing analysis are provided in the annex (section 6).

Figure 7. LULC per settlement (area in km^2) within the 15 km buffer



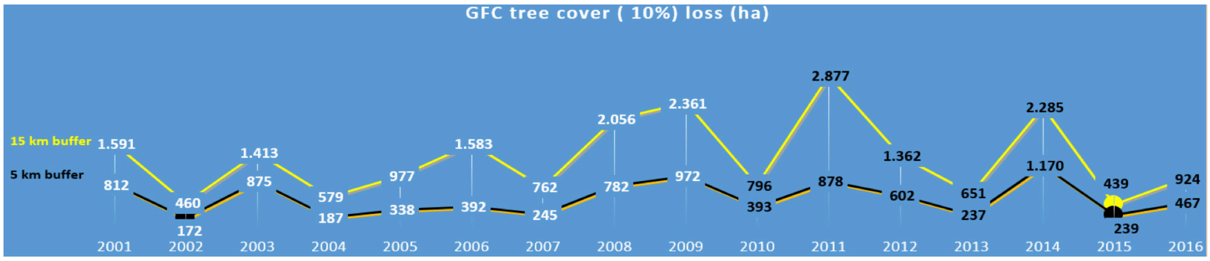
Source: NFA maps 2015.

Note: NFA = National Forestry Authority.

Slopes within the AOI were computed using a digital elevation model (DEM) (RCMRD 2015[10]) and show a range from 0.5 percent to 18 percent. In general, the area is flat or gently undulating, and steepness is not likely to be a factor constraining access by either refugees or local people. Steeper slopes characterize areas near Moyo along the River Nile from the western side of the Maaji settlements and on the southwest of Ayilo II settlement.

The Global Forest Change (GFC) dataset (Hansen et al. 2013) was used to compute tree cover loss from 2001 to 2016. Figure 8 shows the loss detected within both the 5 and 15km buffer zones.

Figure 8. Tree cover loss (in hectares) using 10 percent tree cover threshold within 5 and 15 km buffers (2010–2016 in black)



Source: GFC data.

10 The data represent the 30 m DEM from Shuttle Radar Topography Mission (SRTM) (http://geoportal.rcmrd.org/layers/servir%3Auganda_srtm30meters).

Tree cover loss shows one peak (in 2014) for the 5km buffer and two peaks (in 2011 and 2014) for the 15km buffer. The 2011 peak was three times higher for the 15km buffer than the 5km buffer, although possible causes were not investigated. The 2014 peak could be linked to the establishment of some refugee settlements and the GFC dataset may have detected clear-cuts covering extensive areas. Considering only 2014–2016, the GFC dataset does not show a significant increase in tree cover loss that might be associated with the refugees' arrival. This could be partly explained by the challenges in detecting changes in complex landscapes (Mitchard et al. 2015, Hansen et al. 2013, Tyukavina et al. 2015). However, the map presenting biomass changes between 2013 and 2018 (Figure 10) shows a reduction in biomass stocks around the whole area, especially northern Bidibidi and around Ayilo and Palabek. Details are provided in Table 9 and Table 10.

Degradation and loss within the settlements and the 5 and 15km buffer zones was mapped by combining existing LULC maps (2010 and 2015) and clipping to the AOI with a ''degradation/loss mask' obtained from the Breaks for Additive Seasonal and Trend (BFAST, 2010)[11] algorithm to detect vegetation cover changes for the two periods. The results were used to create two biomass maps for 2010–2013 and for 2014–2018 (Figure 9) by applying the biomass stocking factors from the biophysical survey.

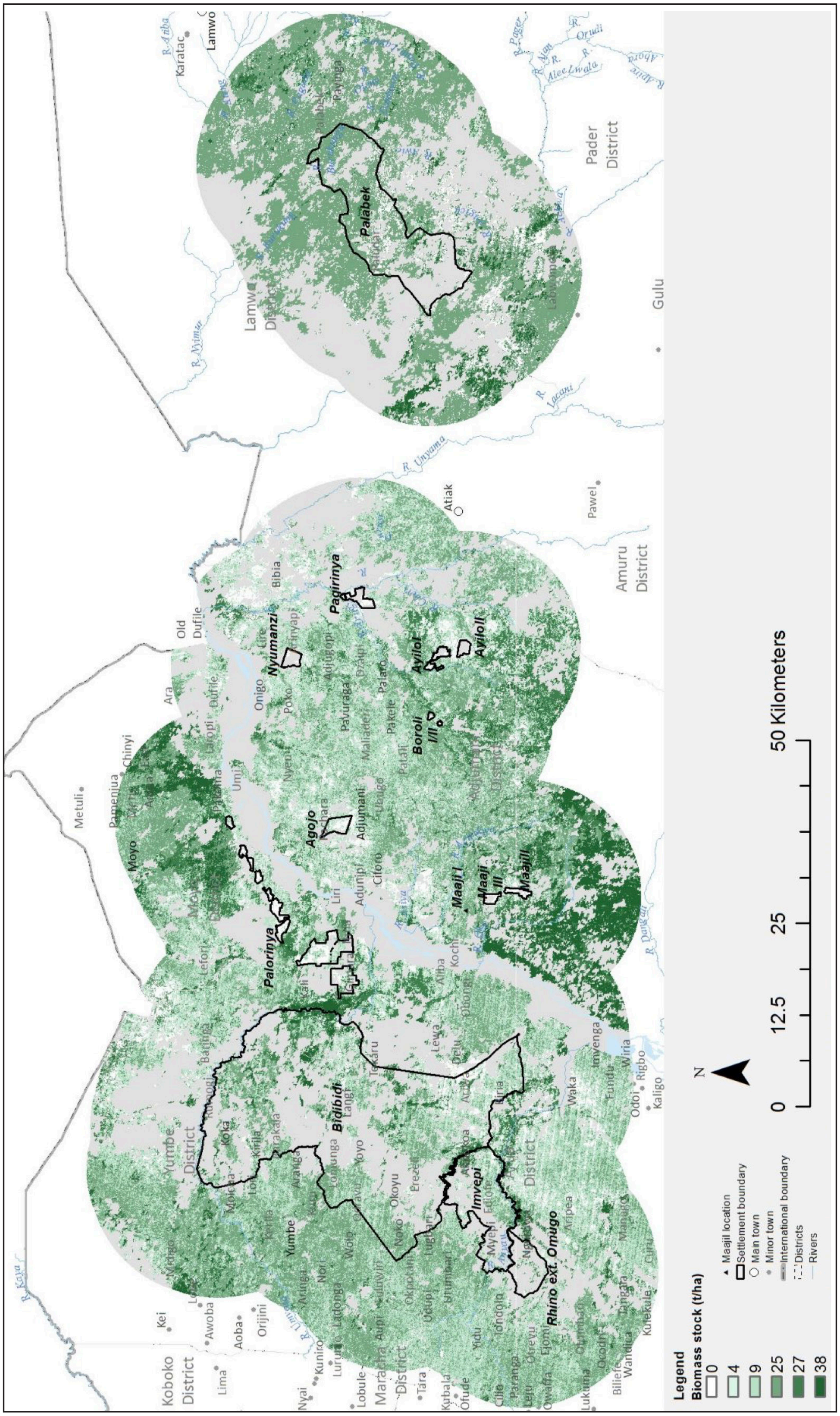
The 2010 and 2015 LULC maps were reclassified into just four classes based on their prominence in the landscape, accessibility, and biomass stocking: 1. woodland, 2. bushland, 3. cropland, and 4. other. The classes of the land cover maps were combined with the two classes of the change maps (loss and degradation). In more detail, 'intact woodland' and 'intact bushland' are vegetated areas that remain 'stable', without degradation and loss. Degraded classes refer to partial vegetation removal while loss occurs when there is complete vegetation removal.

Palorinya, Moyo district

Bidibidi, Yumbe district

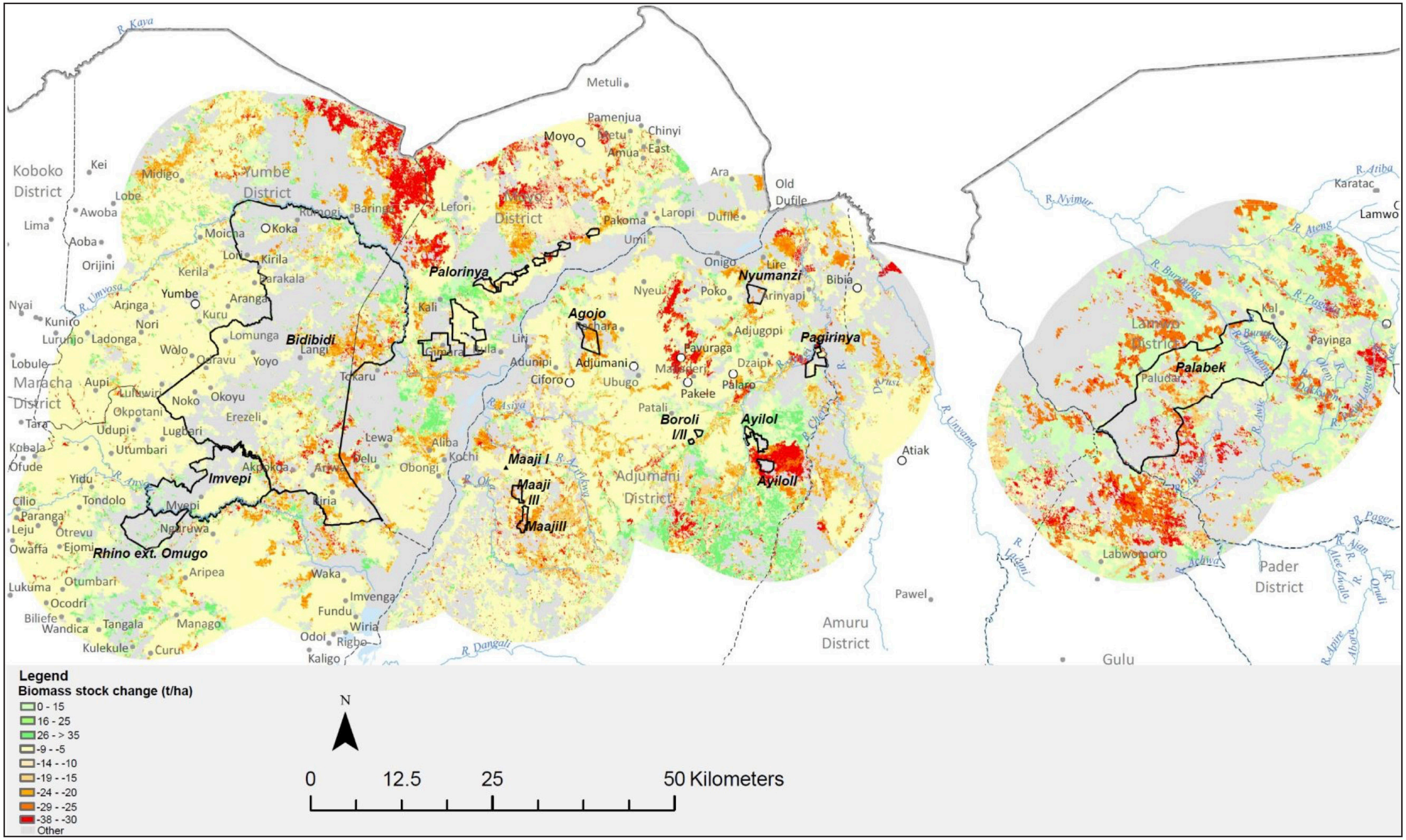
11 For more information on BFAST: http://bfast.r-forge.r-project.org/.

Figure 9. Biomass stock within the settlements and 15km of settlement boundaries, early 2018



Source: UNHCR - Settlements extents, administrative data.
Note: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the UN.

Figure 10. Biomass stock changes between 2013 and 2018 within settlements and 15 km buffers



Source: UNHCR - Settlements extents, administrative data.

Note: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the UN.

According to the results for the 5km buffer zone (Table 9), the total tree cover loss between 2010 and 2013 was about 1,919ha, while degradation covered about 5,664ha (in woodland and bushland, including the areas of the settlements themselves). Meanwhile, from 2014 to 2018, there was 34,112ha of loss and 29,604ha of degradation. Between the two periods, there was about a 12 percent increase in areas affected by degradation and loss on the total areas within the 5km buffer zone. Total biomass loss accounts for the total loss, including the loss from degraded land.[12]

The overall picture indicates a significant increase in loss and degradation, not only within the 5km buffer near the refugee settlements but also in the extended 15km buffer from their boundaries. The latter is especially interesting as it is unlikely to have any direct link to the presence of the refugees but suggests extensive ongoing degradation cause by host communities.

Table 9. Loss and degradation (ha) and biomass (AGB) changes in selected land cover classes within 5 and 15 km of the refugee settlement boundaries

Loss and degradation	5km buffer				15km buffer			
	2010–2013		2014–2018		2010–2013		2014–2018	
	Total area (ha)	AGB stock (tons)	Total area (ha)	AGB stock (tons)	Total area (ha)	AGB stock (tons)	Total area (ha)	AGB stock (tons)
Loss in woodland	157	5,961	3,288	124,950	536	20,358	9,253	351,614
Loss in bushland	703	19,532	6,998	194,543	1,428	39,696	14,015	389,624
Loss in cropland	1,060	10,521	23,826	236,591	2,141	21,255	54,311	539,306
Total loss	**1,919**	**36,015**	**34,112**	**556,084**	**4,104**	**81,309**	**77,579**	**1,280,544**
Degraded woodland	1,425	36,088	10,558	267,427	4,073	103,164	25,872	655,341
Degraded bushland	4,240	16,704	19,047	75,044	8,797	34,660	38,787	152,822
Total degradation	**5,664**		**29,604**		**12,870**		**64,660**	
Biomass loss in degraded woodland	—	27,169	—	201,336	—	77,668	—	493,381
Biomass loss in degraded bushland	—	44,728	—	200,942	—	92,809	—	409,207
Total biomass loss from degraded land	—	71,897	—	402,277	—	170,477	—	902,588
Total biomass loss		**107,912**		**958,361**		**251,786**		**2,183,132**

12 The biomass factor used to compute biomass loss in degraded land is taken as the difference between the biomass factors for intact woodland (38 tons per ha) and degraded woodland (25.3 tons per ha), which is 12.7 tons per ha. Similarly, for the bushland class, it is the difference between the biomass factors for intact bushland (27.8 tons per ha) and degraded bushland (3.9 tons per ha), which is 23.9 tons per ha.

