Rapid Assessment of Natural Resources Degradation in Areas Impacted by the Refugee Influx in Kakuma Camp, Kenya

Technical Report

November 2018

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Acknowledgements

Between April and August 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 Kenya and Uganda*'. 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.

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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 Seasonal and Trend
CBO	Community-based organization
DRA	Department of Refugee Affairs
DRDIP	Development Response to Displacement Impacts Project
FAO	Food and Agriculture Organization of the United Nations
GIZ	German Agency for International Cooperation
GoK	Government of Kenya
IBEK	Improved Basic Earth Kiln
IDA	International Development Association (World Bank)
KEFRI	Kenya Forestry Research Institute
LOKADO	Lotus Kenya Action for Development Organization
LULC	Land use/land cover
NGO	Non-governmental organization
pppd	per person per day
RUM	Resource Utilisation Monitor
UN	United Nations
UNDP	United Nations Development Programme
UNHCR	United Nations High Commissioner for Refugees
VHRI	Very high resolution image
VSLS	Village Savings and Loans Scheme
WFP	World Food Programme
WHO	World Health Organization

Executive summary

As of February 2018, the total number of registered refugees and asylum-seekers in Kenya is 483,597. Most are hosted in the refugee camps of Dadaab and Kakuma, located in the drylands in the east and north of the country, respectively. These camps were established in the early 1990s following instability in neighbouring countries. Kakuma camp in Turkana County hosts more than 180,000 refugees, of whom 57 percent are South Sudanese and 18 percent are Somali. The remaining are of various nationalities (Burundian, Congolese, Eritrean, Ethiopian, Rwandese and Ugandan).

Woodfuel is the dominant source of energy for cooking and heating in homes and institutions in Kenya, and accounts for 69 percent of the country's total primary energy consumption. The high dependence on woodfuel at national level is paralleled within the refugee camps.

The World Bank commissioned the Food and Agriculture Organization of the United Nations (FAO) to undertake a rapid assessment of natural resources degradation around Kakuma camp in northern Kenya, 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 Kenya.

Main findings

The assessment revealed the following key findings:

- **Both refugee and host communities are engaged in various income-generating activities,** although **the majority of the refugee community relies on humanitarian agencies and non-governmental organizations (NGOs)** for sustenance. **The host community**, on the other hand, **relies heavily on the sale of firewood and charcoal** for sustenance. Other income-generating activities among the refugee and host communities include businesses such as hairdressing, tailoring, brewing alcohol, temporary employment and civil service.

- **Host and refugee communities rely entirely on woodfuel** to meet their energy needs for cooking. The refugee and host communities obtain their woodfuel from different sources. The majority of the refugees obtain part of their woodfuel from the UN/NGOs. Since the wood provided by the UN/NGOs is not enough, the refugees complement the supply by buying from the market, exchanging their food rations for woodfuel, and by collecting firewood from the surrounding woodlands. The vast majority of the host community households obtain their woodfuel from surrounding shrublands and *Prosopis* species.

- The average **daily consumption of firewood by the refugees is 1.0 kg per person and among host communities is 0.9 kg**. **Taking into account the additional use of charcoal**, average daily fuel consumption rises to a total of **2.6 kg per person** in firewood equivalent among refugees and **2.1 kg** among households of host communities.

- **Collection of firewood** among the refugee and host communities **is primarily done by adult females** who (in the process of wood collection) are **exposed to several risks and challenges,** including thorn pricks, snake bites, long distances causing fatigue, fear of bandit attacks and even rape.

- While a **high percentage (91%) of the refugee population has adopted some type of improved cookstove, a significant proportion (93%) of the host community still use the inefficient 3-stone fire.**

The use of such an inefficient system exposes the population to health-related risks such as indoor air pollution, besides threatening the existence of the forests and forest resources. The source of stoves varies between the host and refugee communities, with the majority of the refugees obtaining their stoves from the UN/NGOs and the majority of the hosts self-producing their (mostly 3-stone fire) stoves.

- **With the increasing population of refugee and host communities, demand for woodfuel is expected to increase.** Given the **scarce natural resources in the area** surrounding Kakuma camp and the **pressure on the indigenous vegetation**, the woody biomass from ***Prosopis*** **represents an important energy source** for refugee and host communities. However, its production, harvesting and use require a management plan to control the risks of further ecological impacts and **to support the energy needs and local economy**.
- From the remote-sensing analysis, it was possible to quantify biomass stock changes in the three buffer zones (i.e. 25-50-100 km) around Kakuma camp and, in particular, loss and gain in the period 2014-2018. **In the 25 km buffer, there are not major losses and instead *Prosopis* expansion seems to be the prevailing biomass stock change.** In the **50 and 100 km buffers, major losses are detected (especially outside the Kenyan boundary in Ugandan territory).** The vegetation cover where most losses were detected is shrubland with indigenous species, while the major increase in the extent of *Prosopis* is observed along the main rivers and their tributaries, although some areas show a significant reduction in the extent of *Prosopis.*
- The assessment estimated that the **total standing biomass stock** from the area of ***Prosopis*** **riverine** within 100 km radius around Kakuma is **1,917,000 t**, while **total woodfuel demand** from refugee and host communities is estimated at **173,000 t/year**. The efficient use of this standing biomass from ***Prosopis*** **could help meet the energy needs for cooking** required by the whole refugee and host communities while controlling the spread of *Prosopis* **and providing an income-generating opportunity** for members of the host communities involved in *Prosopis* harvesting and processing.

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:

- **Rehabilitation of degraded land**. This intervention should target the degraded lands within and around the refugee settlement camp in order to restore the productivity of the land for livestock and human sustenance. The rehabilitated areas will then form "greenbelts" around the camp. These are essentially protected areas planted with indigenous species that provide a buffer zone between the refugee camp and surrounding bushlands, and a genetic stock for ongoing and future regeneration.
- **Control and management of *Prosopis* through its utilization**. Since the eradication of *Prosopis* in the area has been tried without success, intervention measures should be directed towards utilization. One silvicultural way to manage and control is thinning and pruning to less dense spacing. This practice can provide different products such as firewood, charcoal and poles, and discourage or reduce the establishment of new *Prosopis* seedlings through an increased growth of indigenous shrub and grass species, thereby resulting in biodiversity and productivity improvements.
- **Promotion of sustainable management of indigenous vegetation**, to address causes of unsustainable harvesting of native woodlands and degradation of the native vegetation. This intervention includes awareness and training on harvesting methods for indigenous trees and appropriate harvesting cycles, and restricting harvesting of native trees to only dead and dying wood.
- **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.

The table below shows the summary of the indicative costs for the implementation of the proposed interventions targeting the area in and around Kakuma camp in northern Kenya.

Recommended intervention	Total (US$)	% of total
Rehabilitation of degraded woodlands	13,668,000	53.7
Control and management of *Prosopis* through its utilization	3,440,000	13.5
Promotion of sustainable management of indigenous vegetation	810,000	3.2
Enhancement of energy efficiency	7,522,000	29.6
Total	**25,440,000**	**100**

The recommended package of interventions should be coordinated under **an integrated energy and environment programme that has the necessary institutional capacity and resources** to undertake more in-depth analysis, implementation and management at site level, carry out monitoring and evaluation, and ensure sound learning, sharing and interaction with other programmes of a similar nature, both in Kenya and elsewhere. This will ensure that the measures do not take place in isolation or in a scattered, ineffectual and short-term way. 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

As of February 2018, the total number of registered refugees and asylum-seekers in Kenya is 483,597.[2] Most are hosted in the refugee camps of Dadaab, Kakuma and Kalobeyei located in the drylands in the east and north of the country, respectively. These camps were established in the early 1990s following instability in neighbouring countries. Kakuma camp in Turkana County hosts 185,449 refugees, of whom 57 percent are South Sudanese and 18 percent Somali. The remaining are of various nationalities (Burundian, Congolese, Eritrean, Ethiopian, Rwandese and Ugandan).

Woodfuel[3] is the dominant source of energy for cooking and heating in homes and institutions in Kenya, and accounts for 69 percent of the country's total primary energy consumption. The high dependence on woodfuel at national level is paralleled within the refugee camps. A study conducted by the Moi University Centre for Refugee Studies found that wood-based fuel accounts for 88 percent of the energy used by refugees in Kakuma Camp (Muia, 2005)[4]. Firewood consumption rate was estimated at 1.3 kilograms (kg) per person per day (pppd), according to a 2004 report by the United Nations High Commissioner for Refugees (UNHCR) and the German Agency for International Cooperation (GIZ). A more recent report gives a similar per capita consumption figure and estimates total demand for firewood in the camp at about 237 tonnes (t) per day.[5]

Kenya is benefitting from a new International Development Association (IDA) 18 sub-window to support countries impacted by refugees.[6] The fact that Kenya hosts a large number of refugees in the Horn of Africa region enhances its prospects for support under this window. Kenya 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 the South Sudan Refugee Influx in Kenya and Uganda*".[7] The assessment was expected to provide a clear profile of the scope of the environmental impacts of the refugee influx at Kakuma camp,[8] 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 IDA 18 sub-window, and to inform ongoing World Bank support under DRDIP.

1.2 Objectives of the assessment

The purpose of the assessment was to conduct a rapid diagnostic assessment of land and forest resource degradation in areas around Kakuma camp in northern Kenya, and 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 socio-economic assessment of woodfuel consumption and associated challenges in the Kakuma camp and two local villages, alongside of a study on biophysical parameters in pre-selected hotspots in a buffer zone of 100 kilometres (km) radius.

The assessment builds on the methodology developed in the joint FAO–UNHCR technical handbook, *Assessing*

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[2] http://www.unhcr.org/ke/wp-content/uploads/sites/2/2018/03/KENYA-Statistics-Package-February-2018-1.pdf
[3] In FAO's terminology, the term "woodfuel" includes both fuelwood (synonymous with "firewood") and charcoal.
[4] Muia, M. F. (2005). Woodfuel Impact on Environment in Kenya: A Case of Dadaab Refugee Camps.
[5] UNHCR Strategy and Plan of Action for Refugee Operations in Kenya 2015 – 2018
[6] The refugee sub-window was created under the 18th replenishment of the World Bank Group's International Development Association (IDA).
[7] World Bank Contractual Agreement no. 7185743; FAO Project Symbol: OSRO/GLO/801/WBK
[8] While the funding is linked to the South Sudanese refugee influx, the study considers the impacts of all refugees at Kakuma.

Woodfuel Supply and Demand in Displacement Settings (FAO & UNHCR, 2016).[9] The methodology comprised three components: 1) assessment of woodfuel demand and associated challenges; 2) assessment of woodfuel supply, including above-ground biomass stock, land-cover classification and changes; and 3) identification of interventions to address issues related to energy access, natural resource degradation and livelihoods.

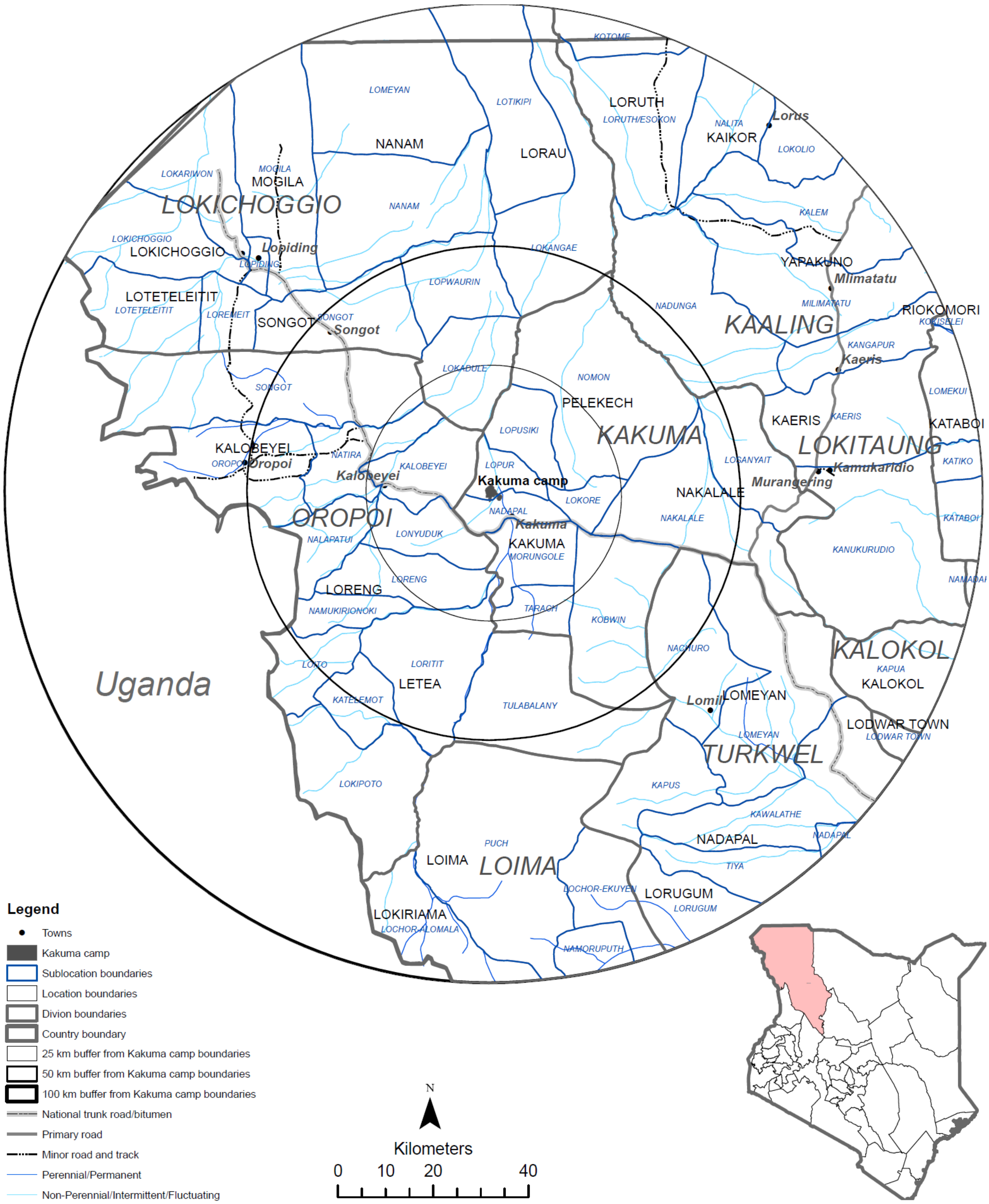
The methodology for the socio-economic analysis, biophysical field inventory and remote sensing analysis is described in detail in the Annex.

1.3 Area of interest

Kakuma Camp is situated in Kakuma ward, Turkana West sub-county. The sub-county comprises seven wards: Kakuma, Letea, Lolobeyei, Lopur, Songot, Lokichogio and Nanam. The area of interest (AOI) for the assessment comprises a buffer zone of 100 km from the boundaries of the camp (Figure 1) and extends into Kakuma, Lokichoggio and Oropoi wards including several locations and sub-locations. The extent of the buffer zone was defined according to the main current locations of firewood harvesting sites under an annual sub-agreement that UNHCR has awarded to the local non-governmental organization (NGO) Lotus Kenya Action for Development Organization (LOKADO).

[9] http://www.fao.org/3/a-i5762e.pdf

Figure 1. Area of interest in Turkana County around Kakuma Camp,



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Sources and data provider: UNHCR- Roads, Rivers

2. Socio-economic findings

2.1 Refugee and host community political framework

The Government of Kenya (GoK) and UNHCR are the key players in refugee governance. In 1992, upon GoK's invitation, UNHCR assumed a leading role in refugee status determination (RCK, 2012). In 2006, Kenya enacted a **Refugee Act** to put in place a legal framework and assume partial responsibility over refugee status determination (Library of Congress, 2016). In 2009, Kenya developed **Refugees Regulations to implement the Act.**

The Refugee Act saw GoK taking stronger responsibility for the management of refugee matters through the creation of a new institutional framework comprising the Department of Refugee Affairs (DRA), the Refugee Affairs Committee and the Refugee Appeals Board. The DRA is charged with administration, coordination and management of activities and programmes for refugees, while the Refugee Affairs Committee is charged with recognition of persons as refugees. The Act tasks the Refugee Appeal Board with hearing and determining grievances arising from the refugee status determination process (Republic of Kenya, 2006).

