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Nigeria: Borno State

Woodfuel supply and energy demand assessment

2013–2018

Assessing changes in woodfuel availability and multi-sectoral challenges associated with woodfuel in displacement settings

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Foreword

Globally, the number of conflicts is increasing which is the main cause of much of the recent deterioration of the global food security situation. This situation is exacerbated by climate related shocks. Since 2009, a combination of man-made and natural disasters has disrupted livelihoods, threatened food security and forcibly displaced millions of people in northeast Nigeria. The conflict, in northeast Nigeria, takes on a central role in the ongoing food crisis by severely curtailing the ability of populations to access land and other natural resources such as woodfuel, the central object of this analysis. This situation is worsened by the prolonged character of the security crisis in the region, going now into its tenth year.

Furthermore, northeast Nigeria is facing an increasing number of climate-induced disasters such as droughts, erratic rainfall, soil erosion and flooding. The combined impact of these events has a severe impact on the lives of vulnerable populations. Drought has been recognized as the main natural disaster in the region, affecting a huge population that depends on crop and livestock production for their subsistence. The economic and social consequences of this phenomenon go beyond the geographical scope and focus of this assessment.

Access to energy is as basic to the exercise of human rights as access to food itself. A precondition to food security, both are often highly constrained during crises. The ways in which energy is produced and used, can aggravate the vulnerability of populations to a number of risks and challenges by exposing them to malnutrition and other health conditions, reduced resilience to natural hazards and to environmental degradation, a disproportionate work burden for women, protection risks, conflicts and unsustainable livelihood activities.

FAO, UNHCR and WFP have been promoting the multi-sectoral Safe Access to Fuel and Energy approach (SAFE) in the context of forced displacement in different parts of the world. In this way, we seek an effective response to the diverse challenges and to contribute to building the resilience of vulnerable populations in emergencies and protracted crises. The starting point of such a response in northeast Nigeria is this woodfuel supply and energy demand assessment, which provides a baseline for designing comprehensive interventions that take into account the energy needs of affected populations. The desired outcome of the SAFE approach is to “satisfy the fuel and energy needs for cooking, heating, lighting, and powering in a safe and sustainable manner, without fear or risk to health, well-being, and personal security of crisis-affected populations”. The multi-sectoral nature of the SAFE approach has the potential to enhance protective livelihoods.

The SAFE approach could make an effective and significant contribution to improve food security and nutrition, and ensure the sustainable management of natural resources. In addition, it will positively affect livelihoods, women and youth empowerment, protection and health risks. By taking adequate climate change mitigation and adaptation measures, the SAFE approach will also help to increase the resilience of vulnerable populations in the face of natural hazards and disasters, and contribute to peaceful coexistence between IDPs and local communities.

Suffyan Koroma, FAO representative in Nigeria
Antonio Jose Canhandula, UNHCR representative in Nigeria
Myrta Kaulard, WFP representative in Nigeria

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Abbreviations

AOI	Area of Interest
BFAST	Breaks For Additive Season and Trend
CH	*Cadre Harmonisé*
CILSS	Comité Inter-Etats pour la Lutte contre la Sécheresse au Sahel
DTM	Displacement Tracking Matrix
FAO	Food and Agriculture Organization of the United Nations
FMARD	Federal Ministry of Agriculture and Rural Development
GACC	Global Alliance for Clean Cookstoves
GBV	Gender-Based Violence
IASC	Inter-Agency Standing Committee
IDP	Internally Displaced Person
IEA	International Energy Agency
IOM	International Organization for Migration
IVI	Importance Value Index
km	Kilometre
kg	Kilogram
LGA	Local Government Area
LPG	Liquefied Petroleum Gas
LULC	Land Use and Land Cover
mm	Millimetre
NDVI	Normalized Difference Vegetation Index
NFIs	Non-food items
NPFS	National Programme for Food Security
PSEA	Protection from Sexual Exploitation and Abuse
REDD+	Reduce Emissions from Deforestation and Forest Degradation
SAFE	Safe Access to Fuel and Energy
SDG	Sustainable Development Goals
SEI	Stockholm Environment Institute
SEPAL	System for Earth Observations, Data Access, Processing and Analysis for Land Monitoring
SPOT	Satellite Pour l'Observation de la Terre
UNHCR	United Nations High Commissioner for Refugees
UNITAR	United Nations Institute for Training and Research
VHR	Very High Resolution
VTS	Vaccination Tracking System
WFP	World Food Programme

Executive summary

The Conflict in northeast Nigeria has had devastating effects on food security and livelihoods. Millions of people have been driven away from their homes and access to agricultural lands and assets have been hampered, creating massive humanitarian needs in the area. The conflict has spilled over to neighbouring countries, more specifically Cameroon, Chad and Niger.

Due to the ongoing conflict, the three states of Adamawa, Borno and Yobe in the northeast Region of Nigeria are facing massive displacement of people, significant human, social and economic losses and food insecurity. The International Organization for Migration (IOM) Displacement Tracking Matrix (DTM) Round 25 (October 2018) (IOM, 2018) indicates that 2 026 602 people are internally displaced in northeast Nigeria, of which 1 475 605 or 71.5 percent are located in Borno State. Host communities are also affected with poor access to the needed resources for their own food production, facing high levels of poverty and malnutrition. The *Cadre Harmonisé* (CH) analysis of food and nutrition insecurity (October 2018) (CILSS, FAO & NPFS, 2018) indicates that the main food, nutrition and livelihood indicators remain alarming. In Borno State, an estimated 835 772 people are currently in the three critical food insecurity categories (CH Phase 3-5), with an expected increase to around 1.38 million people during the coming lean season (June and August 2019).

The context of conflict is further compounded by climate variability that negatively impacts the production systems, resulting in poor crop yields and livestock productivity with direct negative impact on people's livelihoods and food security. Drought is the main natural disaster in the region. It affects more than 50 percent of the population that directly depends on crop and livestock production for their livelihood sustenance, hampering irrigated agriculture and reducing water for livestock production. In addition, a significant proportion of land in Borno State is degraded as the result of inappropriate soil management practices, deforestation and over-exploitation of rangelands that has led to a progressive and severe loss of the original vegetation cover.

Limited access to energy has been identified as a very pressing issue in Borno State. It has exposed vulnerable people to a number of challenges and risks; which directly hampers food security and nutrition (e.g. insufficient fuel to cook food), increases deforestation (e.g. unsustainable felling of trees for household fuel) as well as protection risks (e.g. harassment, assault, physical and sexual violence when collecting woodfuel) and health risks (smoke inhalation provoking respiratory illnesses). Additionally, the use of night lighting in all Internally Displaced Populations (IDPs) camps has been a challenge due to ongoing military operations. Movements in the dark have exposed IDPs – especially new arrivals (returnees and IDPs) - to protection risks.

Therefore, an assessment was jointly initiated by FAO, UNHCR and WFP to assess the supply and demand of woodfuel resources in Borno State. This assessment included three steps: 1) assess the energy demand including woodfuel (firewood and charcoal) and the associated challenges experienced by IDPs, returnees and host communities, 2) assess the woodfuel supply including the aboveground biomass stock, land cover classification and changes over time, and 3) identify relevant inter-linkages and gaps as well as develop and propose possible future scenarios in which improved cookstoves, the use of other biomass feedstock and afforestation interventions can be implemented.

Main findings

Seventy nine percent of the 8 937 surveyed households depend solely on firewood for their daily cooking energy needs, 8.1 percent depend solely on charcoal and 8.4 percent depend on a combination of firewood and charcoal. In addition, 3.2 percent rely on a mixture of other organic biomass sources, including agricultural and animal waste products, most often in combination with firewood and/or charcoal. This means that 98.7 percent, or 8 819 of the total number of respondents, use biomass as their only energy source for cooking. Only 1.3 percent of surveyed households indicate to use fossil fuels, such as kerosene, Liquefied Petroleum Gas (LPG) or non-organic waste materials (e.g. plastic), as part of their household energy mix. Among IDPs, a higher dependence on less efficient energy sources (agricultural or animal waste) was noticed, while host community members showed a slightly higher incidence of combining firewood and charcoal as their daily cooking energy source. In order to assess knowledge and openness to other energy sources, 20.8 percent of respondents, who use traditional biomass as energy resource, indicated that they would change their current energy source if given the opportunity. The top choices as alternative energy sources indicated by the respondents, are kerosene and LPG. Surveyed households were also asked the maximum amount they would invest in an improved cookstove. The average willingness to pay (WTP) of the sample is 4 530 Nigerian Nairas (NGN) or 12.44 US Dollars (USD) per household.

The sourcing of woodfuel is mainly through local sellers or market places (roadside, at IDP camp entrance, etc.). 64.1 percent of respondents source their fuel in this way. A total of 21.5 percent of respondents indicated that they only collect firewood from the surrounding environment (they do not purchase woodfuel), with an additional 14.4 percent indicating they source their fuel by combining different approaches (buying, collecting and receiving from humanitarian actors). The high number of people who buy firewood can be explained by the widespread protection risks, the strict security perimeters around towns, the restriction of movement of petroleum, oil and lubricant products in some locations and the expensive cost of kerosene[1] out of Maiduguri.

[1] "Emissions from kerosene use for cooking, heating and lighting lead to levels of health-damaging pollutants which exceed WHO Air Quality Guidelines, and considerably so for use of wick-type devices" (WHO, 2012).

The most vulnerable people, who do not have sufficient means to access energy, cannot go out to collect firewood. In many cases, they are forced to sell food products or other assets, in order to buy woodfuel, leaving them more vulnerable to undernutrition and sexual exploitation and abuse. It should also be mentioned that the most vulnerable IDPs have adopted the collection of firewood as a means of livelihood. While risking their life, going into unsafe and insecure areas, they collect firewood in order to sell it in the IDP camp. This practice has been observed in all four locations.

Ninety eight percent of respondents use inefficient cooking technologies, hence requiring large amounts of woodfuel (charcoal and wood) to satisfy basic cooking needs. 64.9 percent of the surveyed households rely on the traditional three stones fire, while 24.2 percent rely on the traditional mud stove. More than 15 percent make use of multiple cooking technologies at the same time. In large and highly congested IDP camp settings, using appropriate and safe cooking technologies is important to reduce the risk of fire outbreaks. In some cases, newly arrived IDPs receive a local metal stove, as part of the Non Food Items (NFI) package. Other alternatives could be the organization of communal cooking spaces.

Considering the current energy sources and technologies (traditional biomass resources and inefficient cooking technologies), it is not surprising that 76 percent of respondents report to have insufficient access to energy sources to cover their daily energy needs for cooking. The average woodfuel consumption (calculated for respondents who solely depend on firewood) is 0.855 kg per individual per day. This consumption is slightly above the lowest range of the fuelwood consumption for cooking in refugee camps found in the literature (0.7 kg to 3 kg per person per day) (Gunning, 2014). Given the specific context of the four Areas of Interest (AOIs), namely Auno, Dusuman, Gwoza and Ngala, differences can be noted in the average woodfuel consumption. While Dusuman and Ngala are characterized by large-scale IDP camps, Auno and Gwoza present a situation where IDPs are installed within the host community settings.

The assessment reveals that the total estimated woodfuel consumption over the period 2013 to 2016 is 244 221 tonnes per year in Auno and Dusuman while the observed degradation in that period corresponds to an amount exceeding 150 287 tonnes per year. Therefore, the loss in woody biomass represents 61.5 percent of the local woodfuel consumption. In other terms, only around half of the woodfuel consumed in the AOI is sourced in the immediate environment. Biomass for local consumption is in large part sourced from outside of the area of interest (two circles with a 15 km radius from the city centres of Auno & Dusuman). The woodfuel consumption corresponds to 28 percent of the available biomass (913 919 tonnes in 2016).

In Gwoza, the estimated loss in woody biomass is 2 127 tonnes per year for the period 2013–2017, whereas the consumption is 28 319 tonnes per year for the same period. The loss in woody biomass represents only 7.5 percent of the local woodfuel consumption. This demonstrates that the woodfuel consumed within the AOI is transferred from outside of the area to be consumed by IDPs, returnees and host community members. The reason for the transfer is the very insecure situation around the town due to ongoing attacks and instability. Movement of people is restricted to the town boundaries and therefore they cannot collect wood. In the Gwoza area, based on the current study, the total existing biomass was 496 112 tonnes in 2017. Therefore, local woodfuel consumption represents only 6 percent of the available biomass.

In Ngala, the average estimated woodfuel consumption is 35 322 tonnes per year whereas 97 529 tonnes of biomass was available in 2017. The estimated biomass consumption for energy accounts for 36 percent of the biomass available. The main IDP camp in Ngala was only established in 2016. Since degradation on wood resources is a long phenomenon, no biomass loss was performed for this AOI.

Recommendations

If the different users manage natural resources in an integrated way, the environment should be able to supply the total woodfuel demand. In order to reduce the current pressure on the environment, technical solutions taking into account age, gender, diversity, multisectoral perspective and community based-approach are proposed to reduce the demand by 1 to 15 percent. Efficient cookstove production and briquette promotion are the most suitable options to reduce wood energy demand.

Fuel-efficient biomass cookstove promotion

It is fundamental to raise awareness on efficient cookstoves and their advantages for reducing fuel needs of the local population and other benefits, such as reducing wood collection time and burden, protection risks and the prevalence of respiratory diseases. Promotion of fuel-efficient cookstoves should be integrated in an effective delivery model, focusing on customer service and satisfaction. This will ensure a more profound impact of fuel-efficient cookstove adoption in the longer term. Building demand and therefore a market for fuel-efficient cookstoves also creates employment opportunities in manufacturing and distribution. This approach requires that humanitarian and development actors as well as local authorities provide a long-term engagement and a continued support.

To strengthen sustainability in the short, medium and longer term and avoid weakening local markets, it is recommended to diffuse energy products, such as appliances and fuels, through existing distribution networks and market systems. Energy vouchers can enable beneficiaries to access energy products at retailers' kiosks, distribution outlets, open markets or special relief shops, choosing among different models and brands. Products can also be obtained from commercial manufacturers at local, national or import level, depending on availability. This effort is meant to ensure that products are closer to the needs of users and do not end up unused or resold. In addition, products are made available to the community at large, reaching beyond the scope of the intervention.

The practical implementation of these modalities remain under the responsibility of local actors such as the energy and environmental technical working group together with the cash technical working group (Food Security Sector, 2018).

Briquette promotion

Briquette diffusion can have three advantages: replacing a significant amount of unsustainably sourced woodfuel, constituting a livelihood activity for woodfuel collectors (cash for work activity) and provide access to modern and clean energy to local communities. However, a techno-economic analysis needs to be performed at field level to define (i) the availability and accessibility of biomass residue materials, (ii) the collection, distribution and commercialization costs, (iii) the preferred technical processes, (iv) the most suitable management modalities, and (v) the size of the market and the marketing strategy to replace a certain amount of the woodfuel consumed.

Other energy solutions

Beyond cookstoves and briquette production, developing access to clean and sustainable energy services should remain the goal of any intervention. The provision and distribution of solar lighting taking into account age, gender and diversity in the IDP camps will increase protection, safety and productivity of conflict-affected people. Regarding latrine areas in camps settings where public lights are not authorised due to the security context, the use of luminescent ink to identify male and female structures may contribute to the reduction of sexual assault and rape incidents at night. Existing initiatives related to fuel-efficient stoves using ethanol could also represent an alternative to the use of woody solid biomass. To replace traditional cooking fuels, ethanol can be produced from sugar cane, corn, sorghum or cassava among others. Biogas digesters using a variety of feedstock (manure, human excreta, crop residues) could also be supported for energy and fertilizer production.

Off-grid solar systems can improve energy access in both IDP camps and host communities for cooking but also for productive uses. These interventions require a profound understanding of the local context and culture. When taking on an integrated approach to food-energy production, traditional food processing methods can be upgraded such as fish drying, cereal milling and food conservation.

Supply-side measures: afforestation and reforestation

Tree planting interventions have a great potential. On average, 1 000 ha of tree plantation for woodfuel production can cover 4 to 5 percent of the energy needs, based on the woodfuel consumption figures in the Business as Usual scenario. Combined with demand-side measures, such as promotion of fuel-efficient cookstoves and briquetting technologies, 1 000 ha of tree plantation could cover 6 percent of the total woodfuel consumption. Starting from existing structures of environmental management, such efforts should be supported with technical expertise and provision of inputs. Community-based approaches to sustainable forest management can be used, involving host community members, IDPs and returnees. Environment committees can be established or supported for the development of initiatives such as tree nurseries and communal woodlots. Regional, national and state-level afforestation programmes should also be supported. Based on FAO experience in promoting and monitoring forestry programs, the technical support to existing nurseries and the development of new nurseries could be envisaged in collaboration with the local forestry department and agents. Three tree species adapted to the local conditions, could be used for reforestation: *Acacia Nilotica Ssp. Adstringens*, *Annogeisus Leiocarpus* and *Azadirachta Indica*. Besides energy, each of these species add an extra benefit in terms of livelihood (gum from *Acacia Nilotica*, medicinal uses and fertilization for *Azadirachta Indica*) and environment (agroforestry, soil erosion for *Annogeisus Leiocarpus*).

<u>Awareness raising</u>

Energy access is intrinsically linked to local values and norms. Therefore, it is essential to contextualize and take on a culturally sensitive perspective. For example, the collection of woodfuel and cooking on three stones fires are very widespread practices in Borno State and are strongly interlinked with gender roles. Awareness raising activities on the multiple challenges and risks related to an unsustainable and unsafe energy access should accompany any energy-related intervention, touching on issues such as food insecurity, protection risks including gender-based violence (GBV) and protection from sexual exploitation and abuse (PSEA), women’s work burden, climate change and safety hazards. By providing an alternative technology and by demonstrating its usefulness in this way, the interventions mentioned above will be more sustainable in the longer term.

In situations of prolonged conflict, tensions over natural resources can be aggravated, especially when large displaced populations enter a host community. Interventions related to enhancing energy access for conflict-affected populations should therefore be conflict sensitive, and peaceful management of natural resources should be mainstreamed. Conflict sensitivity refers to the practice of understanding how aid interacts with conflict dynamics in a particular context, to mitigate unintended negative effects, and to influence conflict positively wherever possible, through humanitarian, development and/or peacebuilding interventions. Conflict sensitivity therefore refers to the ability of an organization to: (i) understand the context in which it is operating, particularly intergroup relations; (ii) understand the interactions between its interventions and the context/group relations; and (iii) act upon the understanding of these interactions, particularly in programme design, in order to avoid negative impacts and maximize positive impacts.

A conflict-sensitive approach should be incorporated in any energy access mechanism. Depending on the local context and power/conflict dynamics, there are a few examples of programmes that could be used to support objectives around social cohesion and conflict prevention over natural resources: the Joint Community Peace Committees, the Dimitra Clubs or cross-border dialogue mechanisms. Capacity building and institutional strengthening of local governments to create an enabling environment for inter-communal dialogue is key in this regard.