Table 10 shows estimates of loss and degradation in the settlements and within the 5km buffer. The remaining AGB or net woody biomass is the sum of the biomass from degraded classes with the biomass from the intact classes.

Only changes derived from the time series analysis (BFAST) are considered, rather than changes between the intact woodlands and bushlands derived from the two mapped periods. In other words, changes within 'intact' classes (that is, intact woodland, intact bushland, and cropland) between the two periods (2010–2013 and 2014–2018) should not be compared with the change estimates (loss and degradation) resulting from BFAST results since they refer to two different datasets and approaches. More details are described in the annexed methodology.

The LULC maps were used to classify changes wexample, it is evident that the loss observed in the Rhino Camp extension and Palabek is mainly related to loss in woodland, probably due to agricultural expansion. Meanwhile in Agojo and Ayilo II, major losses are found in cropland and bushland, while in Nyumanzi it is bushland that is most affected by human impact.

Overall, the results presented in Table 10 show an increase in degradation and loss in both woodland and bushland after the refugees' arrival. For instance, in Bidibidi, AGB decreased from 1.6million tons in 2013 to about 1million tons in 2018 and the area of degraded woodland increased from 470 to 4,409ha in the 5km buffer zone. Ayilo settlements (I and II) are the most affected in terms of degradation, especially in woodland. Agojo, Nyumanzi, and Rhino extension also show degradation, though at a more restricted scale. Other settlements showing an increase in loss and degradation are Imvepi and Maaji I, Nyumanzi, and Palabek. More details are provided in Table 10. However, while there is an increase in observed degradation, the spatial distribution of biomass loss (as mapped in Figure 10) does not provide strong evidence that this results primarily (or even majorly) from refugee woodfuel harvesting. The highest losses are seen in host community areas set back from the settlement boundaries.

Zoka Central Forest Reserve (Adjumani District)

Table 10. Degradation and loss within the refugee settlements and 5 km buffer zone, with net biomass estimates for 2010–2013 and 2014–2018

	Bidibidi				Imvepi				Rhino extension - Omugo				Agojo			
	2010–2013		2014–2018		2010–2013		2014–2018		2010–2013		2014–2018		2010–2013		2014–2018	
Land cover class	ha	tons	ha	tons	ha	tons	ha	tons	ha	tons	ha	tons	ha	tons	ha	tons
Intact woodland	11,592	440,513	5,713	217,095	2,620	99,549	1,482	56,327	1,438	54,648	233	8,854	94	3,570	28	1,081
Intact bushland	22,102	614,449	6,888	191,481	2,597	72,205	1,269	35,273	541	15,050	407	11,315	2,189	60,846	289	8,024
Cropland	62,222	568,705	59,168	540,798	18,583	169,850	15,637	142,920	5,938	54,271	6,465	59,090	8,511	77,789	8,710	79,614
Other	62,498	—	66,801	—	17,469	—	16,410	—	14,792	—	12,094	—	3,506	—	1,987	—
Degradation																
Degraded woodland	470	11,916	4,409	111,692	137	3,458	1,635	41,411	61	1,543	1,181	29,912	3	82	68	1,710
Degraded bushland	1,446	5,697	8,145	32,092	170	670	1,588	6,258	29	116	695	2,738	169	667	570	2,246
Total AGB remaining (tons)		**1,641,279**		**1,093,157**		**45,733**		**282,189**		**125,628**		**111,908**		**142,955**		**92,674**
Loss																
Loss in woodland	52	1,969,92	1,287	48,903	12	469	393	14,949	3	123	233	8,871	0	10	19	728
Loss in bushland	170	4,726	3,324	92,396	28	776	460	12,788	2	48	125	3,463	15	413	188	5,217
Loss in cropland	424	3,876	5,284	48,300	153	1,398	2,829	25,858	31	279	878	8,029	77	703	2,714	24,805
Total loss (ha)	**646**		**9,895**		**193**		**3,682**		**35**		**1,237**		**92**		**2,921**	

	Ayilo I				Ayilo II				Boroli I/II				Maaji I			
	2010–2013		2014–2018		2010–2013		2014–2018		2010–2013		2014–2018		2010–2013		2014–2018	
Land cover class	ha	tons	ha	tons	ha	tons	ha	tons	ha	tons	ha	tons	ha	tons	ha	tons
Intact woodland	2,855	108,479	16	602	3,289	124,974	14	551	254	9,641	36	1,378	542	20,602	259	9,860
Intact bushland	1,666	46,307	1,967	54,689	1,947	54,121	1,760	48,924	1,709	47,508	1,605	44,618	2,852	79,281	417	11,589
Cropland	4,022	36,762	6,988	63,874	2,009	18,366	4,553	41,619	6,739	61,593	6,946	63,485	3,997	36,535	3,782	34,568
Other	4,764	—	1,410	—	3,862	—	1,356	—	2,113	—	902	—	329	—	2,210	—
Degradation																
Degraded woodland	158	4,008	5	121	152	3,857	18	456	15	392	27	684	16	397	116	2,939
Degraded bushland	244	960	1,496	5,895	229	901	1,692	6,667	104	408	1,017	4,006	100	395	334	1,314
Total AGB remaining (tons)		**196,516**		**125,180**		**202,219**		**98,216**		**119,542**		**114,172**		**137,210**		**60,270**
Loss																
Loss in woodland	34	1,303	—	—	37	1,416	1	34	1	31	1	31	3	116	44	1,662
Loss in bushland	51	1,419	662	18,39	66	1,821	986	27,407	7	208	134	3,733	14	378	236	6,563
Loss in cropland	155	1,412	1,412	12,904	85	778	1,265	11,560	126	1,152	397	3,632	33	300	458	4,188
Total loss (ha)	**240**		**2,073**		**188**		**2,252**		**134**		**532**		**50**		**738**	

	Maaji II				Maaji III				Nyumanzi				Pagirinya			
	2010–2013		2014–2018		2010–2013		2014–2018		2010–2013		2014–2018		2010–2013		2014–2018	
Land cover class	**ha**	**tons**	**ha**	**tons**	**ha**	**tons**	**ha**	**tons**	**ha**	**tons**	**ha**	**tons**	**ha**	**tons**	**ha**	**tons**
Intact woodland	3,562	135,340	3,032	115,210	28	1,081	1,036	39,374	217	8,249	89	3,379	651	24,751	13	489
Intact bushland	6,263	174,117	1,237	34,387	289	8,024	711	19,771	3,348	93,062	480	13,331	3,201	88,986	261	7,263
Cropland	2,327	21,268	4,343	39,699	8,710	79,614	4,938	45,136	6,561	59,968	5,850	53,471	2,093	19,132	4,248	38,825
Other	135	—	3,070	—	1,987	—	3,110	—	2,727	—	4,052	—	8,121	—	7,974	—
Degradation																
Degraded woodland	42	1,074	277	7,021	68	1,710	490	12,418	4	89	164	4,158	85	2,154	121	3,073
Degraded bushland	185	730	194	765	570	2,246	370	1,458	97	384	1,077	4,245	460	1,811	494	1,947
Total AGB remaining (tons)		**332,529**		**197,082**		**92,674**		**118,157**		**161,751**		**78,584**		**136,834**		**51,597**
Loss																
Loss in woodland	6	239	36	1,358	19	728	73	2,784	—	—	24	930	8	287	141	5,342
Loss in bushland	48	1,331	146	4,046	188	5,217	227	6,318	5	128	259	7,188	77	2,142	168	4,671
Loss in cropland	24	223	254	2,318	2,714	24,805	731	6,684	17	158	971	8,877	51	465	1,293	11,817
Total loss (ha)	**79**		**436**		**2,921**		**1,032**		**22**		**1,254**		**135**		**1,602**	

	Palorinya				Palabek			
	2010–2013		2014–2018		2010–2013		2014–2018	
Land cover class	**ha**	**tons**	**ha**	**tons**	**ha**	**tons**	**ha**	**tons**
Intact woodland	6,534	248,278	3,595	136,626	17,939	681,668	1,347	51,184
Intact bushland	9,699	269,633	4,665	129,681	1,721	47,833	425	11,827
Cropland	11,510	105,204	7,976	72,903	8,998	82,240	33,070	302,257
Other	19,662	—	21,164	—	38,889	—	23,706	—
Degradation								
Degraded woodland	126	3,187	2,494	63,177	457	11,579	1,476	37,376
Degraded bushland	1,602	6,312	5,277	20,791	64	253	403	1,586
Total AGB remaining (tons)		**632,614**		**423,178**		**823,572**		**404,230**
Loss								
Loss in woodland	12	462	375	14,251	37	1,406	1,118	42,473
Loss in bushland	321	8,915	1,631	45,344	4	123	121	3,353
Loss in cropland	150	1,373	2,420	22,115	49	445	6,488	59,302
Total loss (ha)	**483**		**4,426**		**90**		**7,727**	

Table 11 highlights the total degradation and loss (including the partial loss in degraded bushland and woodland). The settlements most affected by major changes in woodland, bushland and cropland can be noted by comparing the total loss and degradation within the 5km buffer zone from the boundaries of each settlement (plus the areas of the settlements themselves) over the two periods.

Table 11. Summary of degradation and loss (ha) per settlement within 5km

			2010–2013			2014–2018		
Settlement	District	Total area (ha)	Degradation (ha)	Loss (ha)	% loss and degradation	Degradation (ha)	Loss (ha)	% loss and degradation
Bidibidi	Yumbe	161,131	1,916	646	-1.6	12,555	9,895	-13.9
Imvepi	Arua	41,765	307	193	-1.2	3,223	3,682	-16.5
Rhino ext. - Omugo	Arua	22,884	90	35	-0.5	1,876	1,237	-13.6
Agojo	Adjumani	14,568	173	92	-1.8	638	2,921	-24.4
Ayilo I	Adjumani	13,949	402	240	-4.6	1,501	2,073	-25.6
Ayilo II	Adjumani	11,640	381	188	-4.9	1,710	2,252	-34.0
Boroli I/II	Adjumani	11,061	119	134	-2.3	1,044	532	-14.2
Maaji I	Adjumani	7,854	116	50	-2.1	450	738	-15.1
Maaji II	Adjumani	12,589	228	79	-2.4	471	435	-7.2
Maaji III	Adjumani	11,714	638	2,921	-30.4	860	1,032	-16.2
Nyumanzi	Adjumani	12,962	101	22	-0.9	1,242	1,254	-19.3
Pagirinya	Adjumani	14,709	545	135	-4.6	615	1,602	-15.1
Palorinya	Moyo	49,633	1,728	483	-4.5	7,771	4,426	-24.6
Palabeka	Lamwo	68,131	521	90	-0.9	1,878	7,727	-14.1
					-4.5			-18.1

Note: a. Changes in Palabek consider only the most recent years, 2017–2018.

3.3 Linking woodfuel demand and supply

Table 12 shows estimated woodfuel supply and demand for each refugee settlement, including both firewood and charcoal (the latter converted to firewood equivalent). Potential supply takes into account annual AGB growth from woodland and bushland within 5km of the settlement boundaries. Woodfuel demand estimates are based on the official refugee population data from December 2017. Since a refugee verification exercise is ongoing at the time of writing this report, the confirmed number of refugees is likely to change.

Table 12. Estimated woodfuel demand and supply in the target refugee settlements and within 5 km buffer zone

Settlement	Refugee population (December 2017)	Woodfuel demand refugees (tons per year - DM)	AGB stock (tons)	Annual AGB growth (tons per year)	Annual AGB loss/gain (tons per year)	Annual net loss/gain (%)
Bidibidi	287,087	155,611	1,093,157	34,249	-121,362	-11
Imvepi	127,926	69,340	282,189	9,276	-60,064	-21
Rhino extension - Omugo	20,411	11,063	111,908	2,915	-8,149	-7
Agojo	3,026	1,640	92,674	444	-1,196	-1
Ayilo I	23,210	12,580	125,180	929	-11,651	-9
Ayilo II	11,260	6,103	98,216	1,043	-5,060	-5
Boroli I/II	12,415	6,730	114,172	929	-5,800	-5
Maaji I	695	376	60,270	1,459	1,082	2
Maaji II	17,434	9,450	197,082	13,539	4,089	2
Maaji III	16,235	8,800	118,157	5,338	-3,462	-3
Nyumanzi	43,508	23,582	78,584	1,020	-22,563	-29
Pagrinya	32,055	17,375	51,597	427	-16,948	-33
Palorinya	165,587	89,753	423,178	21,301	-68,452	-16
Palabek	37,650	20,407	404,230	7,933	-12,474	-3
Total	798,499	432,812	3,250,598	100,802	-332,010	-10

Note: DM = dry matter. Woodfuel demand converted to dry basis assuming 18 percent moisture content. AGB growth rates taken from the NBS as averages for the agroecological zone of the AOI, which is classified as semi-moist lowland (see Table 8). Growth rates of degraded woodland and bushland estimated by using correction factors of 0.33 and 0.85, respectively, as estimation from the ratio of AGB stock of the degraded to the intact classes. Estimate of annual AGB loss takes into account household woodfuel demand based on December 2017 refugee population, though field observations highlighted other demand for woody biomass for construction, energy for commercial and economic activities, agricultural activities, and losses to fire.

In a scenario with a verified refugee population that is reduced in the target area by 15 percent, 30 percent, and 45 percent, assuming woodfuel demand per person remains stable, the annual biomass loss would decrease from the current estimated 10 percent to 8 percent, 6 percent, and 4 percent, respectively (Table 13). It is, therefore, important to revisit these conclusions once the refugee's verification process is complete.