The Refugee Act also gives refugees the right to secure identification documents and to earn a living. With this, the Act domesticates the provisions of relevant international conventions on the rights of refugees (Maina, 2016). However, the right to earn a living is yet to be fully realized, given that the same law requires refugees to reside in camps and thus restricts their movements and ability to secure paid work. Refugees therefore have limited access to employment opportunities in any practical sense (Maina, 2016). Recent terrorist attacks are said to have also prompted GoK to introduce even stricter encampment measures. For instance, in 2014, the government directed all asylum seekers and refugees living in urban areas to relocate to designated camps (Library of Congress, 2016). Moreover, an amendment to the Act in 2014 capped the maximum number of refugees in the country at 150,000 and permits forced repatriation (Republic of Kenya, 2006, revised 2014).

2.1.1 Stakeholders involved in environment-energy initiatives in Kakuma

The relevant government entities for energy and environmental issues in refugee camps are the Ministry of Energy, Kenya Forest Service, Kenya Wildlife Service, Kenya Forestry Research Institute (KEFRI), Kenya Industrial Research Development Institute and National Environment Management Authority of the Turkana County Government. These government entities are mostly involved in "shaping" the energy and environmental sector in Kakuma camp and its environs through policy development, legislation and enforcement.

Several United Nations (UN) agencies and NGOs are also involved in energy and environment-related initiatives in and around Kakuma. UN agencies involved include FAO, UN Habitat, UNHCR and the World Food Programme (WFP). NGOs involved include BBOXX, Crown Agents, GIZ, World Agroforestry Center, LOKADO, Netherlands Development Organization, Rural Development Solutions, Sanivation and World Vision, among others. Although several UN and NGOs are involved, UNHCR, LOKADO and WFP play the most significant roles in terms of provision of woodfuel to the refugees.

2.1.2 Relevant institutional framework for environment-energy initiatives

Several national policies and legal frameworks are relevant to environmental and energy initiatives in and around Kakuma refugee camp. First among these, is the Kenya Constitution of 2010. The Constitution devolves the implementation of energy, agriculture, environment, and forestry policies to county governments, while also empowering county assemblies to enact relevant legislation i.e. to domesticate national legislation and policies. It also devolves "implementation of specific government policies" on forestry to counties, including farm forestry and extension, and sets for the country a target of achieving 10 percent tree cover. It is thus incumbent upon the Turkana County Government to implement policies and programmes to enhance adoption of and access to clean energy sources and technologies, and to put in place strategies to conserve the environment, including forests on county and communal lands.

While the **Turkana County Government** has enacted a charcoal policy and identified fuel-saving stoves and biogas for schools and the promotion of solar energy for domestic use as flagship projects, there is a need to increase budgetary allocation and human resources to realize these ambitions. Moreover, since regulation of the charcoal trade is devolved to counties, there is a need for the County Government to develop charcoal laws and regulations, which it has not yet done.

The **National Energy Policy (2004)**[10] and the **Energy Act (2006)**[11] are the overarching policy frameworks governing renewable and biomass energy in Kenya. Recognizing the importance of biomass energy, the policy promotes sufficient and sustained supply of firewood and charcoal while minimizing the environmental impacts associated with biomass energy consumption. The policy has set an ambitious target of ensuring that 100 percent of the urban population and 60 percent of the rural population adopts efficient charcoal stoves by 2020. The policy also aims for adoption of improved stoves by 30 percent of the population by the same year. Implementation of these energy policy and legislative frameworks at the Turkana County Government level is still in its infancy. However, the provisions outlined in the **Turkana County Investment Plan for 2016-2020** provide a good basis for implementation of the policies. Moreover, there are significant attempts by the County Government of Turkana to implement forestry and energy policy, as evidenced by support to **Community Forest Associations**, and the desire to encourage adoption of renewable energy sources and technologies. That said, it should be noted that the policies and programmes at the county and national levels do not directly mention energy access for refugees.

2.2 Woodfuel demand and consumption in and around Kakuma refugee camp

2.2.1 Population and household characteristics

This survey covered 228 households drawn from both the Kakuma refugee community (57%) and two local villages (Loreng and Morun’gole villages) (43%). A majority (88%) were female (95% in the host sample and 83% in the camp) (Table 1).

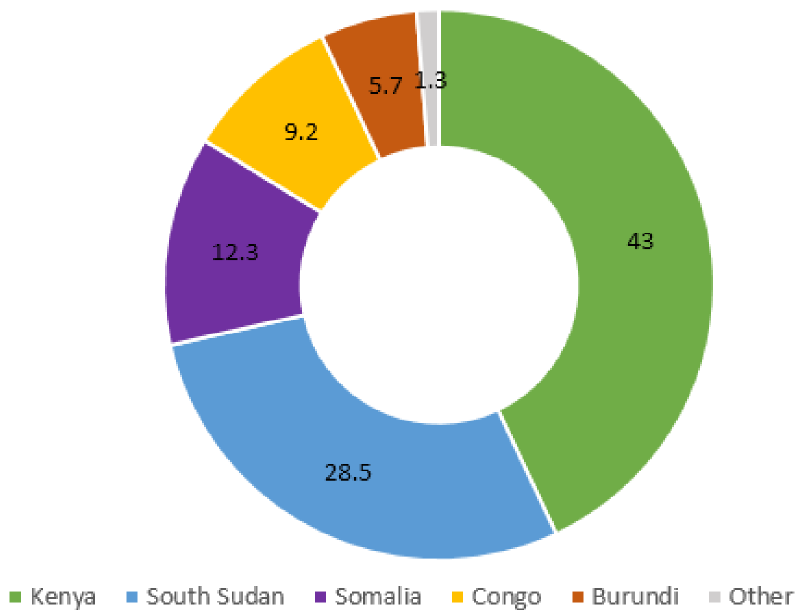
Table 1. Representation of respondents by gender

	Male (%)	Female (%)
Refugee community	5	95
Host community	17	83

Fifty percent of the interviewed refugees were South Sudanese and 22 percent were Somali. The rest belong to different nationalities, as summarized in Figure 2. The mean age of the interviewees was 34 years, suggesting that the majority are in their youth.

[10] Government of Kenya (2004). Energy Policy 2004.
[11] Government of Kenya (2006). Energy Act 2006.

Figure 2. Percentage of respondents by country of origin



Two thirds of the interviewed refugees arrived at the camp within the last decade, while a significant 33.8 percent have been there for at least 13 years (Table 2).

Table 2. Years of arrival at the refugee camp

Year of arrival	Number of refugees	Total respondents (%)
1990-1995	13	10.0
1996-2000	15	11.5
2001-2005	16	12.3
2006-2010	36	27.7
2011-2015	47	36.2
2016-2017	3	2.3
Total	**130**	**100.0**

2.2.2 Size of households

The average refugee household size was 6.6 persons, with a range from one person to 19, while the average was slightly smaller (6.0) among locals (Table 3).

Table 3. Variation in household sizes of the respondents

Respondents	Mean	Minimum	Maximum	Range
Refugee community	6.6	1	19	18
Host community	6.0	2	15	13
Total respondents	6.3	1	19	18

A total of 115 households were male-headed while the remaining 113 households were female headed (Table 4). A majority of the refugee households (63%) are female-headed while male-headed households dominate in the host community (68%).

Table 4. Gender of household head

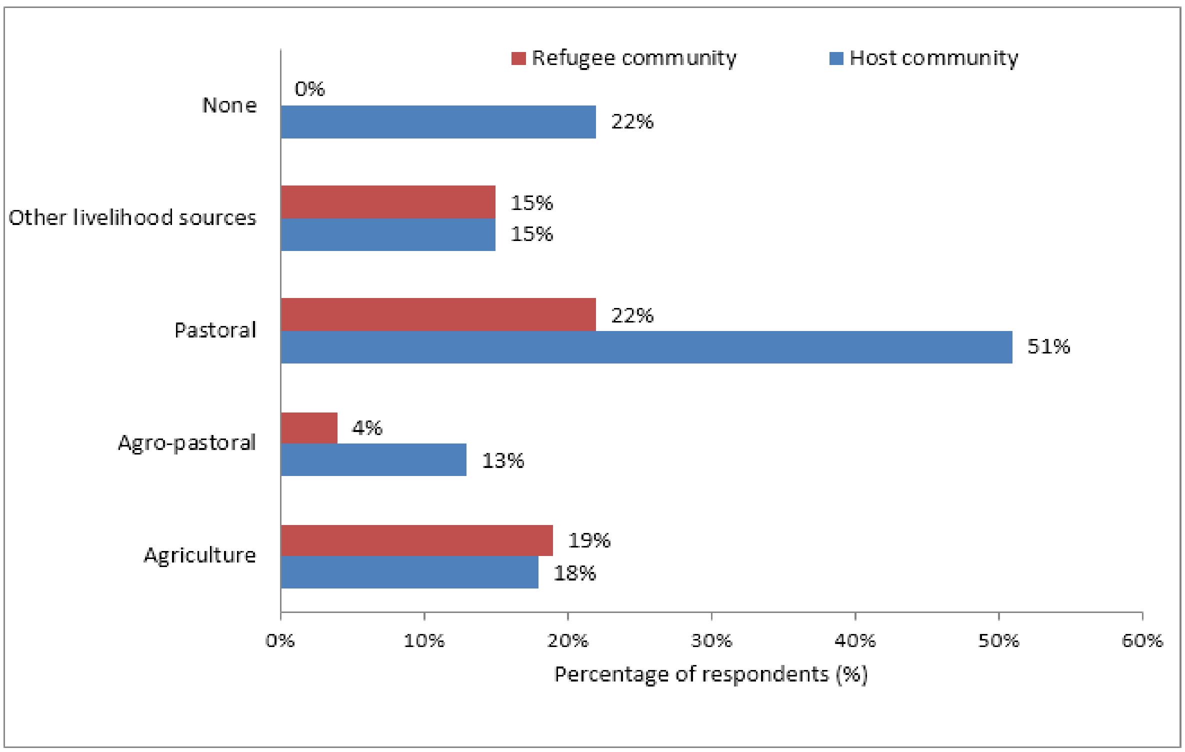
Gender of household head	Refugee community (%)	Host community (%)
Male	36.9	68.4
Female	63.1	31.6

2.2.3 Livelihood background of respondents

The interviewed host community households were identified with some type of a livelihood background. However, a remarkable 20 percent of the interviewed refugee households did not identify with any livelihood background. This is because some fled their home countries during infancy and had no livelihood before their displacement. One respondent observed that she could not recall what her parents or in-laws were engaged in for a living.

Overall, a majority of the interviewed refugee and host community households had a pastoral background (22% and 51%, respectively) (Figure 3). Agriculture (crop farming) was reported as a livelihood background by 19 percent and 18 percent of the refugee and host community households, respectively.

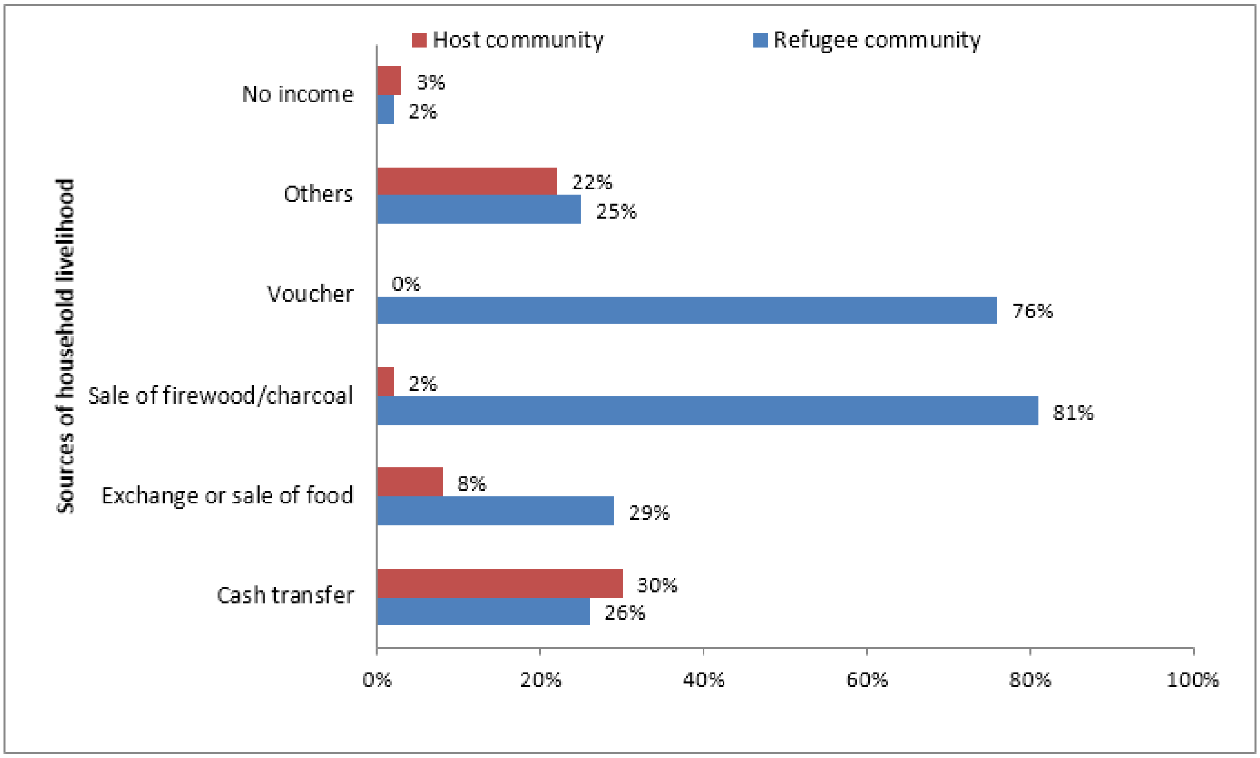
Figure 3. Livelihood backgrounds of respondents



Respondents were also queried on sources of income. Several households have at least one member with a source of income, including vouchers, sale of firewood, or exchange of food and cash transfers. In general, a larger percentage (76%) of refugee households rely on vouchers for their sustenance, 29 percent of them sell or exchange food, and a further 26 percent highlighted cash-transfers as their main source (Figure 4). A significant proportion (25%) are also engaged in other sources of income generation such as temporary employment with NGOs, or operation of small businesses such as electronic shops, hairdressing and tailoring. Only a small proportion (1.5%) of refugee households have no regular source of income at all.

A significant proportion of the host community households (81%) are engaged in the sale of firewood or charcoal as their main sources of income, while 29.6 percent rely on cash transfers and 8 percent on exchange or sale of food. A total of 22.4 percent of host respondents are engaged in other activities to generate income, including activities similar to those of refugees, as well as the sale of alcohol and employment within the Kenyan civil service (such as teaching).

Figure 4. Sources of household income



2.2.4 Woodfuel consumption

All respondents use firewood as their primary source of energy, although 50 percent of refugee households and 24 percent of hosts also use charcoal (Table 5).

Table 5. Proportion of households using firewood and charcoal for cooking in the refugee and host communities

	Population using firewood (%)	Firewood consumption (kg pppd)	Population using charcoal (%)	Charcoal consumption (kg pppd wood equivalent)*	Total woodfuel consumption (kg pppd)
Kakuma refugee camp	100	1.0	50	1.5	2.6
Loreng and Murungóle villages	100	0.9	23.5	1.2	2.1

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.

Average consumption of firewood by the refugees is 1.0 kg pppd, slightly higher than the host community (0.9 kg pppd). Per capita consumption of charcoal (expressed in firewood equivalent) is also higher, and averages 1.5 kg pppd for refugees and 1.2 kg pppd in the host community. Higher energy consumption by refugees may be attributable to differences in diet (slow-cooking beans vs. the local staple of ugali made of millet or sorghum) and the fact that host community households tend to prepare fewer meals.

Total woodfuel consumption in Kakuma refugee camp and in each sub-location

Table 6 shows estimates of woodfuel consumption in Kakuma refugee camp and in each sub-locations within a radius of 100 km buffer. The figures for each sub-location are based on weighted averages extrapolated from the household surveys conducted Loreng and Morun'gole villages. 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%).