Conclusion

The conflict in northeast Nigeria has considerably impacted the local population, especially in Borno State. Livelihoods of host communities, IDPs and returnees are disrupted, increasing their vulnerability to the negative impacts of climate change. The lack of access to sustainable and safe energy increases vulnerabilities linked to food insecurity, protection issues and unsustainable management of wood resources. If adequately managed, the natural resources in the area are sufficient to meet the needs of the local communities.

Sustainable natural resource management implies a drastic reduction of the woodfuel demand (combined measures could reduce it by 18 percent) as well as major restoration efforts with multi-purpose tree plantations (1 000 ha could cover 6 percent of the improved demand). The deployment of alternative energy sources (non woody biomass, ethanol, fossil fuels or improved electricity access) should also be pursued. It is also recommended to support innovative humanitarian delivery models shifting from items or fuel distribution to energy vouchers in stable areas. In insecure areas, distribution of lightweight fuel efficient stoves and solar lanterns to reduce protection risks would remain the short term norm.

It is essential to monitor natural resources in a continuous and participatory manner. Local authorities with the support of technical partners should lead replantation, restauration and afforestation efforts. These efforts must include local communities (displaced, returned and host) in mapping and management.

Introduction

Context

The conflict in northeast Nigeria has had devastating effects on food security, livelihoods and protection. Millions of people have been driven from their homes and access to agricultural lands and assets have been hampered, creating massive humanitarian needs in the area. The conflict has spilled over to neighbouring countries, more specifically Cameroon, Chad and Niger.

Figure 1 - Map of Lake Chad Basin region, indicating conflict-affected areas (Source: (FAO, 2017)).

Due to the ongoing conflict, the three states of Adamawa, Borno and Yobe in the northeast Region of Nigeria are facing massive displacement of people, significant human, social and economic losses and food insecurity. The International Organization for Migration (IOM) Displacement Tracking Matrix (DTM) Round 25 (October 2018) (IOM, 2018) indicates that 2 026 602 people are internally displaced in northeast Nigeria, of which 1 475 605 or 71.5 percent are located in Borno State. Host communities are also affected with poor access to the needed resources for their own food production, facing high levels of poverty and malnutrition. The *Cadre Harmonisé* (CH) analysis of food and nutrition insecurity (October 2018) (CILSS, FAO & NPFS, 2018) indicates that the main food, nutrition and livelihood indicators remain alarming. In Borno State, an estimated 835 772 people are currently in the three critical food insecurity categories (CH Phase 3-5), with an expected increase to around 1.38 million people during the coming lean season (June and August 2019).

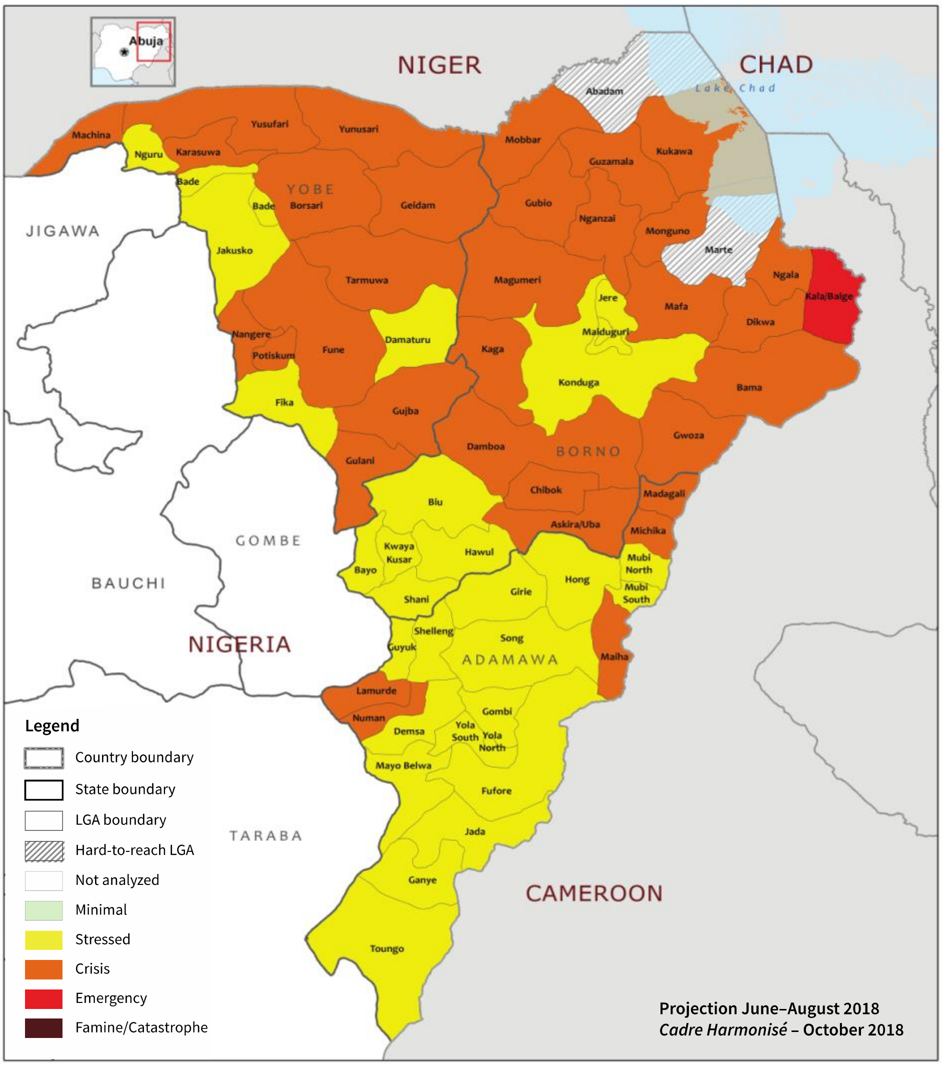

Figure 2 – Projected food security outcomes for northeast Nigeria, August to September 2019 (Source: (CILSS, FAO & NPFS, 2018))

The context of conflict is compounded further by climate variability that negatively impacts the production systems resulting in poor crop yields and livestock productivity with direct consequences on the livelihoods and food security of households. Drought is the main natural disaster in the region. It affects more than 50 percent of the population that directly depends on crop and livestock production for their livelihood sustenance, hampering irrigated agriculture and reducing water for livestock production. In addition, a significant proportion of land in Borno State is degraded as the result of inappropriate soil management practices, deforestation and over-exploitation of rangelands that has led to a progressive and severe loss of the original vegetation cover.

Borno State has four distinct agro-ecological zones (Figure 3). The north is part of the Sahel agro-ecological zone, receiving under 500 mm of rainfall per year. The main livelihood activities are rainfed cropping (short rainy season between July and September) and livestock herding (small ruminants, cattle and camels). The zone also include the Nigerian part of the Lake Chad. The Sudan Savannah agro-ecological zone covers the central part of Borno and receives between 500 and 700 mm of rainfall per year. The rainy season starts in June and stretches to September, making rainfed farming (including a variety of vegetables) the main livelihood activity. Dry season farming is carried out from October until March in fadamas (areas which have shallow water aquifers enabling the construction of wells and irrigation systems). The third agro-ecological zone in Borno is the northern Guinea Savannah, which forms a transition belt between the Sudan Savannah and the Southern Guinea Savannah zone. It receives between 800 to 1 000 mm of rainfall each year, between May and October. The fourth agro-ecological zone is the Southern Guinea Savannah, which covers the southern part of Borno.

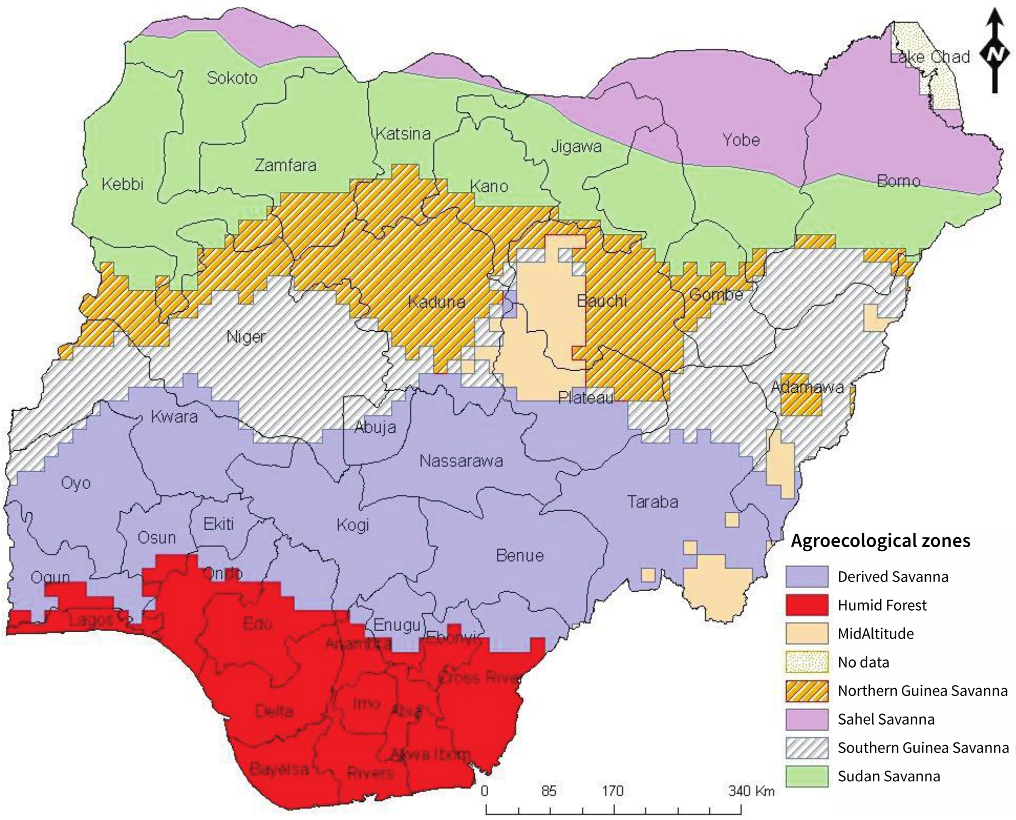

Figure 3 - Map showing Agro-ecological zones of Nigeria (Source: (O. T. Alamu, 2013)).

Certain areas in Borno are currently in transition stage from conflict and humanitarian crisis to stable security, recovery and development, while other areas (such as northern and south-western Borno) still face significant constraints in terms of security and access to land. Different components in the humanitarian-resilience nexus, such as food security, nutrition, protection, health and environmental sustainability, need to be integrated for an increased impact on communities' resilience to climate related hazards in order to ensure that target people have more tools to rebuild sustainable livelihoods.

Access to energy

A large part of the world's population relies on burning traditional solid biomass, such as fuelwood, charcoal or animal waste, on open fires or inefficient stoves as their primary energy source for cooking, lighting and heating. Estimates vary between 2.4 and 3 billion people who rely on these inefficient and polluting means of cooking (FAO, 2016; IEA, 2016; GACC, 2015; Lambe, 2009). In Sub-Saharan Africa, more than 80 percent of the population cook their meals with these types of energy sources (The World Bank, 2014). When considering vulnerable populations, including refugees, Internally Displaced Person (IDP) and host communities, access to cooking fuel is often very limited. The specific context of displacement, and its effects on the energy situation of vulnerable people, is not yet explicitly considered in the Sustainable Development Goals (SDGs), but emerges in major global policy processes, such as the Global Plan of Action for Sustainable Energy Solutions in Situations of Displacement supported by FAO, UNHCR and WFP among other organizations (UNITAR, 2018). Refugee and IDP camps are often established in fragile and sparsely forested areas, where the influx of large groups of displaced people puts pressure on the surrounding environment. Competition over these scarce natural resources can increase tension between host communities and displaced people.

In Borno State, limited access to energy has been identified as a very pressing issue. It has exposed vulnerable people to a number of challenges and risks, directly linked to food insecurity and malnutrition (e.g. insufficient fuel to cook food), deforestation (e.g. unsustainable felling of trees for household fuel), protection (e.g. harassment, assault, physical and sexual violence when collecting woodfuel) and health (smoke inhalation provoking respiratory illnesses). Additionally, the use of night lighting in all IDP camps has been a challenge due to ongoing military operations. Movements in the dark have exposed IDPs – especially new arrivals (returnees and IDPs) - to protection risks (Oxfam International and WEDC, 2018).

Energy access is an often overlooked issue in emergency responses, falling in between humanitarian sectors. The Safe Access to Fuel and Energy (SAFE) approach provides a multi-sectoral response to diverse challenges and contribute to resilience building of vulnerable people. Energy-related interventions can have important multiplier effects encompassing improved food security, reduced malnutrition, sustainable management of natural resources, small-scale employment generation, livelihood diversification, women and youth empowerment, improved health, climate change mitigation and adaptation, increased resilience in the face of natural hazards and disasters, and sustaining peace.

In this light, a SAFE Working Group for northeast Nigeria was established under the Food Security Sector in August 2017, with the objective to bring organizations together and coordinate an effective response to the issue of energy access. The SAFE Working Group also aims to bring the issue to higher coordination levels. The lack of evidence based knowledge, however, has been identified as one of the major constraints in mobilizing resources and raising awareness.

Global Coordination mechanisms of energy in humanitarian settings

In March 2007, the United Nations Inter-Agency Standing Committee Task Force on Safe Access to Firewood and Alternative Energy (IASC Task Force on SAFE) was established “to reduce exposure to violence, contribute to the protection of and ease the burden on those populations collecting wood in humanitarian settings worldwide, through solutions which will promote safe access to appropriate energy and reduce environmental impacts while ensuring accountability” (IASC, 2009). Member agencies, including FAO, WFP and UNHCR, participated in the task force to help create a formal commitment to addressing the pressing needs and challenges relating to cooking fuel in humanitarian settings. Two critical tools were created for the humanitarian system aimed at ensuring the predictable development of holistic fuel strategies in diverse regions around the world:

- SAFE Matrix on Agency Roles and Responsibilities. The Matrix is a framework for addressing cooking fuel needs in emergency and protracted response settings. It sets out who (which agency and/or cluster) is responsible for what (which fuel-related activities), and when (emergency preparedness and contingency planning; acute emergency; and protracted crises, transition and durable solutions).
- SAFE Decision Tree Diagram. The Decision Tree outlines factors affecting the choice of fuel strategy in humanitarian settings to help determine which cooking fuel options will be most appropriate in diverse response settings.

SAFE formally expanded in early 2014 to become Safe Access to Fuel and Energy, thereby incorporating humanitarian energy needs more broadly. Today, SAFE is led by the SAFE Humanitarian Working Group, a consortium of key partners (including IOM, FAO, UNHCR, the Global Alliance for Clean Cookstoves, and WFP among others) working to meet the energy needs of crisis-affected populations around the world. Each agency contributes with specific expertise critical to addressing the energy needs for the world's most vulnerable populations, and the group is committed to ensuring that relevant stakeholders at all levels take action for energy implementation to achieve large-scale impact and long-lasting sustainable outcomes.

Objectives of the assessment

This report presents the key findings of the multidisciplinary approach to assess the woodfuel supply and demand situation in Borno State, northeast Nigeria. The main objective of this assessment is to quantify the woodfuel energy consumption (the demand) and the woodfuel availability around the four areas of interest (the supply). The consumption of other energy sources is also assessed as well as multi sectoral challenges associated with woodfuel such as nutrition, protection, health and safety and possible tensions over the management of natural resources. This assessment is a collaborative effort between three UN organizations. The drivers and impacts of displacement in acute and protracted crises are intimately linked to the global mandates of all three organizations. Overall, the work has been led by FAO, through its sub-office for northeast Nigeria and with critical support from the team working on FAO's Strategic Programme 5 – Increase resilience of livelihoods to threats and crises, the FAO Energy Team and the FAO REDD+ team. The close collaboration between FAO, UNHCR and WFP is a step towards strengthening resilience partnerships to better support displaced people, decrease protection risks in conflict-affected areas and improve the sustainable management of natural resources in these contexts.

On the global level, FAO, WFP and UNHCR are also closely involved in the Safe Access to Fuel and Energy (SAFE) Humanitarian Working Group, in order to identify and implement appropriate solutions to address the energy-related challenges faced by crisis-affected populations, including both displaced and host communities. The objective of the SAFE initiative is to "satisfy the fuel and energy needs for cooking, heating, lighting, and powering in a safe and sustainable manner, without fear or risk to health, well-being, and personal security of crisis affected populations".

Methodology

This woodfuel supply and demand assessment builds on the methodology developed in the joint FAO UNHCR Technical Handbook "Assessing Woodfuel Supply and Demand in Displacement Settings" (FAO & UNHCR, 2016). The methodology includes three programmatic phases: 1) to assess the woodfuel (fuelwood and charcoal) demand and the associated challenges experienced by IDPs, returnees and host communities, 2) to assess the woodfuel supply including the aboveground biomass stock, land cover classification and changes over time (2013 to 2016/2017), and 3) to identify relevant inter-linkages and gaps as well as to develop and propose possible future scenarios in which improved cookstoves, the use of other biomass feedstock and afforestation interventions are implemented.

The combination of the supply and demand assessment enables to test the hypothesis that the progressive and observed environmental degradation can be related to population influxes and suboptimal energy management. Under that hypothesis, future consumption can be projected based on population growth and the potential degradation to address can be quantified. The assessment involves a combination of desk review of existing documents, a household survey, Focus Group Discussions, field plot measurements and analysis of satellite imagery.

Selection of locations

Borno State, in the northeast region of Nigeria has an area of 57 799 km^2 and consists of 27 Local Government Areas (LGAs), with a population of 4 171 104 persons according to the most recent census of 2006 (National Population Commission, 2006). The capital is Maiduguri, which is located within the Maiduguri Metropolitan Council (MMC) Local Government Area (LGA). The assessment was carried out in four LGAs in Borno State (Konduga, Jere, Gwoza and Ngala). Within each LGA, one community was identified, according to specific characteristics, such as status of majority of people (host community members or IDPs and returnees), geographical location and state of available biomass, in order to broaden the perspective on the issue of energy access in Borno State (figure 4). Around the central point of each community, a perimeter with a radius of 15 km (Auno and Dusuman) and 10 km (Ngala and Gwoza) was defined for assessing the energy demand and potential supply.

- Auno community in Konduga LGA is located at 25 km west of Maiduguri. It is a small town, divided in Auno North and Auno South, consisting mainly of host community members and informal IDPs, who are being hosted within community member's dwellings or in informal IDP camps. The total population within a 15 km radius around Auno town is 53 154 host community members and 10 540 IDPs, of which

10 367 are hosted by the community, not residing in IDP camps. The number of returnees in Auno is 1 313 (VTS, 2018; IOM, 2018).