Table 13. Scenario with refugee population changes

			Refugee population (-15%)			Refugee population (30%)			Refugee population (-45%)		
Settlements	AGB stock (tons)	Annual AGB growth (tons per year)	Woodfuel demand refugees (tons per year - DM)	Annual AGB loss/gain (tons per year)	Annual net loss/gain (%)	Woodfuel demand refugees (tons per year - DM)	Annual AGB loss/gain (tons per year)	Annual net loss/gain (%)	Woodfuel demand refugees (tons per year - DM)	Annual AGB loss/gain (tons per year)	Annual net loss/gain (%)
Bidibidi	1,093,158	34,249	132,269	-98,020	-9.0	108,927	-74,678	-6.8	85,586	-51,337	-4.7
Imvepi	282,189	9,276	58,939	-49,663	-17.6	48,538	-39,262	-13.9	38,137	-28,861	-10.2
Rhino ext. - Omugo	111,909	2,915	9,404	-6,489	-5.8	7,744	-4,830	-4.3	6,085	-3,170	-2.8
Agojo	92,675	444	1,394	-950	-1.0	1,148	-704	-0.8	902	-458	-0.5
Ayilo I	125,181	929	10,693	-9,764	-7.8	8,806	-7,877	-6.3	6,919	-5,990	-4.8
Ayilo II	98,217	1,043	5,188	-4,145	-4.2	4,272	-3,229	-3.3	3,357	-2,314	-2.4
Boroli I/II	114,171	929	5,720	-4,790	-4.2	4,711	-3,781	-3.3	3,701	-2,772	-2.4
Maaji Ia	60,270	1,459	320	-1,139	-1.9	264	1,195	2.0	207	1,252	2.1
Maaji IIa	197,082	13,539	8,032	-5,507	-2.8	6,615	6,924	3.5	5,197	8,342	4.2
Maaji IIIa	118,157	5,338	7,480	-2,142	-1.8	6,160	-822	-0.7	4,840	498	0.4
Nyumanzi	78,584	1,020	20,045	-19,026	-24.2	16,508	-15,488	-19.7	12,971	-11,951	-15.2
Pagrinya	51,597	427	14,769	-14,342	-27.8	12,162	-11,736	-22.7	9,556	-9,130	-17.7
Palorinya	423,178	21,301	76,290	-54,990	-13.0	62,827	-41,527	-9.8	49,364	-28,064	-6.6
Palabek	404,230	7,933	17,346	-9,413	-2.3	14,285	-6,352	-1.6	11,224	-3,291	-0.8
Total	3,250,598	100,802	367,890	-67,088	-8.2	302,969	-202,167	-6.2	238,047	-137,245	-4.2

Note: a. Settlements established in 1997 and reopened in 2015

4. RECOMMENDED TECHNICAL INTERVENTIONS

Wood is the main source of energy for both refugee and host communities in northern Uganda. Demand for woodfuel is expected to increase with rising population, as other energy options for cooking are unaffordable or inferior. This could widen the gap between demand and sustainable supply, placing growing strains on the well-being of both hosts and refugees and causing degradation of woody resources in and around the refugee settlements. On the other hand, official refugee populations may be downscaled once verification is complete, and the future balance between supply and demand is therefore somewhat unpredictable. A precautionary approach is advisable and the following intervention options can help support sustainable environmental management, ensure energy access for cooking, and contribute to building livelihood resilience in both refugee and host communities.

1) **Rehabilitation of degraded forests:** A combination of natural and assisted regeneration to restore areas of degraded native forest and boost productivity over the longer term.
2) **Establishment of woodlots for energy and other purposes:** Establishment of woodlots with trees planted at a high density to maximize biomass production and with short rotation length for a sustainable source of fuelwood as well as for poles to construct shelter and other products such as fruits, leaves, and fodder.
3) **Development of agroforestry systems:** Consisting in interplanting of trees and crops for different purposes such as energy, food, and fodder.
4) **Enhancement of energy efficiency:** To reduce demand for woodfuel through improvement in household cooking efficiency and charcoal production efficiency.

Each option is described in more detail

4.1 Rehabilitation of degraded forests

The rehabilitation of degraded forests surrounding the refugee settlements is a relatively cost-effective means of sustainably managing native resources, in which wood harvesting can be controlled and regulated by a continual series of felling cycles through dedicated harvesting plans, in accordance with practical needs and the socioeconomic and ecological characteristics of specific sites. The objective is to restore forest productivity with a view to producing a sustainable supply of woodfuel and ecosystem services. Extraction of woodfuel seems to be one of the drivers of degradation and loss, after the expansion of agricultural activities (although agricultural activities do play an important part in refugee integration and development). This intervention should target

- Areas owned by host communities and individuals;
- Protected areas managed by the NFA; and
- Areas assigned to the refugees.

Rehabilitation of woodland can be achieved through a combination of scattered tree planting and measures to assist natural regeneration as a mechanism of recovery. The field survey determined that wildlings and saplings, especially coppice shoots, are common in degraded woodland and bushland. This intervention could involve enrichment planting using nursery-grown seedlings of native species to accelerate the natural rehabilitation process. Capacity building at the refugee and host community levels should focus on strengthening of existing tree nurseries to produce appropriate species. The species selection for rehabilitation and protection should take into account the suitable measures for rehabilitation at the site level, although the preference is for species that are fast-growing, are adapted to the local climate and topography, and have strong root systems. A total of 70 tree species were recorded in the field work of this assessment, of which *Acacia spp., Combretum spp.* and *Lannea spp.* were dominant.

Maintenance is needed in the early years after outplanting to reduce the impact of weeds. Grasses need to be slashed to enhance the growth of wildlings and planted seedlings in the first two to three years; fire protection must also be undertaken to protect areas under rehabilitation.

An important element of sustainable forest management is community participation management. In fact, it is vital for the success of this approach that the right to access the land and to harvest wood and non-wood forest products should be understood and agreed with local communities (including with the refugees). Experiences of participatory forest management in Uganda include

- Community-based forest management, whereby forest resource management is exclusively based on efforts of the communities, and user rights over the forest resources belong to the community;
- Collaborative forest management, where communities and other key stakeholders work in partnership on the management of forests; and
- Private forests, where local community members manage their own trees on private land. (Turyahabwe et al. 2012).

These approaches emphasize decentralization or devolution of forest management rights and responsibilities to communities. Sustainable use of the forest resources in and around the settlements can contribute significantly to the resilience of refugee and host communities by providing access to additional income, food, and other household resources. It is therefore important that both refugees and hosts are engaged in the rehabilitation of degraded forests through a participatory approach to ensure the wise use of natural resources and provide both groups with ongoing benefits.

This passive rehabilitation strategy should be carefully planned, as the nature and extent of recovery depend on the ecology and disturbance of the areas and the condition of the landscape. Detailed land use assessment is required for each settlement to define areas for regeneration and restoration of forest productivity. The biophysical and socioeconomic barriers to rehabilitation require in-depth site assessment to determine the suitability of different rehabilitation measures.

The intervention should include natural rehabilitation of degraded areas as well as assisted natural regeneration of areas with total woodland and bushland loss. Table 14 first provides indicative costs for the natural rehabilitation of degraded woodland and bushland, by protecting remnant trees from firewood harvesting, livestock grazing, and other destructive agents (for example, fire).

Table 14. Indicative costs for natural rehabilitation of degraded areas, per hectare basis over five years

	Years	1	2	3	4	5	Cost (US$)
Protection	**US$ per ha**						
Fire protection	14.2	1	1	1	1	1	71.0
Watching	24.0	1	1	1	1	1	120.0
Tree marking	3.5	1			1		7.0
Overhead cost	**US$ per ha**						
Surveying	26.6	1				1	53.2
Technical management	3.0	1	1	1	1	1	15.0
Administration	1.5	1	1	1	1	1	7.5
Total	**US$ per ha**						**274.0**

The proposed rehabilitation intervention in the areas of woodland and bushland with total loss, detected through the remote sensing analysis, also includes enrichment planting of additional trees and further maintenance operations in the form of fire protection and weed control (year 1–2). Table 15 provides indicative costs for rehabilitation in areas of major degradation and loss through assisted natural regeneration.

Table 15. Indicative costs for assisted natural regeneration, per hectare basis over five years

	Years	1	2	3	4	5	Cost (US$)
Site preparation	**US$ per ha**						
Land preparation	11.3	1					11.3
Marking and pitting	6.4	1					6.4
Other preplant operations	19.7	1					19.7
Planting	**US$ per ha**						
Planting	32.0	1					32.0
Survival count	1.8	1	1				3.6
Blanking	6.4		1				6.4
Post-planting slashing	4.4	1	1				8.8
Post-planting weeding	6.2	3	2				31.0
Protection	**US$ per ha**						
Fire protection	14.2	1	1	1	1	1	71.0
Watching	24.0	1	1	1	1	1	120.0
Overhead cost	**US$ per ha**						
Surveying	26.6	1				1	53.2
Technical management	3.0	1	1	1	1	1	15.0
Administration	1.5	1	1	1	1	1	7.5
Total	**US$ per ha**						**386.0**

Table 16 summarizes the indicative costs per hectare (if divided over the nursery served) to set up a nursery with an annual production capacity of 250,000 seedlings. Assuming that enrichment planting for rehabilitation would require 400–800 seedlings per ha, the nursery costed would typically cover 470ha of rehabilitation.

Table 16. Indicative costs to set up a nursery for assisted natural rehabilitation, per hectare basis

Description	Years	1	2	3	4	5	Cost (US$)
Nursery construction	**US$**						
Water supply (tank, pump, irrigation system) Protection (fence, shed net) Structure (poles, bricks, polythene sheet) Others	8,333	1					8,333
Maintenance (10%)	833	1	1	1	1	1	4,165
Labor	**US$**						
Bed construction Seed sowing Watering Weeding and so on	280	1	1	1	1	1	1,400
Tools	**US$**						
Assorted (wheelbarrows, rakes, hoes, knives, sprayers, and so on)	500	1					500
Consumables	**US$**						
Chemicals, poles, nails, food, and so on	250	1	1	1	1	1	1,250
Total	**US$**						**15,648**
Average cost per hectare	**US$ per ha**						**33**

Combining the costings from the three previous tables, Table 17 summarizes the total cost of rehabilitation for each refugee settlement over five years, according to the measured extent of degradation and loss of woodland and bushland within 5km. Costs of rehabilitation can vary significantly from district to district and are dependent on land type, vegetation, and other site-specific biophysical and socioeconomic factors. Further investigations are required to analyze site-specific conditions and assess feasibility.

Table 17. Indicative costs of rehabilitation of degraded and lost woodland and bushland in the target refugee settlements

Settlement	Degraded woodland and bushland (ha)	Cost of natural rehabilitation of degraded areas (US$)	Area of loss in woodland and bushland (ha)	Cost of assisted natural regeneration (US$)	Total cost (US$)
Bidibidi	12,555	3,436,304	4,611	1,931,548	5,367,851
Imvepi	3,223	882,135	853	357,322	1,239,457
Rhino ext. - Omugo	1,876	513,461	358	149,966	663,427
Agojo	638	174,621	207	86,712	261,333
Ayilo I	1,501	410,824	662	277,312	688,136
Ayilo II	1,710	468,027	987	413,454	881,481
Boroli I/II	1,044	285,743	135	56,552	342,294
Maaji I	450	123,165	280	117,292	240,457
Maaji II	471	128,913	182	76,240	205,153
Maaji III	860	235,382	300	125,670	361,052
Nyumanzi	1,242	339,935	283	118,549	458,484
Pagrinya	615	168,326	309	129,440	297,766
Palorinya	7,771	2,126,923	2,006	840,313	2,967,236
Palabek	1,878	514,009	1,239	519,017	1,033,026
Total	**35,834**	**9,807,766**	**12,412**	**5,199,387**	**15,007,153**

Note: Covers area of lost and degraded woodland and bushland within settlements and 5km buffers.

4.2 Establishment of woodlots for energy and other purposes

Firewood and charcoal are the main sources of energy for refugee and host communities in northern Uganda and the rapid increase of population due to the arrival of refugees has inevitably increased pressure on natural resources and resulted in an imbalance between demand and available supply within accessible walking distance.

Interventions for the establishment of woodlots are recommended over a period of at least three to five years, to ensure sufficient time to establish adequate production capacity and proper transfer of knowledge to ensure sustainability. The objective should be to maximize biomass production in a short time and increase tree density to reach the optimum growth per unit of area. Fast-growing tree species and short-rotation coppice management should be adopted to enable early harvesting for fuelwood. In addition, the use of multipurpose species can increase people's motivation to manage trees effectively because of the provision of other benefits (for example, building poles, fence posts, non-wood forest products such as fruits and fodder, and ecosystem services such as soil conservation and soil fertility). It is important to highlight that labor needed for planting and tending for trees is particularly intense for at least the initial three years before they produce an appreciable quantity of biomass. This intervention should target

- Areas owned by host communities and individuals;
- Protected areas managed by the NFA; and
- Areas assigned to the refugees.

Most species can be used for fuel, but quality varies greatly. Some species burn very fast while others produce a lot of smoke and are more difficult to dry. In Uganda, eucalyptus is mainly grown for domestic and industrial fuelwood, but other species have also been promoted for energy purposes such as *Gmelina arborea, Grevelia robusta, Markhamia lutea, Acacia mangium,* and *Acacia auriculiformis.*

It is important that refugee and host communities are involved and are given the responsibility for tree planting and management and for other aspects of this intervention (including dialogue and decision making). Beneficiaries should be organized into groups to encourage and promote tree planting. A participatory approach through consultation at all levels is required to allocate land for plantation and to agree on implementation modalities. Rules and rights need to be communicated and enforced. For refugee communities, site-specific formal agreements supporting tree planting are required to provide clarity on the land ownership of new plantations, including the land, trees, and other assets, and who will benefit from the eventual harvest of wood (FAO and UNHCR 2018). In addition to the land already assigned to the refugees for agricultural activities, refugee groups could acquire other communal land with the support of the OPM using the same process by which land is secured for refugee households. The local committees including the OPM, District Forestry Office, landlords, host and refugee community leaders, and relevant partners should be established in each settlement to identify available land and discuss in detail the management and ownership of proposed woodlots.

FAO and the UNHCR are already investigating options for expanding the Sawlog Production Grant Scheme, Phase III (SPGS III) model into the refugee-hosting areas of northern Uganda, where land ownership is mainly communal, and to move to results-based financing for medium and large-scale tree planting. A verification process should be carried out to ensure physical establishment of plantations and adherence to quality standards (for example, use of appropriate species, seeds quality, survival rate of seedlings, conservation of ecosystem practices, and social issues such as labor management and community relations). Rather than paying 100 percent of funds up front for employed labor, only a portion of the financial support could be paid at the time of woodlot establishment followed by retrospective disbursements after verification of outputs and tree survival rates at agreed milestones. This would be an incentive for planning carefully the expected returns from the investment and at the same time guarantee that both refugee and host community groups have sufficient funds to establish and manage the plantations.