Table 6. Estimated annual woodfuel consumption in Kakuma camp and surrounding communities

Sub-location/refugee camp	Population 2018	Total woodfuel consumption (t/yr firewood equivalent)*
Kaeris	7,171	3,094
Kanakurudio	5,809	2,506
Kataboi	5,436	2,345
Kawalathe	1,905	822
Kibish	1,480	638
Lodwar Town	18,193	7,849
Loitanit	5,480	2,364
Lokangae	12,218	5,271
Lokiryama	4,676	2,017
Lokudule	3,387	1,461
Lopusiki	6,299	2,718
Loreng	4,152	1,791
Loritit	11,029	4,758
Lorugum	6,127	2,643
Lotikipi	9,579	4,133
Lowarengak	7,089	3,059
Mogila\Lokichogio	18,815	8,117
Nakalale	4,562	1,968
Namadak	5,206	2,246
Nanam	7,247	3,127
Songot	2,450	1,057
Tarach	7,678	3,312
Tiya	3,781	1,631
Turkwel	10,527	4,542
Kakuma refugee camp	185,449	118,456
Total	**355,744**	**191,926**

Note: The host population of the sub-locations are based on national statistics as of 2009 (KNBS, 2010), and projected to 2018 based on an average annual growth rate of 2.9 percent as reported in the Population Situation Analysis Report for Kenya (PSA, 2013). Data for Kaaling sub-location are not provided as there was no population data available in the 2009 census. Firewood consumption expressed on air-dry basis. The refugee population of Kakuma is based on UNHCR data as of January 2018.

* Firewood equivalent is expressed on an air-dry basis.

The vast majority (98%) of both refugee and host community households use charcoal or firewood for cooking (Table 7). Nine percent of the host community households use charcoal for both cooking and commercial purposes compared to none for refugee households for this combination. Table 7 summarizes the main uses of firewood and charcoal among refugee and host community households.

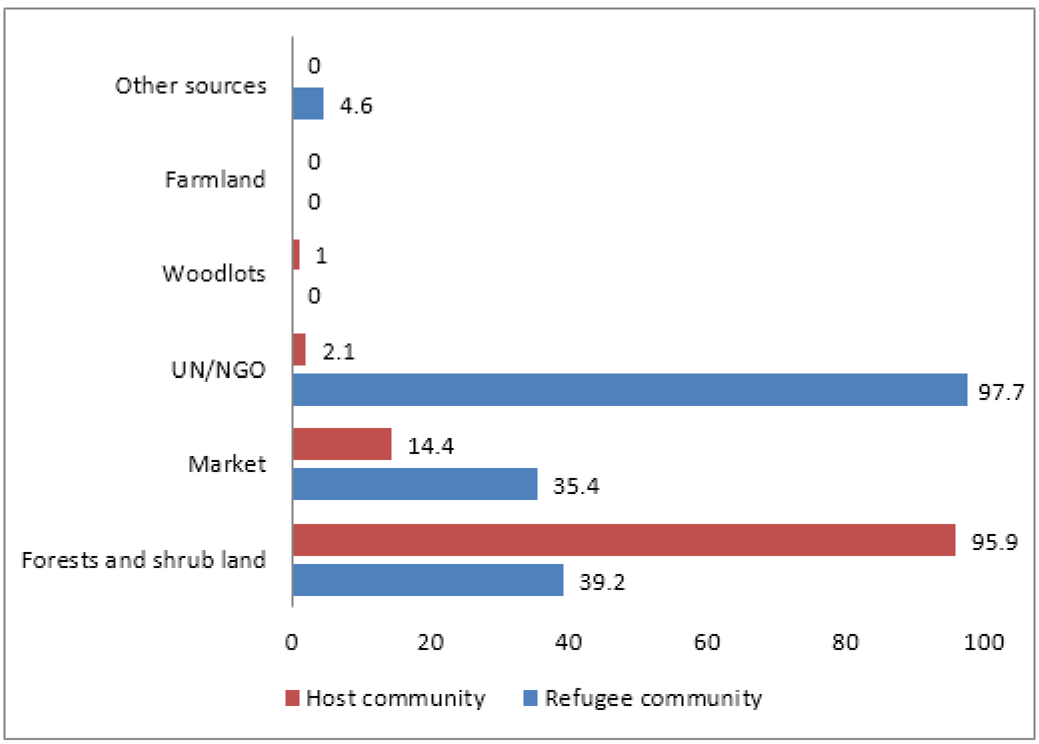
Table 7. Main uses of woodfuel among refugee and host community households

Main use of fuel	Charcoal		Firewood	
	Refugee (%)	Host (%)	Refugee (%)	Host (%)
Cooking and heating	2	0	1	0
Cooking and commercial use	0	9	1	3
Cooking	98	91	98	97

2.2.5 Woodfuel source

Figure 5 compares sources of firewood between refugee and host communities. It shows that the vast majority (98%) of refugees receive firewood from UN/NGOs while only 2 percent of the host households receive firewood from this source. On the other hand, most (96%) host community households collect firewood from forests and shrublands. It should be noted, however, that 39 percent of the interviewed refugees also obtain their firewood from surrounding forests and shrublands. None of the host and refugee households obtain their firewood from farmlands.

Figure 5. Current sources of firewood



2.2.6 Access to woodfuel

There is a significant variation in hours taken to collect firewood between the refugee and host community households. Refugee community households take an average of three hours per trip while their host counterparts take an average of two hours per trip, suggesting that the hosts are closer to the source areas.

Figure 6. Firewood on sale by host communities to refugees in Kakuma III camp

The study also examined the number of headloads of firewood collected per week. Table 8 below shows that a majority (37.9%) of the host community collect firewood once per week while a further 26.3 percent collect twice per week. On the other hand, a majority (42.5%) of the refugee households collect (or transport from the firewood distribution center) two headloads of firewood per week with a further 23.3 percent collecting firewood once per week. This can be explained by the fact that refugee households have relatively larger household sizes, prepare more meals in a day and prepare meals that require more firewood to cook.

Table 8. Number of headloads of firewood collected per week by refugee and host community households

No. of headloads per week	Host community (%)	Refugee community (%)
1	37.9	23.3
2	26.3	42.5
3	14.7	10.9
4	11.6	9.6
5	4.2	2.7
6 and above	5.3	11.0

The majority of respondents (82% of refugee households and 77% of hosts) collect dead firewood. A total of 21 percent of the hosts and 6 percent of refugees collect green firewood. There is clear variance on species used, as hosts tend to use *Acacia* spp. (61%), followed by *Prosopis* (39%), while all refugee respondents use mainly *Prosopis* and only 33 percent also use *Acacia spp*.

As Table 9 below shows, the majority of firewood collectors are adult females in both the refugee (86.7%) and host community (95.9%). A total of 9 percent of collectors are male adults in refugee households compared to only 1 percent in the host community.

Table 9. Household members responsible for firewood collection in refugee and host communities

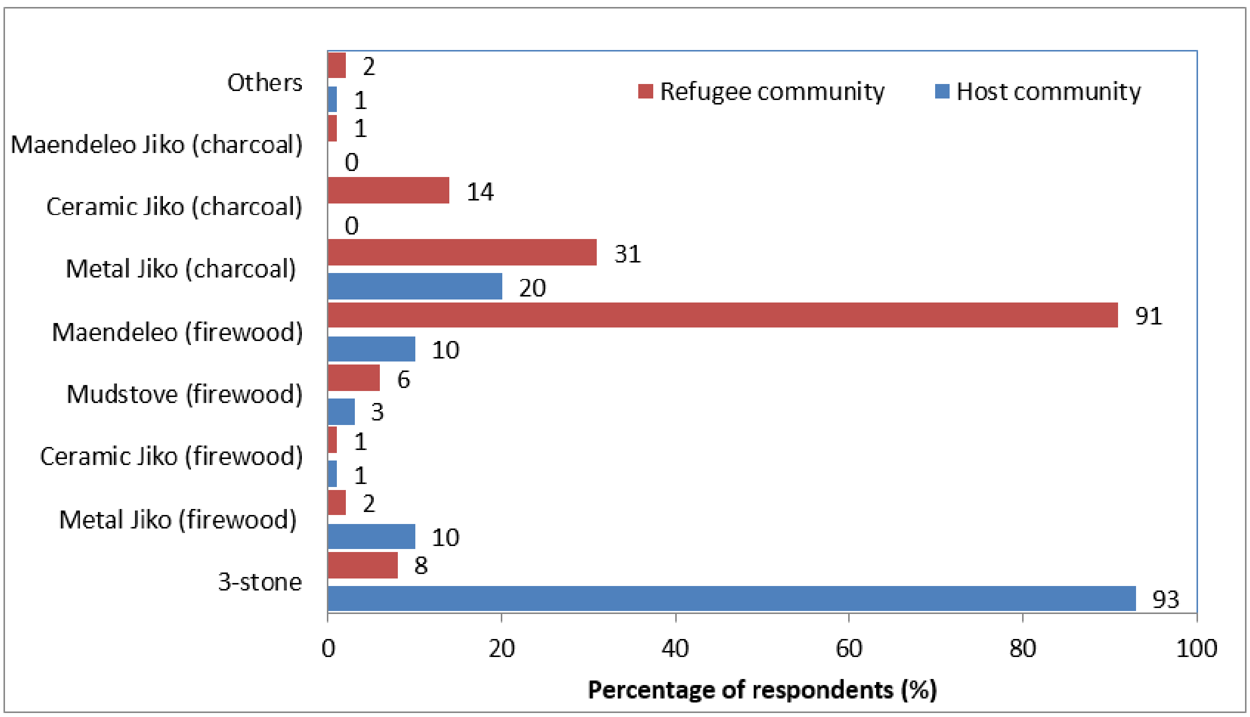
Firewood collector	Host community (%)	Refugee community (%)
Female adult	95.9	86.7
Male adult	1.0	9.3
Female child	2.1	2.7
Male child	1.0	1.3

Firewood collection was reported to expose collectors to several risks, including thorn pricks, snake-bites, long distances causing fatigue, fear of bandit attacks and even rape. Risks of attacks by hosts were also mentioned by refugee respondents.

2.2.7 Cooking stoves and practices

The primary cooking device for the vast majority (93%) of host community households is a traditional 3-stone fire, while for 91 percent of refugee households the primary appliance is a 'Maendeleo' firewood stove (Figure 7). These have been produced for many years at a facility within the camp, and are given away to all new arrivals. The metal charcoal stove is the third most widely used appliance, used by 31 percent and 20 percent the refugee and host community households respectively.

Figure 7. Stove technologies used in the refugee and host communities



A total of 58 percent of the host community households use only the 3-stone fire, while 42 percent use other stoves in combination; 44 percent of refugee households rely solely on the Maendeleo stove and 4 percent use only a 3-stone fire. A total of 52 percent use a combination of different stoves.

A higher percentage (66%) of the refugee households have dedicated kitchens compared to 36 percent in the host communities (Table 10). Conversely, 60 percent of the host communities have their stoves located outdoors compared to 32 percent for the refugee community.

Table 10. Stove location among the host and refugee households

Stove location	Refugee community (%)	Host community (%)
Dedicated kitchen	66.2	35.7
Sleeping room	1.5	3.1
Living room	0	2
Outdoors	32.3	59.2

Further analyses compared the location of the two most commonly used cookstoves: Maendeleo firewood and 3-stone fire (Figures 8 and 9). Results show that 59 percent of 3-stone fires and 34 percent of Maendeleo firewood cookstoves are located outdoors. Some 37 percent of 3-stone fire and 65% of Maendeleo firewood cookstoves are used in a dedicated kitchen.

Figure 8. Maendeleo firewood stove in use in the host community

Figure 9. 3-stone fire in host community home

Some 96 percent associated 3-stone fire with too much smoke while 81 percent associated Maendeleo firewood with this disadvantage (Table 11). A total of 28 percent of the respondents associated 3-stone fire with high firewood consumption while 16 percent associated Maendeleo firewood with this disadvantage; 13 percent of respondents associated the 3-stone fire with other disadvantages while 23 percent associated Maendeleo firewood with other disadvantages. These 'other' disadvantages associated with latter included being heavy and irreparable. 'Other' disadvantages associated with 3-stone fire included being unstable, making it cumbersome to use. The 3-stone fire is usually preferred in situations where various sizes of sufurias/cooking pot are used because it is easily adjustable, compared to the Maendeleo firewood.

Table 11. Disadvantages associated with using Maendeleo stove and 3-stone fire

Disadvantages experienced	Proportion of respondents (%)	
	Maendeleo firewood users	3-stone fire users
Food is undercooked	1.6	0.0
Too much smoke	81.1	96.0
Requires a lot of fuel	15.6	28.3
Expensive to use because of fuel costs	3.3	5.1
Other	23.0	13.1

2.2.8 Source of cookstoves

Most (92%) refugee households sourced their stoves from the UN and NGOs, compared with only 20 percent of host community households (Table 12). By contrast, most (66%) host community households make the stoves themselves while only 10 percent of the refugees do so. A significant minority of both refugees (18%) and host community households (26%) buy their stoves from the market. This is likely to be the case for all charcoal stoves.

Table 12. Respondents and their multiple cookstove sources

Cookstove source	Proportion of respondents (%)	
	Refugee community	Host community
UN/NGOs	91.5	20.4
Market	17.7	25.5
Self-produced	10.0	65.5
Relatives	0.0	2.0

2.2.9 Number of meals cooked

Respondents prepare an average of 2.6 meals per day, with the number slightly higher among refugee households (Table 13).

Table 13. Number of daily meals by status of households

Household status	Average no. of meals prepared per day
Refugee community	2.7
Host community	2.4
Total	**2.6**

3. Woody biomass resources findings

3.1 Biophysical field measurements

Woody biomass was measured on 33 sample plots within the AOI over a period of two weeks. (See the Annex for methodological details.) Table 14 illustrates the main results of this biophysical field assessment and gives an indication of the potential woody biomass available in each land-use/land-cover (LULC) category.

Table 14. Biomass stock by land use/land cover category

LULC class	No. of plots surveyed	No. of trees/ha	Aboveground biomass (trees & shrubs) (t/ha)	Deadwood (t/ha)
Mixed vegetation (indigenous and *Prosopis*)	5	185 +/-166.53	52.80 +/-53.72	0.57 +/-1.13
Prosopis riverine	8	414 +/-147.29	43.63 +/-5.98	1.25 +/-1.44
Prosopis plain	5	461 +/-351	21.44 +/-10.67	0.23 +/-0.45
Indigenous trees	3	281 +/-39.32	6.76 +/-2.85	-
Shrubland	8	107 +/-52.63	3.65 +/-3.44	-
Other	4	-	-	-

A total of 320 trees and 232 shrubs were individually measured during the assessment (see the Annex). A relatively small range of just 9 tree species and 11 shrub species were recorded, of which *Prosopis juliflora* was the most numerous in both categories. Among the indigenous species, *Acacia reficiens* was dominant in both categories.

Mixed vegetation (indigenous and *Prosopis*) plots have the greatest total above-ground biomass (AGB) of 52.8 t/hectare (ha). This estimate, however, has the greatest uncertainty, with a confidence interval of +/-53.72 due to the wide variability found in this class in the field. The variability arises from the indigenous species mixture as well as the overall heterogeneous tree sizes. When the biomass attributed to indigenous species is removed from the analysis, the remaining *Prosopis* biomass is typical of that in *Prosopis* plain. It was observed that this class is typically found near settlements and in the riverine zones and therefore, depending on the species composition, could be exposed to higher levels of human interference, hence contributing further to the observed variability.

Prosopis riverine and *Prosopis* plain yield biomass of approximately 44 t/ha and 21 t/ha, respectively. A such wide range of yield can be explain as result of higher soil moisture content and more fertile soil of riverine leading to more nutrient availability compared to plains. The AGB in *Prosopis* plain is thus roughly half of that of *Prosopis* riverine. The average tree count in *Prosopis* plain is slightly higher than that in *Prosopis* riverine. However, it is more variable, with a confidence interval of +/-10.67 (compared to+/-5.98 in *Prosopis* riverine). Furthermore, the trees in *Prosopis* plain are typically stunted, resulting in significantly lower biomass. Although this was not empirically tested, it was speculated that water and nutrient availability are the main limiting factors, with *Prosopis* riverine receiving higher amounts of both - especially during periodic flooding events.

The class *Indigenous trees* contains approximately 7 t/ha of biomass, mostly due to their slow growth rate. The vegetation in this class showed few signs of disturbance, even if livestock grazing was found to be frequent. The soils are typically poor with little moisture, making it difficult for *Prosopis* to colonize. As a result, the species typically found in this class are hardy and slow-growing, with diameters below 10 centimetres (cm) (DBH). It is important to note that the plots in this class were all situated in areas with open tree cover, while the remote sensing analysis detected higher tree cover density of indigenous trees in few zones within the AOI. Therefore, the figures of biomass of this class should be considered a conservative estimation.

Woody biomass in the class *Shrubland*, dominated by *Acacia spp.*, is estimated at 3.6 t/ha, with a confidence interval of +/- 3.4.