- Dusuman community in Jere LGA is located 15 km northeast of Maiduguri. Due to the vicinity to Maiduguri, the largest urban center in Borno State, the population within the 15 km radius is significantly higher, including part of the peri-urban population in the northeast of Maiduguri. In addition, a number of large IDP camps are located in this area, of which Muna Garage is one of the most important ones in terms of population size (36 756 registered IDPs). The total host population within the 15 km radius is 578 910, the total IDP population is 325 486 and the total returnee population is 7 050.
- Gwoza community is located in southeast Borno, at 125 km from Maiduguri and near the Cameroonian border. The town has a very strict security perimeter, due to ongoing attacks and instability. Movement in and out of Gwoza town is therefore very restricted, with the town boundaries as the security perimeter. Three formal IDP camps with a total of 10 217 IDPs are located within the town boundaries. The majority of IDPs (52 177), however, are hosted by host community members. The host community consists of 51 055 members, and there is a sizeable returnee population of 36 168 individuals.
- Ngala community is located in northeast Borno, at 140 km from Maiduguri and near the Lake Chad and the Cameroonian border. The security situation is more stable, with a wider perimeter around the town. In Ngala, people are able to go out up to 10 km around the town, in order to collect firewood or engage in other activities (e.g. farming). The host community consists of 66 042 people, with a total IDP population of 54 165 and a total returnee population of 53 046. The largest IDP camp in the area is the International School Camp with 40 349 people.

Figure 4 - Areas of interest of the study, at the border between Cameroon, Chad and Niger, near the city of Maiduguri (Google Street Map as background).

The location of these Areas of Interest (AOIs) can be seen on Figure 4. The buffer zone was determined from results of previous similar studies as a proxy for the maximum walking distance for woodfuel collection.

Data collection for energy demand

The assessment of woodfuel demand was carried out through a household survey and Focus Group Discussions. The objective was to provide data and information on types of woodfuel used, types of energy technologies used and the multi-sectoral challenges faced when collecting energy resources in conflict-affected areas. The questionnaire for the household survey was jointly developed by FAO, UNHCR and WFP, based on previous experiences of SAFE assessments in different countries (e.g. Chad, Kenya and Uganda). The questionnaire (annex 1) was adapted to the local context of Borno State in northeast Nigeria. A template with guidelines and questions for conducting Focus Group Discussions (FGD) was also developed. A total number of 24 enumerators were trained in the questionnaire and FGD. During the training, the questions were further modified, in consultation with the enumerators. Data for the household survey was collected through the Kobo platform.

Figure 5 - Weighting of firewood bundles.

A total of 8 937 households were interviewed and 32 Focus Group Discussions conducted in the four locations over a period of four weeks (December 2017 – January 2018).
A preliminary visit to each location was done before the arrival of the enumerator team, to rapidly assess the location and meet with traditional leaders, government officials and military command to explain the objective of the assessment. Upon arrival of the survey team in each location, another meeting was set up with these stakeholders in order to ask for permission to interview people and conduct Focus Group Discussions. Surveyed households were selected randomly among each category (host communities, IDPs and

returnees). Concerning the FGDs, in each location eight FGD were conducted, segregated along gender, age and status of the household (male/female, under 18 years/above 18 years, Host/IDP and returnee).

The data was then processed and analysed, using the Microsoft Office Excel software, in order to assess major trends in energy demand needs and challenges. The Focus Group Discussions were used to cross-check the information from the household survey and increase the accuracy of the conclusions.

Figure 6 - Focus-Group Discussion with Internally Displaced men in Gwoza.

Data collection for woodfuel supply

Satellite data for land cover mapping

Satellite imagery was acquired for the four locations. For Auno and Dusuman, the Area of Interest (AOI) is defined by a buffer of 15km around the centre of the towns. These two locations were grouped together to include satellite imagery of the city of Maiduguri in the centre. For Gwoza and Ngala, a 10km buffer was used. The Ngala buffer was further adapted to exclude the cross border area with Cameroon (since populations do not cross the border to collect wood) and the irrigated agricultural land surrounding the town. The buffer was determined based on results of previous similar studies as a proxy for the maximum walking distance for woodfuel collection (FAO & UNHCR, 2016). The total AOI of each site is presented in table 1.

Table 1 - Area of Interest over each selected site.

Number	Settlement name	Area (hectares)	Year of study
1	Auno & Dusuman	175 696	2013 and 2016
2	Gwoza	34 368	2013 and 2017
3	Ngala	15 217	2017
Total		**225 281**	

Satellite data for change map

To perform the change mapping, the freely available Landsat data was used. The data was downloaded using the FAO System for Earth Observations, Data Access, Processing and Analysis for Land Monitoring (SEPAL) cloud computing platform.

Biophysical field inventory

The small-scale forest inventory assessed the biophysical parameters of forest and other woodlands. There is no previous local inventory of forests for comparison and determination of the present situation. The Forest Resource Situation Assessment of Nigeria, conducted by FAO in 1999, provides an inventory of high forests in the southern part of the country, but excluded the current AOI (Ameh, 1999).

Due to insecurity and constraints regarding physical access in Ngala and Gwoza, the small-scale forest inventory was only conducted in Auno and Dusuman. Field plots were measured in terms of living aboveground woody biomass stock using a methodology adapted from standard forest inventory (Gregoire & Valentine, 2008; Köhl, Magnussen, & Marchetti, 2006; Mandallaz, 2008; Schreuder, Gregoire, & Wood, 1993; Schreuder, Ernst, & Ramírez-Maldonado, 2004). Deadwood and litter were not considered, since their presence in all sample plots was negligible. All deadwood and litter is immediately collected for consumption as energy source.

Upon arrival in the locations, a meeting with the traditional village leaders and the military command was organized, in order to explain the objective of the field work. Permission was asked for conducting the research and the accessible areas were defined by the military command. In Auno, a perimeter for physical access was set at 8 km. In Dusuman, the security situation raised more concerns, especially to the north of the town. Therefore, access was only granted up to 5 km in the southern direction. In both cases, the military commander provided a military escort to the field team.

Sampling strategy and sample plots

Twenty eight plots were selected in Auno and Dusuman (fourteen in each location), according to a random sampling design. The option of using a stratified sampling methodology was considered, but was deemed unnecessary due to the homogenous character of the area. Empty plots, without any measurable living aboveground biomass, were taken into account to provide a realistic view of the highly degraded environment.

The field work was carried out over a period of 5 days, during which a range of qualitative and quantitative information was collected, including: tree measurements, tree scientific and vernacular names, land use and forest condition. Field data was collected using a specifically designed field form (annex 2) and was entered in Microsoft Office Excel for further analysis.

The forest inventory sample plots are circles of 12 m radius (Figure 7). All living and dead standing trees and shrubs of diameter at breast height (DBH) greater than 2 centimetres falling within the boundaries of the plot have been inventoried with the aid of a tree calliper or a girth diameter tape depending on the size of the tree[2]. All trees measured within the circle have been identified and given both scientific and vernacular names in Hausa. The general condition of the forest and soil in the sample plot was also assessed.

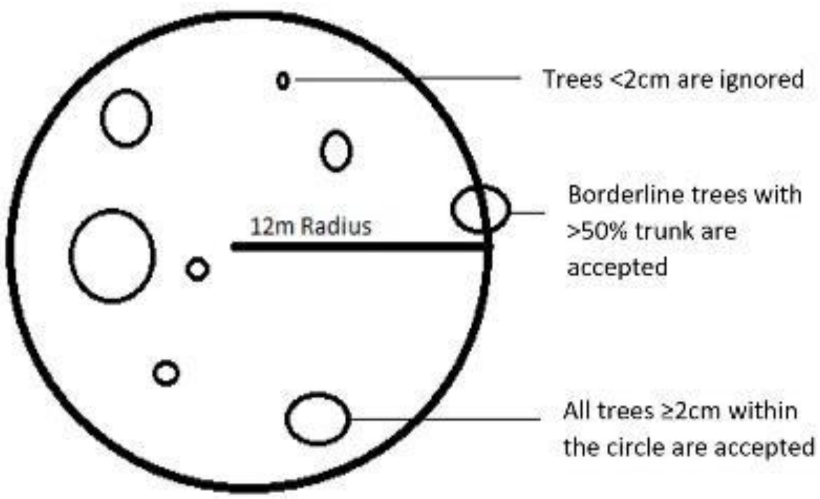

Figure 7 - Biometric measurement of all trees and shrubs within the plot.

[2] The diameter of one tree (*Adansopia digitata*) was larger than the tape length. In this case, an electronic Haga Hypsometer was used.

Remote sensing analysis

The remote sensing analysis was based on multi-date, multi-resolution satellite imagery (from 30 m to 0.5 m) for the four locations. Image processing was performed combining a semi-automatic classification of land cover with change detection processes, as well as using existing global datasets of annual tree cover loss.

Acquisition of images

Very high-resolution (VHR) images were acquired for the four selected sites (shown in figure 4 (AOIs)) for year 2013, and 2016 and 2017. The availability of VHR for the period of interest was a major constrain. The only available images were from different seasons for the different years. In 2013, the only available images were from the dry season (May) and in 2016, the images were from the post rainy season (October and November). The details of the image acquisition are given in Table 2.

No.	Settlement	Satellite	Resolution	No. of tiles	Buffer (km)	Period
1	Auno	SPOT 6	1.5 m	4	15	2013–2016
2	Dusuman	SPOT 6/7	1.5 m	4	15	2013–2016
3	Gwoza	SPOT6/7	1.5 m	1	10	2013–2017
4	Ngala	Pleiades	0.5 m	12	10[3]	2017

Table 2 - Details of the buffer and satellite data for each zone (Source: data collected).

- The Auno and Dusuman communities are located respectively on the western and eastern part of Maiduguri city. The buffer zone for each town was defined as a 15 km radius from the centre of each town. Both communities were combined by overlapping the buffer of 15 km with Maiduguri city and was treated as one AOI in this. Therefore, this AOI includes, Auno, Dusuman and Maiduguri city. In April 2017, Satellite Pour l'Observation de la Terre (SPOT) 6/7 images were acquired for the year 2013 and 2016 for Auno & Dusuman.
- For the Gwoza area, the most recent SPOT 6 images from October and November 2017 were used by keeping the same initial time (2013) of Auno & Dusuman and images with a spatial resolution of 1.5 meter were acquired.
- Ngala is located very close to the border with Cameroon, the major IDP camp in Ngala was established in early 2016. As the time period for detecting change was very small, it was agreed to map only the most recent existing biomass in the area using Pleiades VHR images (0.5 m) of October and November 2017.

[3] The buffer of Ngala was further refined to exclude the irrigated land area to the southwest and the cross border area with Cameroon.

Land cover mapping

Wood resources are distributed unevenly among land use and land cover (LULC) classes in the AOI. The resolution of the imagery for 2013, 2016 and 2017(1.5 m) enables to identify single land cover objects and aggregates this information into detailed land cover classification.

The LULC classes used in the assessment of woody biomass supply and changes of supply are:

- Fuelwood (trees and shrubs): all land cover classes that potentially contain biomass used for fuelwood
- Cropland: land cover classes that contain some vegetation but no sufficient ligneous resources
- Bare and built-up: land cover classes that do not contain any noticeable vegetation

Pre-processing and training data

SPOT 6/7 images with a 1.5 meter resolution were obtained for all AOIs, except Ngala. The Auno-Dusuman area was larger than the other and was delivered in several tiles. Gwoza was covered by a single tile. The images obtained were from two different seasons: the dry and the post rainy seasons. To minimize the effect of seasonality, an histogram was matched and was run on each tile before the final processing. Training data for each land category was collected over each tile manually.

Supervised classification

The training data was collected manually over the two AOIs, using four classes: Trees, Shrubs, Cropland and Built-up for the supervised classification. The polygons were delineated in order to represent pure classes, of relatively small size. In order to increase the ease of use, the training data of 2013 was duplicated and features moved to pure patches to create a balanced 2016/17 training dataset. Then the random forest algorithm was used for the supervised classification which was executed using the random Forest QGIS plugin dzetsaka (Breiman & Cutler, 2015). The classification was pixel-based.

Merging tiles and cleaning

Once the processing chain was executed on all available tiles, the results were merged to create a full AOI level product of classification for each time period. An example of this operation can be seen in Figure 8.

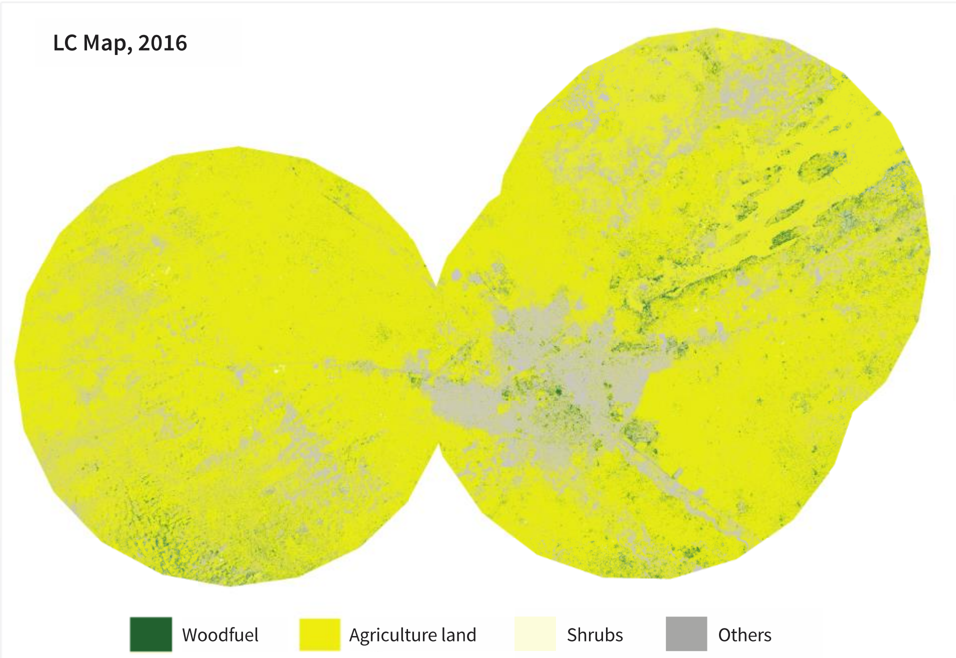

Figure 8 - Mosaic of all land cover tiles over Auno and Dusuman.

The images were processed to produce a land cover map with the above mentioned classes for both the initial (2013) and the final (2016/17) time period. The corresponding plugin, with detailed comments for every step is available on the GitHub at https://github.com/lennepkade/dzetsaka.

Change detection – the BFAST Approach

To establish the change map, Landsat 7 and 8 images with a 30 meters spatial resolution were used. The Landsat data is freely available and can be downloaded from different sites. For the current study, Normalized Difference Vegetation Index (NDVI) time series of Landsat images were downloaded for the time period of 2010 to 2017 using the SEPAL[4] cloud computing system of FAO.

For this study, the Breaks For Additive Season and Trend (BFAST) approach was adopted to perform a change detection within the reference time period. The BFAST methodology tracks a single vegetation index, the Normalized Difference Vegetation Index (NDVI), through time in order to detect both unambiguous and subtle changes in vegetation cover. It requires several parameters to be set in order to define the scope of the analysis, including the time over which the analysis will be carried out, the historical period defining an expected behaviour for each pixel, and a monitoring period indicating from and to dates for detecting any deviations (breaks) from 'normal' pixel behaviour.

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[4] https://github.com/openforis/sepal/wiki

Therefore, breaks can be considered the variations from the seasonal patterns, as a result of abrupt changes (e.g. deforestation, fires) and/or more gradual changes (e.g. encroachment, gradual land degradation) (figure 9).

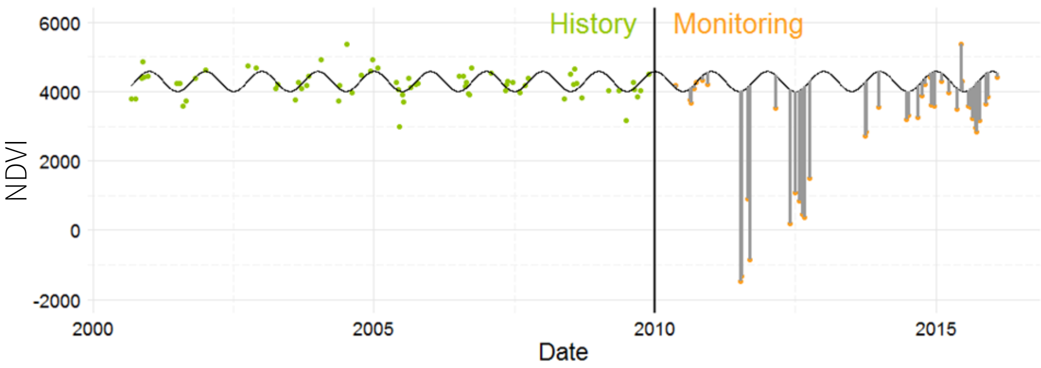

Figure 9 - Graphic representation of the BFAST approach

For the change detection map, the following change categories were further defined:

- Loss: land cover that lost woody biomass between 2013-2016/17
- Gain: land cover that gained woody biomass between 2013-2016/17
- Others: land cover that did not contain woody biomass in 2013 nor in 2016/17.

The parameters used for this analysis are as follows:

- Beginning of historical period: 1 January 2010
- Beginning of monitoring period: 1 January 2013
- End of monitoring period: 31 December 2016 (Auno & Dusuman) and 31 December 2017 (Gwoza).

The processing chain generates a 3-band raster dataset covering the AOI, where the date of break and the magnitude of change is recorded for each pixel. Only the breaks corresponding to the years after settlement establishment were considered (breaks registered between 2013 and 2016/2017 as this is defined as the time period of interest).

The package was tested in SEPAL, the cloud-based platform developed by FAO for the parallel processing of remote sensing data (https://sepal.io). It has been adapted recently into a functional processing chain that uses SEPAL for the preparation of the time series and processing of the algorithm itself. The tools were used and applied directly to the AOI to detect tree-cover changes.

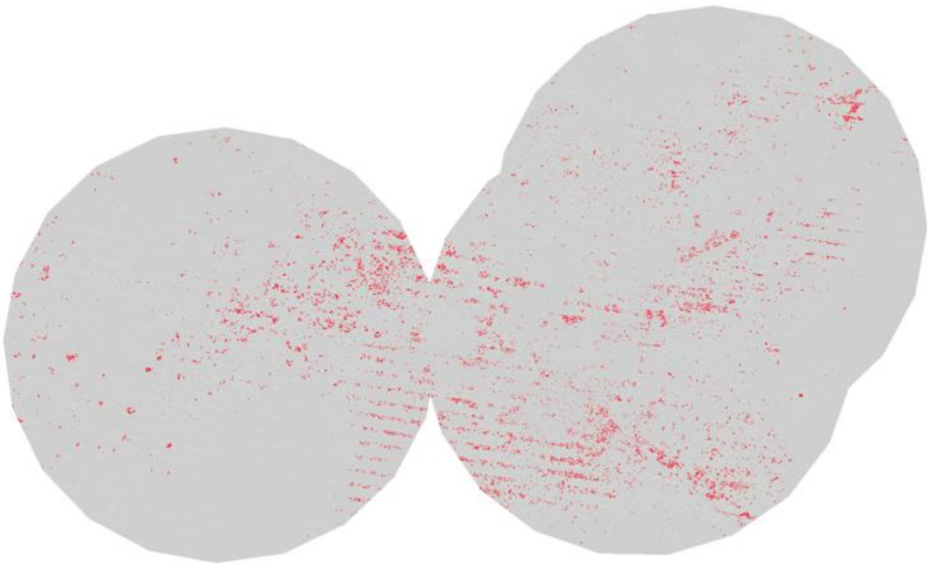

Figure 10 - Change map over the Auno-Dusuman area, with two land cover change classes: loss (red pixel) and no loss (grey areas).