Institutional woodlots should also be supported. There is a need to explore the possibility of obliging all institutions to have a minimum number or acreage under trees, with clear objectives and management plans. Institutions offer defined land ownership and can provide opportune locations to increase tree planting in the region, for example, faith-based communities, educational establishments, health facilities, and government offices at parish, subcounty, and district levels. Authorities are also willing to put in place bylaws that oblige initiatives that remove trees to plant others in return; for instance, when space is opened to settle refugees, trees should be planted along the new roads opened.

Table 18 provides indicative costs of investment and operations for the energy woodlot working cycle. Establishment costs can vary significantly from district to district and are dependent on land type, vegetation, and other site-specific biophysical and socioeconomic factors.

Table 18. Indicative investment and operational costs of establishing woodlots for energy, per hectare basis

	Years	1	2	3	4	5	Cost (US$)
Site preparation	**US$**						
Land clearing	79.9	1					79.9
Land preparation	68.1		1				68.1
Marking and pitting	38.5		1				38.5
Other preplant operations	118.4		1				118.4
Planting	**US$ per ha**						
Outplanting	192.4	1					192.4
Survival count	1.8		1				1.8
Blanking	38.5		1				38.5
Postplanting and protecting	**US$ per ha**						
Ring-hoeing	20.7	3					62.1
Slashing	26.6	1	1				53.2
Weeding	37.0	3	2				185.0
Termite control	118.4		1				118.4
Tending	50.3			1			50.3
Fire protection	14.2	1	1	1	1	1	71.0
Road works	**US$ per ha**						
Road construction	17.8	1					17.8
Road maintenance	3.0			1	1	1	9.0
Harvesting	**US$ per ha**						
Coppicing and pollarding	108.6					1	108.6
Overhead cost	**US$ per ha**						
Land lease	7.4	1	1	1	1	1	44.4
Surveying	26.6	1					53.2
Technical management	3.0		1	1	1	1	15.0
Administration	1.5		1	1	1	1	7.5
Total	**US$ per ha**						**1,333.0**

Table 19 provides indicative costs to set up a nursery for raising seedlings with an annual production capacity of 250,000 seedlings (able to support up to 50 ha of woodlot establishment).

Table 19. Indicative costs to set up a nursery

Description	Years	1	2	3	4	5	Cost (US$)
Nursery construction	**US$**						
Water supply (tank, pump, irrigation system) Protection (fence, shed net) Structure (poles, bricks, polythene sheet) Others	8,333	1					8,333
Maintenance (10%)	833	1	1	1	1	1	4,165
Labor	**US$**						
Bed construction Seed sowing Watering Weeding and so on	280	1	1	1	1	1	1,400
Tools	**US$**						
Assorted (wheelbarrows, rakes, hoes, knives, sprayers)	500	1					500
Consumables	**US$**						
Chemicals, poles, nails, food, and so on	250	1	1	1	1	1	1,250
Total	**US$**						**15,648**
Average cost per hectare	**US$ per ha**						**33**

Under this intervention, productive woodlots in Uganda commonly achieve mean annual increments of 20–26 m^3 per ha. Assuming 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 AGB increment achievable with tree plantations would be 18.0–23.4 tons per ha per year. To compensate fully for the estimated annual loss of biomass (Table 12) and guarantee a fuel security for cooking, the minimum area of woodlots needed to meet the total woodfuel demand of the current refugee population in each settlement has been calculated (Table 20).

Table 20. Woodlot requirements for energy and indicative establishment and maintenance costs over five years

Settlement	AGB loss/gain (tons per year)	Woodlot area (ha)	Cost of woodlots and nurseries (US$)	Minimum woodlot area per household (m2)
Bidibidi	-121,362	5,186	8,537,350	38
Imvepi	-60,064	2,567	4,225,271	40
Rhino extension	-8,149	348	573,251	37
Agojo	-1,196	51	84,134	36
Ayilo I	-11,651	498	819,603	41
Ayilo II	-5,060	216	355,952	39
Boroli I/II	-5,800	248	408,008	40
Maaji I	1,082	—	—	—
Maaji II	4,089	—	—	—
Maaji III	-3,462	148	243,538	27
Nyumanzi	-22,563	964	4,815,335	42
Pagrinya	-16,948	724	877,498	42
Palorinya	-68,452	2,925	4,815,335	37
Palabek	-12,474	533	877,498	33
Total	**332,010**	**14,409**	**26,632,772**	

Note: AGB loss/gain refers to the settlement areas plus a 5km buffer.

4.3 Development of agroforestry systems

Agroforestry is another intervention option to address land degradation while also providing woodfuel, food (for example, fruits, nuts, edible leaves), timber, fodder for livestock, and other non-wood products. The integration of trees into farming systems can enhance livelihood opportunities and increase the resilience of both host and refugee communities, contributing to food and nutrition security and generating income. In addition, agroforestry represents a suitable activity for the restoration of degraded lands, bringing people involved to identify and implement specific practices in which woody perennials (trees, shrubs, palms, and bamboos) are combined with agricultural crops and/or animals on the same land management unit. Trees planted in agroforestry systems can provide a number of other benefits, for example, fixing nitrogen, stabilizing the soil, providing shade, defining boundaries, and supporting pollination services.

The establishment of trees and shrubs in strategic places, such as the residential plots assigned to the refugees, can diversify and increase agricultural production while also providing an opportunity to bridge the humanitarian response and sustainable development. These systems can take advantage of small patches of land to produce woodfuel, food, and fodder and to make living fences for delineation of refugees' household plots.

Other areas suggested for this type of intervention are the cultivated fields of both host and refugee communities in the surroundings of the refugee settlements. For example, Palabek, Ayilo I and II, Agoyo, Bidibidi, Maaji II, and Pagirinya, where large areas are under cultivation. Local landlords, cooperatives, and other group or individuals of refugee and host communities can also be supported through incentive schemes (for example, microfinance) to motivate investments in agroforestry and cover the start-up costs.

Possible species for agroforestry interventions in this context are calliandra (*Calliandra calothyrsus*) and other multipurpose trees such as sesbania (*Sesbania spp.*), tephrosia (*Tephrosia spp.*), pigeon pea (*Cajanus cajan*), gliricidia (*Gliricidia sepium*), and moringa (*Moringa oleifera*), which fix nitrogen and provide woodfuel, mulch, and fodder. The most important crops in northern Uganda for possible intercropping are cassava, beans, groundnuts, sesame, millet, sorghum, maize, and okra. The use of bamboo species in agroforestry could occupy an interesting multipurpose role such as in providing building materials, erosion control, stream bank stabilization, livestock fodder, demarcation, etc. Although before introducing bamboo species as part of agroforestry systems, it is important to carefully evaluate effective management strategies to avoid risks on invasiveness with negative impacts on the environment.

As part of this intervention, it is important to introduce training to raise awareness on the benefits of agroforestry, provide technical support and extension services, and encourage both host and refugee communities to adopt agroforestry systems. The involvement of the District Forestry and Agricultural Offices could start with the support of relevant partners to establish demonstration plots, tree nurseries, and training centers in the refugee settlements and surrounding villages. The World Agroforestry Centre (also known as ICRAF) has recently implemented an agroforestry pilot project at Rhino Camp and Imvepi refugee settlements, showing that agroforestry systems can be rolled out in a refugee situation targeting both refugee and host communities.

A major challenge to implementing agroforestry interventions occurs when there is land (and hence tree) tenure insecurity, which is why the refugees' own household plots are considered particularly important for this intervention. The time required before harvesting depends on the species selected, and this might create a disincentive to invest in trees, particularly in view of uncertainty over the refugees' duration of stay. Multipurpose and fast-growing woody species (for example, pigeon pea, moringa, caliandra, leucaena) should be considered to increase the motivation of people to manage trees effectively, by providing several benefits such as materials for fencing, fruits, fodder, and ecosystem services such as soil conservation and soil fertility.

Table 21 summarizes the estimated costs for agroforestry on a hectare basis. In this scenario, labor for land preparation, harvesting, and other field operations is provided by the households, so it is not costed.

Table 21. Indicative costs of agroforestry intervention, per hectare basis

	Years	1	2	Cost (US$)
Community tree/garden center (one per 30 ha of agroforestry)	US$ per ha			
Establishment	312	1		312
Management	26.5	1	1	53
Agricultural inputs	US$ per ha			
Seeds	20	1	1	40
Fertilizers	60	1	1	120
Training package	US$ per ha			
Agroforestry experts and communication	20	1	1	40
Total	**US$ per ha**			**565**

Table 22 costs a scenario in which both refugee and hosting populations are involved in agroforestry within the settlements and the 5 km buffer zone. The potential cropland for an agroforestry intervention is estimated to estimate the cost. On average, the hosting population in northern Uganda cultivates 1.7 ha per household (Mwaura 2016), while the land allocated to the refugee households for production differs by settlement and may be 30 x 30 m, 50 x 50 m, or 100 x 100 m. For costing purposes, an average of 50 x 50 m is assumed. The number of households is derived from the total refugee and hosting populations and the average number of members (7.9 and 6.3, respectively) and by considering that 25 percent of the refugee population is engaged in farming activities (UNHCR 2017b), while 48 percent of host households in northern Uganda depend on subsistence farming (UBOS 2017).

Table 22. Indicative costs of agroforestry intervention within refugee settlements and 5 km buffers

Settlement	Refugee population	No. of refugee agricultural households	Local population within 5km buffer[a]	No. of local agricultural households	Estimated land for agroforestry (ha)	Agroforestry investment (US$)
Bidibidi	287,087	9,085	436,782	33,279	58,845	33,247,383
Imvepi	127,926	4,048	45,901	3,497	6,957	3,930,900
Rhino extension	20,411	646	11,116	847	1,601	904,715
Agojo	3,026	96	74,193	5,653	9,634	5,443,040
Ayilo I	23,210	734	21,326	1,625	2,946	1,664,404
Ayilo II	11,260	356	15,017	1,144	2,034	1,149,290
Boroli I/II	12,415	393	21,473	1,636	2,879	1,626,909
Maaji I	695	22	12,101	922	1,573	888,669
Maaji II	17,434	552	7,454	568	1,103	623,420
Maaji III	16,235	514	10,728	817	1,518	857,655
Nyumanzi	43,508	1,377	33,340	2,540	4,663	2,634,331
Pagrinya	32,055	1,014	5,611	428	980	553,902
Palorinya	165,587	5,240	73,918	5,632	10,884	6,149,553
Palabek	37,650	1,191	32,701	2,492	4,533	2,561,383
Total	**798,499**	**25,268**	**801,661**	**61,080**	**110,150**	**62,235,554**

Note: a. Population estimates (Source: CIESIN 2016 as local population ('pop2015') according to the local population density calculated in 5km buffers around the settlements.

4.4 Enhancement of energy efficiency

Although the assessment shows that to a certain extent the refugee communities have embraced and adopted improved fuel-saving cookstoves, much can be done to increase coverage. Improved mud-stoves remain the most appropriate cooking solution and are already well-known and culturally acceptable to the refugee and local population. Although the results show a reasonable adoption of the improved mud-stoves for firewood among refugees (62.1 percent) and host communities (51.8 percent), there are still significant proportions using the 3-stone fire, particularly in the host communities. Therefore, extending the use of improved cookstoves to ensure that all households will shift at least to an improved mud-stove is also an intervention option to consider to reduce the pressure on natural resources.

Work is needed mainly to continue sensitization campaigns and demonstrations, especially in host communities where coverage is still low. From the perceptions of both refugee and host respondents, there is an indication that many people still need to be sensitized on how to improve the construction and use of improved cookstoves to enhance further energy efficiency.

Modern prefabricated cookstoves are available in regional markets, but neither refugees nor locals have the funds to buy them in significant numbers, and free distribution should carefully consider a combination of local specific factors to minimize uptake failure. Modern prefabricated stoves with very high efficiency should be installed at institutional levels (for example, schools, clinics, reception, and administrative centers) as well as at commercial level such as restaurants and bakeries. Other fuel-saving technologies and practices should be explored in relation to other common economic and commercial activities practiced in northern Uganda such as charcoal production, brick making, and tobacco curing.

Reducing demand for fuelwood while providing access to alternative, locally sourced fuels can reduce the exposure of women and children to associated risks and reduce the time needed for collecting fuel and could thus have a significant impact on the quality of life, releasing some of their time for productive activities, education, or leisure. Reducing the amount of wood needed for cooking and providing alternative and sustainable livelihood opportunities can also help reduce environmental degradation, reduce expenditure on fuel, and improve food and nutrition security.

Along with the use of more fuel-efficient cookstoves, the following energy-saving measures should be promoted to reduce energy consumption for cooking (FAO and UNHCR 2017):

- 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, so they will cook in a shorter time.
- Drying fuel before use and processing into smaller pieces. Using dry wood would increase cooking energy efficiency, reducing the quantity required for cooking and with the side benefit of reducing harmful smoke emissions.
- 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.
- Sharing cooking facilities among families.
- 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.

Support to the development of more sustainable charcoal value chains should also be considered under this intervention, including the provision and training on use of improved charcoal kilns. Through this intervention, technical and business skills and entrepreneurship training should be provided to groups of refugees and host communities. Links with existing microfinance services should be established for these groups. A shift from traditional charcoal kilns to a more efficient alternative could increase the wood conversion efficiency from 15–20 percent to 25–30 percent, with better preparation and stacking of the wood and more careful management of the pyrolysis process. The use of more efficient kilns means the more efficient use of wood, thereby increasing output and reducing inputs in terms of wood and labor. Improved charcoal kilns can be produced in Uganda in various sizes, and key advantages should be considered—such as mobility.

A portable steel kiln was considered in the costing analysis (Table 23) with a production capacity of 150 tons of charcoal operating 300 days per year. This type of portable kiln might have a cost up to US$2,200 per unit plus US$500 per unit for other costs for the start-up and US$1,000 per unit for a training package to improve technical and business skills. In addition to the improved portable kiln, this intervention proposes the improvement of management of traditional kilns such as the improved basic earth kiln (IBEK) through training, exchange, and dialogue between charcoal producers to enhance energy efficiency by making small adjustments to the technology already widely in use. A training package at the household level is also included in this intervention to enhance energy-saving practices for cooking.