3.2 Remote sensing analysis

The aim of the remote sensing analysis was to map biomass change for the period 2014-2018, in order to understand the degree and extent of land cover and biomass changes within three buffer zones of 25, 50 and 100 km from Kakuma camp. The analysis also sought to quantify standing biomass stock around the settlement and monitor the expansion of *Prosopis*.

3.2.1 *Prosopis* expansion

Prosopis is considered an invasive alien species which poses a threat to Kenya's biodiversity as well as having profound effects on the ecological and economic well-being of society. Compared to other common alien shrubby and tree plant species introduced earlier, such as *Lantana camara, Acacia mearnsii, Senna siamea, Psidium guajava, Tithonia diversifolia* and some *Eucalyptus* species, none has spread so quickly and so widely in arid areas as *Prosopis*. Figure 10 shows the rapid expansion of *Prosopis* in the AOI from 2009-2014.

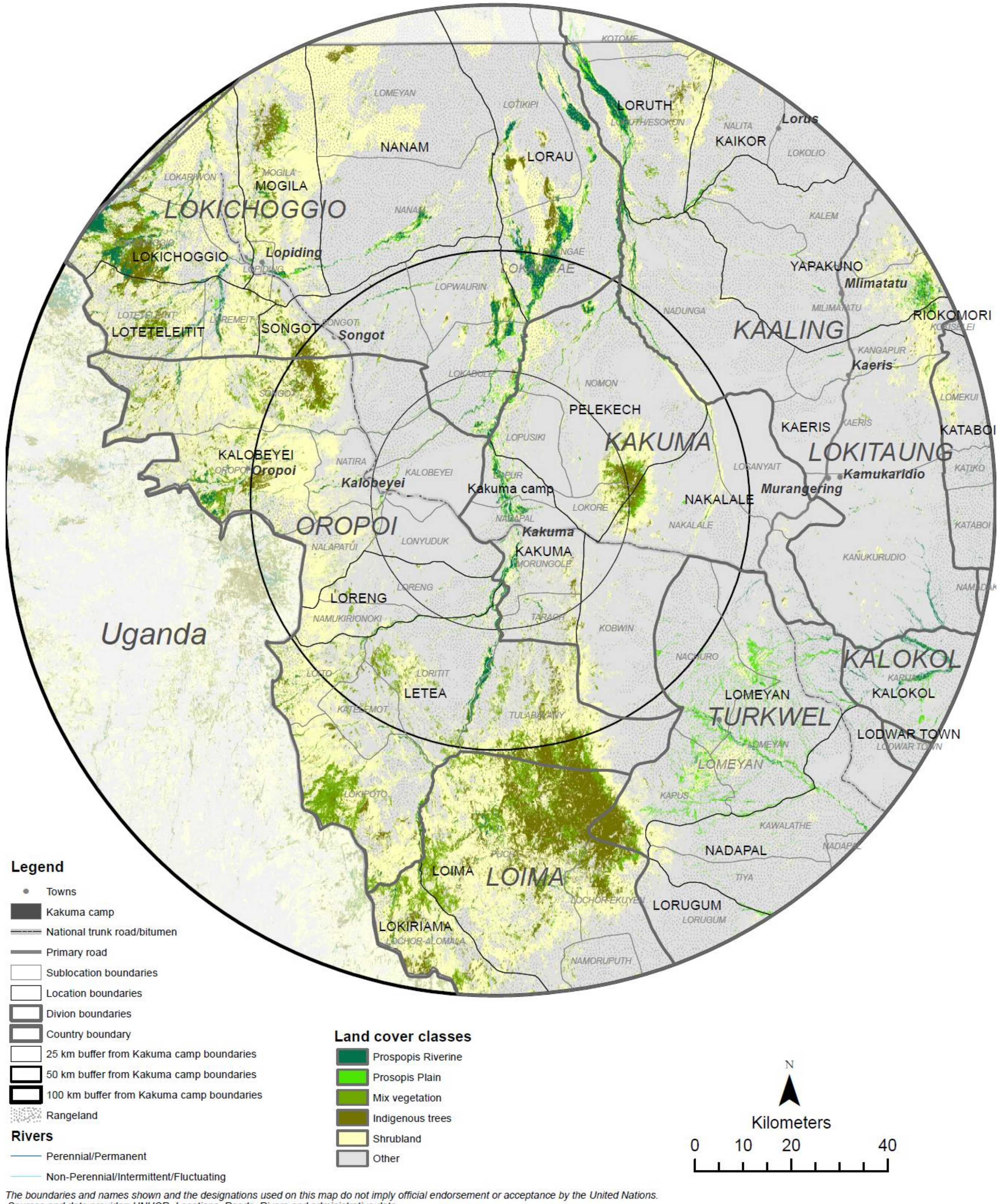
Figure 10. Prosopis spreading along a seasonal river near Kakuma (2009-2014)

Note: Google Earth images dates (from left): 8 March 2009 – 2 October 2013 – 12 July 2014

3.2.2 Land cover map 2018 and current biomass stock

In order to assess biomass loss in the settlement during the period of interest, a land cover map was produced and is presented in Figure 11. The methodology for the production of this map can be found in the Annex (Methodologies).

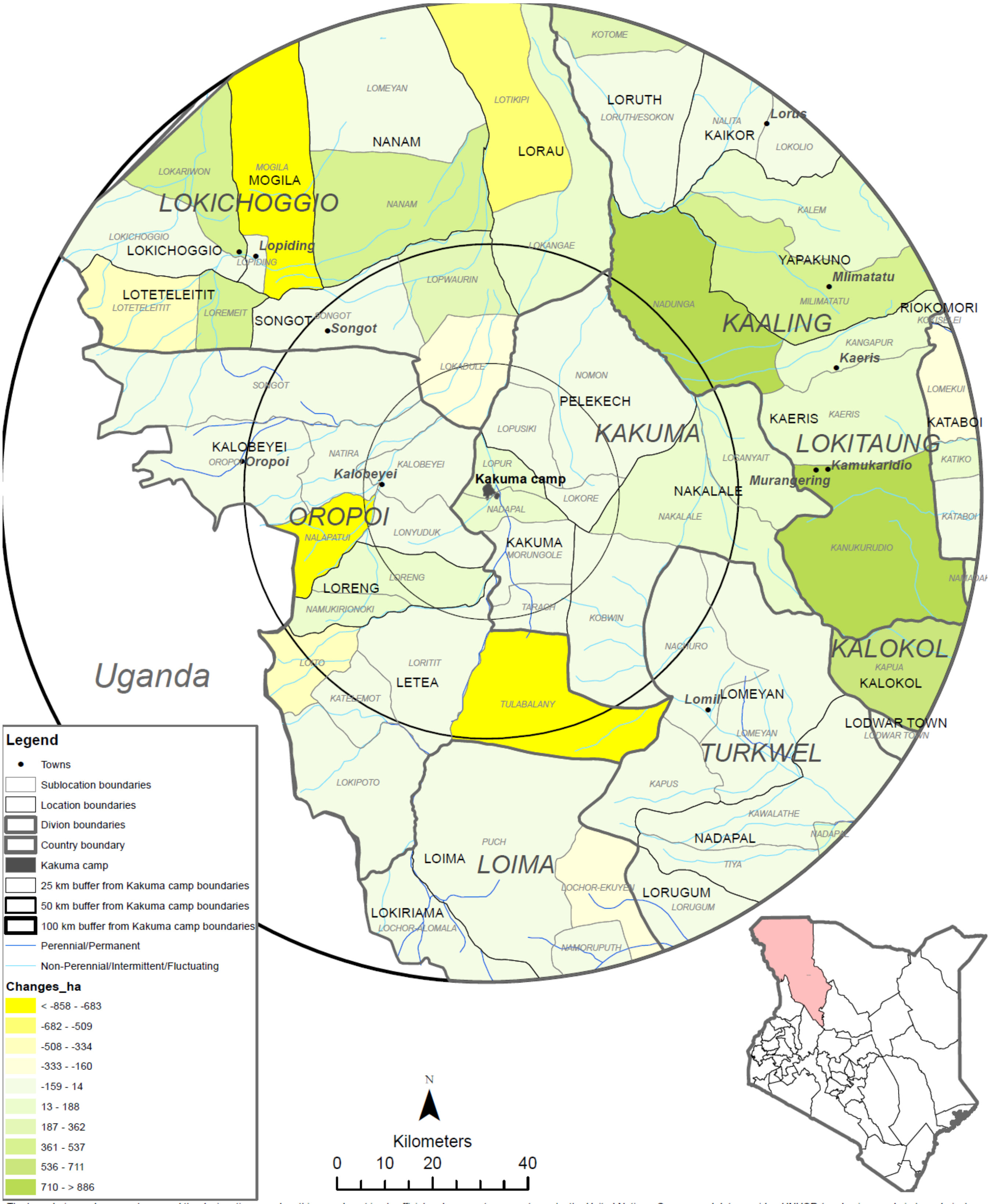
Figure 11 Map of land cover up to 100 km from Kakuma camp (2018)



The 2018 map shows the presence of scattered areas of woody vegetation especially in the areas between 25-100 km buffers. However, the main vegetation cover is shrubland. Despite the challenges encountered in differentiating between mixed vegetation and indigenous trees from *Prosopis* (e.g. due to the similar spectral signature of evergreen *Prosopis* and evergreen or semi-evergreen native species) and that comparing maps does not account for the single map's, statistics of changes of *Prosopis* riverine extent per sub-locations have been calculated and showed in the map in Figure 12.

The area around the camp of 100 km buffer highlights an overall increase in the extent of *Prosopis* along the waterbodies. However, there are some sub-locations which show a significant decrease, notably Mogila, Tulabalany and Nalapatui. One possible cause of the loss of *Prosopis* riverine between 2014 and 2018 in certain areas is the severe drought in 2017 that has caused a temporary dieback. On the other hand, we can notice an increase (i.e. dark green areas) on the west site, Nadunga, Kanakurudio sub-locations.

Figure 12 *Prosopis riverine* changes (hectares) between 2014-2018 by sub-location



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Sources and data provider: UNHCR (roads, rivers, admin boundaries).

Statistics on current biomass stock per land cover class were obtained by applying the biomass factors from the biophysical field survey. This analysis aims to provide current available resources around the refugee camp using the three buffer boundaries. Table 15 shows that moving from 25 km out to 100 km the available resources increase, with the biomass stock goes up 20-fold, mainly due to the mixed vegetation and shrubland. However, the increase of woody vegetation from 25 to 100 km buffer is not significant considering the extent of the buffers: woody biomass proportions[12] over the total buffer areas are respectively of 16, 26 and 31 percent for the 25-50 and 100 km buffers respectively. Therefore, although woody resources are available around the refugee camp, the accessibility becomes a limiting factor for the hosted population since the resources are located outside the walking distance. In other words, the refugee camp strongly depends on outer support and to accessibility to wood fuel markets.

Table 15. Biomass stock per land cover class in 25-50-100 km buffers around Kakuma camp (2018)

Year 2018	**25 km buffer**			**50 km buffer**			**100 km buffer**		
Land cover class	**Area (ha)**	**% (over total area)**	**Biomass stock (t)**	**Area (ha)**	**% (over total area)**	**Biomass stock (t)**	**Area (ha)**	**% (over total area)**	**Biomass stock (t)**
Prosopis riverine	4,128	1.8	180,114	14,107	1.7	615,471	44,058	1.61	1,922,257
Prosopis plain	3,184	1.4	68,265	7,503	0.9	160,863	30,469	1.11	653,245
Mixed vegetation	2,946	1.3	155,547	24,063	2.8	1,270,528	85,600	3.12	4,519,703
Indigenous trees	2,310	1.0	15,615	18,281	2.2	123,577	90,879	3.32	614,343
Shrubland	22,682	10.0	82,788	157,230	18.5	573,891	603,603	22.02	2,203,151
Total biomass (t)			**502,329**			**2,744,330**			**9,912,699**
Total woody area (ha)	35,250			221,184			854,609		
Total area of the buffer (ha)	*227,334*			*849,617*			*2,741,068*		

3.2.3 Biomass stock changes (2014-2018)

Biomass loss was mapped by combining the land cover maps for 2014 and 2018 with the results of the time series analysis obtained from the Breaks for Additive Seasonal and Trend (BFAST). Details are provided in the methodology section (see the Annex). The net woody vegetation changes have been computed by difference between gain and loss extents in the three buffer zones (i.e. 25-50-100 km) (*Figure 13*). It is possible to note that in the smallest radius from the camp, there are not major losses and instead *Prosopis* spp. expansion seems to the prevailing biomass stock change. However, the limited change in this buffer might be also explained by the limited woody biomass resources available. In the 50 and 100 km buffers instead, it is possible to note that main losses are found in the areas between 50-100 km and especially outside the country boundary (e.g. a loss of 6,663 ha of shrubland has been detected in the entire 100 km buffer *versus* a loss of 2,539 ha of shrubland only in the Kenyan territory). The vegetation cover where most losses were detected in the 50 km buffer is shrubland (-108 ha in 50 km), while net positive changes in *Prosopis* classes in the 50 km buffer was detected (e.g. *Prosopis plain* +317 ha in 50 km *versus* 29 ha in the 100 km considering only Kenyan territory).

[12] It is calculated computing the proportion of the total woody area (ha) over the total area of the buffer for the three buffers.

Figure 13. Net gain and loss within the 25, 50 and 100 km buffer

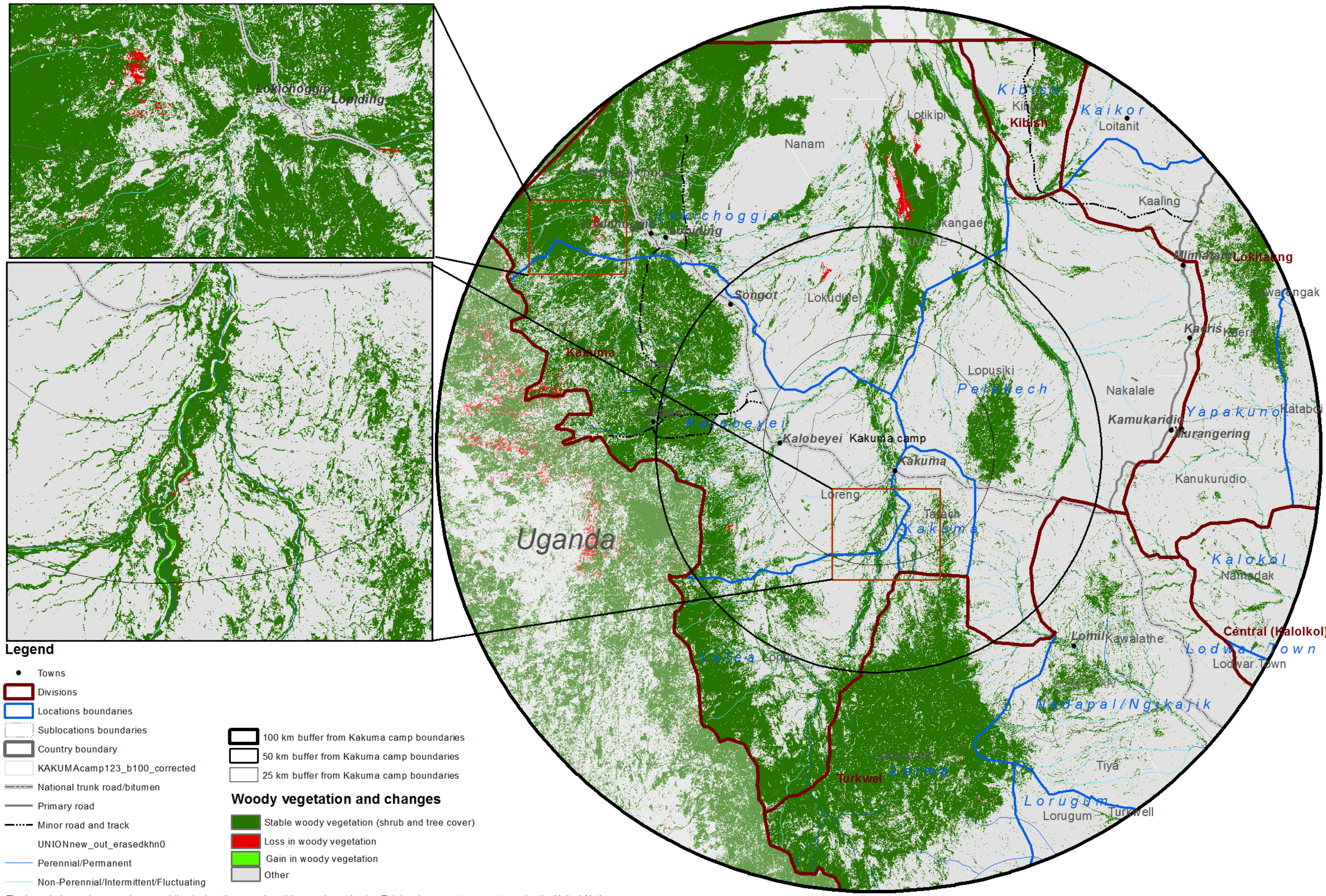
Net (+gain & -loss) LULC and biomass 2014-2018										
	25 km		50 km				100 km			
LULC	ha	t	ha (entire 50 km buffer)	t (entire 50 km buffer)	ha (only Kenya)	t (only Kenya)	ha (entire 100 km buffer)	t (entire 100 km buffer)	ha (only Kenya)	t (only Kenya)
Prosopis riverine	+213	+9,279	+1,422	+62,056	+676	+29,486	-2,284	-99,674	+562	+24,526
Prosopis plain	+152	+3,249	+537	+11,511	+317	+6,796	-165	-3,537	-29	-625
Mix vegetation	+45	+2,390	+219	+11,545	+164	+8,663	-1,007	-53,086	-320	-16,898
Indigenous trees	-2	-15	-981	-6,632	-89	-600	-3,406	-23,026	-697	-4,708
Shrubland	+135	+494	-5,051	-18,436	-108	-394	-6,663	-24,320	-2,539	-9,268

Figure 14 shows the scattered gain and loss in woody vegetation in the AOI. There are few areas of visible change (and in particular loss), but the change that is occurring is highest in the 100km buffer area. The selected zoomed area shows the presence of change along the Tarach river, indicating that the collected wood could come from areas close to the seasonal watercourse and within the 25 km buffer. This is due to the fact that the vegetation is mainly concentrated here. From the other side, loss detected areas such those in Lotikipi can be explained by the shortage of water during dry years since *Prosopis* is highly water-dependent.