To identify the changes in the area of interest, the layer of change magnitude, which is computed as the median residual (‘difference or distance’) between the predicted and observed values within the monitoring period, was used. The index is a dimensionless value which provides information on the variations in the intensity of the changes (both positive and negative). For example, very large negative values mean large distances of the observed values (at pixel level) from the ones predicted (fitting the model) which refers to abrupt changes (e.g. complete vegetation removal). Based on this, only pixels classified as medium, large and very large negative change were considered. The threshold used in this case was a range of values falling between -662 and -407 to reclassify the data into a change/no change mask. The single value threshold was used to finalise the BFAST results for the change map. Narrowing down the threshold was very difficult but best results was achieved within -662 and -407 range. In some areas with very sparse vegetation and small trees around Auno, this loss range gave slightly exaggerated results.

For the change detection, the BFAST approach was adopted and a change map was produced. The processing chain was run using the System for Earth Observations, Data Access, Processing and Analysis for Land Monitoring (SEPAL) cloud computing system of FAO. The processing chain is available on GitHub at: https://github.com/yfinegold/runBFAST. Both approaches will be further explained.

Integration of field biomass data

The data obtained from the measurements in the field produced plots of aboveground level biomass. For each plot, the count of pixels from each class of the change map was performed and a linear model fitted in order to predict average biomass per class.
The biomass change was made spatially explicit by applying the parameters of the model to produce biomass calculation over the full AOI for 2013 and 2016/17.

Free and open source tools

The tools used for the execution of this processing chain were all Free and Open Source, ensuring a high level of transparency and reproducibility. The characteristics of the different software and libraries are presented in Table 3.

Table 3 - Description of the working environment

Description	Software/tool used
Working environment	Ubuntu 16.04.3 64bits i5-6200U CPU @ 2.30GHz × 4
Processing languages	Bash 4.3.46
	Python 2.7.12
	Perl 5.22.1
Spatial data processing	Open Foris Geospatial Toolkit 1.26.6
	Orfeo Toolbox 5.8.0
Calculations	R 3.4.1
	Rstudio 1.0.153
Visualization, spatial editing, rendering	QGIS 2.18.3
Accuracy assessment	Open Foris Stratified Area Estimator

Energy demand results

A total of 8 937 households were surveyed in the four locations in Borno State, following a questionnaire specifically designed for this energy demand assessment (Annex 1). In addition, 32 Focus Group Discussions were conducted. The questionnaire and FGD were structured around four main topics of interest, namely (1) socio-economic data, (2) energy resources, (3) energy technologies and (4) multi-sectoral challenges related with energy access. The locations were Auno in Konduga LGA, Dusuman in Jere LGA, Gwoza in Gwoza LGA and Ngala in Ngala LGA.

Socio-economic data

The 8 937 surveyed households represent 61 320 individuals, resulting in an average household size of 6.86 for the study. The majority of the households interviewed have a size between 4-8 members. The average household size per location ranges from 6.86 in Auno, 6.71 in Dusuman, 7.08 in Gwoza and 6.86 in Ngala. The distribution of household size is shown in figure 11 with the Y-Axis representing the number of households for each category.

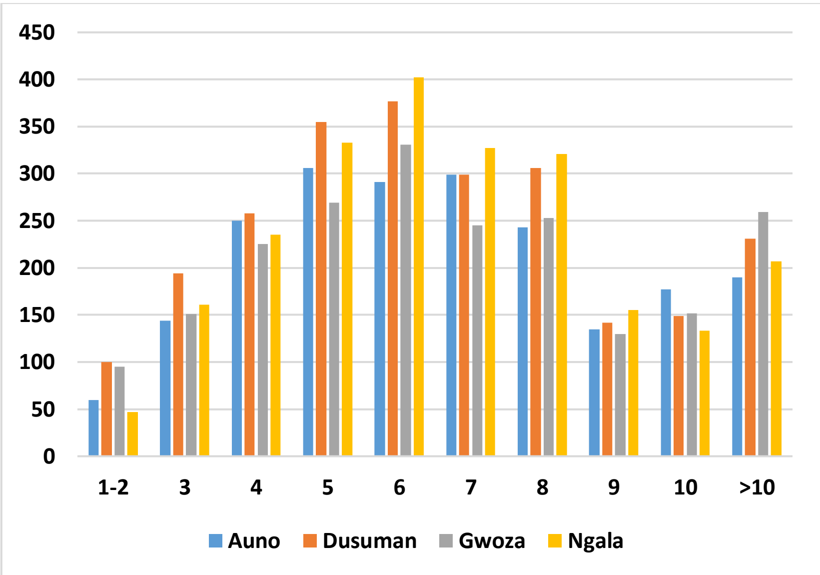

Figure 11 - Distribution of household size over the four sites (source: data collected).

Out of 8 937 respondents, 5 045 are female and 3 892 are male. The overall analysis of age ratios shows that most people belong to the age group of 30-39 years (2 869 respondents). The age repartition per gender is shown in figure 12 with the Y-Axis representing the number of households for each category. The graph demonstrates a predominance of female respondents in the age category < 40 years old and a predominance of male respondents in the category ≥ 40 years old.

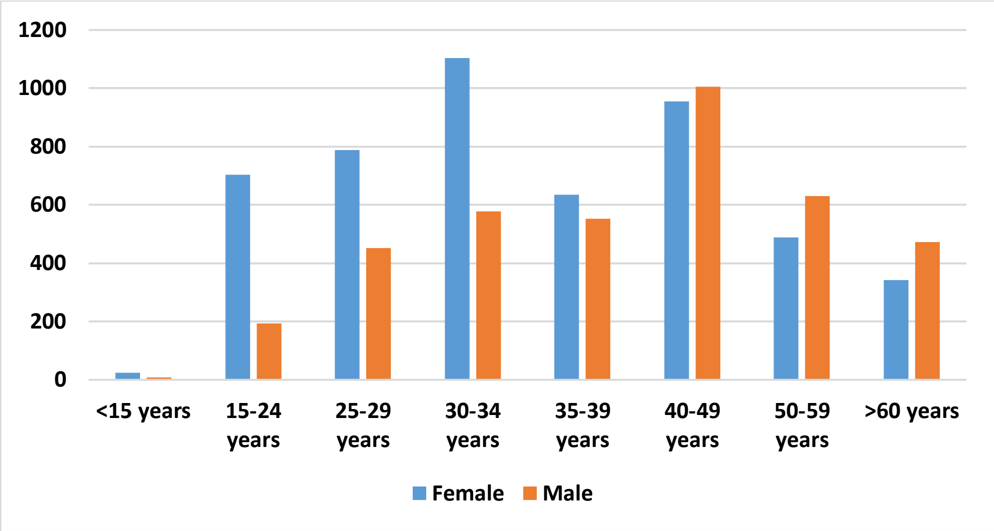

Figure 12 - Age and gender distribution of the sample (source: data collected).

Figure 13 presents the status of interviewed households with the Y-Axis representing the number of households for each category. In the sample, 66 percent of households are IDPs, 10 percent returnees and 24 percent host community members. In Auno and Gwoza, a larger proportion of households surveyed are host community members when compared with Dusuman and Ngala. This can be explained by the set-up of the household survey to achieve an inclusive view on the issue of energy access. In Auno town, no formal IDP camps are present. Displaced persons are hosted informally within the community. In Gwoza, IDP camps are more evenly spread out in and around the town. In Dusuman and in Ngala, on the other hand, there are large-scale IDP camp settings when compared to Auno and Gwoza. The focus of the enumerators was on Muna Garage Camp in Dusuman and the International School Camp in Ngala. The Muna Garage camp site is one of the largest IDP camps surrounding the Maiduguri urban center, with a population of 36 756 IDPs. The International School Camp is gradually becoming an important center for displaced persons in the northern region of Borno State, with a population of 40 349 IDPs (IOM, 2018).

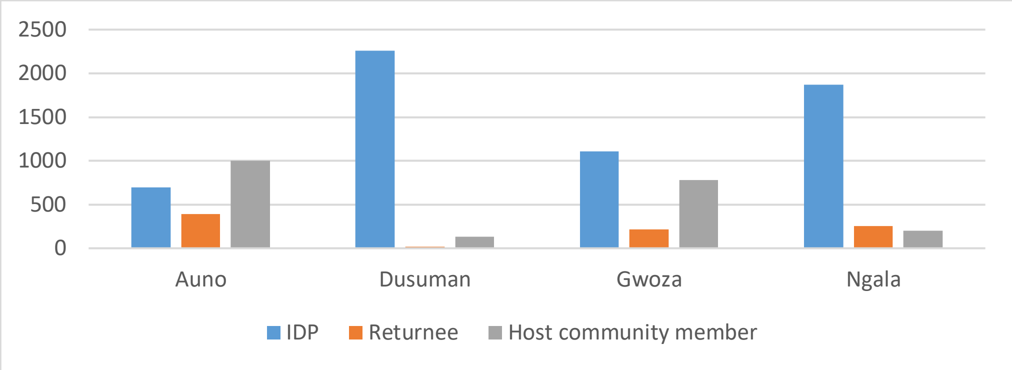

Figure 13 - Status of respondent households (Source: data collected).

Most respondents indicated to rely on agricultural activities as the main source of livelihood (Figure 14 with the Y-Axis representing the percentage of households for each category). Almost an equal number of people indicated to have no source of livelihood at the moment. Other popular sources of livelihood are handicrafts such as cap making and food vending. The majority of households without livelihood options are located in Gwoza and Ngala. The greater distance to the urban center of Maiduguri presents an explanation. The Dusuman and Auno areas are better connected in terms of access to goods and services, which ensures the availability of alternative ways of livelihoods. In addition, the security situation in Gwoza is still very critical. Farmers cannot cross the town boundaries to grow crops in the fields around the town. A strict perimeter has been set in order to avoid attacks and kidnappings. The issue of access to farming land is different in the case of Auno, Dusuman and Ngala, where farmers can move further beyond town boundaries to plant crops.

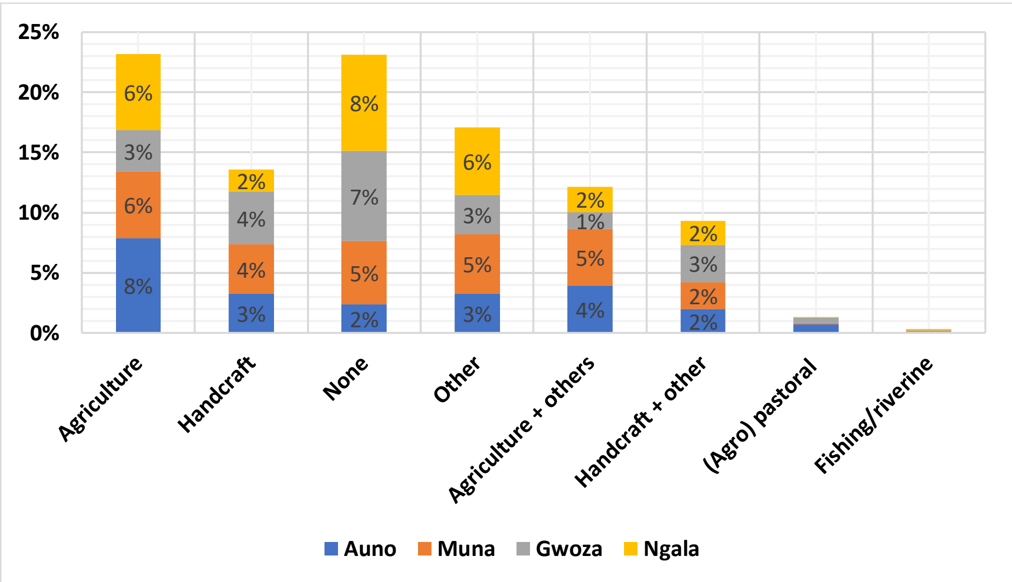

Figure 14 - Livelihood sources in the different locations of the study area (Source: data collected).

Energy resources

In total, 79 percent of the surveyed households indicate to solely depend on firewood for their daily cooking energy needs, 8.1 percent solely depend on charcoal and 8.4 percent depend on a combination of firewood and charcoal. In addition, 3.2 percent rely on a mixture of organic biomass energy sources, including agricultural and animal waste products, most often in combination with firewood and/or charcoal. This means that 98.7 percent, or 8 819 of the total number of respondents, make use of biomass as their only energy source for cooking. The remaining 118 respondents, or 1.3 percent of the total, indicate the use of fossil fuels, such as kerosene, Liquefied Petroleum Gas (LPG) or non-organic waste materials (e.g. plastic), as part of their household energy mix.

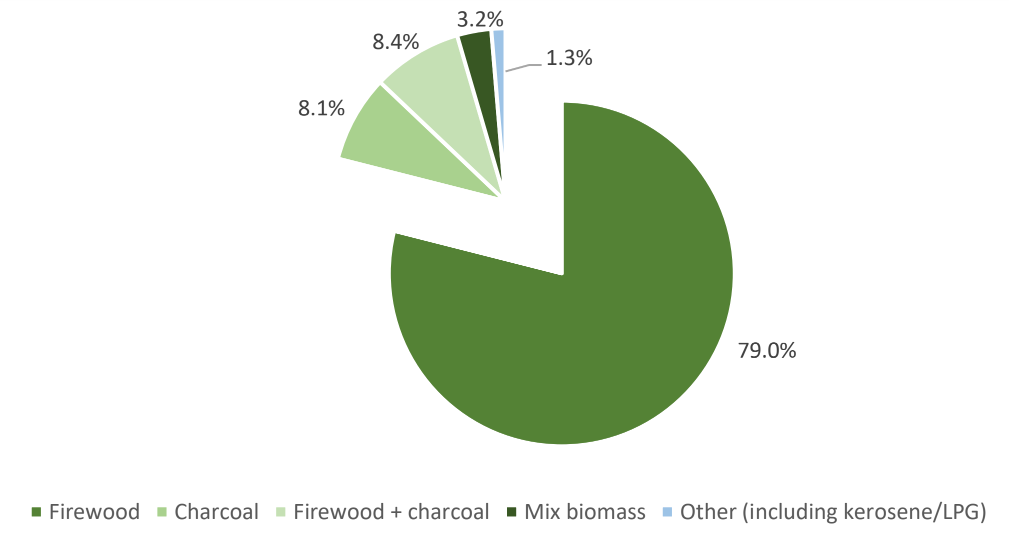

Figure 15 - Overview of the current fuel sources of the respondent households (Source: data collected).

In the following table, the current energy sources per status of household are presented. In general, IDPs (95.2 percent), returnees (96.3 percent) and host community members (95.7 percent) depend on firewood, charcoal or a combination of both to meet their daily cooking needs.

Table 4 - Overview of current fuel sources per status of household (Source: data collected).

Current fuel source	IDP		Returnee		Host	
Firewood	4 680	78.8%	680	77.3%	1 697	80.1%
Charcoal	507	8.5%	92	10.5%	127	6.0%
Charcoal & Firewood	472	7.9%	75	8.5%	203	9.6%
Mix of biomasses	204	3.4%	22	2.5%	60	2.8%
Other (including kerosene and LPG)	75	1.3%	11	1.3%	32	1.5%
Total	**5 938**	**100%**	**880**	**100%**	**2 119**	**100%**

Although host community members rely more on firewood (80.1 percent) and less on charcoal (6 percent) when compared to IDPs and returnees, they make more use of the combination of firewood and charcoal (9.6 percent). A possible explanation for having this greater freedom to choose can be the higher degree of resilience of host community members, allowing them to complement more easily firewood with charcoal. Furthermore, IDPs show a higher dependence on a mixture of traditional biomass sources, in which firewood and charcoal are complemented with less efficient energy sources such as agricultural and animal waste materials. In IDP camps, where sufficient traditional energy resources (firewood and charcoal) are lacking, IDPs often resort to the uncommon and inefficient practice of using animal dung for cooking. In many cases, non-organic waste materials (e.g. plastic bags) are used for kindling.

Figure 16 - Selling of firewood bundles at entrance of Muna Garage Camp (Dusuman).

Figure 17 - Drying of animal dung to be used as energy in International School Camp (Ngala).

Figure 18 - Improvised cooking area, with plastic kindling, in 20 Housing IDP Camp (Gwoza).

In order to assess the knowledge of and openness to other energy sources, the respondents were asked what type of energy source they would prefer if they would have the choice. A total of 77.9 percent would prefer to keep using traditional biomass energy sources (firewood, charcoal, agricultural and animal waste materials). This is a decrease of 20.8 percent compared to the actual situation, with kerosene and LPG filling up this space, being the top choices as alternative energy sources. Only 29 households indicated to prefer solar energy when given a choice. This can be explained by the current predominance of traditional biomass energy sources and the low availability and knowledge of alternative energy sources, including solar energy. Furthermore, it clearly makes visible the need for sensitizing the population on the negative impacts of using traditional biomass resources, not only for health reasons, but also for deforestation and the longer term effects on climate change.

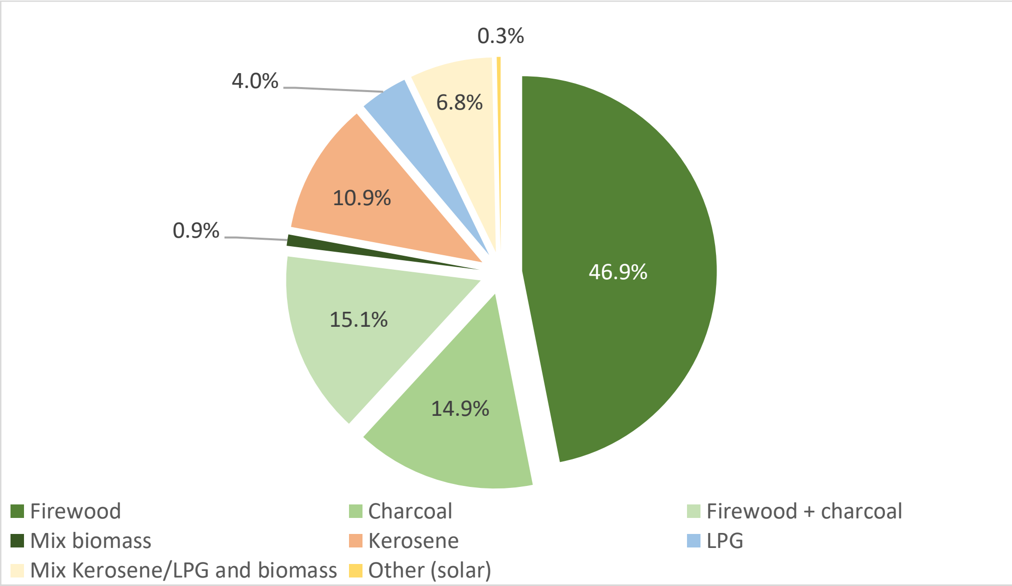

Figure 19 - Overview of preferred fuel sources (Source: data collected).