Table 23. Indicative costs for energy efficiency enhancements

	Years	1	2	Cost (US$)
Household training package	US$ per ha			
Demonstrations for energy-saving measures at the household level	5	1	1	10
Equipment and materials	15	1		15
Total per household (HH)	**US$**			**25**
Improved charcoal production	US$ per unit			
Improved kiln (portable or IBEK)	2,200	1		2,200
Start-up cost	500	1		500
Kiln demonstration and training	1,000	1	1	2,000
Training package	US$ per ha			
Agroforestry experts and communication	20	1	1	40
Total per charcoal unit	**US$**			**4,700**

Note: HH = household.

Table 24 shows the indicative costs of provision of improved kilns and a training package, taking into account the total households and the current charcoal consumption in the refugee and surrounding host communities living within the 5km buffer zone of each settlement.

Table 24. Indicative cost for the provision of improved charcoal kilns and training packages by refugee settlements

Settlement	Refugee households	Host households	Total households	Household training packages (US$)	Charcoal consumption in settlement and 5 km buffer (tons per year)	Number of improved kilns	Improved charcoal production (US$)	Total (US$)
Bidibidi	36,340	69,330	105,671	2,641,765	7,037	47	220,493	2,862,258
Imvepi	16,193	7,286	23,479	586,976	2,289	15	71,722	658,698
Rhino ext.	2,584	1,764	4,348	108,703	387	3	12,126	120,829
Agojo	383	11,777	12,160	303,993	470	3	14,727	318,719
Ayilo I	2,938	3,385	6,323	158,076	489	3	15,322	173,398
Ayilo II	1,425	2,384	3,809	95,224	264	2	8,272	103,496
Boroli I/II	1,572	3,408	4,980	124,498	319	2	9,995	134,494
Maaji I	88	1,921	2,009	50,219	80	1	2,507	52,726
Maaji II	2,207	1,183	3,390	84,750	319	2	9,995	94,746
Maaji III	2,055	1,703	3,758	93,948	318	2	9,964	103,912
Nyumanzi	5,507	5,292	10,799	269,985	879	6	27,542	297,527
Pagrinya	4,058	891	4,948	123,706	540	4	16,920	140,626
Palorinya	20,960	11,733	32,693	817,335	3,045	20	95,410	912,745
Palabek	4,766	5,191	9,956	248,911	783	5	24,534	273,445
Total	**101,076**	**127,248**	**228,323**	**5,708,089**	**17,219**	**115**	**539,529**	**6,247,619**

4.5 Additional recommended measures

The recommended technical interventions should be coordinated under an integrated energy and environment program that has sufficient institutional capacity and resources to undertake more in-depth analysis, implementation, and management at the site level; carry out monitoring and evaluation; support systematic efforts to promote these interventions across the associated host communities; and ensure sound learning, sharing, and interaction with other programs of a similar nature both in Uganda and elsewhere. This will ensure that the measures do not take place in isolation or in a scattered, ineffectual, and short-term manner. Such integrated energy and environment program could complement the community-driven approaches adopted under the DRDIP which is likely to focus on shorter-term development needs of host communities.

The following additional measures are recommended to ensure that the proposed interventions are grounded in a holistic and effective institutional structure and are well informed by suitable contextual information and deep understanding of the issue:

- **Development of forest management plans.** Forest management plans would 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. When designing forestry interventions, the following aspects should be considered: mobilization of relevant stakeholders for a coordinated response at local and national levels, identification and demarcation of potential sites for the rehabilitation of degraded forests and the establishment of woodlots, clarification of the tree and land tenure regimes, assessment of site suitability for intervention, identification of stewards who will maintain the woodlot and appropriate agroforestry systems, review of existing land use plans, and identification of land use arrangements among local stakeholders. After site demarcation, site suitability assessments should be conducted by forestry experts and local authorities to assess physical and socioeconomic attributes of selected sites (for example, road accessibility, natural regeneration, terrain, edaphic conditions, distance, water availability, hydrology, risks, and other local conditions).
- **Trials for species suitability.** Trials should be set up at the institutional level to test and demonstrate the suitability of a range of species (and species mixes) for different purposes such as high planting densities to maximize woodfuel yields on specific sites and agroforestry systems to grow trees, crops, and/or livestock on the same plot, providing a range of goods and ecosystem services.
- **Field testing of cookstoves performance.** Improved cookstoves and traditional methods for cooking in use at household and institutional levels should be tested through internationally agreed protocols that measure efficiency, pollutant emissions, and safety, to design site-specific interventions to enhance energy efficiency including possible improvements in the cooking practices.
- **Promotion of integrated approaches.** To improve the management and use of natural resources as well as to enhance the resilience of refugees and host communities, participatory forest management approaches should be adopted. An integrated approach to the management of natural resources, including forests and other woodlands, is a prerequisite, given the links between the biophysical, social, economic, and political dimensions of the proposed interventions and recognizing the importance of stakeholder participation in their management and development at local and national levels.

- **Establishment of local associations/cooperatives.** The establishment of local associations or cooperatives should be explored as a way of boosting the economic benefits of specific environmental and energy interventions, with arrangements that provide equal opportunities for participation by both the refugee and host communities.
- **Promotion of entrepreneurship.** An incentive mechanism (for example, microcredit scheme) should be created to integrate and support refugees and host communities to become entrepreneurs capable of contributing to Uganda's socioeconomic development by enhancing business skills and capacities to provide forest-related services and thereby assist in the implementation of the interventions proposed in this study.
- **Local capacity building.** Efforts should be made to build capacity among local authorities and partners to increase the technical and managerial skills needed for the rehabilitation of forests and other woodlands and the management of plantations and agroforestry systems. There is a need to identify specific areas of need and relevant targeted people/groups for skills enhancement and to develop local technical capacities for the sustainable collection, production, and use of woodfuel. Capacity development of local governments should include monitoring and managing of woodfuel supply and demand; developing forestry management plans that support both host and refugee populations; and linking the importance of collective action on environmental conservation measures (for example, sustainable forest management, energy-saving measures at institutional and household levels) to improved livelihoods, which in turn will contribute to ensuring food security and nutrition. Relevant stakeholders should use or revive/strengthen existing structures such as local environment committees and resource/water user committees. These structures can then be linked to local government structures to ensure service provision at local levels.
- **Secure land and tree tenure.** Issues regarding secure land and tree tenure need to be cleared and include incentive mechanisms for the adoption of sustainable land management by refugees and host communities. The allocation of additional land for specific purposes to ensure a sustainable supply of fuelwood such as the establishment of dedicated energy woodlots needs to be agreed upon between the parties regarding land ownership, period of use, right to harvest, and security. The OPM should adopt the approach it uses to negotiate with landlords to acquire land for settling refugees, but with the specific objective of tree planting and suitable terms. The area of land potentially available for interventions needs to be identified in situ through the participation of host communities, refugees, the OPM, and district authorities. Secure tree and land tenure is a prerequisite for the broader engagement of refugee and host communities to undertake tree planting.
- **Awareness raising on sustainable forest management.** Awareness should be raised about the importance of sustainable forest management and the business potential of wood energy plantations, agroforestry systems, and enhancement of energy efficiency to ensure full understanding and support among the refugee and host communities and other stakeholders.
- **Monitoring.** Degradation of land and other natural resources in areas affected by refugee influx should be monitored continuously with the support of the NFA. This will also include monitoring the progress made by implementation of activities.

5. CONCLUSIONS

The population in northern Uganda has increased dramatically following the settlement of over 1 million refugees in Uganda since 2014, and this presents a risk of competition with host communities for natural resources such as land, water, and wood, which will ultimately cause deforestation and/or environmental degradation.

Woodland and bushland in areas surrounding the refugee settlements and nearby villages are the main sources of the wood needed as fuel for cooking, while cropland represents an additional source of firewood for the host communities. Impacts on the surrounding environment of refugee settlements resulting from the collection and production of fuelwood and charcoal can be lasting and damaging.

This assessment indicates a steady increase in degradation and vegetation loss over the hosting area, and map comparisons reveal increased land cover changes in the woodland and bushland. The areas within the settlements and the buffer zone of 5 km around their boundaries have been subjected to changes after the refugee arrival, and in some of the target settlements, competition for the available resources could be a source of tension between the refugee communities and hosts living in the immediate surroundings.

It is important to highlight that deforestation and forest degradation are not new phenomena in Uganda. The total net loss of Uganda's forests during 2000–2015 was estimated at 1.8 million ha, equivalent to an average annual net loss rate of 4 percent—one of the highest in the world. In 2000, forest covered 19.4 percent of the land area, which decreased to 10.4 percent in 2015. This is alarming and largely unrelated to the refugee influx.

The livelihoods of refugee and host households are highly dependent on forests and other woodlands as primary sources of woodfuel for cooking. Average daily consumption of firewood by refugees is 1.6kg per person and about 30 percent higher among host communities (2.1kg). Taking into account the use of charcoal, the average daily fuel consumption rises to 1.8 kg per person in firewood equivalent among refugees and 2.2kg among households of host communities.

Refugee woodfuel consumption at Bidibidi has significantly reduced, about half the amount as identified in a survey conducted in March 2017, probably due to greater wood shortages, a more diverse diet with fresher food, the use of drier wood, and improved stoves. Total cooking fuel demand in the target refugee settlements is about 500,000 tons per year—about five times the quantity of tree growth within 5km of the settlements—which means that harvesting exceeds sustainable limits (pending verification of population data, which may have a significant bearing on this conclusion). Due to the straight connection between the estimated cooking fuel demand and the refugee numbers, and since the refugee verification exercise in Uganda is ongoing at the time of writing, the estimated woodfuel demand may vary.

Communities are constructing improved cookstoves from locally available materials. Generally, there are more refugee households using such devices than host communities, and in Bidibidi settlement there is a noticeable increase in their adoption and use compared to the previous year. However, the challenges associated with firewood access and use are still preeminent—a problem for both refugee and host communities. Modern prefabricated cookstoves are available in regional markets, but neither refugees nor locals have the funds to buy them, and free distribution should carefully consider a combination of local-specific factors to minimize uptake failure. Improved mud-stoves are likely to remain a practical cooking solution and are a 'technology' already well-known and culturally acceptable to the refugee population.

The livelihoods of refugee and host households are highly dependent on natural resources such as land and water for subsistence farming as well as woodland and bushland as a source of fuelwood for cooking. In addition, the majority of households have constructed semipermanent structures and have improved their homes with latrines and dedicated kitchens, and a few have bathing shelters, animal sheds, and poultry or bird pens. In this regard, households also need wood to build and maintain these structures.

Although natural resources depletion is a major concern for the government and partners, very few organizations working in refugee-affected areas are focusing on the issue of environment and energy. The few organizations that do work in the sector are mainly operating at a small scale with 12-month budget cycles. To ensure an effective and harmonized approach with suitable technical expertise and adequate resourcing, there is a need for a joint action to implement multicomponent interventions through a multiyear and multiagency arrangement. This will effectively address the environmental degradation factors.

Planning for the sustainable supply of energy plays a crucial role in minimizing environmental impacts and conflicts with host communities over the use of natural resources. Dedicated woodlots provide for a sustainable supply of woodfuel and rehabilitation interventions on degraded land enhance availability and productivity of forest products (wood and non-wood forest products) and ecosystem services. Agroforestry interventions along with a more efficient use of energy for cooking and charcoal production can reduce these environmental impacts.

It is expected that refugee and host communities will continue using fuelwood and charcoal for the foreseeable future as their primary sources of energy. Therefore, responsible planning for sustainable harvesting, production, and use of fuelwood is crucial for enabling sustainable development by ensuring energy access and, in turn, building resilience in the refugee-affected areas and contributing to food and nutrition security.

REFERENCES

BFAST (Breaks for Additive Seasonal and Trend). 2010. Spatial R package. www.loicdutrieux.net/bfastSpatial/

Chave, J., Rejou-Mechain, M., Burquez, A., Chidumayo, E., Colgan, M.S., Delitti, W.B.C., Duque, A., Eid, T., Fearnside, P.M., Goodman, R.C., Henry, M., Martinez-Yrizar, A., Mugasha, W.A., Muller-Landau, H.C., Mencuccini, M., Nelson, B.W., Ngomanda, A., Nogueira, E.M., Ortiz-Malavassi, E., Pelissier, R., Ploton, P., Ryan, C.M., Saldarriaga, J.G. and Vieilledent, G. 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. Global Change Biology, 20(10): 3177–3190.

CIESIN (Center for International Earth Science Information Network). 2016. High Resolution Settlement Layer. Source Imagery 2016 DigitalGlobe, Inc. Columbia University, New York. www.ciesin.columbia.edu/data/hrsl/. Accessed February 2018

DeVries, B., A. K. Pratihast, J. Verbesselt, L. Kooistra, and M. Herold. 2016. "Characterizing Forest Change Using Community-Based Monitoring Data and Landsat Time Series." *PLoS ONE* 11 (3): e0147121. www.ncbi.nlm.nih.gov/pmc/articles/PMC4809496/pdf/pone.0147121.pdf

Dutrieux, L. P., J. Verbesselt, L. Kooistra, and M. Herold. 2015. "Monitoring Forest Cover Loss Using Multiple Data Streams, a Case Study of a Tropical Dry Forest in Bolivia." *ISPRS Journal of Photogrammetry and Remote Sensing, 107(2015): 112-125.*

FAO (Food and Agriculture Organization of the United Nations). 2015. *Global Forest Resources Assessment 2015.* Rome. www.fao.org/3/a-i4782e.pdf.

FAO, and UNHCR (United Nations High Commissioner for Refugees). 2016. *Assessing Woodfuel Supply and Demand in Displacement Settings.* Rome. www.fao.org/3/a-i5762e.pdf.

———. 2017. *Rapid Woodfuel Assessment: 2017 Baseline for the Bidibidi Settlement, Uganda.* Rome, FAO, and Geneva, Switzerland, UNHCR. www.fao.org/3/a-i7849e.pdf.

———. 2018. *Managing Forests in Displacement Settings: Guidance on the Use of Planted and Natural Forests to Supply Forest Products and Build Resilience in Displaced and Host Communities.* Rome, FAO and UNHCR. www.fao.org/3/I8309EN/i8309en.pdf.

Forest Department. 2002. *National Biomass Study.* Technical Report. Kampala, Ministry of Water Lands and Environment.