It is important to bear in mind that statistics are derived from the pixels count from the maps and therefore precision and accuracy are not provided here[13]. However, estimates should give indication on the current trends, which indicate that probably there is not a significant impact on the refugees in the nearest surrounding considering that losses could be actually related to natural phenomena (such as drought). However, changes are mostly detected between 50-100 km buffers where woody collection for charcoal is collected by local institutions to meet the refugee's needs. Shrubland seems to be the most affected vegetation cover but by extending the analysis including the portion of the 100 km buffer that fall in Uganda, major changes are found in tree cover areas as well.

[13] The uncertainty of the maps in terms of accuracy and precision could be assessed by comparing the maps with higher quality reference data (FAO & UNHCR, 2016).

Figure 14. Woody vegetation changes within 100 km of Kakuma between 2014 and 2018



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
Sources and data provider: UNHCR- Locations, Roads, Rivers and administrative data.

3.3 Linking woodfuel demand and supply

Table 16 shows estimated potential woodfuel supply from Prosopis and demand for Kakuma camp and for each sub-location falling in the AOI. The population of each sub-location has been accounted for their entirety also for those that are sliced by the external limit of the AOI (100 km buffer radius). The woodfuel is expressed as oven-dry matter – including both firewood and charcoal (the latter converted to firewood-equivalent). Assuming that the total standing biomass stock from *Prosopis* riverine is used as the only source of woodfuel for cooking at household level, current stocks could meet the demand of host and refugee communities for more than 10 years.

Table 16. Estimated woodfuel demand and supply from Prosopis riverine per each sub-location in the AOI (100 km buffer)

Sub-location/refugee camp	Population 2018	Annual woodfuel consumption (t/yr)	Biomass stock from *Prosopis* riverine (t)
Kaeris	7,171	2,740	37,920
Kanakurudio	5,809	2,220	25,563
Kataboi	5,436	2,077	14,462
Kawalathe	1,905	728	81,463
Kibish	1,480	565	64,527
Lodwar Town	18,193	6,953	1,995
Loitanit	5,480	2,094	1,402
Lokangae	12,218	4,669	305,741
Lokiryama	4,676	1,787	83,022
Lokudule	3,387	1,295	193,763
Lopusiki	6,299	2,407	60,346
Loreng	4,152	1,587	117,059
Loritit	11,029	4,215	139,127
Lorugum	6,127	2,341	2,988
Lotikipi	9,579	3,661	74,984
Lowarengak	7,089	2,709	12
Mogila\Lokichogio	18,815	7,190	302,407
Nakalale	4,562	1,743	17,564
Namadak	5,206	1,989	111,153
Nanam	7,247	2,769	55,339
Songot	2,450	936	210,506
Tarach	7,678	2,934	10,111
Tiya	3,781	1,445	6,208
Turkwel	10,527	4,023	8
Kakuma refugee camp	185,449	108,302	-
Total	**355,745**	**173,379**	**1,917,670**

Note: Woodfuel consumption has been converted from air-dry basis to oven-dry basis assuming a firewood moisture content of 15 percent in order to compare with data of potential supply. *Estimate of woodfuel demand takes into account only the household consumption, although field observations highlighted other woody biomass demand for construction and energy for commercial and economic activities, particularly from host communities. The refugee population of Kakuma is based on UNHCR data as of January 2018.*

4. Recommended technical interventions

Wood is the main source of energy for both refugee and host communities in Kenya. Demand for woodfuel is expected to increase with rising population, as other modern and clean energy options for cooking are unaffordable or unavailable. This could increase an imbalance between demand and sustainable supply, placing growing strains on the wellbeing of both hosts and refugees, and causing a risk of environmental impacts in and around the refugee settlement. 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 woodlands**
2. **Control and management of *Prosopis* through its utilization**
3. **Sustainable management of indigenous vegetation**
4. **Enhancement of energy efficiency**

Each option is described below in more detail.

4.1 Rehabilitation of degraded woodlands

The increasing woodfuel demand and the associated land degradation threatens the livelihood of the area, whose economic activities include pastoralism, firewood and charcoal production and trade. Thus, it is recommended that the degraded lands within and around the refugee settlement camp be rehabilitated in order to restore the productivity of the land for livestock and human sustenance. The rehabilitated areas will then form "greenbelts" around the camp. These are essentially protected areas planted with indigenous species that provide a buffer zone between the refugee camp and surrounding bushlands, and a genetic stock for ongoing and future regeneration at such time in the future when the camp should close. It is crucial to define rehabilitation goals such as recovery of indigenous species and ecosystem functions, taking into account the biophysical and socio economic factors in order to identify the most cost-effective strategy. In this study, the proposed approach is the assisted natural regeneration that involves the deliberate protection of degraded land from pressures to enhance and accelerate natural processes with the aim of re-establishing healthy, resilient and productive ecosystems (FAO, 2015). This intervention also includes the enrichment of tree-planting whereby nursery-grown seedlings are planted that favour the use of native species within existing vegetation to complement natural regeneration processes.

Being a dry ecosystem, specific tree species which are adapted to this type of climate and topography are encouraged. Studies show that tree species such as *Acacia elatior, Cordia sinensis* and *Balanites aegyptiaca* are adaptable to the ecosystem (Muturi *et al*., 2014). These could be grown in existing nurseries and out-planted in the field. It is not recommended that new nurseries be established, but rather that seedlings of appropriate species be purchased from existing nurseries. This will incentivize the nursery operators and promote biodiversity conservation among the population, in particular for the host community, and thus enhance sustainability of rehabilitation measures.

In order to improve the survival of the regenerating vegetation, exclusion of animals and people by building enclosures is recommended. There is already successful experience with regeneration and establishment of greenbelts through enclosures in the area. For example, the Zurich Foundation sponsored LOKADO to establish 11 ha of enclosed greenbelt. GIZ also previously established greenbelts through enclosures in the area, and an additional 30 ha of enclosed greenbelt was restored through WFP's climate change resilience project. The recommended intervention would involve identifying and demarcating bare and degraded areas in consultation with the host community and local leaders/ authorities. The next step would be to establish a fence around the areas using barbed wires or chain link, or through traditional approaches such as hedges. Micro-catchments can then be constructed to harvest and store water for planting suitable indigenous tree species. Planting should be done during the rainy season, when water is available to ensure high establishment and survival rate.

Figure 15. Assisted natural regeneration in a fenced enclosure

To ensure no encroachment into the enclosures, caretakers would be needed. The concept of community Resource Utilization Monitors (RUM) has already been embraced in the area, and these could be used to protect the enclosures. RUMs are members of the community tasked with monitoring and ensuring compliance with agreed conservation, woodland management and grazing rules. They can also be trained to provide technical support to different interest groups (such as firewood collectors and charcoal producers) within the community. For instance, they could be trained on various biomass harvesting technologies, improved charcoal kilns, and *Prosopis* harvesting and utilization, among others topics. In turn, the RUMs can impart the same skills to other community members and interest groups during their routine monitoring exercises, as well as undertake awareness campaigns, training and other rehabilitation support activities.

According to remote sensing analysis, the total area of biomass loss within the AOI (100 km buffer) is 3,585 ha. In order to give an indicative cost of rehabilitation, this was divided into 358 greenbelts of 10 ha each (Table 17).

Table 17. Indicative cost of assisted natural regeneration per 10 ha greenbelt

Buffer zones of AOI	**Woody vegetation loss 2014-2018 (ha)**					**Number of 10 ha greenbelts**
	Prosopis riverine	***Prosopis plain***	***Mixed vegetation***	***Indigenous trees***	***Shrubland***	
0-25 km buffer	-	-	-	2	-	-
25-50 km buffer (only Kenya)	-	-	-	87	108	19
50-100 km buffer (only Kenya)		29	320	608	2,431	339
Total		**29**	**320**	**697**	**2,539**	**358**

The indicative cost of establishing these 358 greenbelts is provided in Table 18. The costing is based on a unit cost of US$ 38,180 per 10 ha greenbelt over 5 years of management. This includes the cost of land identification and demarcation, fencing (fencing posts, barbed wire, chain link, nails, etc.), land preparation (digging bunds and pitting), seedlings, out-planting, guarding and administrative overheads, among others.

Table 18. Indicative investment and operational costs of establishing greenbelts

Description	Years	1	2	3	4	5	Cost per one greenbelt (10ha)	No. of greenbelts	Total cost
	US$						US$		US$
Fencing, micro-catchments, seedlings	25,000	1					25,000	358	8,950,000
Enrichment planting and tending	300		1	1	1	1	1,200	358	429,600
Protection	900		1	1	1	1	4,500	358	1,611,000
Community outreach	500		1	1	1	1	2,500	358	895,000
Administrative overheads (15%)	3,960		1	1	1	1	4,980	358	1,782,840
Total							**38,180**		**13,668,440**

However, for maximum benefit, this enclosure approach should be integrated with grazing management. Where the seed load of grasses within the soils is low, it is recommended that grass species be broadcasted/ intercropped with the regenerating trees to provide pasture for livestock. A detailed land use plan should be developed for each degraded area that integrates the other land use activities into the regeneration process.

One major hindrance to natural regeneration is livestock. Therefore, it is recommended that areas under regeneration could be set aside for a system of deferred grazing, where livestock are only allowed into the enclosures after the areas have undergone sufficient rehabilitation. Such a deferred grazing system is consistent with the traditional transhumance practices of the local population whereby the community members have seasonal grazing areas that are clearly delineated and designated for wet and dry season grazing (Muturi *et al*., 2014).

An important enabling factor for rehabilitation and grazing management is the active involvement of the local community in the design, planning and implementation of the rehabilitation and grazing management project. This calls for training of community members on various methods of woodland regeneration and rehabilitation, and the benefits they are likely to reap. Local leaders, especially the elders, should be involved in the management of the deferred grazing system and in the regeneration process. Refugee communities should also be sensitized on the need for and benefits of the regenerating green belts.

4.2 Control and management of *Prosopis* through its utilization

Since its introduction in the 1970s in Kakuma, *Prosopis* has become invasive and is aggressively replacing the native species, especially in degraded areas and along the riverine areas and other water-ways. This is especially the case along Kakuma, Kalobeyei and Tarach Rivers, and in Lokangai and Lopur areas. In some areas, such as the riverine, *Prosopis* thickets have become very dense and sometimes impenetrable for opportunistic harvesting, which would have served to reduce its spread - although from the field data and observations, the existing areas of Prosopis riverine have a high potential to increase the supply of woodfuel and other products (e.g. poles). Table 16 above shows the sub-locations with considerable hectarage of *Prosopis* riverine (derived from remote sensing analysis).

Since, the eradication of *Prosopis* in the area has been tried without success, intervention measures should be directed towards utilization. This is also in line with the Kenya's Vision 2030, which has prioritized exploitation and utilization of *Prosopis* as a control and management strategy. One silvicultural way to manage and control is thinning and pruning to less dense spacing. This practice can provide different products such as firewood, charcoal and poles, and discourage or reduce the establishment of new *Prosopis* seedlings through an increased growth of indigenous shrub and grass species, thereby resulting in biodiversity and productivity improvements (Muturi *et al*., 2014).

There is thus a need for a concerted multi-year programme to control and manage the spread of invasive *Prosopis* and to protect the natural vegetation and enable native species to reduce the spreading of *Prosopis*. A cost-effective means of control could be to scale up the commercial use of *Prosopis* and to support the establishment of new enterprises to foster the already existing use of this invasive species as a source of fuel for the refugee settlements and to provide woodfuel further afield to markets in Lodwar and the rest of Kenya. Similar initiatives have been successfully piloted for *Prosopis* in Baringo and Bura in Kenya. Since firewood supply by UNHCR/LOKADO has been reported to meet only up to 30 percent of refugee demand, increasing its firewood provision to 50 percent, or beyond, of the refugee household woodfuel demand represents an interesting market for firewood harvesters and charcoal producers. This increased supply would result into more cutting of *Prosopis* for woodfuel and thereby control its spread and would have great benefits for local people all over the area in terms of cash injections while improving energy access of refugees too.

The major challenges to production of woodfuel from *Prosopis* include negative publicity on the species, non-commercialization of charcoal production and trade, low recoveries, low technical skills in charcoal production and high cost of improved kilns. Yet *Proposis* spp. (also known as mesquite) are indeed known worldwide to produce a good firewood and high-quality charcoal (exemplified in Oduor and Githiomi, 2013), and hence can be exploited for charcoal production.

Interventions should include training of woodfuel producers in appropriate silvicultural methods such as thinning, pruning and correct spacing and number of stems of trees to be left standing. Other silvicultural measures could entail organizing *Prosopis* harvesting areas into coupes and specifying what dimensions (diameter limits) of tree can be harvested. The wood harvesters can then harvest the coupes in a rotational manner.

Additionally, there is a need for the host community to organize into associations for harvesting, charcoal production, transportation, and marketing. The formation of associations is in line with the charcoal regulations, which require commercial charcoal producers to organize into charcoal associations to ensure self-governance of charcoal production. Linkage with the County Government is needed, as the entire charcoal production has been devolved. Thus, the intervention would also involve supporting the Turkana County Government to develop charcoal laws and regulations and to take a lead role in regulating charcoal trade in the county.

According to remote sensing analysis, there are 25 sub-locations in the AOI with *Prosopis* thickets (see Table 16 above) and where *Prosopis* control and management are required. These are the areas where the *Prosopis* management should be focused. The proposed activities and the indicative cost to promote the *Prosopis* management are provided in Table 19. They include the cost of raising awareness on *Prosopis* in each sub-location, sensitizing communities on *Prosopis* harvesting and silvicultural management practices, setting up and running *Prosopis* management demonstrations in each sub-location, training/technical support, and support to Turkana County Government. The cost of technical support to the County Government includes the cost of: sensitizing Members of County Assemblies and respective County Assembly Committees on devolved forestry functions and the need for County Charcoal Laws and Regulations; supporting the relevant County Executive Committee Member (for Environment and Natural Resources) to draft Charcoal Bills and Subsidiary Legislation for presentation to the Assembly for debate; holding public consultations on the Draft Bill and Regulations; among others.