When looking at where these different fuel types are sourced, 5 731 people (64.1 percent) indicated that they buy firewood from local sellers and market places, and 1 921 people (21.5 percent) depend on the collection of firewood from the surrounding environment. The remaining 1 285 people (14.4 percent) are sourcing the fuel by combining different approaches of buying, collecting or receiving from humanitarian actors. As regards the frequency of sourcing firewood, most people (44.2 percent) indicated they collect or buy firewood two to three times per week. A total of 1 620 people go out four to six times a week and 502 people on a daily basis.

This high number of people who buy firewood can be explained by the widespread protection risks and the strict security perimeters around towns. The most vulnerable people, who do not have sufficient means to access energy, can also not go out to collect firewood. In many cases, they are forced to sell food products or other assets, in order to buy firewood, leaving them more vulnerable to undernutrition. It should also be mentioned that the most vulnerable IDPs have adopted the collection of firewood as a means of livelihood. While risking their life, going into unsafe and insecure areas, they collect firewood in order to sell in the IDP camp. This practice has been observed in all four locations.

Figure 20 - Chopping of firewood at the entrance of Muna Garage Camp (Dusuman).

Figure 21 - Transport of firewood in the International School Camp (Ngala).

Cooking technologies

In total, 64.9 percent of interviewed households use the traditional three stones stove technology for cooking their food. More than 50.7 percent of the total respondents indicated that they make use of this technology exclusively, while 14.2 percent make use of another type of stove in addition to the three stones fire. The mud stove is the second most common type of cooking technology, with 24.2 percent of people making use of the mud stove exclusively for their daily cooking needs. The third type of stove is the locally produced metal stove. Only 69 people make use of other types of energy technologies, such as the kerosene stove, gas stove or solar cooker.

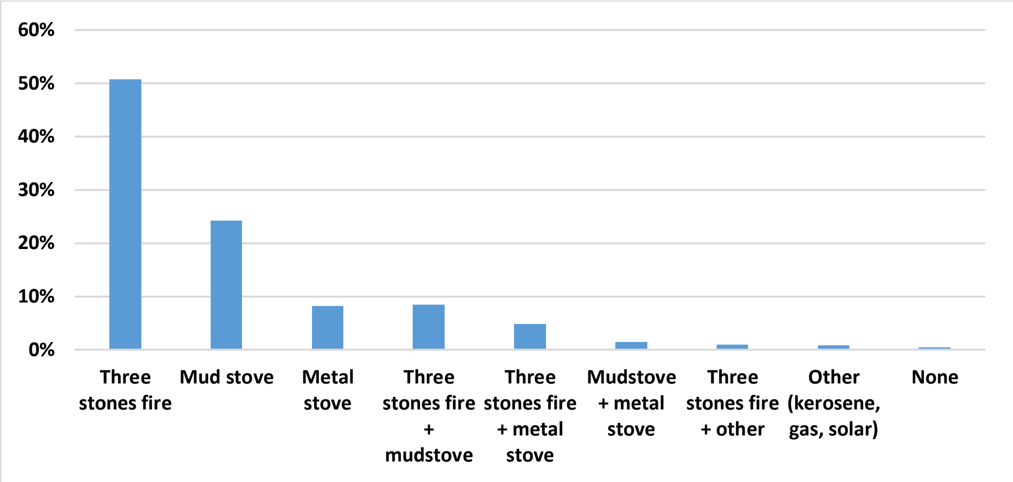

Figure 22 - Overview of current cooking technologies (Source: data collected).

It is important to note that more than 98 percent of respondents make use of inefficient energy technologies, requiring large amounts of energy to satisfy basic cooking needs, and that more than 15 percent of the respondents make use of multiple energy technologies at the same time. Furthermore, the majority of people use their stove 2 times per day (48.2 percent) followed by three times per day (47.6 percent).

Figure 23 - Most common cooking technologies (left to right: three stones fire, mud stove, metal stove).

In large and highly congested IDP camp settings, using appropriate and safe cooking technologies is important to reduce the risk of fire outbreaks in the camp. A metal stove is in some cases part of the Non Food Item (NFI) package that new IDPs receive upon arrival in the camp. This is to decrease the amount of open flames in the camp. Other solutions can be the organization of communal cooking spaces, where IDPs come to certain designated areas of the camp to cook. The success of such interventions depends on the willingness of IDPs to participate, since communal cooking is not a common practice in Borno State and can cause tension among IDPs.

Figure 24 - Communal cooking area with three stones fires in the International School Camp (Ngala).

Figure 25 - Shelter with a kitchen and food processing areas in Muna Garage Camp (Dusuman).

The main type of food cooked per surveyed household (Figure 26) is sorghum (48.2 percent) followed by rice (14.3 percent), maize (14.2 percent) and millet (12.6 percent). Wheat (2.7 percent) and beans (1.7 percent) are less often cooked as the main type of food. It is worth noticing that in Gwoza 102 respondents (or 4.8 percent) indicated that there main type of food is a fortified food supplement, distributed by humanitarian organizations.

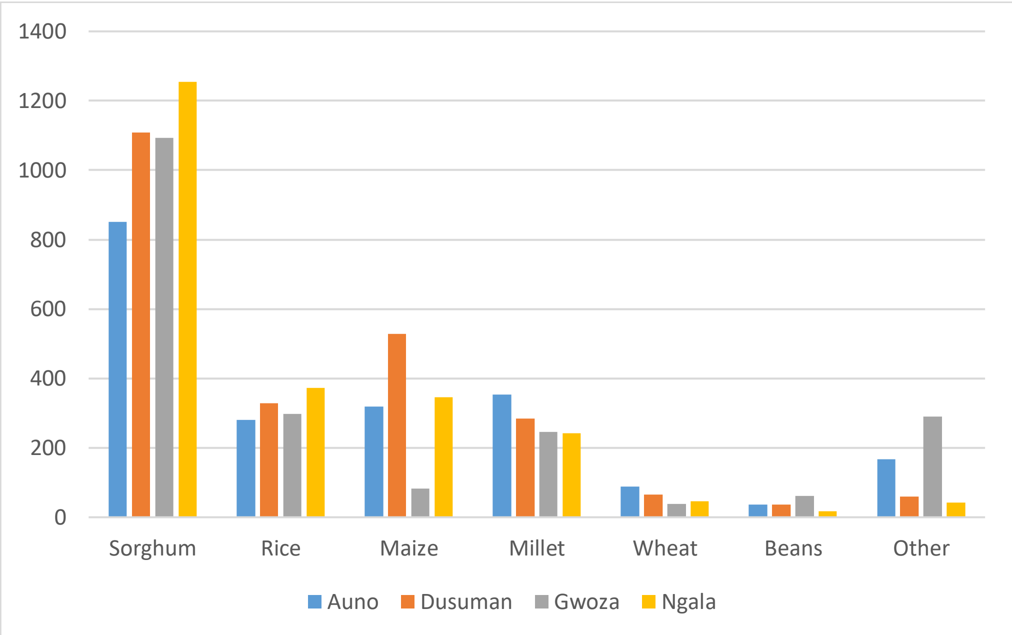

Figure 26 - Most common food cooked by the surveyed households in the four areas of interest (Source: data collected)

These food items were associated with different cooking times by respondents ranging in average from 20 minutes for wheat pasta, 30 minutes for the fortified food supplement, 40 minutes for rice, 50 minutes for maize and sorghum and 60 minutes for beans and millet.

Respondents to the questionnaire were also asked the maximum price they would be willing to pay for their preferred stove (figure 27). The average willingness to pay (WTP) is 4 530 Nigerian Nairas (NGN), the equivalent of 12.44 US Dollars (USD). It is important to notice that for 1 475 respondents (or 16.5 percent) the WTP is higher than 5 000 NGN. This is positively linked to the preferred type of cooking technology, indicated by these respondents, namely gas stove, kerosene stove or cooking with solar energy. The prices for these types of technologies are higher than for the fuel-efficient biomass technologies. When this top 16.5 percent is not considered, the average WTP for the remaining 83.5 percent of respondents drops significantly to 1 508 NGN (4.14 USD). The technologies referred to below 5 000 NGN are primarily fuel-efficient cookstoves, both metal or ceramic, for different types of biomasses (firewood and/or charcoal). A total of 422 respondents (or 4.7 percent), of which 332 are IDPs, are not willing to pay for a new energy technology and indicated that they will continue to cook on the three-stone fire. One explanation for this is the high vulnerability, especially of IDPs, who might have limited perspective of improving on their current situation.

This information is of major importance to promote the development of a local fuel-efficient stove market. It can support the development of innovative delivery models, recommended by this assessment, by entrepreneurs to support the strained energy needs of the local communities.

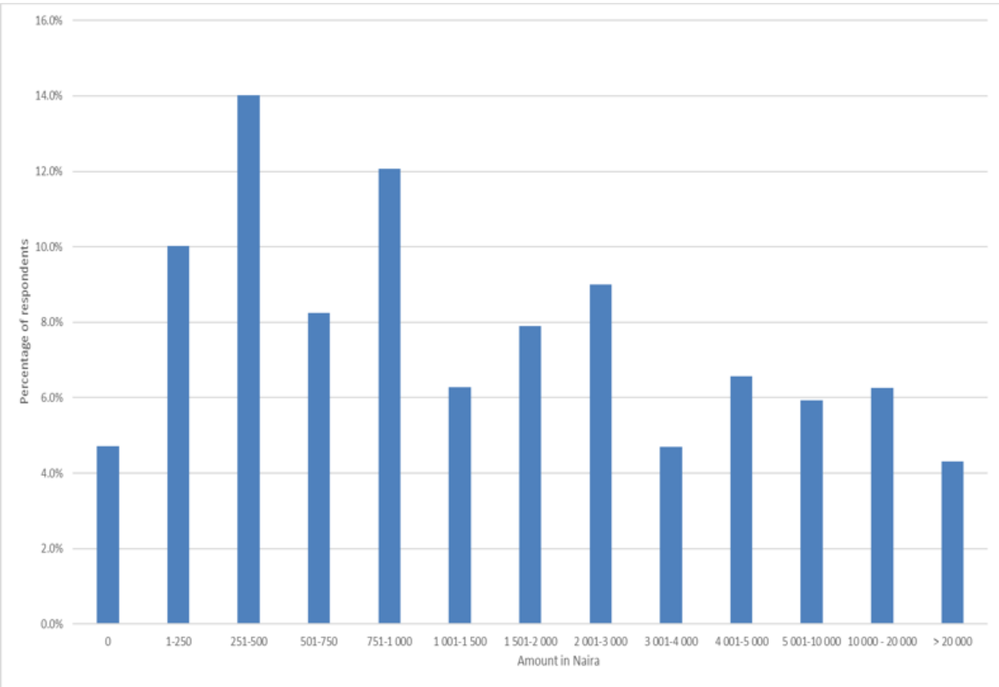

Figure 27 - Willingness to Pay of respondents (Source: data collected)

Biomass consumption

Considering the current energy sources and technology (traditional biomass resources and inefficient energy technologies), it is not surprising that 76 percent of the respondents have reported to have insufficient access to energy sources to cover their daily energy needs for cooking. In terms of consumption of biomass for energy purposes, 6 815 households (who indicated to exclusively use firewood, irrespective of the type of stove used) consume an estimated 1 199.96 tonnes of firewood per month. The average biomass consumed per household per day is 5.869 kg, which results in 0.855 kg per individual per day for firewood. This is within the range of energy consumptions for cooking in displacement settings found in the literature: 0.7 kg to 3 kg per person per day (Gunning, 2014).

The following tables provide a more detailed perspective, taking into account the energy technology, location and status of households. In order to improve accuracy of data, only respondents who indicated to use firewood exclusively and who indicated to use one energy technology exclusively (three stones fire, mud stove or metal stove) were considered (5 634 households in total).

Table 5 - Firewood consumption of 5 634 surveyed households, per energy technology, location and status (Source: data collected).

Auno (1 292 HH)			
Energy source and technology	Status HH	Total HH	kg/ind/day
Firewood - three stones fire	IDP	357	0.838
	Returnee	212	0.861
	Host	513	0.812
Firewood - mudstove	IDP	21	0.871
	Returnee	40	0.793
	Host	70	0.869
Firewood - metal stove	IDP	15	0.843
	Returnee	36	0.933
	Host	28	0.804
		Average	**0.834**

Dusuman (1 631 HH)			
Energy source and technology	Status HH	Total HH	kg/ind/day
Firewood - three stones fire	IDP	467	0.830
	Returnee	3	0.722
	Host	30	0.578
Firewood - mudstove	IDP	1.030	0.820
	Returnee	8	0.952
	Host	26	0.925
Firewood - metal stove	IDP	46	0.706
	Returnee	4	0.599
	Host	17	0.697
		Average	**0.815**

Gwoza (1 490 HH)			
Energy source and technology	Status HH	Total HH	kg/ind/day
Firewood - three stones fire	IDP	773	0.868
	Returnee	129	0.865
	Host	411	0.737
Firewood - mudstove	IDP	32	0.589
	Returnee	9	0.728
	Host	37	0.852
Firewood - metal stove	IDP	27	1.036
	Returnee	13	1.007
	Host	59	0.805
		Average	**0.826**

Ngala (1 221 HH)			
Energy source and technology	Status HH	Total HH	kg/ind/day
Firewood - three stones fire	IDP	541	0.947
	Returnee	8	0.773
	Host	22	1.166
Firewood - mudstove	IDP	277	0.969
	Returnee	85	0.974
	Host	26	1.064
Firewood - metal stove	IDP	236	0.971
	Returnee	18	0.767
	Host	8	1.119
		Average	**0.962**

These figures need to be interpreted in relation to the particular context and location.

- In Auno, the majority of surveyed people, who only use firewood for cooking, make use of the three stones fire. Only 210 out of 1 292 people (or 16.2 percent) use a mud stove or metal stove. Mostly host community members and returnees have access to these energy technologies. It should be noted that no formal IDP camp is present in Auno, with IDPs being informally hosted by relatives or friends within the town.

- Gwoza presents a similar scenario. The three stones fire is the most common energy technology, used by 1 313 out of 1 490 people. The gap between IDPs and returnees/host community members in terms of accessing mud stoves and metal stoves is slightly smaller. The presence of official IDP camps in Gwoza is a possibly explanation. In this way, IDPs in Gwoza are better documented and more visible to receive external support.
- Dusuman presents a different scenario, because of the predominance of IDPs that were surveyed in the Muna Garage camp. It is important to notice that for people who only make use of firewood for cooking, the mud stove is the most common energy technology (65.2 percent of people, mostly IDPs), followed by the three stones fire.
- In Ngala, the households surveyed were mostly IDPs in the International School camp. A significant higher number of people indicate to have access to a metal stove, which can possibly be linked to the inclusion of the metal stove in the Non Food Item (NFI) kit received upon registration in the camp.

Compared to Auno and Gwoza, the use of mud stoves and metal stoves is more widespread in the large-scale camp settings of Dusuman (Muna Garage) and Ngala (International School Camp). The support provided by the government and the humanitarian actors in the field of camp management, shelter, food security and other key sectors could provide an explanation in this context.

Figure 28 - Firewood merchant in Maiduguri.

Figure 29 - The firewood market of Maiduguri.

Biomass consumption for the AOIs

A rapid woodfuel market assessment (FAO, 2018) was performed in Maiduguri to define the ratio of local woodfuel (firewood and charcoal) which was sold on the market in order to integrate the local supply and fuel demand information. It is estimated that 80 percent of the wood and 20 percent of the charcoal sold in the market comes from outside of Borno State and the AOIs. Based on this assessment, a low conversion efficiency rate of wood to charcoal of 15 percent was used for the calculations (see figure 30 and 31). Finally, when households declare using two sources of woodfuel, half of the individual charcoal consumption of the specific category was imputed together with half of the individual woodfuel consumption of the specific category.

Figure 30 – During the first step of the charcoalization process, burnt wood logs are assembled to form a pyre.

Figure 31 - After lighting, the pyre is covered with soil until the end of the process.

The total woodfuel consumption for year y (W_{ycH}), expressed in tonnes per year, is calculated as follows:

Equation 1 - Total woodfuel consumption for year y.

$$W_{ycH} = \sum_{Household\ status\ Category} W_c \times P_{cy}$$

Where:

W_c = Wood consumption per individual per year for the household status category (Host, IDP or returnee) in tonnes

P_{CY} = Population of the household status category, for year y

The average woodfuel consumption of the households per year, expressed in tonnes per year, is calculated as follows:

Equation 2 – Average woodfuel consumption per household per year

$$Average = \frac{\sum_{y=2013}^{2016} W_{ycH}}{3}$$

The results are presented in Table 6.

Table 6 - Household woodfuel consumption for cooking in the three areas of interest in 2017 in tonnes - (Source: data collected).

Fuel source for cooking	Auno & Dusuman		Gwoza		Ngala	
	Population	Total woodfuel consumption in tonnes per year	Population	Total woodfuel consumption in tonnes per year	Population	Total woodfuel consumption in tonnes per year
Wood	796 948	237 027	127 684	38 579	122 107	45 057
Wood and charcoal	89 615	19 846	15 990	3 653	23 485	5 096
Charcoal	33 215	4 793	2 352	366	25 292	2 043
Wood and other source(s)	15 051	12 257	1 022	306	493	172
Wood, charcoal and other source(s)	20 908	4 504	1 541	361	1 320	303
Charcoal and other source(s)	2 329	361	8	1	0	0
Crop residues and dung	16 172	0	287	0	99	0
Kerosene	1 049	0	138	0	261	0
Liquefied Petroleum Gas	196	0	369	0	107	0
Non organic waste	0	0	0	0	76	0
Do not cook	970	0	225	0	13	0
Total	**976 453**	**278 788**	**149 617**	**43 266**	**173 253**	**52 672**

In order to integrate the woodfuel demand with the supply, it is necessary to align the woodfuel demand in 2017 with previous years of the study period (2013 to 2016 or 2015 in the case of Auno & Dusuman) in the three areas. The total estimated household woodfuel consumption in each area over the period 2013 – 2017 is presented in table 7.

The changes of population and the displacement dynamics over the period (2013 to 2017) were taken into account based on the relevant literature (IOM, 2018; UNDESA, 2017). The displacement dynamics differ in the three AOIs according to the security situation. The majority of IDPs in Ngala were displaced in 2016. The majority of refugees from Borno State to neighboring countries (Cameroon, Chad and Niger) were displaced in 2015 (UNHCR, 2018). Also in 2015, the majority of IDPs in Gwoza were displaced whereas it was in 2014 for Auno & Dusuman.