Hansen, M. C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S. J., Loveland, T. R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., Townshend, J. R. G. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." *Science* 342(6160): 850–853.

Lambin, E. F. 1999. "Monitoring Forest Degradation in Tropical Regions by Remote Sensing: Some Methodological Issues." *Global Ecology and Biogeography* 8 (3–4): 191–198. http://doi.wiley.com/10.1046/j.1365-2699.1999.00123.x.

Mitchard, E., Viergever, K., Morel, V., and Tipper, R. 2015. *Assessment of the Accuracy of University of Maryland (Hansen et al.) Forest Loss Data in 2 ICF Project Areas – Component of a Project That Tested an ICF Indicator Methodology.* https://ecometrica.com/wp-content/uploads/2015/08/UMD_accuracy_assessment_website_report_Final.pdf.

Mwaura, F. M., and A. Adong. 2016. "Determinants of Households' Land Allocation for Crop Production in Uganda." *Journal of Sustainable Development 9* (5): 229-246.

RCMRD (Regional Centre for Mapping of Resources for Development). 2015. Digital Elevation Model (DEM) from Shuttle Radar Topography Mission (SRTM). Available online: http://geoportal.rcmrd.org/layers/servir%3Auganda_srtm30meters

Silveira, E. M. O., I. T. Bueno, F. W. Acerbi-Junior, J. M. Mello, J. R. S. Scolforo, and M. A. Wulder. 2018. *Using Spatial Features to Reduce the Impact of Seasonality for Detecting Tropical Forest Changes from Landsat Time Series. Remote Sensing* 2018 (10): 808: doi:10.3390/rs10060808.

Tyukavina, A., A. Baccini, M. C. Hansen, P. V. Potapov, S. V. Stehman, R. A. Houghton, A. M. Krylov, S. A. Turubanova, and S. J. Goetz. 2015. "Aboveground Carbon Loss in Natural and Managed Tropical Forests from 2000 to 2012." *Environmental Research Letters* 10 (7): 074002. http://iopscience.iop.org/article/10.1088/1748-9326/10/7/074002/meta;jsessionid=B9B73099EC8D83B90613AB8104E7CD66.c1.

Turyahabwe, N., J. G. Agea, M. Tweheyo, and S. B. Tumwebaze. 2012. Collaborative Forest Management in Uganda: *Benefits, Implementation Challenges.* College of Agricultural and Environmental Sciences, Makerere University, Kampala.

UBOS (Uganda Bureau of Statistics). 2017. *Uganda National Household Survey 2016/17.* Kampala, Uganda Bureau of Statistics (UBOS).

UNEP-WCMC. 2016. *World Database on Protected Areas User Manual 1.4. UNEP-WCMC: Cambridge, UK.* Available at: http://wcmc.io/WDPA_Manual

UNHCR (United Nations High Commissioner for Refugees). 2017a. *Livelihoods Socio-economic Assessment in the Refugee Hosting Districts.* Reev Consult International, Kampala.

———. 2017b. *Livelihoods Strategy.* UNHCR Uganda Operation 2017-2020, Kampala.

———. 2018. *Uganda Country Refugee Response Plan. The Integrated Response Plan for Refugees from South Sudan, Burundi and the Democratic Republic of the Congo.* UNHCR, Regional Refugee Coordination Office (RRC), Nairobi, Kenya.

Verbesselt, J., R. Hyndman, G. Newnham, and D. Culvenor. 2010. "Detecting Trends and Seasonal Changes in Satellite Image Time Series." *Remote Sensing of Environment* 2010 (114): 106–115.

ANNEX 1: METHODOLOGIES

Woodfuel data collection and analysis

A woodfuel demand assessment was conducted in March 2018 by an FAO team supported by OPM representatives and four enumerators. A quantitative household questionnaire (see annex 2) and qualitative interviews in the refugee and host communities generated information on energy consumption for cooking, average time spent by households to collect fuelwood, types of cooking system used, associated challenges, and related livelihood issues.

The survey was implemented in 174 refugee households in Bidibidi settlement (Yumbe) and Maaji settlement (Adjumani), as well as in 168 households in host communities in Ciforo (Adjumani) and Okangali (Yumbe) subcounties. Data from these locations were extrapolated across the other target refugee settlements in northern Uganda. The selection of the sample sites took into account the establishment date of the settlements. Maaji is part of the group of settlements dating back to 1997, while Bidibidi is one of the settlements established as a result of the new refugee influx after 2014. In addition, the team agreed to return to Bidibidi for monitoring the trends of data from the earlier woodfuel assessment conducted in the same settlement by FAO and the UNHCR in 2017. The analysis considered that the other settlements present similar characteristics in terms of woodfuel consumption with no significant invalidation of data collected in the selected sample sites.

The enumerators were pretrained on questionnaire implementation and the use of a weighing scale to measure firewood and charcoal consumption. Data collection was guided and supervised by FAO and OPM staff. Systematic sampling was employed for the selection of households, selecting every tenth households in each location. Key informant interviews were also carried out by the field supervisor on specific areas of interest. Additional observations were made daily and shared with the field supervisor. They included differences between refugee and host communities in income sources, foods, and cookstove use. Data collection also included photographs, some of which are shared in this report. The team was able to perform a quality check of completed questionnaires before leaving the sampled locations. Overall checking of the questionnaires was carried out by the FAO field supervisor. The quantitative analysis was integrated with data from qualitative data and document review.

Biophysical field inventory

Biophysical field data were collected to estimate biomass stocks for the different strata described in the scoping report and adjusted (as explained below) into five classes: woodland, bushland, cropland, woodland depleted, and bushland depleted. The latter two classes were created by overlaying loss/depletion layers on existing LULC maps developed by the NFA. For this study, 'intact' refers to those areas within the bushland and woodland classes where BFAST did not indicate change.

Since the focus of the assessment was on LULC classes with potential woodfuel resources, grasslands were not considered as they contain very low AGB. However, field results show that an overwhelming majority of the plots expected to fall within the degraded bushland class were classified by enumerators as 'grassland'. Given that grassland is considered to be the resulting class of bushland that is slowly degraded over time, its biomass expansion factor was therefore used to calculate the AGB of the degraded bushland class.

Originally planned to be included in the biophysical survey, tropical high forests (THFs) were ultimately excluded as their location was found to be too far for refugees to access, situated 10 km south of the Maaji settlements (Adjumani District). Furthermore, this stand represents the only stand of THF in the AOI and is intact because it falls within the Zoka Central Forest Reserve, considered off-limits for fuelwood collection.

Biophysical data were gathered from plots located in two preidentified sampling zones (as described in the intermediate report) and used to estimate the AGB stock for the selected LULC classes. Hotspot 1 covered a heavily affected area located between the three refugee settlements of Bidibidi, Rhino, and Imvepi, which together host more than 500,000 refugees.[13] The dominant land use is subsistence cropland and grassland, with remnants of previously intact woodland. Hotspot 2 was on the opposite bank of the Nile amidst dense woodland vegetation some 10 km south of the Maaji settlements, albeit fragmented due to agricultural expansion.

The distribution of woody biomass was mapped using remote sensing, and stock changes within the AOI were measured for 2010–2013 ('before South Sudan crisis') and 2014–2018 ('after South Sudan crisis').

Plot sampling approach

A statistical stratified sampling design was adopted, with 95 plots spread between Hotspot 1 and Hotspot 2 (Figure 11 and 12). Plot allocation targeted an equal distribution across classes (15 plots per class regardless of the area proportion[14]) and ensured that rare classes (in particular degraded woodland and degraded bushland) were well represented. A preassessment of the plots was carried out using Collect Earth to validate their land cover type and the actual presence of degradation (for the depleted land cover classes) and to reach the target sample number for each stratum. A total of 67 out of 95 plots were measured in the field. The majority of the plots south of Maaji settlements turned out to be inaccessible and could not therefore be measured.

13 Population data from UNHCR, December 31, 2017: Bidibidi 287,087; Imvepi 127,926; Rhino 96,199. Rhino extension - Omugo (20,411) is not directly within the hotspot.
14 This is also because the team would end up having more plots in cropland and due to limitations in time and human resources.

Figure 11. Area 1: Plot allocations on 2015 LULC map

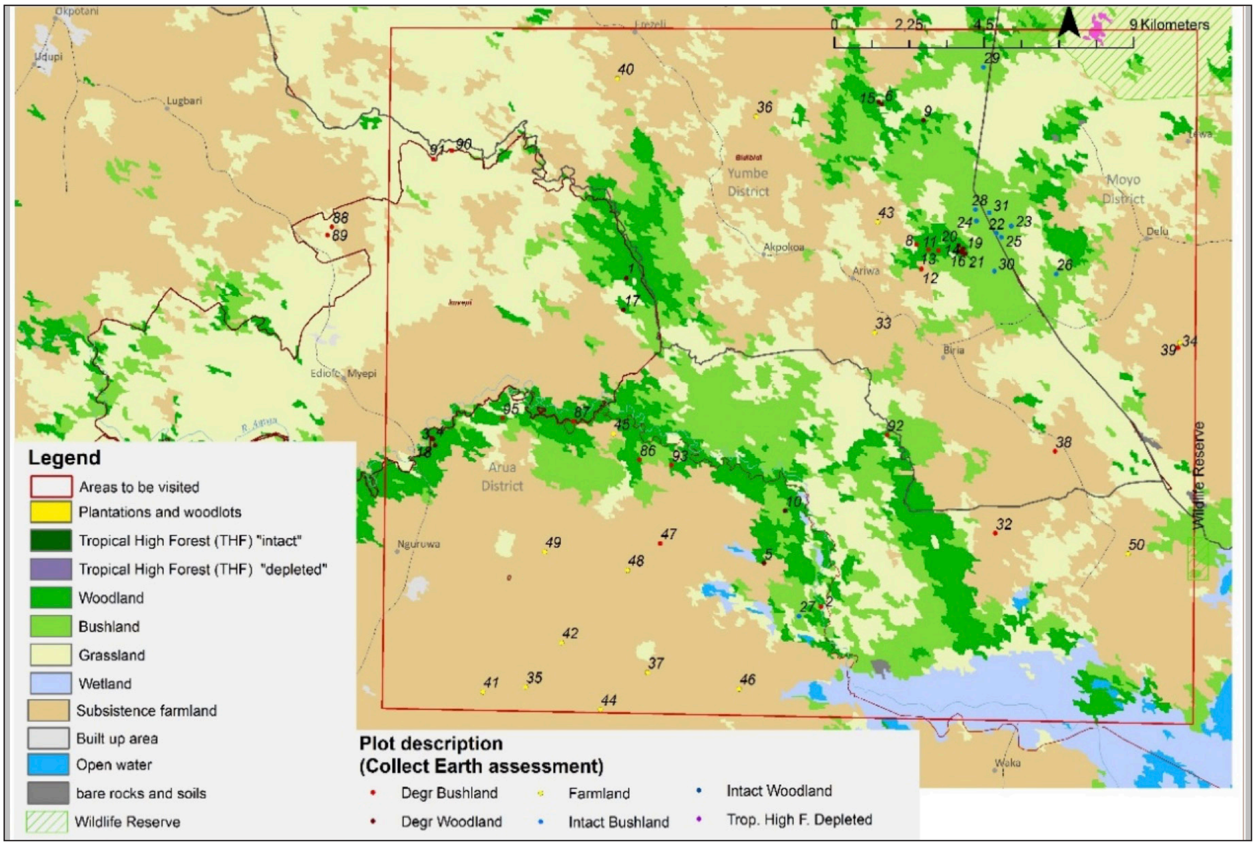
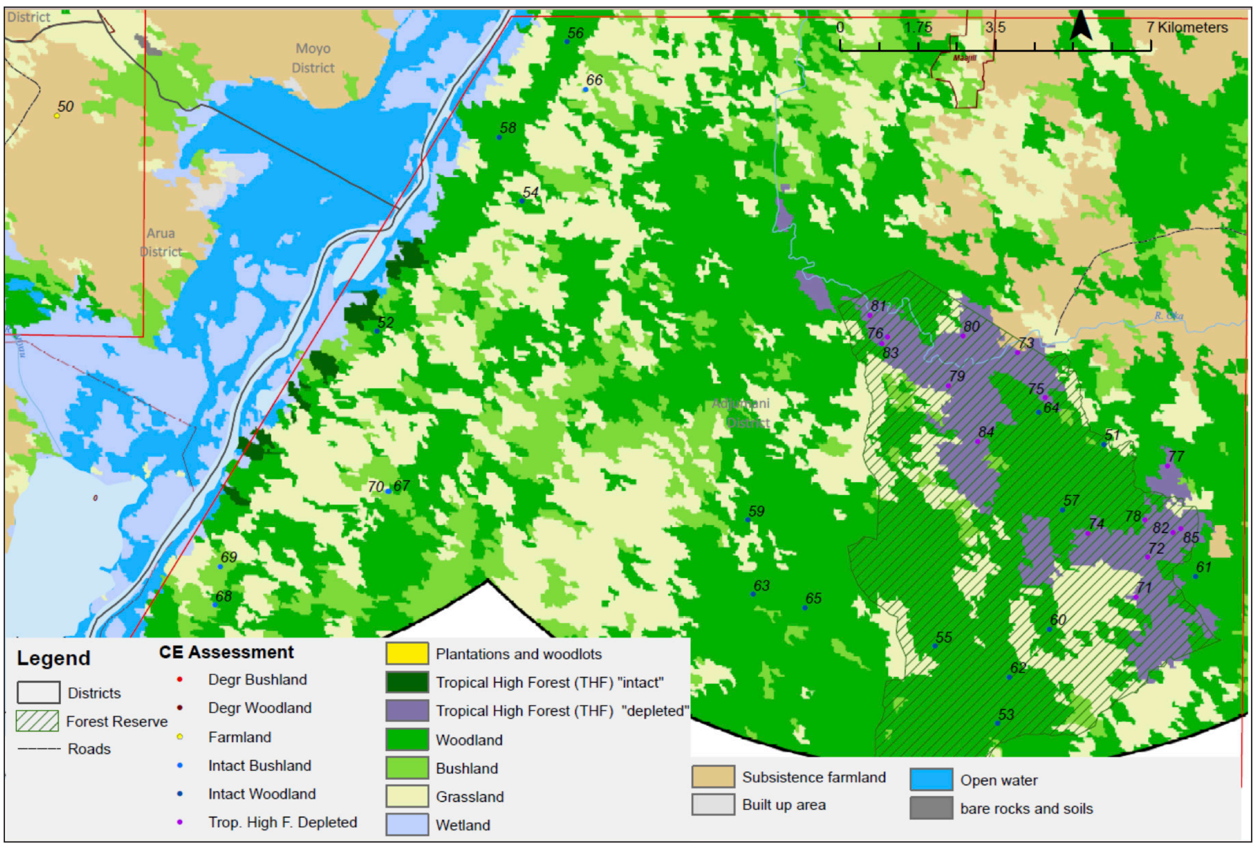