Table 19. Indicative cost of capacity-building to control and manage Prosopis

Activity	**Estimated cost per sub-location**	**No. of sub-locations**	**Total cost**
Creating awareness on *Prosopis* and associated benefits, harvesting methods and silviculture	30,000	25	750,000
Developing guidebooks and pamphlets on silvicultural management practices	20,000	25	500,000

Setting up and running demonstration plots on silvicultural practices	30,000	25	750,000
Training of firewood harvesters and charcoal producers in harvesting methods and silvicultural management	17,500	25	437,500
Supporting County Government (County laws and regulations)			1,000,000
Total			**3,437,500**

Another resource that could be extracted from *Prosopis* for commercial purpose are the pods. Some studies show that *Prosopis* pods contain 10–20 percent protein, 30–60 percent carbohydrates (of which up to half can be sugar), and acceptable levels of minerals and amino acids (MoAWFLMR, 2014), and can thus be used as livestock feed. However, the exploitation of pods for feedstock production needs further analyses. Key issues to be considered include availability of market and willingness to pay, yield and availability of pods, required technology for pod processing (e.g. pod milling plant) and skills required to run a pod-milling enterprise. Finally, beekeeping could also be integrated into the *Prosopis* management plan. The flowers are reported to provide high quality honey; as such, bee hives could be introduced and honey harvesting by host communities for commercial sale promoted.

It is important to note that the current access to the *Prosopis* harvesting areas is often very limited by poor or non-existent roads and bridges. This means that harvesting is restricted to those areas that are reachable by lorries (especially during the rainy season), resulting in disproportionately higher stocks in inaccessible areas compared to accessible ones. Given the fast regeneration of *Prosopis*, there is little motivation to access untouched stock in relatively accessible areas. In future as the benefits of firewood sale become clear to the larger population, a detailed plan on the management of *Prosopis* will be required to organize appropriate harvesting rotations according to its availability and accessibility among the community members.

4.3 Promotion of sustainable management of indigenous vegetation

Demand for woodfuel at Kakuma camp, overgrazing and invasion of *Prosopis* are the three main causes of loss of native vegetation in Turkana County. In Turkana West sub-county, the biggest cause of vegetation degradation is arguably harvesting of trees for woodfuel. It is this degradation that drives the current call for rehabilitation of land around the camp and in other areas of the county. The key drivers of degradation while harvesting firewood are:

1. Unsustainable methods of harvesting the trees;
2. Intensified harvesting of trees in proximity to the refugee camps and local villages;
3. Excessive demand for woodfuel arising from inefficient production and utilization technology;
4. Overgrazing by the host and surrounding communities; and
5. Lack of planning for sustainable natural resource utilization.

The proposed intervention is intended to address the above causes of unsustainable harvesting of native woodlands and degradation of the native vegetation. This intervention includes awareness and training on harvesting methods of indigenous trees and appropriate harvesting cycles, and restricting harvesting of native trees to only dead and dying wood. Degraded native woodlands will be restored through the rehabilitation proposed in section 4.1. Thus, the intervention proposed here focusses on un-degraded native woodlands. These native woodlands can be organized into harvesting coupes and movement from one coupe to the next controlled by the RUMs. The latter would also be charged with training the harvesters, during routine monitoring exercises, on suitable harvesting methods. Table 20 summarizes the indicative cost of the proposed activities under this intervention. These include the cost of creating awareness in each sub-location every year for 26 sub-locations, setting up and running demonstrations, and training and facilitating RUMs to provide technical support to different user groups in the respective sub-locations.

Table 20. Indicative cost to promote sustainable management of indigenous species

Activity	Year 1	Year 2	Year 3	Year 4	Year 5	Total (US$)
Awareness and training (harvesting methods and cycles)	26,000	13,000	26,000	13,000	13,000	91,000
Demonstration plots (harvesting methods and cycles)	130,000	10,000	5,000	10,000	5,000	160,000
Resource Utilization Monitors	112,320	112,320	112,320	112,320	112,320	561,600
Total						**812,600**

4.4 Enhancement of energy efficiency

Many attempts have been made to increase the uptake of improved cookstoves by the refugee and host communities. Although there is appreciable adoption of improved cookstoves among the refugees, estimated at 91 percent for Maendeleo firewood stoves, a significant proportion (estimated at 58%) of host community households still use the 3-stone fire which is inefficient, produces much smoke, and poses environmental and health hazards (Chepkurui, 2016; WHO, 2018). Nevertheless, it is noteworthy that 42 percent of the host community households use the 3-stone fire in combination with improved stoves, indicating that they are receptive to improved options. Moreover, several respondents from both the host and refugee communities prefer the Maendeleo firewood stove to other improved cookstoves, citing fuel conservation, familiarity and convenience benefits. This further indicates that there is willingness on the part of both categories of households to use improved cookstoves.

Therefore, efforts should be made to extend the adoption of improved cookstoves to the entire host and refugee population. Especially for the host community, this will ensure replacement of the 3-stone fire. To facilitate adoption of improved cookstoves, there is need for enhanced sensitization on their environmental and health benefits. With a potential reduction in firewood consumption of about 55 percent compared to the 3-stone fire, a full adoption of Maendeleo stove among the host populations could reduce the firewood consumption by about 13%. Table 21 below illustrate potential saving from 100 percent adoption of improved stoves among the refugees and host communities.

Table 21. Estimated reduction in firewood consumption resulting from adoption of Maendeleo firewood stoves

Sub-location	Population 2018	Annual firewood consumption (t/yr)	Estimated reduction in firewood consumption (t/yr)
Kaeris	7,171	2,356	1,604
Kanakurudio	5,809	1,908	1,299
Kataboi	5,436	1,786	1,216
Kawalathe	1,905	626	426
Kibish	1,480	486	331
Lodwar Town	18,193	5,976	4,070
Loitanit	5,480	1,800	1,226
Lokangae	12,218	4,013	2,733
Lokiryama	4,676	1,536	1,046

Lokudule	3,387	1,113	758
Lopusiki	6,299	2,069	1,409
Loreng	4,152	1,364	929
Loritit	11,029	3,623	2,467
Lorugum	6,127	2,013	1,371
Lotikipi	9,579	3,147	2,143
Lowarengak	7,089	2,329	1,586
Mogila\lokichogio	18,815	6,181	4,209
Nakalale	4,562	1,499	1,021
Namadak	5,206	1,710	1,165
Nanam	7,247	2,381	1,621
Songot	2,450	805	548
Tarach	7,678	2,522	1,717
Tiya	3,781	1,242	846
Turkwell	10,527	3,458	2,355
Kakuma refugee camp	185,449	67,689	64,338
	Total consumption	**123,632**	**102,436**
Reduction in consumption from adoption of Maendeleo firewood stoves			**21,196**

Note: The host population of the sub-locations are based on national statistics as of 2009 (KNBS, 2010), and projected to 2018 based on an average annual growth rate of 2.9 percent as reported in the Population Situation Analysis Report for Kenya (PSA, 2013). Data for Kaaling sub-location are not provided as there was no population data available in the 2009 census. The refugee population of Kakuma is based on UNHCR data as of January 2018.

For both the host and refugee communities, the most effective technologies are likely to be those that have low household investments, require low levels of technological skills to make and operate, are familiar to them, and especially for the hosts, are compatible with their transhumance lifestyle. As such, focus should be to promote and make easily accessible improved cookstoves such as the Maendeleo firewood stoves. Other stoves that could be promoted are the various types of Rocket stoves. A cost-effective approach is to promote enterprise in improved stove production and sales within the host population through training in construction/fabrication of the stoves and support in establishing start-up facilities and materials and linking them to markets. Two or -three people could be trained on construction of Maendeleo stoves or similar technology among the host communities, who in turn could venture into stoves construction/installation at a fee. This model has worked well in other parts of the country and in Kakuma refugee camp and has increased household use of improved cookstoves. Such installers could also be trained on making liners for fabrication of Maendeleo stoves. The indicative cost of this activity is detailed in Table 22 below. The cost entails training two or three stove constructors and installers in each sub-location for all 26 sub-locations in the AOI.

Table 22. Indicative cost for promotion of improved cookstoves in the host communities

Description	**Years**	**1**	**2**	**3**	**4**	**5**	**Total**
	US$						US$
Awareness creation among host communities	400,000	1	1	1	1	1	2,000,000
Training of improved cookstoves installers and repairers (fixed local improved stoves/ fixed Maendeleo/Jiko Kisasa)	100,000	1	0.5	1	0.5	0.5	350,000

Development of demonstrations for fixed local improved stoves/fixed Maendeleo/Jiko Kisasa	50,000	1	0.2	1	0.2	0.2	130,000
Support to improved Jiko entrepreneurs (firing kilns, moulds, etc.)	50,000	1	1	1	1	1	250,000
Total							**2,730,000**

The intervention to enhance the energy efficiency also considers support to the development of more sustainable charcoal value chains, including the provision and training on the use of improved charcoal kilns. A high proportion of both refugee (50%) and host (24%) community households use charcoal for cooking. Through this intervention, technical and business skills and entrepreneurship training should be provided to groups of host communities. Linkages with existing micro-finance services should be established for these groups. A shift from traditional charcoal-making kilns to more efficient alternatives could increase wood conversion efficiency from 15-20 percent of the traditional kilns 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 labour. Improved charcoal kilns can be produced in Kenya in various sizes, and key advantages, such as mobility, should be considered.

A portable steel kiln was considered in the costing analysis (Table 23), with a production capacity of 150 t of charcoal per batch, operating 300 days per year. This type of portable kiln might 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 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$)
Household training package	US$/household			
Demonstrations for energy-saving measures at household level	5	1	1	10
Equipment and materials	15	1		15
Total per household	**US$**			**25**
Improved charcoal production	US$/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
Total per charcoal unit	**US$**			**4,700**

The reasons to invest in charcoal production are four-fold: (i) to reduce pressure on harvesting of indigenous species as charcoal feedstock and thus enhance conservation; (ii) to enhance utilization and control of the invasive *Prosopis* by using it as charcoal feedstock; (iii) to enhance host community livelihoods by improving charcoal productivity per unit feedstock, hence increase incomes for those engaged in charcoal production; and (iv) to improve access to charcoal by those refugees who prefer this fuel over firewood such as the Somalis and Ethiopians, and those involved in cottage and service industries, such as restaurants.

Current charcoal production in the area is largely informal and characterized by use of inefficient traditional earth kiln technology, with a conservative recovery rate of less than 20 percent. With an average daily charcoal consumption of 0.3 kg pppd in Kakuma Camp and for a population of 185,449 refugees, this translates to about

30 tonnes of charcoal per day for the 50 percent of the refugee households that use charcoal. If the recovery rate is improved to 30 percent (Muia, 2005) through adoption of improved kilns, this would lead to a saving of 19 t of biomass feedstock per day. This is equivalent to a saving of 6,848 t per year, with a consequential decrease in pressure on the use of the wood biomass for charcoal production in the area.

Figure 16. Charcoal on sale by the roadside

Table 24 shows the indicative costs of providing of improved kilns and a household training package (at a cost of US$ 25 per household), taking into account the total households and the current charcoal consumption in the refugee and surrounding host communities within the AOI (see Table 5 above).

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

Refugee camp/ sub-location	Population 2018	Total HHs (based on average HH size reported)	Total HH training package (US$)	Estimated charcoal consumption (t/yr)	Number of improved kilns	Cost of improved kilns (US$)	Total cost of training package & improved charcoal (US$)
Kaeris	7,171	1,195	29,875	738	5	23,124	52,999
Kanakurudio	5,809	968	24,200	598	4	18,737	42,937
Kataboi	5,436	906	22,650	560	4	17,547	40,197
Kawalathe	1,905	318	7,950	196	1	6,141	14,091
Kibish	1,480	247	6,175	152	1	4,763	10,938
Lodwar Town	18,193	3,032	75,800	1,873	12	58,687	134,487
Loitanit	5,480	913	22,825	564	4	17,672	40,497
Lokangae	12,218	2,036	50,900	1,258	8	39,417	90,317
Lokiryama	4,676	779	19,475	481	3	15,071	34,546
Lokudule	3,387	565	14,125	349	2	10,935	25,060
Lopusiki	6,299	1,050	26,250	648	4	20,304	46,554
Loreng	4,152	692	17,300	427	3	13,379	30,679
Loritit	11,029	1,838	45,950	1,135	8	35,563	81,513
Lorugum	6,127	1,021	25,525	631	4	19,771	45,296

Lotikipi	9,579	1,597	39,925	986	7	30,895	70,820
Lowarengak	7,089	1,182	29,550	730	5	22,873	52,423
Mogila\lokichogio	18,815	3,136	78,400	1,937	13	60,693	139,093
Nakalale	4,562	760	19,000	470	3	14,727	33,727
Namadak	5,206	868	21,700	536	4	16,795	38,495
Nanam	7,247	1,208	30,200	746	5	23,375	53,575
Songot	2,450	408	10,200	252	2	7,896	18,096
Tarach	7,678	1,280	32,000	790	5	24,753	56,753
Tiya	3,781	630	15,750	389	3	12,189	27,939
Turkwell	10,527	1,755	43,875	1,084	7	33,965	77,840
Kakuma refugee camp	185,449	30,908	772,700	50,767	338	1,590,699	2,363,399
Total cost							**3,622,273**

Note: The host population of the sub-locations are based on national statistics as of 2009 (KNBS, 2010), and projected to 2018 based on an average annual growth rate of 2.9 percent as reported in the Population Situation Analysis Report for Kenya (PSA, 2013). Data for Kaaling sub-location are not provided as there was no population data available in the 2009 census. The refugee population of Kakuma is based on UNHCR data as of January 2018. (HH: household)

There is need to promote and encourage use of efficient carbonization technologies such as improved earth, drum, portable metal and the casamance kilns. These improved kilns have a potential efficiency of over 25 percent and can reduce the harvesting of trees for charcoal production, thereby reducing pressures on the environment (Muia, 2005). They also have a relatively shorter carbonization period compared to earth kilns (UNDP, 2015) and a higher through put compared the traditional earth kiln. KEFRI and FAO have already trained some charcoal producers in Turkana County on the use of the improved kiln, and this could be scaled up.

Barriers to adoption of improved charcoal kilns include their relatively high initial cost and the low awareness and limited technical skills to operate the kilns among charcoal producers. Another barrier is the lack of organization of the producers into associations that can enable them to pool resources, invest in better technologies and have a collective bargaining and lobbying power. Thus, the proposed intervention also includes formation and strengthening of charcoal producer associations (CPAs).

The most effective means to drive this intervention is to promote formation of one charcoal producer group in each sub-location comprising all those members of the host community involved or willing to engage in charcoal production. These groups can then organize into and be part of the larger CPA. Once the CPA is formed, the awareness, training and support will then target the charcoal producer groups. Training should not be limited to skills on improved kilns only, but also to appropriate harvesting methods, business skills, basic book-keeping, and savings and finance management.

With regard to firewood provision to the refugee community, the current arrangement in which LOKADO purchases firewood from host communities through an elaborate tendering process seems to be working very well. However, the arrangements need further strengthening, including through better organization of the firewood harvesters. Interviews with LOKADO showed that it has established 15 firewood-harvesting committees to manage the tendering process. However, these committees do not cover all areas with *Prosopis* within the AOI. Thus, there is need to expand coverage of the committees and strengthen the current arrangement by organizing firewood harvesting committees – along with the charcoal producer groups proposed above - into woodfuel producer associations. These are larger and more diversified groups that include both current and new firewood harvesters and charcoal producers. The intervention recommends that one association be established in all the locations in the AOI. In other words, charcoal producers in each sub-location are organized into CPAs, the firewood collection committees established by LOKADO are expanded to cover all the 25 sub-locations with *Prosopis* thickets, then the two – CPAs and firewood collection committees – congregate to form the woodfuel producer associations for marketing and lobbying. There are 16 locations in the AOI and thus we propose the formation of 16 woodfuel producer associations. The associations will enable commercialization of production and supply of woodfuel (both firewood and charcoal) by the communities, which will help the communities to get better returns, and contribute to sustainable management and control of *Prosopis*, and conservation of indigenous vegetation.

Additionally, we recommend that the members of the associations (and other user groups under the association) organize into Village Savings and Loans Schemes (VSLS) to encourage a culture of savings and investments, and improve the lives of woodfuel producers. From experience elsewhere, the VSLS will also serve as a critical glue bringing the community together after the end of the project because of the individual interest in the financial success of the scheme. The associations will also provide an avenue for reaching communities with rehabilitation and sustainable management of forest resources and trainings and awareness campaigns. The associations and their constituent user groups can be trained on different skills and technologies including peace building and conflict management, improved harvesting and management of indigenous species, silvicultural management practices for *Prosopis*, efficient charcoal production, group dynamics, and general business skills. The indicative cost for supporting one woodfuel producer association in each location over a five-year period is provided in Table 25 below. The activities to be supported under this intervention are also indicated.