Table 7 - Total estimated woodfuel consumption in the three AOIs in tonnes per year

	Auno & Dusuman		Gwoza		Ngala	
Year	Population	Woodfuel	Population	Woodfuel	Population	Woodfuel
2017	976 453	278 788	149 617	43 266	173 253	52 672
2016	951 405	271 637	145 779	42 157	117 502	35 722
2015	962 106	274 692	84 157	24 337	118 823	36 124
2014	812 684	232 030	81 964	23 702	115 727	35 183
2013	791 355	225 941	79 813	23 080	112 690	34 259
Average	**224 221**[5]		**28 319**		**35 322**	

In the Auno & Dusuman area, the total estimated woodfuel consumption over the period 2013 to 2016 is 224 221 tonnes per year. The total estimated woodfuel consumption over the period 2013 to 2017 is 28 319 tonnes per year in Gwoza and 35 322 tonnes per year in Ngala.

Multi-sectoral challenges related to energy access

A limited access to safe and sustainable energy resources and safe and efficient energy technologies significantly impacts the life of vulnerable people. This is especially true in the case of displaced populations in conflict-affected areas. The issue of energy access should take on a multi-sectoral perspective, in order to grasp the full extent of the risks and challenges.

[5] For the Auno & Dusuman area, the average total estimated woodfuel consumption is calculated between 2013 to 2016 instead of 2013 to 2017 in Gwoza and Ngala to respect the time period of the satellite imagery.

Protection

Collecting firewood for daily cooking needs is a laborious task, which requires walking for long distances to find sufficient energy resources. In the context of Borno State, which is a conflict-affected with ongoing insecurity situation, this poses serious risks to men, women, boys and girls who go out to collect firewood. Since fuel is lacking in camps, they are forced to go out in unsafe and insecure areas in order to meet their energy needs.

Overall, 84.8 percent of the people indicated that they have faced protection risks or that other people in their community have faced protection risks when going out to collect firewood. Protection risks include harassment, physical or sexual and gender-based violence, abduction and killings. Out of the 8 937 interviewed household, more than half (58.7 percent) indicated that they know somebody in their community who has lost his or her life while collecting firewood and 55.7 percent (4 980 households) reported that they know somebody in their community who was abducted during firewood collection.

The analysis of data collected showed that 58.4 percent of interviewed household indicated that firewood is mainly collected by adults alone, without any children or youth accompanying. Firewood collection in the four locations is traditionally carried out by women and children. The perception of protection risks being high, however, one of the strategies adopted is for adult men to go out and collect firewood (39.8 percent). Eleven percent of households reported that adult women go out alone to collect firewood and 7.2 percent of households indicated that adult men and women go out together. Regarding child protection especially, 11.9 percent of interviewed households indicated that children and youth (up to 25 years of age) go out alone to collect firewood.

The reason for this shift towards more involvement of men in collection of firewood is the high rate of protection issues faced during the past years. Information collected during focus group discussions revealed that host community members, IDPs and returnees are organizing the search for firewood differently, in this way adapting to the ongoing conflict situation. These coping mechanisms can have an impact on the local power relations between men and women. It is clear that protection risks related to the collection of firewood remain a major issue and require particular attention of actors in conflict-affected areas in terms of prevention and response.

Most people who indicated that they do not face any protection risks when accessing firewood are living in Auno (798 households) and Dusuman (421 households). This is a remarkable difference with the low number of people in Gwoza (87 households) or Ngala (53 households), who indicated to face no protection risks. An explanation can be provided by the more stable security situation in Auno and Dusuman, due to their vicinity and connection to Maiduguri. Safe access to fuel is in this case strengthened because of the presence of a large urban centre.

In the case of Gwoza, the security perimeter coincides with the town boundaries. People are not allowed to go out to collect firewood. A system is in place, however, in which people can go out and collect firewood once or twice per month, after a larger perimeter has been secured under military escort. These initiatives are helpful, but they are not sufficient to meet the energy needs of the total population in Gwoza. In Ngala, the security perimeter is larger and people can move around with less restrictions. Due to the large distances they need to cover to find firewood and the unstable security situation, they still face serious protection issues including conflict-related sexual violence. A different system was set up, in which large groups of people (up to 100 people), consisting of women and men, go out together to collect firewood.

Nutrition

Ensuring access to energy is intrinsically linked to the goal of improving nutrition. When cooking fuel is not readily available, it can have a considerable impact on the nutrition of vulnerable populations. Moreover, the time people spend collecting fuelwood directly affects the time available for other productive or caring activities, such as feeding of children. Limited access to energy negatively affects the quantity, quality and nutritional value of the food consumed if it results in inadequate cooking time. In the context of forced displacement, this problem is even more pronounced. Yet, the distribution of food, e.g. dried beans, grains and flour to IDPs, is most often not complemented with the distribution of cooking fuel or fuel-efficient technologies in Borno State.

89.5 percent of the people interviewed indicated that they face challenges related to nutrition as a result of an insufficient access to energy resources. A number of coping strategies exist, such as:

- Skipping of meals, which can lead to malnutrition especially in children (indicated by 81.2 percent)
- Switching to less nutritious food products with shorter cooking times (indicated by 42.2 percent)
- Selling and/or trading of food to obtain cooking fuel (indicated by 33.1 percent)
- Undercooking of food, which increases the risk of foodborne illnesses (indicated by 29.7 percent)
- Insufficient boiling of water, resulting in consumption of contaminated water (indicated by 16.5 percent)

Deforestation

Borno State is experiencing the negative impacts of climate change, with droughts, erratic rainfalls and soil erosion, leaving the conflict-affected people more vulnerable. The limited adaptive capacity in the region is linked to the ongoing insurgency, which has disrupted farming activities (including forestry) and extension services. While before the start of the conflict, tree nurseries were operated by the Borno State Ministry of Environment in each of the 27 LGAs of Borno State, these have been abandoned due to the violence and insecurity. The tree nursery in Maiduguri is one of the only functional ones left.

When large IDP camps are established near existing communities, it increases the pressure on the natural surroundings. A total of 90.7 percent of the surveyed people noticed a decrease in the availability of firewood resources in the surrounding environment in the past year. People unsustainably harvest wood resources in the immediate environment, forcing them to move further into insecure areas to collect sufficient firewood. Less than half, or 39.2 percent, of the surveyed households indicated that they solely collect dead wood for cooking purposes. Major differences among the four locations were not observed. A total of 50.7 percent includes living wood resources (complete tree, branches and shrubs) in their energy mix. In most cases, harvesting of living wood resources is undertaken in an unsustainable way, leaving the trees and shrubs not sufficient time to heal and regenerate. Furthermore, a total of 630 people make use of bark or roots as cooking energy. It can be stated that these people are part of the most vulnerable group of people. Bark is an inefficient cooking fuel, while digging up roots is a heavy and dangerous task. People only make use of these fuel types in case they have no access to alternatives such as firewood.

Wood resources in the immediate environment are not only used for energy purposes. A total number of 7 219 people or 80.8 percent make use of wood resources for other purposes, such as construction of houses and shelters, medicinal practices, provision of shade for people and livestock, and livestock feed. For these other uses of wood resources, the majority indicated that access and availability is insufficient to meet the needs.

Figure 32 - IDPs returning to the International School Camp (Ngala) after collecting wood for multiple purposes.

Tensions over natural resources

Competition over natural resources, including energy resources, can create tensions between population groups, especially in a situation of displacement, where large groups of newly arrived people rely on the same resources as of the existing community. Further limitations and restrictions of movement, linked to insecurity and violent attacks, can increase such tensions.

A total of 70.3 percent people indicated that they have no access to the woodfuel resources on the land in the immediate environment where they live. In the majority of cases, the reason is the insecure situation and fear of attacks. Only 141 people (1.6 percent) indicated that tensions or problems, related to the collection of firewood, occurred between host community members and IDPs or returnees. The major issue concerns trespassing, when IDPs enter the land of host community members to harvest firewood resources. Other sources of tensions that surfaced are jealousy (IDPs who receive more attention in terms of humanitarian support) and false accusations (IDPs who go out to collect firewood and are falsely accused to be insurgents).

Overall, the majority of people are not aware of any rules or agreements put in place to regulate the collection of firewood in the surrounding environment. In some cases, it was mentioned that firewood collection is planned on certain days, in which both IDPs and host community members participate. For security reasons, there is also the use of a time schedule for people going out to collect firewood, to which they need to conform.

Interestingly, commercial relationships between IDPs, returnees and host communities exist, regarding the collection and selling of energy resources. Almost half of the surveyed households indicated to be aware of such practices, in which firewood, charcoal or animal dung is sold. This is usually an alternative way of livelihood for the most vulnerable people, who risk their life going out in insecure areas to collect firewood. This firewood is subsequently sold in order to buy food and satisfy other basic needs.

Health and safety

In Borno State, women and children are responsible for preparing meals and attending to the cooking fires. The majority of people (87.4 percent) cook outside, in the open air, in the close vicinity of their home, and only 12.2 percent cook inside a closed space. Communal cooking is only practiced by a small minority (30 households). As mentioned earlier, this is not a traditional practice in terms of cooking habits, but is introduced in some IDP camps in order to decrease fire risks.

The practice of cooking on open fires (inside or outside), without any provisions to divert smoke, has a significant impact on the health of women and children. A total of 44.5 percent of people indicated that at least one person in their household experienced respiratory illnesses and lung problems in the last year, while 36.5 percent indicated that at least one person in their household experienced burn wounds related to cooking. These numbers provide a more detailed perspective on the health issues faced by women and children, when attending cooking fires and preparing meals.

Energy for lighting purposes is an important measurement of safety and general well-being. In the absence of energy for lighting, protection risks are further increased, especially for women and children who are exposed to Gender-Based Violence (GBV) (e.g. harassment, physical or sexual assault, rape, abduction) and to a higher degree around community infrastructures such as latrines. Furthermore, having access to a source of light allows for productive and income-generating activities to continue after dark and will contribute to an increased level of education, since students will be able to continue learning and do homework in the evening. In the four surveyed locations, the majority of people (87.86 percent) indicated that they have access to a battery-powered torchlight, 11.61 percent indicated they have access to a solar lantern, while 3.22 percent of households indicated to have no access to lighting. Solar powered torchlight is a common item distributed to IDPs and returnees in the Non-Food Items (NFIs) kit: the majority of respondent (7.19 percent) declared to have received the solar lantern from a humanitarian actor.

Most significant challenges

In order to get a deeper understanding of the risks and challenges associated with energy access, the following question was asked to the 8 937 households at the end of the survey: "What are, according to you, the three most significant risks and challenges related to energy access in your community?". A choice was provided, in relation to the different sectors, namely protection, nutrition, deforestation, tension between communities, and health/safety. The option for 'no challenges' or 'other challenges' was also included.

The most important challenge when accessing energy are the protection risks, with 69 percent of the respondents indicating that it is their main concern. This gives a strong indication of the level of ongoing insecurity and violence, affecting many people who are risking their lives obtaining energy resources.

At the second and third place, challenges related to health and nutrition were indicated by 13 and 12 percent of households respectively. Nutrition challenges associated with insufficient energy access include skipping of meals and undercooking of food. As mentioned earlier, firewood collection is a very laborious task requiring a good health status. As such, deteriorated health conditions may be very challenging to access firewood. The second aspect related to health is respiratory illnesses.

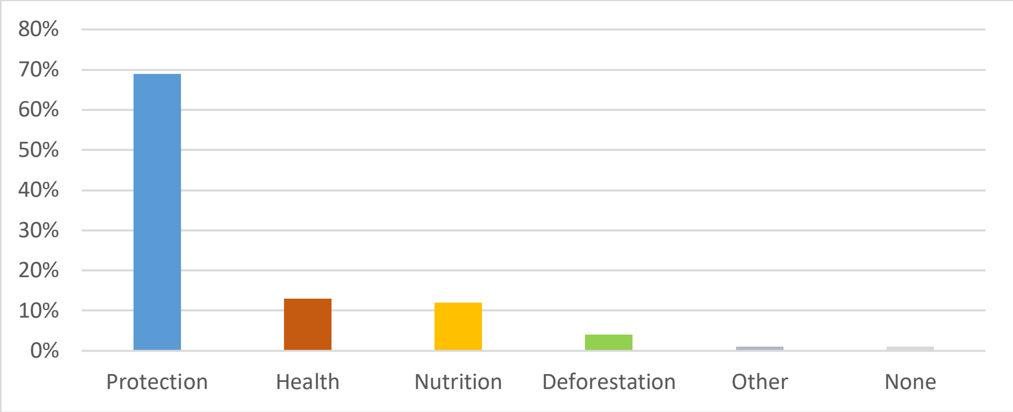

Figure 33 – The most important challenges related to energy access (Source: data collected).

The protection risks, associated with a limited energy access, present immediate and life-threatening situations, which are interfering with the lives of people in profound ways. The second most important challenge related to energy access is for most people related to nutrition (42 percent) and health (35 percent). These challenges are, compared to protection risks, still very pressing but to a smaller degree. Negative effects show themselves on the longer term and are of a less immediate nature.

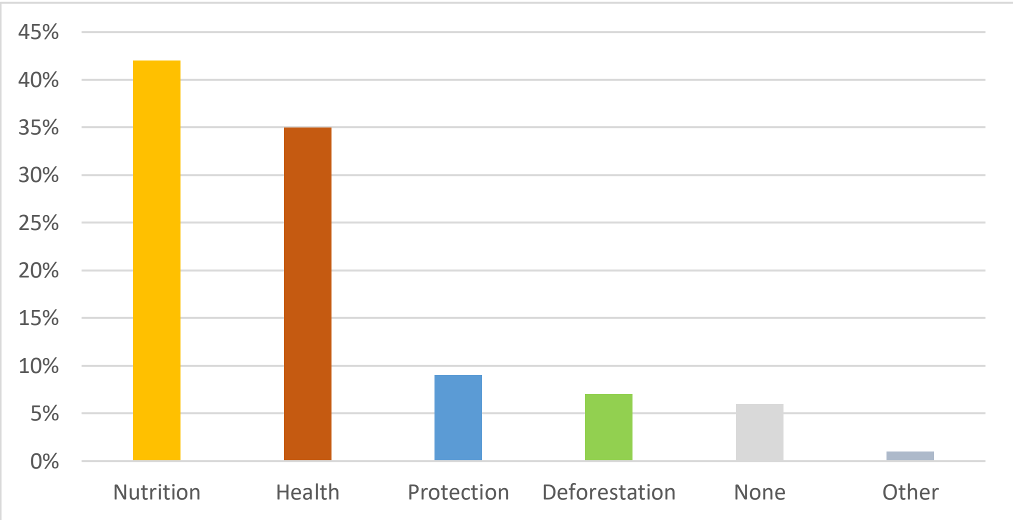

Figure 34 - The second most important challenges related to energy access (Source: data collected).

As regards the third most important challenge, the issue of deforestation was indicated by 42 percent of the people. This is interesting in the way people are aware of the negative impacts of the use of firewood for cooking on the environment. It is, however, not a very pressing issue, compared to protection, health and nutrition risks. The effects of deforestation, in the surroundings of the existing communities and large IDP camps, will become clear in the longer term and are related to the increasing negative impacts of climate change (e.g. droughts, soil erosion or floods). It is important to support the adaptive capacity of vulnerable people in terms of increasing the energy supply, in order to build resilience for future generations.

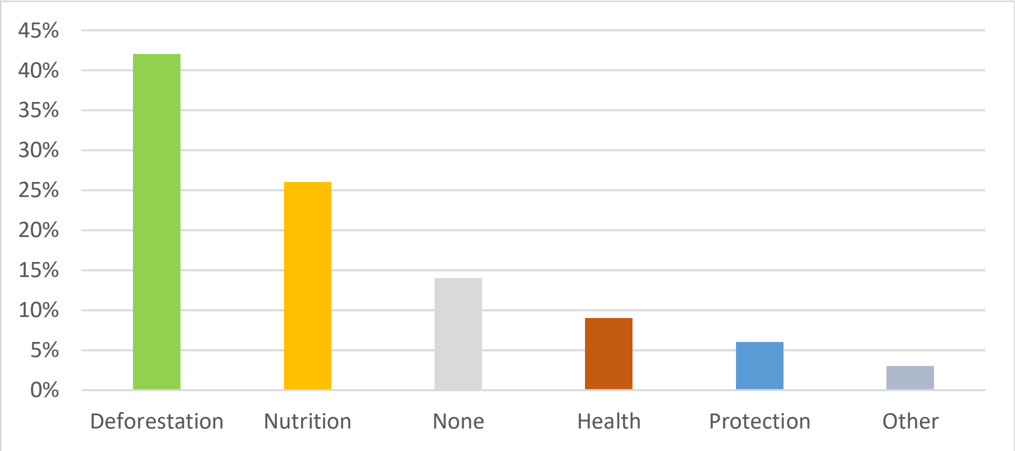

Figure 35 - The third most important challenges related to energy access (Source: data collected).

Woodfuel supply results

The woodfuel supply side of the assessment, including the aboveground biomass stock, land cover classification and changes over time, has been assessed through a combination of remote sensing analysis of satellite imagery and a biophysical forest inventory.

Small-scale forest inventory

A biophysical inventory of sample plots was conducted in the Auno and Dusuman area. Due to the security and access constraints, no biophysical inventory was done in Gwoza and Ngala. In total, twenty eight sample plots were analyzed in Auno and Dusuman (fourteen in each location).

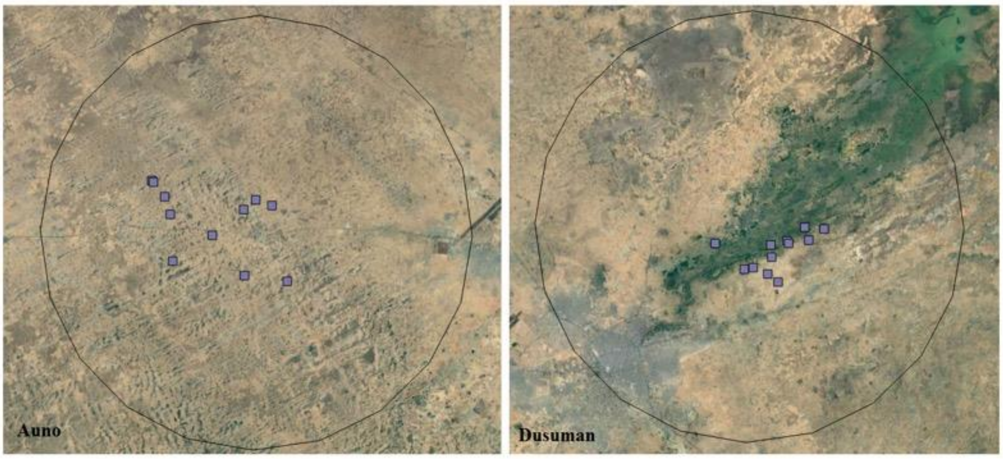

Figure 36 - Field plot locations in the AOIs of Auno and Dusuman.

The vegetation in and around Auno is typical of the Sudano-sahelian ecosystems, usually characterized by low biodiversity and a pronounced scattered vegetation distribution. The landscape is highly degraded, with very sparse vegetation. The frequency of occurrence or abundance of fuelwood species encountered in the 14 sample plots in Auno shows that *Piliostigma reticulatum* is the most abundant of all species. This can be explained by its resilience and adaptive capacities to drought conditions. After a relatively short period after felling of trees, new emerging sprouts are visible in comparison to other species.