Figure 12. Area 2: Plot allocations on 2015 LULC map



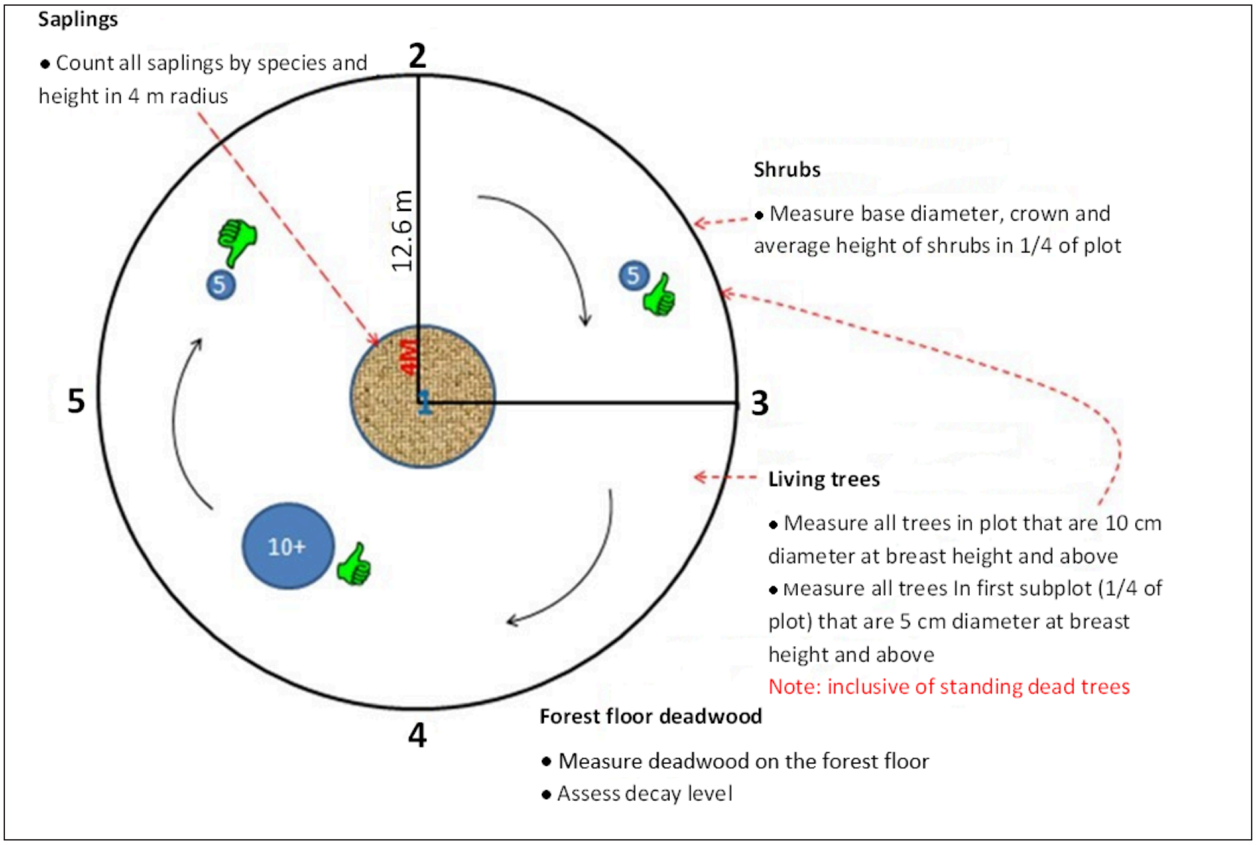
Note: The boundaries and names shown and the designations used on the above maps (Fig. 11-12) do not imply official endorsement or acceptance by the United Nations.

Sources and data provider: UNHCR- Settlements extents, Border crossing, Villages/towns locations. Protected areas: UNEP-WCMC (2016). World Database on Protected Areas User Manual 1.4. UNEP-WCMC: Cambridge, UK. Available at: http://wcmc.io/WDPA_Manual

Plot design and field data collection

At each sampling location, a circular plot of 0.05 ha (12.6 m radius) was established. The plot size in cropland was increased by 0.1 ha (18 m radius) due to high variability of tree biomass in cropland attributable to sparse distribution of trees. Within each plot (Figure 13), subplots of 4 m radius were measured to capture the biomass of small trees and shrubs, which are popular sizes used for firewood.

Figure 13. Plot design for the biophysical inventory



Source: FAO & UNHCR, 2017

Within the first quadrant of the plot (between 2 and 3), shrubs were measured (including basal diameter, crown diameter and average height, and number of stems [in the case of clustered shrubs]). All standing trees (live and dead) of at least 3cm diameter at breast height (DBH) were also measured in the first quadrant. In the rest of the plot, the minimum measured DBH was 5cm. Other tree parameters recorded were species and total height.

Within a smaller radius of 4m (giving a circle of 0.01 ha), all saplings and deadwood were measured.

Four photographs were taken in the cardinal directions and the following variables were also recorded:

- Land use
- Major LULC type(s) of the surrounding area
- Degradation indicators such as
  - » Fire evidence;
  - » Grazing intensity;
  - » Vegetation cover; and
  - » Number of stumps.

The biophysical data were collected by members of the NFA inventory team between March 13 and April 5, 2018, and were recorded on tablets using Open Foris Collect Mobile, an Android App for fast, intuitive, and flexible data collection for field-based surveys.[15]

Enumerators classified the vegetation into categories associated with those within the LULC maps: woodland (closed/open), planted forests, bushland/shrubland, grassland, cultivated land, bare/open land, built-up, water body, THF depleted, and so on. For the rapid assessment, the most common and most likely to be accessed LULCs in the AOI were grouped into five strata and analyzed: woodlands (intact and depleted), bushlands (intact and depleted), and croplands. Overlaying the LULC map with Hansen and time series analysis of overstory loss allowed for the creation of the depleted woodland and depleted bushland strata. The remaining 'THFs depleted' in the area (Hotspot 2), located in the southern part of Adjumani District, 10 km south of the Maaji settlements, were considered too far for refugees to walk for fuelwood collection. Furthermore, they are located in the Zoka Central Forest Reserve, considered off-limits for fuelwood collection. For this reason, THFs were not included in the biomass analysis.

Estimating biomass stocks

Only AGB (in trees and shrubs) and deadwood were targeted in this study, as they represent the primary source of woodfuel for refugees and local people. In each plot, AGB was calculated using the allometric equations of Chave et al. (2014), which were also used in Uganda's NBS. R scripts developed for REDD+[16] in the NBS were used to estimate stocks. Plot-level results were aggregated into LULC classes, as assigned to plots during the field inventory. Shrub biomass was estimated using the NBS equation for small trees.

To categorize field sites as degraded or intact, indicators such as number of stumps, presence of fire, erosion, or grazing woodlands were captured. Those plots with any number of these indicators were considered to be degraded.

To estimate the biomass of the intact areas, NBS data from the West Nile region were ultimately used, as the field crew experienced problems accessing many of the intact rapid assessment sites. Data for closed woodlands measured by the NBS between 1998 and 1999 were reviewed to indicate the average standing stock of woodlands in the region before the impact of degradation.

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

Remote sensing analysis

Datasets used

- A DEM (RCMRD 2015)[17] was used to compute slope in the AOI.
- LULC maps for 2010 and 2015 were used to describe the hotspot areas and to derive changes and degradation in woody vegetation classes (in this case, woodland, bushland and cropland). The maps were vector-based but were converted to pixel-based products to facilitate interpolation with other datasets.
- Landsat time series imagery was analyzed using BFAST (2010), to detect where and with what intensity changes have occurred. BFAST enables per-pixel detection of the date and magnitude of change over time. Overlaying BFAST results with LULC maps indicated where changes had occurred since the 2015 LULC.[18] The use of Landsat's dense time series imagery has been demonstrated for mapping land cover changes, such as deforestation, forest degradation, and impact of fire (Silveira et al. 2018).
- The GFC dataset (Hansen et al. 2013) was used to compute statistics on tree cover loss as a first analysis of the trends in tree cover using existing products, which currently

15 http://www.openforis.org/tools/collect-mobile.html.
16 REDD+ = Reducing Emissions from Deforestation and Forest Degradation.
17 The data represent the 30 m DEM from the SRTM http://geoportal.rcmrd.org/layers/servir%3Auganda_srtm30meters.
18 2015 LULC map is used as 'proxy' of the 2014 situation in the area.

cover 2001–2016. Tree cover loss is defined as complete over-story removal occurring on land with at least 10 percent initial tree cover in 2000 (the only available GFC dataset that includes tree cover percentage). Therefore, statistics were computed using tree canopy cover for 2000 (defined as "canopy closure for all vegetation taller than 5 m in height, as percentage per output grid cell"[19]) subtracting the loss (defined as a "stand-replacement disturbance, or a change from a forest to non-forest state") observed in the selected periods.

- Nevertheless, this dataset could partially depict the real situation since only tree cover changes are considered and sparse tree cover (lower than 10 percent)[20] was excluded. This could therefore confirm the accuracy of the results in detecting changes when tree cover is higher than 20 percent (Hansen et al. 2013) and that human-affected areas could be characterized by other vegetation forms (that is, shrubs).
- Population data at 1 x 1 km resolution from Columbia University's Connectivity Lab and Center for International Earth Science Information (CIESIN 2016)[21] was used to estimate the host population in the 5 km buffers around each settlement, as an indication of total population to compute estimates for each settlement.

Classification and change detection

To provide spatially and temporally explicit information on biomass and changes in biomass over time, a time series approach was used incorporating available Landsat satellite imagery from the U.S. Geological Survey. The Landsat sensor records the electromagnetic reflectance of Earth's surface in multiple wavelengths at a spatial resolution of 30 x 30 m. This reflectance information can be used to determine land surface biophysical characteristics, such as vegetation type. Changes in vegetation result in correlate changes in the detected reflectance. Time series analysis, in which every available satellite image acquired over the study area was analyzed, enabled tracking the reflectance over a long period to detect both subtle and unambiguous changes on the land surface. In the case of this study, subtle negative changes correspond to land surface degradation, and strong negative changes correspond to complete overstory removal. All processing was carried out in the FAO System for Earth Observation Data Access, Processing & Analysis for Land Monitoring (SEPAL)[22] platform.

The results of the BFAST[23] algorithm (DeVries et al . 2016 Dutrieux et al. 2015; Verbesselt et al. 2010) (reclassified into loss and degradation maps for the two periods of interest, 2010–2013 and 2014–2018) were overlaid to the LULC maps (NFA data[24]) (2010 and 2015 map for the two periods, respectively) to know in which land cover types (that is, woodland, bushland, and cropland) changes occurred.

LULC maps for 2010 and 2015 were reclassified and the 13 land cover classes identified during the initial scoping work were reduced to just four based on their prominence in the landscape, accessibility, and biomass content: 1. woodland, 2. bushland, 3. cropland, and 4. other.

The classes of the land cover maps were combined with the two classes of the change maps (loss and degradation) as per the matrix in Table 25. In more detail, 'intact woodland' and 'intact bushland' are vegetated areas that remain 'stable', without degradation and loss. Degraded classes refer to a partial removal of vegetation while loss occurs when there is complete vegetation removal. For these last classes, woody biomass is assumed to be zero. The maps for the two periods (''before arrival') and ('after arrival') are shown in Figure 9 and Figure 10.

19 https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.4.html.
20 Tree cover in 2000, defined as canopy closure for all vegetation taller than 5 m. Encoded as a percentage per output grid cell, in the range of 0 to 100.
21 Center for International Earth Science Information Network. Columbia University. High Resolution Settlement Layer. Source Imagery 2016 DigitalGlobe, Inc. www.ciesin.columbia.edu/data/hrsl/.
22 https://sepal.io/.
23 For more information on BFAST: http://bfast.r-forge.r-project.org/.
24 http://redd.unfccc.int/files/annex_8_mapaa_methodologyresults_ug_frl_1_.pdf.

Table 25. Matrix of resulted classes obtained by combining the LULC map with the mask of loss and degradation

MAP Combination			Degradation and loss classes		
Original map code	Reclassified code	LULC classes	Loss	Degradation	No change
1	1	Plantations and woodlots—deciduous trees/broadleaves ('hardwood')	Loss in woodland	Degraded woodland	Intact woodland
2	1	Plantations and woodlots—coniferous trees	Loss in woodland	Degraded woodland	Intact woodland
3	6	THF—normally stocked	Loss in other	Other	Other
4	6	THF—depleted/encroached	Loss in other	Other	Other
5	1	Woodland—trees and shrubs (average height > 4m)	Loss in woodland	Degraded woodland	Intact woodland
6	2	Bushland—bush, thickets, scrub (average height < 4m)	Loss in bushland	Degraded woodland	Intact bushland
7	6	Grassland—rangelands, pastureland, open savannah; may include scattered trees shrubs, scrubs, and thickets.	Loss in other	Other	Other
8	6	Wetlands – wetland vegetation; swamp areas, papyrus and other sedges	Loss in other	Other	Other
9	3	Subsistence farmland – mixed farmland, smallholdings in use or recently used, with or without trees	Loss in other	Cropland	Cropland
10	6	Uniform commercial farmland—mono-cropped, non-seasonal farmland usually without any trees for example tea and sugar estates	Loss in other	Other	Other
11	6	Built up area—urban or rural built-up areas	Loss in other	Other	Other
12	6	Open water—lakes, rivers, and ponds.	Loss in other	Other	Other
13	6	Impediments (bare rocks and soils)	Loss in other	Other	Other

Note: The map codes are as follows: loss in woodland (10), degraded woodland (11), intact woodland (1), intact bushland (2), loss in bushland (20), degraded bushland (22), cropland (3), loss in other (9), and other (6). Code of the BFAST loss/degradation map are as follows: loss (1), degradation (2), and no change (0). On the left are the 'original code' and 'reclassified code' of the LULC maps. From this, it is possible to know how the original 13 map classes were reclassified.