Table 25. Indicative cost for establishing and strengthening community woodfuel producer associations

Activity	**Years**	**1**	**2**	**3**	**4**	**5**	**Total**
	US$						US$
Sensitization and awareness creation, including community outreach	240,000	1					240,000
Registration of the group and election of office bearers	8,000	1					8,000
Conduct of annual general meeting	6,000	1	1	1	1	1	30,000
Formation of VSLS (one per location)	160,000	1					160,000
Resource utilization monitors/ training of trainers	86,400	1	1	1	1	1	432,000
Peace-building and resource conflict resolution	50,000	1	1	1	1	1	250,000
Administrative overheads	10,000	1	1	1	1	1	50,000
Total							**1,170,000**

Table 26 summarizes the costs presented in this intervention to enhance the energy efficiency:

Table 26. Summary of the costs to enhance energy efficiency

Main activities	**Total (US$)**
Promoting improved cookstoves in the host communities	2,730,000
Providing improved charcoal kilns and training packages	3,622,273
Establishing and strengthening community woodfuel producer associations	1,170,000
Total	**7,522,273**

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 Kenya 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 issues:

- **Development of forest and other woodlands management plans (including *Prosopis* and indigenous vegetation).** When designing forestry interventions in drylands, the following aspects should be taken into consideration: mobilization of relevant stakeholders for a coordinated response at local and national levels; identification and demarcation of potential sites for the rehabilitation of degraded woodlands; clarification of the tree- and land-tenure regimes; and assessment of site suitability for intervention. After site demarcation, site suitability assessments should be conducted by forestry experts and local authorities to assess physical and socio-economic attributes of selected sites (e.g. road accessibility, natural regeneration, terrain, edaphic conditions, distance, water availability, hydrology, and other local conditions and risks).
- **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 linkages between the biophysical, social, economic and political dimensions of the proposed interventions. Such an approach also recognizes the importance of stakeholder participation in the management and development of these dimensions 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.
- **Promoting entrepreneurship.** An incentive mechanism (e.g. micro-credit scheme) should be created to integrate and support refugees and host communities to become entrepreneurs capable of contributing to Kenya’s socio-economic 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 at the County Government, local community-based organization (CBO), host community and refugee community levels. Capacity-building at the county government level should be geared towards enhancing technical and managerial skills of the relevant county government personnel in sustainable management of dry land forests and woodland resources. This is especially needed since most of the forests and woodlands in the county are communally owned and thus fall under the jurisdiction of the County Government. Moreover, the study has recommended commercialization of charcoal production. The entire charcoal trade and value chain including licensing is devolved to the County Government. As such, capacity of the county government

to regulate charcoal trade (including development of legislation and regulations, harvesting methods, and charcoaling technologies) is needed.

Capacity-building at the CBO and host community level should focus on strengthening existing tree nurseries to produce seedlings for enrichment planting in the proposed enclosures. Particularly, the CBOs and host communities (represented by the proposed woodfuel producer associations and the user groups proposed under them) should be trained on collection and processing of seeds of native species, nursery techniques and practices, assisted natural regeneration, and woodland resource and grazing management. The host and refugee communities should be sensitized on the need for greenbelts around the camp, techniques for assisted natural regeneration, and grazing/ rangeland management.

- **Awareness creation.** Awareness should be raised on the importance of and need for sustainable utilization of forests and other woodland resources, and the need for conservation of native vegetation. Specifically, the refugee and host communities should be sensitized on the benefits of *Prosopis*, and possible sustainable utilization technologies, including appropriate silvicultural management practices. Although *Prosopis* could be exploited for pod-milling for livestock feed production and for bee-keeping, these require further analysis to advise on financial viability, technical skill development and potential business models to be adopted. This would involve determining whether communities are better organized into cooperatives or private investment in the venture would be most ideal. Finally, the host and refugee community should be sensitized on the role of RUMs and the proposed woodfuel producer associations. This would also provide an avenue for recruiting members into the different user groups under the associations.
- **Peace-building.** Peace is needed for seamless implementation of the proposed interventions. The relationship between the host and refugee community is fluid and sometimes marred with resource-based conflicts. There are also occasional resource-based conflicts among the host communities especially with regard to competition for grazing and watering resources. Efforts should thus be made to foster community dialogues on peaceful coexistence between the host and refugee communities, as well as among the host communities. Such peace-building initiatives should involve the local leadership, local elders and representatives of the refugees and humanitarian agencies represented in the area.
- **Infrastructure (access roads) development.** Exploitation of *Prosopis* in isolated areas is hampered by limited access to such areas. This means that opportunistic harvesting of *Prosopis* in these areas is limited and thus its spread is not controlled. Investments are needed to build access roads to enable firewood and charcoal producers access in these areas. This will also improve the security situation and improve other livelihood and economic activities.
- **Monitoring.** Land and other natural resources degradation in areas impacted by refugee influx should be monitored continuously. This will also include monitoring the progress made by implementation of activities. Routine monitoring of implementation of interventions and especially protection of the greenbelts would be conducted by the RUMs. However, a structured and monitoring and evaluation framework and plan would be needed to track progress, advise on required adjustments and document emerging lessons.

5. Conclusions

This survey set out to conduct a rapid diagnostic assessment of land and forest resources degradation in areas around Kakuma refugee camp with a view to identifying intervention measures to address the degradation and ensure access to energy for cooking for refugee and host communities.

The study showed that host and refugee communities rely entirely on woodfuel (firewood and charcoal) to meet their energy needs. The refugee and host communities obtain their woodfuel from different sources. The majority of the refugees obtain their woodfuel from the UN/NGOs. Since the wood provided by the UN/NGOs is not enough, the refugees complement the supply by buying from the market, exchanging their food rations for woodfuel, and by collecting firewood from the surrounding woodlands. The vast majority of the host community households obtain their woodfuel from surrounding bush and shrub-lands.

Collection of firewood among the refugee and host communities is primarily done by adult females who (in the process of wood collection) are exposed to several risks (real and perceived) and challenges such as rapes, encounters with wild animals, bandit attacks, host attacks (in the case of refugee firewood collectors), snake-bites, and fatigue due to long distance.

Both refugee and host communities are engaged in various income-generating activities, although the majority of the refugee community relies on humanitarian agencies and NGOs for sustenance. The host community, on the other hand, relies heavily on the sale of firewood and charcoal for sustenance. Other income-generating activities among the refugee and host communities include businesses such as hairdressing, tailoring, brewing alcohol, temporary employment and civil service.

While a high percentage of the refugee population has adopted some type of improved cookstove, a significant proportion of the host community still use the inefficient 3-stone fire. The use of such an inefficient system exposes the population to health-related risks such as indoor air pollution, besides threatening the existence of the forests and forest resources. The source of stoves varies between the host and refugee communities, with the majority of the refugees obtaining their stoves from the UN/NGOs and the majority of the hosts self-producing their stoves.

With the increasing population of refugee and host communities, demand for woodfuel is expected to increase. Given the scarce natural resources found in the area surrounding of Kakuma camp and the pressure on the indigenous vegetation, the woody biomass from *Prosopis* represents an important energy source for refugee and host communities and its production, harvesting and use requires a management plan to control the risks of further ecological impacts and to support the energy needs and local economy.

According to remote sensing analysis, there is an overall increase in the extent of *Prosopis* along the waterbodies, despite some areas shows a significant reduction in the extent of *Prosopis* spp. riverine probably related to the drought occurred on 2017. Furthermore, change detection analysis revealed scattered areas of gain and loss with few zones of visible change of vegetation cover. Statistics on current biomass stock show the presence of woody resource around the camps, especially between a 50-100 km buffer.

This study estimated that the total standing biomass stock from the area of *Prosopis* riverine within 100 km radius around Kakuma is about 1,918,000 t, while total woodfuel demand from refugee and host communities is estimated at 215,370 t/year. The efficient use of this standing biomass from *Prosopis* could help meet the energy demand for cooking of the whole refugee and host communities while controlling the spread of *Prosopis* and providing and income-generating opportunity for members of the host communities involved in *Prosopis* harvesting and processing.

The study has proposed a range of costed interventions to reverse woodland degradation, enhance access to woodfuel resources for both refugee and host communities, while improving the livelihood and income sources of both communities. The interventions proposed include: i) rehabilitation of degraded woodlands; ii) control and management of *Prosopis* through its utilization; iii) sustainable management of indigenous vegetation; and iv) enhancement of energy efficiency. Institutional and soft skills measures to support the implementation of the proposed interventions are formation and strengthening of woodfuel producer associations, firewood and charcoal producer groups, and their training in relevant organizational, enterprise, conflict management and, natural resource management skills, as well as in the use of energy-efficient technologies and practices.

Annex: Methodologies

Woodfuel data collection and analysis

Data were collected through a combination of desk review of key documents, interviews with key informants and a household survey. Sampling of households was conducted in both host communities and the refugee camp. For the host communities, sampling was done in two stages. First, Loreng and Morun'gole villages were purposefully selected based on the recommendations of LOKADO as representative locations close to the camp with people selling firewood to the refugees either in cash or in exchange of food. Finally, the locations were easily accessible. Next, in each of the two villages, systematic sampling was used to select households for interview. A physical feature (i.e. road) was identified, and a transect set from a given point along the road. The first household from the identified point was sampled. Every third household was then sampled in a straight line, on either side of the road.

Refugee household sampling was also done in two stages. Kakuma camp is divided into four sections: Kakuma I, Kakuma II, Kakuma III and Kakuma IV. According to officials of LOKADO – the local NGO contracted by UNHCR to supply firewood to the refugees – three quarters of the refugees in Kakuma II and IV are South Sudanese. Kakuma I and III, on the other hand, house refugees of all the different nationalities Burundian, Congolese, Ethiopian, Eritrean, Rwandan, Somali, South Sudanese, Sudanese/Darfurian and Ugandan. Therefore, in the first stage, all the sections of the camp were selected. The reason to do so was to ensure sampling of all the different nationalities represented. Next, in each section, sampling of households was conducted systematically: 56 respondents (25.6%) in Kakuma I; 36 respondents (15.8%) in Kakuma II; 31 respondents (13.6%) in Kakuma III; 7 respondents (3.1%) in Kakuma IV; 66 respondents (28.9%) in Loreng village; and 32 respondents (14%) in Morun'gole village.
A physical feature (i.e. road passing through the section) was identified, and a transect set from a given point along the road. The first household on either side of the road was selected for interviews. Next, every third household was sampled for interview.

A total of 228 households were sampled in total, 57 percent of them from the refugee camp and the rest from the host communities.

Biophysical field inventory

Biophysical field data were collected to estimate biomass stocks for the following five classes: *Prosopis* riverine, *Prosopis* plain, Mixed vegetation, Indigenous trees, Shrubland.

The biophysical data were collected between 12 and 18 June 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.[14]

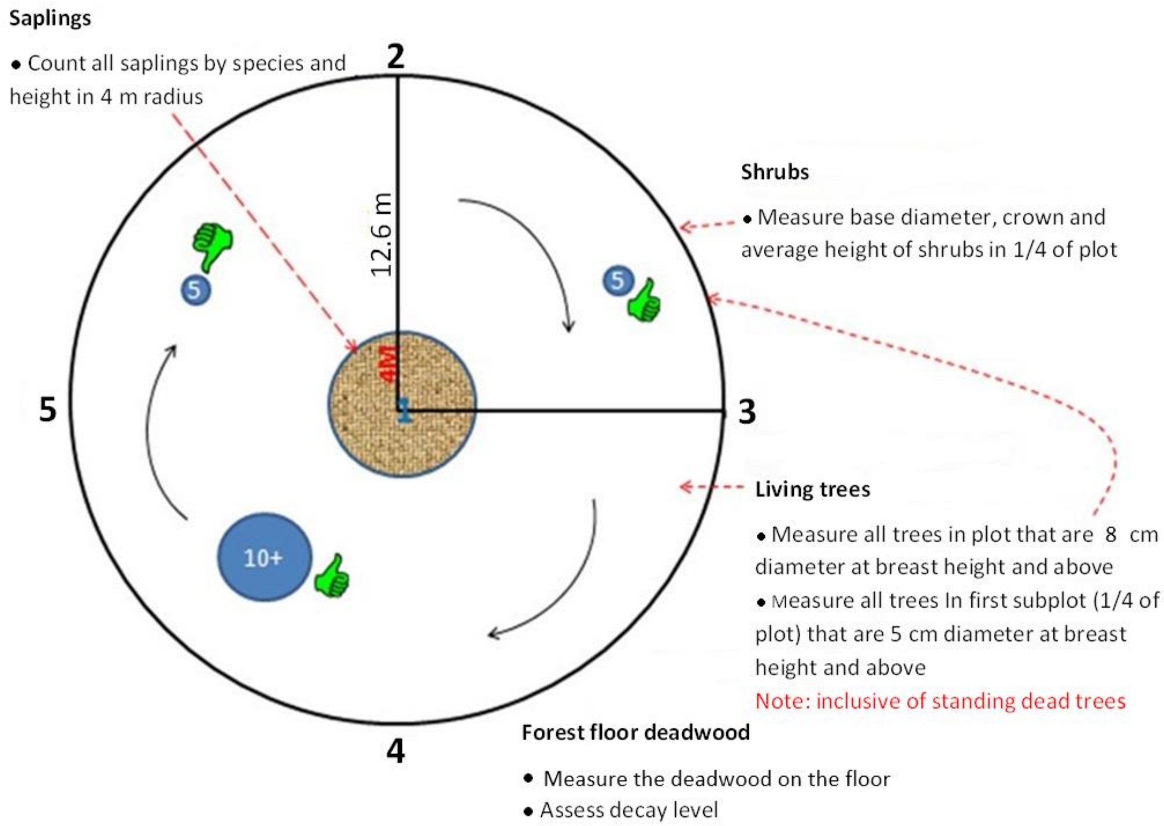
Since the focus of the assessment was on LULC classes with potential woodfuel resources, grasslands were not considered as they contain very low AGB.

Plot design and field data collection

At each sampling location, a circular plot of 0.05 ha (12.6 m radius) was established. Within each plot (Figure 17) subplots of 4 m radius were measured to capture the biomass of small trees and shrubs, which are popular sizes used for firewood.

[14] http://www.openforis.org/tools/collect-mobile.html

Figure 17. Plot design for the field biophysical inventory



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 3 cm diameter at breast height (DBH) were also measured. In the rest of the plot, the minimum measured DBH was 5 cm. Other tree parameters recorded were species and total height.

Within a smaller radius of 4 m (giving a circle of 0.01 ha), all saplings and deadwood were measured. Deadwood was measured by taking the total length in m and the midpoint diameter in cm. However, in plots where the vegetation cover was sparse, all measurements were done within the 0.05 ha plot.

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
  - Number of stumps

Estimating biomass stocks

Dry biomass was estimated using allometric equations as follows:

(a) For trees (all species):

$$AGB_{est} = 0.0673 * (\rho D^2 H)^{0.976}$$

where D (Diameter) is in cm, H (Height) is in m, and ρ (wood density) is in g cm^{-3}. This equation was developed by Chave *et al.* (2014) and was found suitable for all the species after comparison with previous findings and other existing equations.

(b) For shrubs (all species):

The log-transformed allometric equation developed by Feyisa *et al*. (2016) was used:

$$ln(W_t) = -2.31 + 1.53 * ln(DSH) + 0.675 * ln(TH) + 0.310 * ln(CA)$$

where W_t is the dry biomass, DSH is diameter at stump height (measured at 30 cm height), TH is tree height and CA is crown area in m^2 obtained by the formula CA = π x $D^2/4$, where D is crown diameter in metres. The log-transformed equation was restated before application as:

$$W_t = \frac{(DSH)^{1.53} * (TH)^{0.675} * (CA)^{0.310}}{e^{2.31}}$$

where all terms are as defined above.

(c) Deadwood:

The biomass in deadwood was estimated by taking the midpoint diameter of lying deadwood (in cm) and length (in m) and applying the volume formula for a cylinder, which in turn was multiplied by the wood density to estimate the biomass as follows:

$$W_t = \pi \times \frac{D^2}{4} \times L \times \rho$$

Where W_t is the dry biomass, π is the constant 3.14, D is the midpoint diameter, L is the length and ρ is the wood density.