Figure 37 - Land cover in the AOI of Auno (left: sparse tree and shrubs; right: cultivated farmland).

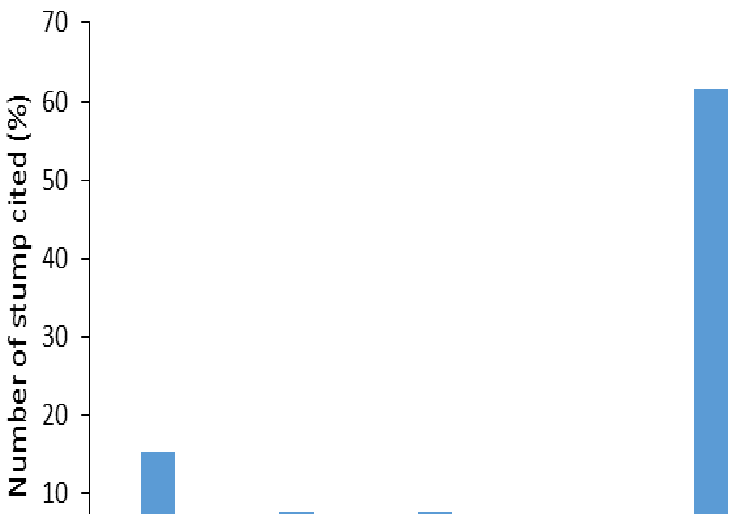

Figure 38 - Main woodfuel species in the AOI of Auno (Source: data collected).

In Dusuman, the landscape is characterized by flat terrain and patches of cultivated trees (mainly *Mangifera indica* and *Azadirachta indica*). It is a low land area on the plains of the river Ngada, which crosses through Maiduguri and drains into the Lake Chad. The river flow provides a reliable seasonal inundation, which makes it possible to carry out seasonal Fadama farming of arable crops such as vegetables, pepper, onion, tomatoes and lettuce. Fadama farming is a Hausa word which can be loosely translated by “flood plain” (Adesoji, Ajayi, & Farinde, 2006). It refers to a specific farming system along streams and river banks. Fadama farmers cultivate vegetables during the dry season when the water has evaporated from their fields. At the end of the dry season and during the first rains, they can also cultivate maize and early maturing vegetables. The natural vegetation is supported by the constant moisture allowing the growth of woody species such as *Acacia sieberiana*, *Balanites aegytiaca* and *Diospyrous mesepiliformis* along the patches of inundation. The vertisolic nature of the soil, with high clay content, allow for the dry season cultivation of crops. In Dusuman, *Azadirachta indica* is the most abundant species which is used for fuelwood. A compiled list of all species is attached in Annex 3 along with their Important Value Index (IVI), which is a measure of how dominant a species is in a given forest area.

Figure 39 - Land cover in the AOI of Dusuman (left: trees and shrubs; right: cultivated farmland).

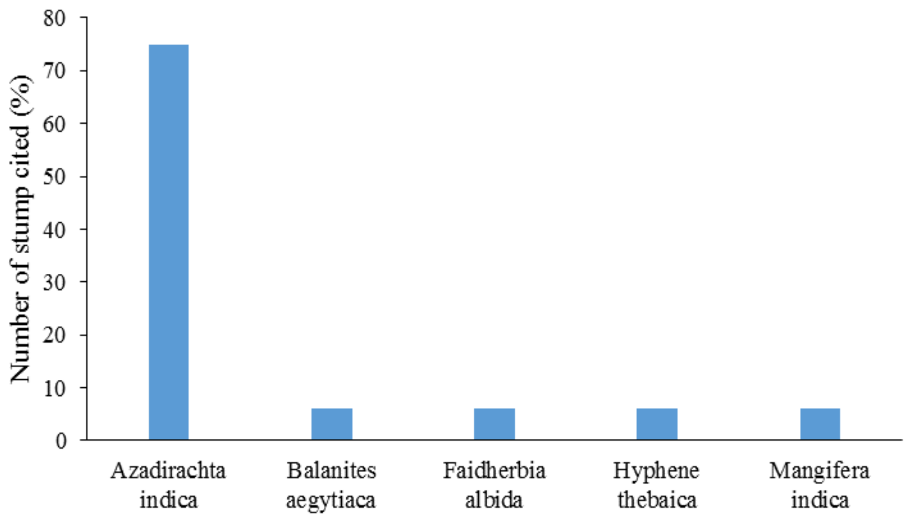

Figure 40 - Main woodfuel species in the AOI of Dusuman (Source: data collected).

Both in Auno and Dusuman, the land use classification is shared between cultivated farmlands and bushlands with scarcely scattered trees. The farmlands are characterized by mono-cropping of sorghum/millet, while the bush lands are dominated by shrubs. The tree species found in both areas are multi-use species. Out of the 17 and 15 species found to be used for fuelwood in Auno and Dusuman respectively, all of them are used to a larger or smaller degree for energy purposes. The general condition of the soil was similar in both locations, with highly degraded soils due to intensive human activities in combination with droughts and erratic rainfall. In terms of vegetation, more trees are present in the Dusuman area when compared to Auno. Also the average tree height is larger in Dusuman, showing that deforestation and pressure on fuelwood sources is higher in Auno area. The presence of natural irrigation potential in Dusuman helps to explain this.

The high pressure on woody biomass resources has a significant impact on forest regeneration. Trees and shrubs are not given sufficient time to recover, with even very small plants being harvested for use as energy source. In most sample plots, there were hardly any trees present with significant dendrometric dimensions. Young emerging sprouts with height and diameter too small to measure were in some cases found in clusters (e.g. *Guirea senegalensis*, *Boscia senegalensis* and *Piliostigma reticulatum*). In five plots, vegetation was completely absent (two plots in Auno and three plots in Dusuman). On these bare grounds, only some grasses were growing, without any tree species. As part of the randomized selection process, these plots were kept. Furthermore, it has been observed that when harvesting fuelwood, in most cases trees are removed completely, with even the roots being dug out. This has a significant impact on the natural regeneration capacities of the environment and negatively affects the ecosystem's defence mechanism against soil erosion. Due to the high demand and overexploitation, dead wood is rarely found. Cemetery grounds are the exception, since it is not allowed to gather firewood or fell trees in these places.

It is important to make a link to the selling of firewood and the production/selling of charcoal in Maiduguri. The vicinity of both locations to this urban centre has provided alternative livelihoods for poor and vulnerable people, who go out in unsafe areas to harvest fuelwood for selling. This practice has significant impact on the environment. For instance in Auno, many areas are left with bare soil.

Change mapping (2013–2017)

The BFAST approach was adopted for a change detection in northeast Nigeria. Interesting results were found over the Auno-Dusuman and Gwoza locations by using this methodology. Following the good practices recommended by (Pontus Olofsson, 2013), the accuracy of the change map was assessed through a stratified random sample of the three different classes (losses, gain and stable features) to calculate the area estimates of the change maps. Dedicated tools (available at https://github.com/openforis/accuracy-assessment) were used to design and analyse the results from the points visually interpreted in terms of change for Auno - Dusuman and Gwoza.

The producer's accuracy of loss class for Gwoza was 46 percent, while in Auno & Dusuman it was considerably lower: 6 percent. The error matrixes of both areas are presented in Annex 4. The accuracy assessment serves to derive the uncertainty of the area estimates. Whereas the map provides a single area estimate for each land cover class without a confidence interval, the sample based stratified area estimates adjust this estimate and also provide confidence intervals as estimates of uncertainty. The sample based stratified area estimates can be considerably higher or lower than the map pixel count (FAO, 2016). However, in this study stratified area estimates have very large confidence intervals, so it was decided to only present the map area with a simple pixel count and multiplying it with the minimum mapping unit (the map resolution).

In the case of Gwoza, the BFAST method performed better compared to Auno & Dusuman. In Auno & Dusuman, dry and very sparse vegetation dominates the landscape. The landscape of Gwoza has a higher vegetation cover compared to Auno & Dusuman and the changes were well-captured by the BFAST methodology although it is very challenging to perform this assessment over a land with sparse tree cover. In Gwoza, the majority of changes were observed in the close vicinity of the settlements (figure 41). This could be explained by the security situation outside of the town which prevent people from collecting wood far from the town. Nonetheless, in our opinion, the change detected in Auno & Dusuman is still slightly overestimated.

The second possible explanation lies in the resolution of the imagery. The 30 meters spatial resolution of Landsat is very efficient in detecting significant changes over a landscape with high vegetation cover. On the other hand, more research is needed to detect changes in sparse vegetation zones using the time series approach like BFAST.

For these reasons, the area provided in the current report for each land class is based on a pixel count multiplied by the map spatial resolution. Since the AOI consists of very sparse vegetation, the comparison between 2013 and 2016 demonstrated highly significant vegetation changes in the case of Auno & Dusuman. The noticeable changes were observed in the woodland class[6]. These changes most probably account from woodfuel consumption. In the different AOIs, the IDPs camps were installed over bare or agriculture land classes. It is estimated that no deforestation occurred for the installation of the displacement settlements as schools, hospitals, stadiums, unfinished residential complexes and bare land were commonly used to host IDPs. The significant changes observed may have been influenced by the satisfaction of the energy needs of the

[6] Woodland is a class combination of two land cover classes: trees and shrubs.

Maiduguri urban population and the localized pressure on natural resources from IDPs concentrated in urban settlements after fleeing their villages.

According to the socioeconomic survey data the link between poor energy access and deforestation appeared to be the third most important challenge by the majority of respondents. Seventy six percent of the surveyed households indicate an insufficient access to energy resources for their daily needs. It demonstrates that the pressure on natural resources has already reached worrying levels. Finally, 98 percent of respondents make use of inefficient cooking technologies, hence requiring large amounts of energy to satisfy basic cooking needs. This can lead to substantial woodfuel removals.

Table 8 - Auno & Dusuman area estimates (2013 – 2016) and Gwoza area estimates (2013 – 2017) (Source: data collected).

Class	Total loss	Per year loss
Auno & Dusuman	4 028 hectares	1 343 hectares
Gwoza	76 hectares	19 hectares

In the case of Gwoza, people have very limited access beyond the town boundaries due to insecurity. A strict perimeter has been established by the military forces. IDPs and returnees are hosted in the three main camps located within the town or are hosted informally by families in town. IDPs, returnees and host community members are only allowed to collect firewood with a military escort, which is organized once or twice a month. Keeping in mind the situation of the area and the limited distance that can be travelled in a limited time, a 10 km buffer zone around the town centre was defined.

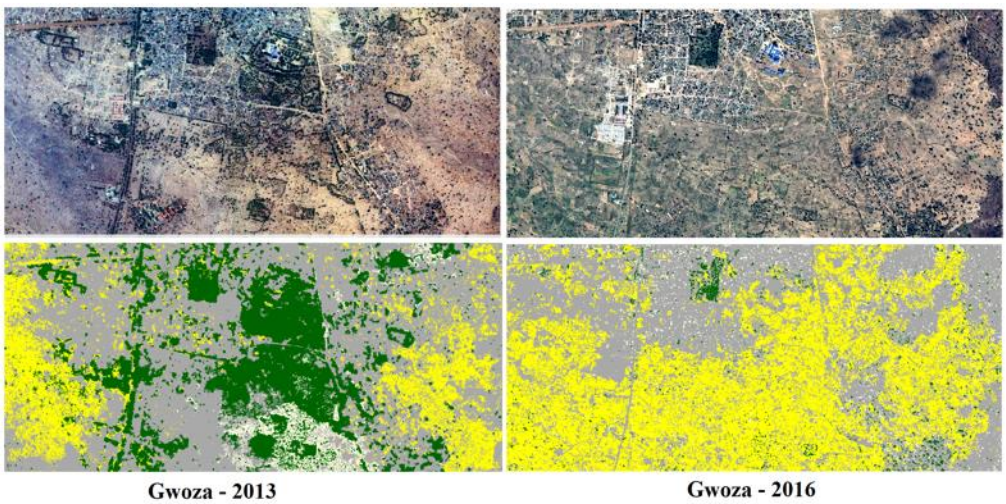

Figure 41 - Loss of fuelwood in the vicinity of Gwoza by comparing images and landcover map from two time periods (2013 - 2016). The green color represents fuelwood, white shrubs, yellow cropland and grey urban or bare land.

In Gwoza, significant changes were observed only in the very close vicinity of the town (figure 41). A total area of 76 ha has observed fuelwood loss over a time-period of four years in the AOI (19 ha/year) with a biomass loss of 8 507 tonnes over the period. In the case of Gwoza, the period of study expands from May 2013 to November 2017. The details of the area estimates are given in table 9.

Land cover mapping results

According to the land cover map 2017 of Ngala, the total area covered by fuelwood (including trees and shrubs) represents only 5 percent of 15 217 ha. While in the case of Gwoza, fuelwood is extended over 12 percent of 34 368 ha land, based on the land cover map 2017. For Auno and Dusuman, only 4 percent of the total land is covered with woodland (table 9). Since their vicinity to Maiduguri city, Auno and Dusuman are treated as one study area with Maiduguri city being included in the AOI linking both communities. So all results presented are combined for Auno and Dusuman sites.

Table 9 - Land Use and Land Cover map area for each AOI (Source: data collected).

Map Class	Auno & Dusuman	Gwoza	Ngala	Total
Trees	5 437 ha – 3%	2 713 ha – 8%	667 ha – 4%	8 817 ha – 4%
Shrubs	1 862 ha – 1%	1 336 ha – 4%	80 ha – 1%	3 278 ha – 1%
Cropland	139 983 ha – 80%	9 287 ha – 27%	5 755 ha – 38%	155 025 ha – 69%
Urban or bare land	28 445 ha – 16%	21 032 ha – 61%	8 715 ha – 57%	58 192 ha – 26%
Total	175 727 ha – 100%	34 368 ha – 100%	15 217 ha – 100%	225 312 ha – 100%

In the case of Ngala, only recent images were considered as the main official IDP camp (International School Camp) was only recently established (January 2016). Therefore, the time period for the analysis was too small to demonstrate significant changes. A total area of 15 217 ha around the camp was monitored. The area is randomly distributed in all dimensions as a first buffer of 10 km was applied and then the resulting area was clipped to exclude the area outside the Nigerian border where local communities do not collect wood. The area was modified a second time to exclude irrigation-dominated cropland area.

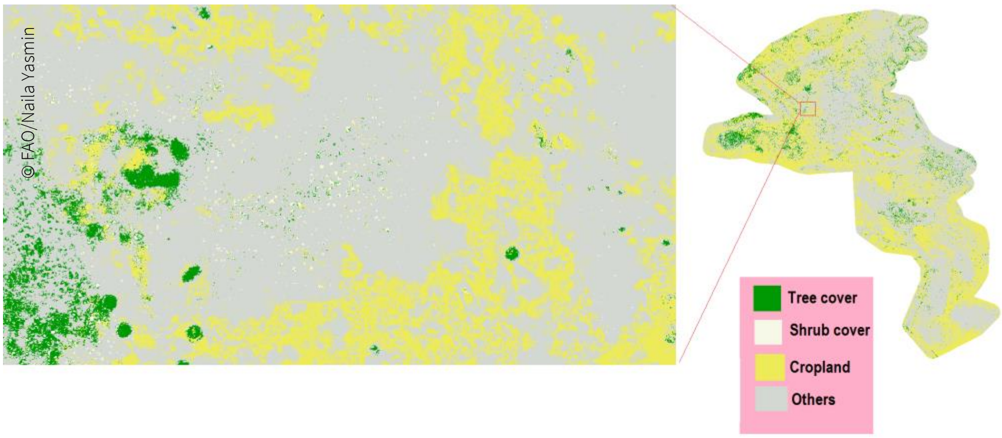

Figure 42 - Ngala land cover map of 2017, the green color represents fuelwood, white shrubs, yellow cropland and the grey shade urban or bare land.

Biomass estimates

A small-scale forest inventory was performed in Auno and Dusuman. However, the security situation in Ngala and Gwoza prevented the team to perform a small-scale forest inventory in the buffer zone. Therefore, proxy biomass factors were used for these two areas. It is assumed that the vegetation in both sites (Ngala and Gwoza) have the same biomass potential as Auno and Dusuman.

During the field inventory, fourteen plots around Auno and Dusuman were surveyed. For the biomass calculation, 23 out of 28 plots were considered and were averaged for biomass. Five out of the 28 plots were excluded due to missing/wrong coordinates (4) or typing errors (1). Biomass factors were calculated from the field data from Auno and Dusuman for each class: 134.38 tonnes/ha for the “trees class”, 98.48 tonnes/ha for the “shrub class” and 13.75 tonnes/ha for the “cropland class”. The biomass factor for the “shrub class” seems slightly overestimated for this type of landscape. During the field survey, current land use category was not recorded. To estimate the biomass for each land cover class, the field data was overlaid over the land cover map of Auno and Dusuman from 2016. To calculate the biomass available in each land cover category, the biomass factor of all respective classes was averaged. The results of the calculation are presented in table 10. The “Urban or bare land” class is considered without biomass and therefore not represented in the table. Due to the security situation, field inventory was only conducted for Auno and Dusuman. The same biomass factor was used for Gwoza and Ngala by assuming that they have the same vegetation and biomass factors.

Table 10 - Biomass estimates (tonnes) for each land cover class over all AOIs (Source: data collected).

Map Class	Auno & Dusuman	Gwoza	Ngala	Total
Trees	730 603 tonnes	364 544 tonnes	89 612 tonnes	1 184 759 tonnes
Shrubs	183 317 tonnes	131 568 tonnes	7 917 tonnes	322 802 tonnes
Cropland	**1 924 735 tonnes**	**127 701 tonnes**	**79 133 tonnes**	**2 131 569 tonnes**

The largest land class “cropland” (69 percent of all AOIs and 93 percent of classes containing non-woody biomass) is the class with the principal biomass resource, which is spread over a large area. The “trees” class is the second largest class containing biomass and represents 4 percent of the total area and 5 percent of classes containing biomass used for woodfuel which is main subject of the current study.

The biomass calculation for the change map was calculated by averaging the biomass of both shrub and tree cover classes because losses were considered change in woody classes without mapping the different classes before and after the change. Because of this limitation of approach followed for change detection using courser resolution imagery, it was not possible to differentiate the pixels with changes for tree cover and shrub cover loss. Therefore, averaged values of both classes were applied to calculate the total loss of biomass over 2013 and 2016/2017 (table 11). The main IDP camp in Ngala was only established in early 2016. Due to this recent establishment and limitation of availability of high resolution imagery for target dates, it was not possible to perform a change detection before and after the camp installation.

Table 11 - Changes in biomass area and tonnage for the two AOIs under the reference period (Source: data collected).