The BFAST methodology tracks a single vegetation index, the Normalized Difference Moisture Index (NDMI), through time to detect both unambiguous and subtle changes in vegetation cover. It requires several parameters to be set to define the scope of the analysis, including the time over which the analysis will be carried out, the historical period defining an expected behavior for each pixel, and a monitoring period indicating 'from' and 'to' dates for detecting any deviations (breaks) from 'normal' pixel behavior. Therefore, breaks can be considered the variations from the seasonal patterns, as a result of either abrupt changes (for example, deforestation, fires) or more gradual changes (for example, encroachment, gradual land degradation). The advantages of using indexes rather than original band observations include minimizing the soil and other background effects, providing a degree of standardization for comparison, and enhancing the vegetation signal (Silveira et al. 2018).

BFAST time series analysis was performed for two time periods, 2010–2013 and 2014–2018. The parameters used for this analysis were as follows:

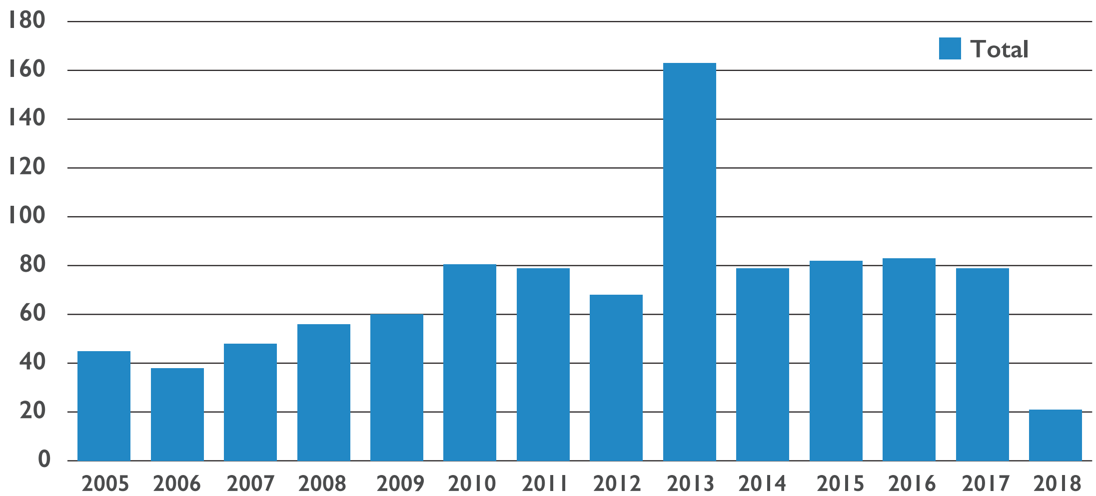
- For the changes between 2010 and 2013
  - » Beginning of historical period: January 1, 2005
  - » Beginning of monitoring period: January 1, 2010
  - » End of monitoring period: December 31, 2013
- For the changes between 2014 and 2018
  - » Beginning of historical period: January 1, 2010
  - » Beginning of monitoring period: January 1, 2014
  - » End of monitoring period: April 16, 2018

The output of the time series analysis is 'magnitude' of change. Magnitude can vary from strongly negative (for example, deforestation) to strongly positive (for example, reforestation or revegetation). Classification of magnitude values requires creating thresholds to distinguish change classes and create classes capable of being summarized and mapped. To relate 'magnitude' values obtained in the analysis with on-the-ground change, the results need to be calibrated based on reliable data. Results in this study were calibrated with field-based observations and very high spatial resolution imagery from Google Earth and Worldview2, 3 and GeoEye1 imagery provided by the United Nations Institute for Training and Research (UNITAR) and using the socioeconomic information on consumption.

The processing generated a three-band raster dataset covering the AOI, where the date of break and the magnitude of detected change are recorded for each pixel (band 1 and band 2 of the resulting output). To identify the changes within the AOI, the layer of change magnitude was used. This is computed as the median residual ('difference or distance') between the predicted and observed values within the monitoring period. According to the different intensities of change, (very) large negative changes were used as proxy for complete tree cover loss and medium negative changes used as potential areas for degradation. The final results were further calibrated based on the socioeconomic results.

The time series Landsat data were created automatically in the SEPAL platform. SEPAL was also used for the processing of the algorithm itself. The computer-intensive process analyzed about 980 Landsat images relating to the AOI (Figure 14). The validation of the maps was carried out using field data and the very high spatial resolution imagery Digitalglobe[25] satellite images provided by UNITAR.

Figure 14. Number of processed satellite images (Landsat 7 ETM+) of the time series for both periods



25 https://discover.digitalglobe.com/

Technical considerations

This section explains some of the technical complications involved in this study and helps explain the discrepancies between the biomass consumption estimates derived from the household study with those obtained from the remote sensing-based analysis in which area deforested and degraded was multiplied by a biomass expansion factor.

Differences between the estimates derived from the remote sensing-based analysis and the household study can likely be ascribed to the following reasons:

- **Inaccuracy of the LULC maps (2010 and 2015 maps).** Even though the LULC national maps are the result of intensive work carried out by the NFA, the application of vector-based products over pixel-based change maps may compound errors, given the probable map errors. It is generally discouraged to combine datasets of different types (vector versus raster) and different spatial accuracy. Furthermore, land cover maps utilized for the study are national scale maps and not intended to be used on a subnational basis. However, due to limited time, using existing and endorsed national products was considered the best approach.

- **Definitions and Land Cover Classification System used.** The classification system adopted and associated definitions of woodland, bushland, and cropland are those adopted by the country in the national mapping activities. However, this classification is rather complex: for example, land cover classes with a tree cover component in the LULC maps for the AOI include THF depleted, woodland, bushland, grassland, subsistence farmland, savannah, and wetland. Furthermore, distinction between bushland and woodland is rather difficult to assess in remote sensing because the height of the objects in the imagery is unknown.

- **Assumption of absolute loss.** For pixels classified as loss, biomass was set to zero. In other words, the assumption for the sake of the study was that there is no remaining biomass after overstory removal, when in reality there is partial loss. For example, inside the settlements (and where loss was mapped out) there is still scattered vegetation.

- **Inaccuracy of the biomass factors applied for each LULC class selected.** Due to the limited time and resources for a more in-depth assessment, only 67 sample plots were surveyed in the field to derive the biomass expansion factor. This meant some rather high margins of error. For example, AGB on degraded woodlands was found to be 25.3 ± 18.5, meaning that the AGB for this LULC could be anywhere from 6.8 to 43.8 tons per ha. Variability would be decreased if there were a larger number of plots surveyed in this class. These estimates were then expanded over the vector data for the respective LULCs.

- **Changes in grassland were not considered because of low biomass for wood fuel collection.** Grassland is one of the major classes in Bidibidi, but grasslands were not considered in the study because they have very low AGB and therefore are unlikely to meet the fuelwood needs of both the host and refugee communities. However, misclassifications on the LULC map are possible given that it was produced as a national product. Therefore, it is possible that some areas where fuelwood collection is indeed occurring were omitted.

- **Validation of remote sensing findings with field data.** Discrepancies found between data collected on the ground and those used in the remote sensing analysis could partly be related to the different spatial resolution of the two sources (spatial resolution of the field plots versus the spatial resolution of the images) and GPS measurements errors (that is, how precise the instrument was able to collect the coordinates for that plot). In addition, the interpretation of the land cover features during the field data collection should be in line with the interpretation of the very high spatial resolution imagery and the data collection phase.

- **The data presented in the socioeconomic findings might present some deviations** resulting from using the indicator fuelwood consumption per person per day assessed in the households sampled to then extrapolate the total woodfuel demand of the whole refugee settlements in the AOI.

Overall, loss changes were mapped with higher certainty with respect to the changes classified as ‘degradation’ (especially in bushland), which were spatially diffused around the AOI. Difficulties were found in discriminating real changes from soil moisture changes, especially in croplands. BFAST is a relatively new approach to assessing forest degradation and is continually being improved.

Making distinctions between vegetation cover changes and degradation processes is problematic when dealing with complex landscapes and change processes. Characterizing a disturbance event is complicated by the fact that deforestation is preceded by several years of forest degradation when driven by subsistence agriculture (DeVries et al. 2016). Due to the complexity of the area, as suggested by Lambin (1999), a “more practical definition of degradation would be a continuous measurable value (for example, in terms of canopy cover).” DeVries et al. (2016) well explain implications of using definitions based on area, height, and canopy cover thresholds.[26] Therefore, the use of classes such as tree cover and shrub cover percentage could be a preferred option to obtain estimates of biomass stock and changes without using the LULC classification system and its associated classification errors. Indeed, extending the analysis to grassland would require more time and a separate assessment most likely using satellite images with better spatial resolution, covering the periods of the analysis and further field data collection.

It is therefore important to underline that estimates presented from the remote sensing analysis may provide an overview of the lands prone to degradation and further natural resources exploitation, and the reasons provided above may not completely reflect the socioeconomic findings.

26 For example, the Intergovernmental Panel on Climate Change (IPCC) defines degradation as changes negatively affecting carbon stocks in forests which remain forests, where a forest is defined based on area, height, and canopy cover thresholds. Degradation can occur when a forest is completely cleared, but the total area cleared is less than the area threshold (that is, 0.5 ha). Degradation can alternatively occur when a larger area of forest experiences negative changes in forest canopy cover, but the canopy fraction still remains above a defined forest threshold (for example, 20 percent). Finally, using the area-based definition implies the evaluation of the total area affected from the disturbance (DeVries et al. 2016).

ANNEX 2: RAPID WOODFUEL DEMAND QUESTIONNAIRE

Country:	Settlement or village:
District:	Block number:
Name of Enumerator:	Plot number:
Date:	

Before starting the interview:

- Begin the session by explaining the format and objectives of the interview.
- Ensure the interviewee can choose in advance not to participate if they are uncomfortable in any way.
- Specify that confidentiality will be maintained at all times. Thus, no record will be kept of participants' names.

1. HOUSEHOLD INFORMATION

How many structures on the plot?			Date of arrival to the camp	
Type of structure on the plot:			Walling material (e.g. wood poles, mud brick)	Roofing material (e.g. straw, bamboo, iron sheet)
House - ☐	How many rooms?			
Kitchen hut - ☐				
Latrine - ☐				
Animal shed - ☐				
Other - ☐				
Fencing - ☐				
Interviewee age:			Relationship with the household (head, spouse, son, daughter, other):	
Head of household gender: 1- ☐ Male 2-- ☐ Female			Interviewee gender: 1- ☐ Male 2- ☐ Female	
Total number of household members:			Number of income/wage earners in the household:	

Number of adults > 18 years		Number of children (2-18 years)		Number of infants < 2 years	
Male	Female	Male	Female	Male	Female

Current livelihood category Agriculture=A, Agropastoral=AP, Pastoral=P, Fishing =F					Current status of household			
A	AP	P	F	Other (specify)	IDP	Refugee	Returnee	Host

What are the current sources of household income?					
No income	Cash transfers	Exchange or sale of food	Selling firewood	Remittances	Other
If other, specify income source and earner:					
What kind of income generation activity would you like to undertake?					

2. CURRENT SOURCES OF FUEL FOR COOKING, HEATING WATER

What fuels do you use for cooking and heating in the household?					
Firewood	Charcoal	Grass/straw	Crop residues (specify)	Animal dung	Other fuel
If 'other fuel', give details:					

What is the usual quantity of fuel you consume per day in the household?		
Fuel type	Measured quantity (kg/day)	**Main uses:** C=cooking; H=heating; AG=agricultural uses (e.g. curing tobacco, drying food, etc.); CM= commercial uses (e.g. baking bread, brewing alcohol, making food for selling). **Type of firewood harvested:** DW= deadwood; GW= green wood
Firewood		
Charcoal		
Grass/Straw		
Crop residues		
Animal dung		
Other		
If 'Other', specify daily household consumption:		

Where do you source your fuel? (multiple responses allowed)						
UN or NGO distribution	Collect from natural forest	Collect from woodlots	Collect from shrub land	Collect from farmland	Buy from the market	Others
If 'Others', specify the source:						

If you collect firewood, how many headloads per week are gathered by people in this household?					
1	2	3	4	5	6 or more

Who within your household is primarily responsible for collecting fuel? (insert number for each box)				
Male adult	Female adult	Female child	Male child	Other
If 'Other', please specify:				
How many hours does the total collection trip take in average? (Going from your house to the main collecting area, cut and collect firewood and back)				
What challenges are you facing during collection of firewood?				

3. TECHNOLOGIES FOR COOKING AND HEATING

What **method/ stoves** are currently used for cooking and heating? (if more than one type of stove is observed, tick multiple boxes)							
Three stone fire	Mudstove (firewood)	Mudstove (charcoal)	Ceramic (firewood)	Ceramic (charcoal)	Metal stove (firewood)	Metal stove (charcoal)	Others
If 'Others', specify which stoves:							

Where is the stove(s) located? (multiple responses allowed)				
In a dedicated kitchen	In a room used also for sleeping	In the living area	In a separate building/structure	Outdoors

Why do you like to cook with this cooking system?

Does it have any disadvantages? (Note for the enumerator: response choices should not be read, tick all that apply)				
Food is undercooked	Too much smoke	It requires a lot of fuel	Expensive to use because of fuel costs	Other
If 'Other', specify these disadvantages:				

If you currently have a stove, where did you get it from?				
Market	NGO/UN org.	Self-produced	Relatives	Other
If 'Other', specify the source:				

What is the main cooking technology you would prefer to use if you had a choice?							
Three stone fire	Mudstove (firewood)	Mudstove (charcoal)	Ceramic (firewood)	Ceramic (charcoal)	Metal (firewood)	Metal (charcoal)	Others
If 'Others', specify preference:							

4. TYPE OF FOOD AND PREPARATION

What are the main types of food usually cooked? Indicate the typical method of cooking for each food and how many times per week it is prepared.		
Type of food	Method of cooking (e.g. Boiling, Stewing, Roasting, Frying, Baking, Dried food)	Times of preparation in a week
....	....	....
....	....	....
....	....	....

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