(d) Developing biomass factors:

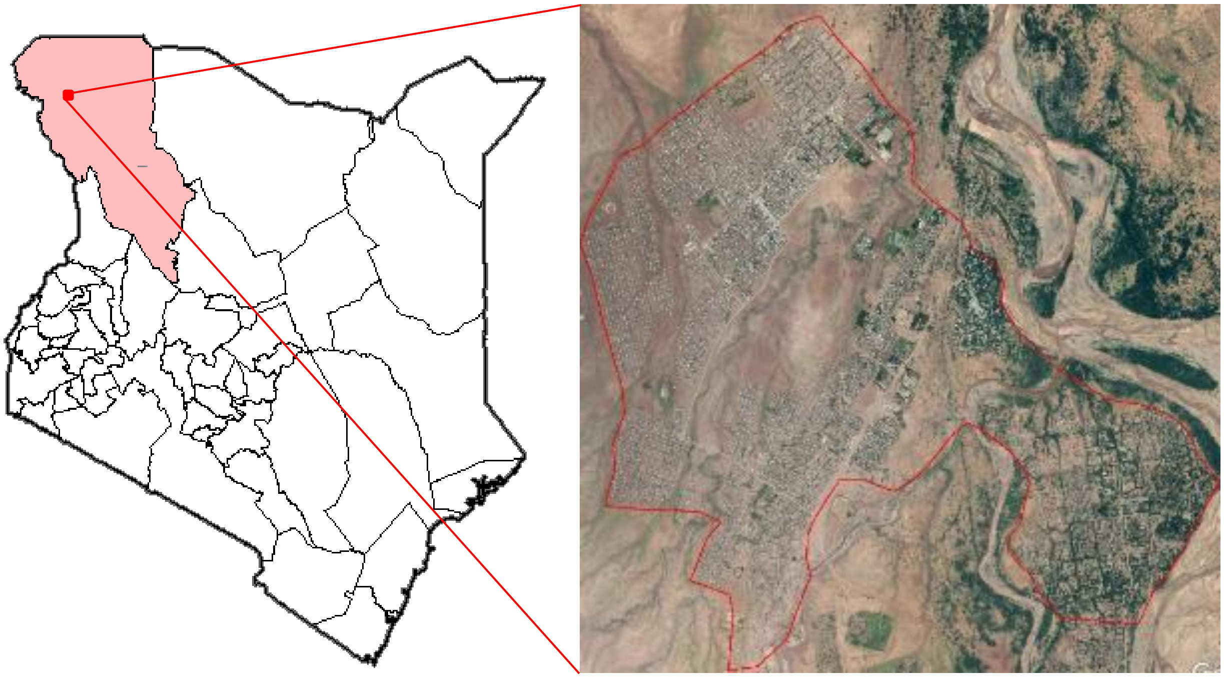
The AGB (in kg) obtained using the selected allometric equations was summed for individual trees/shrubs and deadwood in each plot, divided by the plot area, all divided by 1,000 in order to estimate the AGB in t/ha. The average AGB/ha for each land cover type was then calculated to obtain the biomass factor for each class.

Remote sensing analysis

Delineation of the camp

In order to delineate the boundary of the camp, very high resolution images (VHRIs) available in Google Earth were used as reference data. Figure 18 shows the location and boundary of the camp, which was manually delineated. From the extent of the camps, circular buffers at a distance of 25-50 km and 100 km were created.

Figure 18. Location of Kakuma camp in Turkana County (left) and delineation of Kakuma Camp using Google Earth (right)



Datasets used in analysis

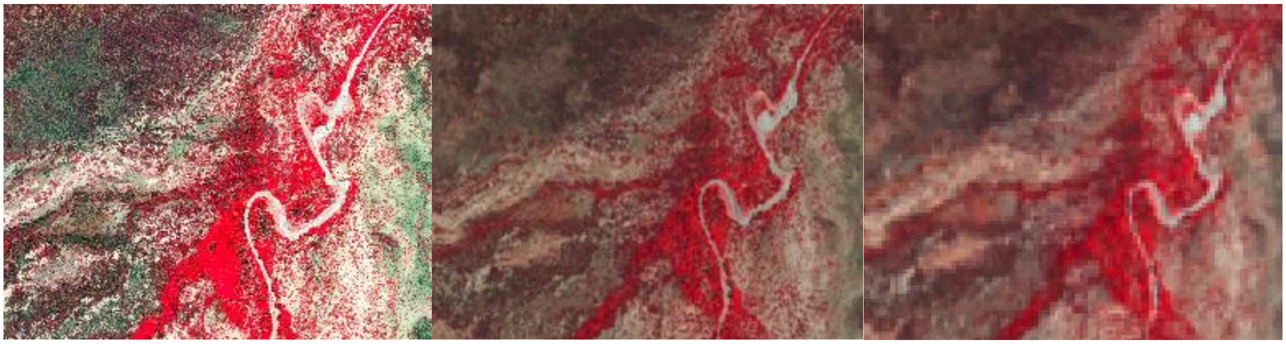
- Landsat 7 (ETM +) and 8 satellite images for the construction of the mosaics for the years 2014 and 2018.
- Landsat time-series imagery was analysed using BFAST[15] to detect location and intensity of changes.
- The Global Forest Change (GFC) dataset (Hansen *et al.,* 2013) is an annual and globally consistent estimate of tree cover percentage, tree cover loss and gain, derived using satellite imagery at a spatial resolution of 30 m. Annual GFC data for the period of interest were investigated using a threshold of 10 percent tree cover loss. Tree cover loss was defined as complete over-storey removal occurring on land with at least 5 percent initial tree cover in the year 2000. However, the dataset shows a limited number of pixels of loss in the AOI and could therefore not be used.
- VHRI (Worldview 1-3) provided by the United Nations Institute for Training and Research, in combination with those freely and openly available in Google Earth, were used during the land cover mapping. They were used for training-data collection and validation.

Legend and land cover mapping

The collection of the training dataset was carried out combining different satellite images with different spatial resolutions (VHRI, Sentinel 2 and Landsat) and field data. A total of about 300 polygons were delineated to represent all map classes rightly across the entire area. It is important to note that plot descriptions collected in the field were used for the interpretation of the satellite images, seeking interpretation consistency across the years (2014 and 2018). Challenges were faced during the interpretation when VHRI were not available, especially in areas which are not covered by dense tree vegetation (Figure 19).

[15] For more information on BFAST: http://bfast.r-forge.r-project.org/

Figure 19. Comparison of satellite images with different spatial resolution (from the left: Worldview (0.5 m), Sentinel-2 (10 m) and Landsat 8 (30 m)

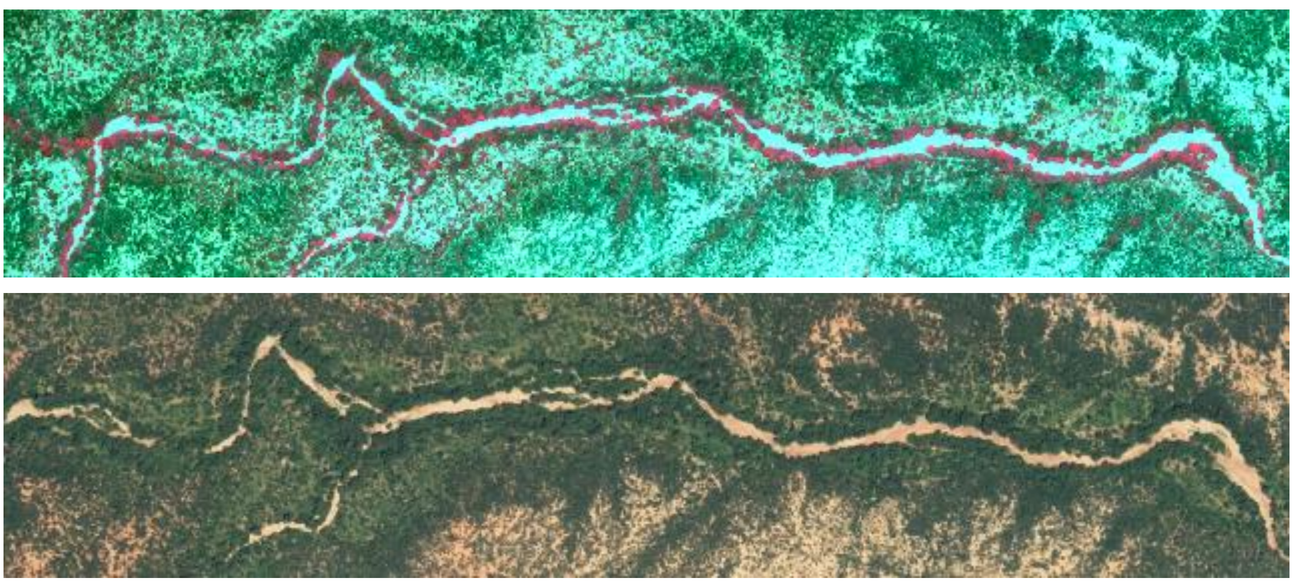


An in-depth description of the classes aims to provide details on the image interpretation and on how the training polygons were collected. It is important to note that in this case training points are polygons defined to better capture heterogeneity which point reference data may not be able to capture (Corcoran J. et al., 2015).

Class 1: *Prosopis* riverine

This first class describes areas mostly dominated by *Prosipis juliflora,* which creates a very dense thicket. This class mainly occurs in proximity to drainage networks (along seasonal watercourses called *laggas*) due to water availability and by the fact that the transportation of seeds along watercourses is a major dispersal route. The minimum tree and shrub cover is 10 percent, meaning that areas with very sparse vegetation cover are excluded.

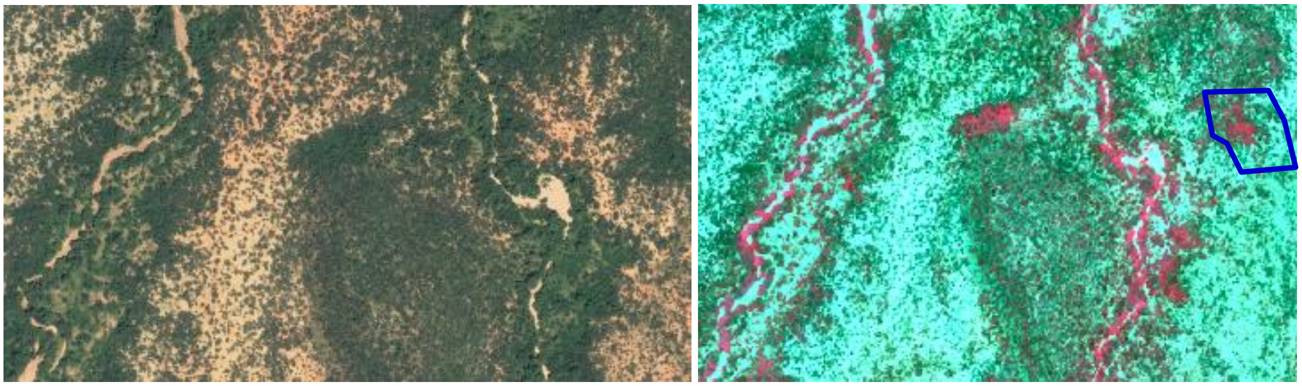
Figure 20. Prosopis riverine (in red) in the above image and below VHRI from Google Earth (8 March 2011)



Class 2: *Prosopis* plain

Prosopis is the dominant species in this land cover category but it occurs in sub-optimal conditions for *Prosopis* to thrive in its initial stages of growth (Figure 21) and in degraded areas (i.e. abandoned and poorly productive areas) and rangelands with sparse native vegetation. These areas are highly susceptible to invasion as *Prosopis* has competitive advantages on nutrient-limited soils and is extremely drought-tolerant due to its articulated root system (Meroni *et al.*, 2016).

Figure 21. Comparison of Google Earth image with a Worldview VHRI



Note: (date: 31 August 2011) 3°46'0.1.25'' N 34°22'01.57''E, date: 11 June 2017 a false colour composite (753). The blue polygon on the right shows an area of Prosopis plain.

Class 3: Mixed vegetation (*Prosopis spp.* and indigenous tree species)

This class includes areas with a mixture of both *Prosopis* and natural vegetation. Training polygons were identified by comparing VHRI available for both wet and dry seasons (Figure 22).

Figure 22. Distribution of evergreen Prosopis and other seasonal vegetation. Left image 2 February 2011 and right image 23 August 2011

Class 4: Indigenous trees

This class describes intact patches of natural vegetation with minimum tree cover of 10 percent. It is mainly found in the mountains (e.g. Mt. Muruasigar, Zulia). This class includes both areas with both dense and open tree cover, as shown in Figure 23.

Figure 23. Training points for class 4, which include both dense and open tree cover. The small polygons on the right are of class 6 ("Other") (2018 image)

Class 5: Shrubland

This habitat type mainly comprises shrubs dominated by *Acacia spp.* (e.g. *A. reficiens, A. melliifera*, *A. tortilis), Boscia sp.*, *Indigofera spp*., *Grewia spp*., *Maerua angolensis*, *Calotropis procera*, *Euphorbia spp*., wild sisal, *Indigofera spinosa* and *Prosopis juliflora*. Mapping shrubland is challenging since these landscapes are sometimes similar to those with mixed vegetation. Field data were useful to provide training data and assist in interpretation.

Change detection

Time series analysis allows tracking of activities, rather than creating a map that represents static conditions at one point in time or a map of change between two given dates. It allows characterization of post-disturbance landscapes and gradual and continuous activities such as reforestation and forest degradation. A direct analysis of Landsat imagery time-series was carried out using the BFAST[16] algorithm (Verbesselt, 2010; Dutrieux, 2015; DeVries, 2016). BFAST enables per-pixel detection of the date and magnitude of change over time. The results of the BFAST algorithm were compared with the VHRI when possible, for a visual assessment of detected changes and to support the reclassification of the results in two classes: pixels of loss and no-loss. The result was combined with the land cover maps: the "stable" forest mask was created by selecting pixels of woody vegetation classes (i.e. shrubland, *Prosopis* classes and mixed vegetation and indigenous trees classes) in both years, meaning that in those areas no loss is assumed to have occurred. BFAST loss was then applied over the remaining pixels that in 2014 were classified as woody vegetation. Similarly, gain pixels were applied on the ones classified as woody vegetation in 2018. The time periods used to run the algorithm in SEPAL are as follows:

- Beginning of historical period: 1 January 2010
- Beginning of monitoring period 1: 1 January 2013 and end of monitoring period 1: 1 January 2015
- Beginning of monitoring period 2: 1 January 2016and end of monitoring period 2: 12 April 2018

Tree and shrubs number of recordings

Table 27. Tree species list and number of recordings from the field inventory per LULC class

	Species name	Mixed vegetation	*Prosopis* riverine	*Prosopis* plain	Indigenous tree	Shrubland	Total
1	*Prosopis juliflora*	39	173	27	1	1	241
2	*Acacia tortilis*	3	0	0	0	0	3

[16] For more information on BFAST: http://bfast.r-forge.r-project.org/

3	*Acacia reficiens*	0	0	0	26	10	36
4	*Boscia coriacea*	5	0	0	0	2	7
5	*Balanites aegyptiaca*	0	0	0	8	3	11
6	*Acacia mellifera*	0	0	0	14	0	14
7	*Cordia sinensis*	1	0	0	0	0	1
8	*Cadaba rotundifolia*	4	0	0	0	0	4
9	*Commiphora africana*	0	0	0	0	3	3
	TOTAL						320

Table 28. Shrub species list and number of recordings from the field inventory per LULC class

	Species name	Mixed vegetation	*Prosopis* riverine	*Prosopis* plain	Indigenous tree	Shrubland	Total
1	*Prosopis juliflora*	22	41	32	0	84	179
2	*Cadaba rotundifolia*	0	0	0	0	3	3
3	*Acacia reficiens*	0	0	0	10	6	16
4	*Cordia sinensis*	1	0	0	0	0	1
5	*Acacia horrida*	11	0	0	0	0	11
6	*Grewia tenax*	1	0	0	0	0	1
7	*Boscia coriacea*	2	0	0	1	3	6
8	*Balanites aegyptiaca*	0	0	0	4	2	6
9	*Salvadora persica*	0	0	0	1	0	1
10	*Acacia nubica*	0	0	0	0	7	7
	TOTAL						232

Firewood harvesting sites

Table 29. Firewood harvesting sites reported

Firewood harvesting sites within 25 km

- Lokore and Lopuski sites, Pelekech location
- Lopur, Kakuma location

Firewood harvesting sites within 25-50 km

- Kalobeieyie, Oropoi location
- Namon

Firewood harvesting sites within 50-100 km

- Nanam
- Mogila
- Lokichoggio
- Oropoi
- Loteteleit
- Songot Posta
- Kaeris
- Nakalale
- Lomeyan
- Lokangae
- Nasinyono
- Loreng

Source: UNHCR-LOKADO

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