Class	Auno & Dusuman (2013 – 2016)	Gwoza (2013 – 2017)
Loss area	4 028 ha	76 ha
Biomass loss	450 861 tonnes	8 507 tonnes

Integration of supply and demand information

The assessment shows that the total estimated woodfuel consumption over the period 2013 to 2016 is 732 663 tonnes in Auno and Dusuman while the observed degradation corresponds to an amount exceeding 450 861 tonnes for the period 2013 to 2016. Therefore, the loss in woody biomass represents 61.5 percent of the local woodfuel consumption. It shows that the woodfuel consumed by the local population is in large part sourced from outside the AOI. Based on the survey, we can estimate that only 36 percent of fuel wood is sourced from within the AOI. This amount corresponds to the proportion of respondent households which primarily collect their firewood. With this proportion of consumption from the local environment, the consumption (100 085 tonnes in 2017) is equal to 67 percent of biomass losses over the period 2013 to 2016. The total available biomass for the study site was 913 919 tonnes in 2016. The average woodfuel consumption over the period corresponds to 27 percent of the biomass available.

In Gwoza, the estimated loss in woody biomass is 2 127 tonnes per year for the period 2013 – 2017, whereas the consumption is 28 319 tonnes per year. The loss in woody biomass represents only 7.51 percent of the local woodfuel consumption. This demonstrates that the woodfuel consumed within the AOI is primarily transferred from outside to be consumed by IDPs, returnees and host community members. The reason for the transfer is the very insecure situation around the town due to ongoing attacks and instability. Movement of people is restricted to the town boundaries and therefore they cannot collect wood. In the Gwoza area, based on the current study, the total existing biomass was 496 112 tonnes in 2017. The average woodfuel consumption corresponds to 6 percent of the available biomass in 2017.

In Ngala, the average estimated woodfuel consumption is 35 322 tonnes per year whereas 97 529 tonnes of biomass is available. The estimated biomass consumption for energy accounts for 36 percent of the yearly biomass available. The major IDP camp in Ngala was established in early 2016. The availability of high resolution images for two dates (2016 to 2017) within a one year period with a full coverage of the AOI was limited. Therefore, it was decided to only map the standing biomass.

The estimated woodfuel consumption, losses and existing biomass for each site are given in table 12.

Table 12 - Estimation of gaps in biomass availability (Source: data collected).

Areas of interest	Total Population (2016 or 2017)	Total estimated woodfuel consumption (2013 to 2016/2017)	Biomass loss (2013 to 2016/2017)	Total available biomass (t in 2016/2017)
Auno & Dusuman	951 405	732 663	450 861	913 919
Gwoza	149 617	113 276	8 507	496 112
Ngala	173 253	141 288	N/A	97 529

Possible scenarios

Different interventions have the possibility to improve energy access, reduce the environmental impact of traditional biomass use, liberate time for women and children from the burden of wood collection and increase the resilience of local livelihoods by developing new business models for improved access to clean energy. Based on the integration of the results from the woodfuel demand and supply assessment, the following scenarios were developed:

- Business as Usual
- Business as Usual with returnees
- Improved charcoal production
- Efficient cookstoves
- Briquette manufacturing
- Tree plantations
- Combined interventions

Business as Usual scenario

This scenario is built on a linear consumption based on national population projection using a medium variant (UNDESA, 2017) with no new returns from the three neighbouring countries (Cameroon, Chad and Niger) (UNHCR, 2018) and with no change in woodfuel consumption patterns.

The total for year y of woodfuel consumption ($Wtotal_y$) under a Business as Usual (BaU) scenario is calculated as follows (tonnes/year):

Equation 3 - Total woodfuel consumption for year y under a business as usual scenario.

$$Wtotal_y = (W_{ycH} + W_{ycNH}) \times P_{AOIy}$$

Where:

W_{ycH} = Total annual woodfuel consumption of households (tonnes per year), for year y

W_{ycNH} = Total annual woodfuel consumption of non-household activities (tonnes per year), for year y

P_{AOIy} = Estimated population of the area of interest, for year y

By using household wood consumption for cooking and heating projections and attributing each category based on demographic data for 2020, 2025 and 2030, we can estimate that the total annual woodfuel consumption for the three areas would be 404 695 tonnes in 2020, 458 757 tonnes in 2025 and 518 386 tonnes in 2030 (Table 13).

Table 13. Calculated (2013 & 2017) and projected (2020, 2025 & 2030) annual woodfuel demand in tonnes per year under a Business-as-Usual scenario (Source: data collected).

Woodfuel consumption in tonnes per year	Year				
	2013	2017	2020	2025	2030
Auno & Dusuman	225 941	278 788	301 085	341 305	385 668
Gwoza	23 080	43 266	46 727	52 969	59 854
Ngala	34 259	52 672	56 884	64 483	72 865
Total	283 280	374 726	404 695	458 757	518 386

Business as Usual scenario with returnees

This scenario is built on a linear consumption based on national population projection using a medium variant (UNDESA, 2017) with the return of refugees from neighbouring countries (Cameroon, Chad and Niger) and with no change in woodfuel consumption patterns of non-household activities. The return of IDPs in their different place of origins is more difficult to assess because their woodfuel consumption would be reported to other areas outside of the AOIs of this study. We assume that woodfuel would be collected in the place of origin of IDPs. However due to the importance of IDPs compared to the Borno State population (25.8 percent of the population), this would have a strong influence on the biomass availability of these areas of origin.

In this scenario, it is estimated that a ratio of refugees established in Niger will join the AOI of Auno & Dusuman and those in Cameroun the AOIs of Gwoza or Ngala (UNHCR, 2018) in 2020. The total for year y of woodfuel consumption ($Wtotal_y$) under a BaU scenario with returnees and the average woodfuel consumption, are calculated as follows (tonnes/year):

Equation 4 - Total woodfuel consumption for year y under a business as usual scenario with returnees.

$$Wtotal_y = (W_{ycH} + W_{ycNH}) \times P_{AOIy}$$

Where:

W_{ycH} = Total annual woodfuel consumption of households (tonnes per year), for year y

W_{ycNH} = Total annual woodfuel consumption of non-household activities (tonnes per year), for year y

P_{AOIy} = Estimated population of the area of interest, for year y

By using wood consumption for cooking and heating projections and imputing each category based on demographic data for 2020, 2025 and 2030 with the return of refugees in 2020, we can estimate that the total annual woodfuel consumption for the three areas would be 412 144 tonnes in 2020, 467 200 tonnes in 2025 and 527 928 tonnes in 2030. The increased consumption compared to the BaU is 1.8 percent.

Table 14 - Calculated (2013 & 2017) and projected (2020, 2025 & 2030) annual woodfuel demand in tonnes per year under a Business as Usual scenario with returnees (Source: data collected).

Woodfuel consumption in tonnes per year	Year				
	2013	2017	2020	2025	2030
Auno & Dusuman	225 941	278 788	306 854	347 846	393 059
Gwoza	23 080	43 266	47 484	53 827	60 823
Ngala	34 259	52 672	57 806	65 528	74 045
Total	283 280	374 726	412 144	467 200	527 928

Efficient cookstoves scenario

According to the field survey, 51 percent of households rely on the traditional three stones fire, 24 percent use a mud stove and 8 percent have a metal stove (see Figure 22). Finally, 16 percent of households depend on a multiple energy technologies (three stones fire with mud stove; three stones fire with metal stove; mud stove with metal stove or three stones fire with other). The vast majority of household (98.8 percent) rely on a biomass stove, 0.8 percent depend on stoves powered by non-biomass fuels (kerosene, gas, solar) and 0.5 percent of sampled households do not cook.

The traditional tree stones fire has an estimated thermal efficiency of 10 to 15 percent (Oliver Adria, 2014). This means that 90 to 85 percent of the energy content of the wood is lost as heat in the environment outside the cooking pot. In average, traditional mud stoves have a thermal efficiency of 17.9 percent (George, 1997). Portable metal stove can reach an efficiency of 26 percent (The Global Alliance For Clean Cookstoves, 2017) and up to 44.8 percent with advanced design and features (The Global Alliance For Clean Cookstoves, 2017).

This scenario is built on the rolling-out of a fuel-efficient stove programme with three types of stove: wood stove, dual-use stove (wood and charcoal) and a charcoal stove. A conservative efficiency of minus 40 percent of biomass consumption for each of these stove models is adopted. The table 15 represents realistic plans for the introduction of fuel-efficient stoves in the three areas of interest. Possible adoption models are discussed in the recommendations section.

Table 15 - Fuel-efficient stove introduction for the three areas of interest.

Type of stove	Host	IDP	Returnee	Total
Auno & Dusuman				
Wood stove	11 300 (15%)	8 500 (17%)	200 (20%)	20 000 (15%)
Dual stove	1 700 (16%)	1 300 (18%)	0	3 000 (17%)
Charcoal stove	550 (16%)	400 (20%)	50 (30%)	1 000 (18%)
Gwoza				
Wood stove	1 000 (16%)	1 400 (15%)	600 (14%)	3 000 (15%)
Dual stove	175 (19%)	200 (19%)	125 (18%)	500 (19%)
Ngala				
Wood stove	1 150 (16%)	1 500 (16%)	850 (16%)	3 500 (16%)
Dual stove	250 (17%)	125 (17%)	275 (16%)	650 (17%)
Charcoal stove	175 (17%)	500 (16%)	125 (16%)	800 (16%)

The changes in consumption patterns were applied only to the following categories in each area (table 16):

- Wood consumption of household for the wood-efficient stove
- Wood and charcoal consumption of household for the dual fuel-efficient stove
- Charcoal consumption of household in Auno & Dusuman and Ngala areas only, for the charcoal-efficient stove.

Table 16 - Woodfuel demand in tonnes in year +1 under the fuel-efficient scenario in the three AOIs (Source: data collected)

Categories	Auno & Dusuman	Gwoza	Ngala	Total
Wood	222 101	36 226	42 134	300 461
Wood and charcoal	18 195	3 267	4 738	26 200
Charcoal	4 430	366	1 912	6 708
Others	17 122	667	476	18 265
Total	**261 849**	**40 527**	**49 260**	**351 636**
Average reduction	- 6.1 %	- 6.3 %	- 6.5 %	- 6.2 %

This scenario could lead to an average reduction of 6.2 percent of the total annual woodfuel consumption compared to the BaU scenario with the best results in Ngala (6.5 percent).

Improved charcoal production scenario

A rapid charcoal assessment was performed in the area following the preliminary findings. Field findings demonstrate that the production of charcoal remains very traditional. Charcoal production is a livelihood activity in rural villages. Local wood is also transported in the outskirts of Maiduguri for the production of charcoal. However, the local consumption of charcoal represents only 20 percent of the demand (FAO, 2018). The estimated efficiency of the current charcoal conversion process is 15 percent of the dry wood weight. Based on these observations and the relatively low importance of local charcoal production, only one efficient technique is proposed: the Casamance (30 percent efficiency) (FAO, 2017). In the Auno & Dusuman area, 1 000 tonnes per year of charcoal could be produced with this technique against 200 tonnes per year in Gwoza and Ngala.

The 1 400 tonnes of more efficient charcoal produced in this scenario represents respectively 34, 30 and 34 percent in Auno & Dusuman, Gwoza and Ngala of the total yearly consumption of charcoal of local origin (20 percent of the total charcoal consumed) .

Table 17 - Consumption of charcoal of local origin and wood equivalent in the three areas of interest in tonnes per year (source: data collected)

Fuel source for cooking	Auno & Dusuman		Gwoza		Ngala	
	Wood equivalent	Charcoal	Wood equivalent	Charcoal	Wood equivalent	Charcoal
Wood and charcoal	19 846	1 488	3 653	274	5 096	382
Charcoal	4 793	719	366	55	2 043	306
Wood, charcoal and other source(s)	4 504	338	361	27	303	23
Charcoal and other source(s)	361	54	1	0	0	0
Total	**29 504**	**2 599**	**4 381**	**356**	**7 442**	**711**

In this scenario, more efficient charcoal will represent between 30 to 60 percent of the total charcoal available on the market. This percentage is then attributed in all categories of users (IDPs, refugees and host) and all fuel sources for cooking using charcoal (table 18).

Table 18 - Woodfuel demand in tonnes of wood equivalent under the improved charcoal scenario in the three AOIs (Source: data collected)

Fuel source for cooking	Auno & Dusuman		Gwoza		Ngala	
	Business as Usual	Charcoal Scenario	Business as Usual	Charcoal Scenario	Business as Usual	Charcoal Scenario
Wood and charcoal	19 846	18 588	3 653	3 303	5 096	4 983
Charcoal	4 793	3 319	366	284	2 043	1 309
Wood, charcoal and other source(s)	4 504	4 239	361	326	303	298
Charcoal and other source(s)	361	250	1	1	0	0
Total	29 504	26 396	4 381	3 914	7 442	6 590
Total all categories	278 788	275 680	42 799	43 266	52 672	51 819
Change	-1.11		-1.08		-1.62	

This scenario could lead to an average reduction of 1.2 percent of the total annual woodfuel consumption compared to the BaU scenario (table 18). Technical-economic analyses should be performed to confirm this potential with strong support from authorities in charge of the regulation of the sector. The distribution of charcoal for crisis-affected populations is a short-term solution which transfers the environmental problem to another part of the country. However, it could represents an alternative if efficient charcoal production techniques are also implemented in these production sites.

Bioenergy from non-woody biomasses

Other non-woody biomasses could be used for energy production. In the area, the main biomass feedstock are the residues produced by the production of millet, sorghum and maize (FAO, 2018). Three energy end-use options could be analysed in this context: direct combustion, briquettes and pellets. In this scenario, 25 percent of crop residues are left on the field for soil fertility and stability, 25 percent is used for animal feed and bedding and 1.27 percent is already used for direct combustion as demonstrated by the results from the survey (BEFS & FAO, 2018).

Table 19 - Scenario of crop residue production in the three areas of interest (Source: (BEFS & FAO, 2018; FAO, 2018)

Baseline	Crop residue	Millet straw	Sorghum straw	Maize Cob	Maize husk	Maize stover	Total
	Yield (t/ha)[7]	0.509	0.261	0.112	0.075	0.440	
	Location of residues	Field collected	Field collected	Processing	Processing	Field spread	
Auno & Dusuman	Area (ha)	9 500	9 500	9 500			28 500
	Production (t)	4 836	2 480	1 064	711	4 180	13 270
Gwoza	Area (ha)	625	625	625			1 875
	Production (t)	318	163	70	47	275	873
Ngala	Area (ha)	375	375	375			1 125
	Production (t)	191	98	42	28	165	524

In the three areas, the biomass could follow three different pathways: direct combustion (50 percent), pelletizing (25 percent) and briquetting (25 percent). For direct combustion, the scenario takes into account local use of woody biomass and higher consumption patterns:

- 0.4 t./ind./yr. in Auno & Dusuman (against 0.31 t./ind./yr.)
- 0.35 t./ind./yr. in Gwoza (against 0.30 t./ind./yr.)
- 0.4 t./ind./yr. in Ngala (against 0.37 t./ind./yr.)

As regards pelletizing, the scenario takes into account a 10 percent process loss and a conversion factor of 4.89 kg of fuel compared to woodfuel. (Young, 2003; BEFS - FAO, 2014). This scenario requires a change of stove from woodfuel stove to a pellet stove. The briquette scenario is based on the replacement of the local charcoal consumption by carbonized briquettes. The conversion factor used is 0.46 percent of biomass weight after carbonization (APFNP, 2018). This scenario also takes into account a 10 percent process loss.

[7] The number of digit has been reduced to only three.

Table 20 - Results of woodfuel energy demand under a scenario using non-woody biomass (Source: (BEFS & FAO, 2018; FAO, 2018).

Area	Energy option	Feedstock (t)	Population served	Charcoal production (t)	Wood equivalent (t)
Auno & Dusuman	Direct combustion	6 634	16 585	N/A	6 634
	Pellets	3 318	36 506	N/A	16 225
	Briquettes	3 318	77 220	1 374	9 158
	Total	13 270	130 312	1 374	32 017
Gwoza	Direct combustion	437	1 249	N/A	437
	Pellets	218	2 741	N/A	1 066
	Briquettes	218	5 084	91	607
	Total	873	9 074	91	2 110
Ngala	Direct combustion	262	655	N/A	262
	Pellets	131	1 441	N/A	641
	Briquettes	131	3 821	54	362
	Total	524	5 918	54	1 264

In this scenario, the total average woodfuel consumption is reduced by 8.1 percent with 9.8 percent decrease in Auno & Dusuman, 4.2 percent in Gwoza and 2 percent in Ngala. Techno-economic analyses should be performed to confirm this potential (FAO, 2017).

Demand driven scenarios

The results of the different demand driven scenarios are summarized in Table 21. For each scenario, only the best performing area is presented in the table. The scenarios for fuel-efficient cookstoves and improved charcoal processing are considered linear: the adoption rate of the technology and associated woodfuel savings remains constant. This is due to the fact that these measures have been tested and implemented in different displacement settings throughout the world.

Table 21 - Estimated total woodfuel demand according to different scenarios in tonnes per year (source: data collected).

Scenario	Business as Usual	Efficient cookstoves		Improved charcoal		Non-woody biomasses		All measures			
Year	Total	Gwoza	Total	Ngala	Total	Auno & Dusuman	Total	Auno & Dusuman	Gwoza	Ngala	Total
2017	374 726	40 527	351 636	51 819	370 298	246 772	339 341	226 724	37 955	47 143	311 822
2018	384 520	41 586	360 826	53 174	379 976	254 058	349 134	233 486	39 002	48 409	320 897
2019	394 506	42 666	370 197	54 555	389 845	261 488	359 121	240 381	40 070	49 699	330 150
2020	404 695	43 768	379 758	55 964	399 913	269 068	369 310	247 417	41 159	51 015	339 591
2021	415 088	44 892	389 510	57 401	410 183	276 800	379 702	254 592	42 270	52 357	349 220
2022	425 684	46 038	399 453	58 866	420 654	284 683	390 298	261 909	43 403	53 726	359 037
2023	436 489	47 207	409 592	60 360	431 331	292 722	401 103	269 369	44 558	55 122	369 049
2024	447 511	48 399	419 936	61 885	442 223	300 922	412 126	276 980	45 736	56 546	379 262
2025	458 757	49 615	430 489	63 440	453 336	309 289	423 372	284 745	46 938	57 999	389 682
2026	470 228	50 856	441 253	65 026	464 672	317 823	434 842	292 666	48 165	59 481	400 311
2027	481 924	52 121	452 228	66 643	476 230	326 525	446 539	300 742	49 415	60 991	411 148
2028	493 849	53 410	463 418	68 292	488 013	335 396	458 463	308 975	50 690	62 532	422 197
2029	506 003	54 725	474 823	69 973	500 024	344 439	470 617	317 367	51 989	64 102	433 458
2030	518 386	56 064	486 443	71 686	512 261	353 651	483 001	325 917	53 313	65 702	444 932
Change compared to BaU		-6.3%	-6.2%	-1.6%	-1.2%	-9.8%	-8.1%	-17%	-11.6%	-10.1%	-15.4%

If all scenarios are implemented, the demand could be reduced by 15.4 percent (see table 22). Different scenarios have different results according to the area. For instance, fuel-efficient stoves would have the best results in Ngala (-6.5 percent, see table 17), improved charcoal in Ngala (-1.6 percent) and non-woody biomass use in Auno & Dusuman (-17 percent).

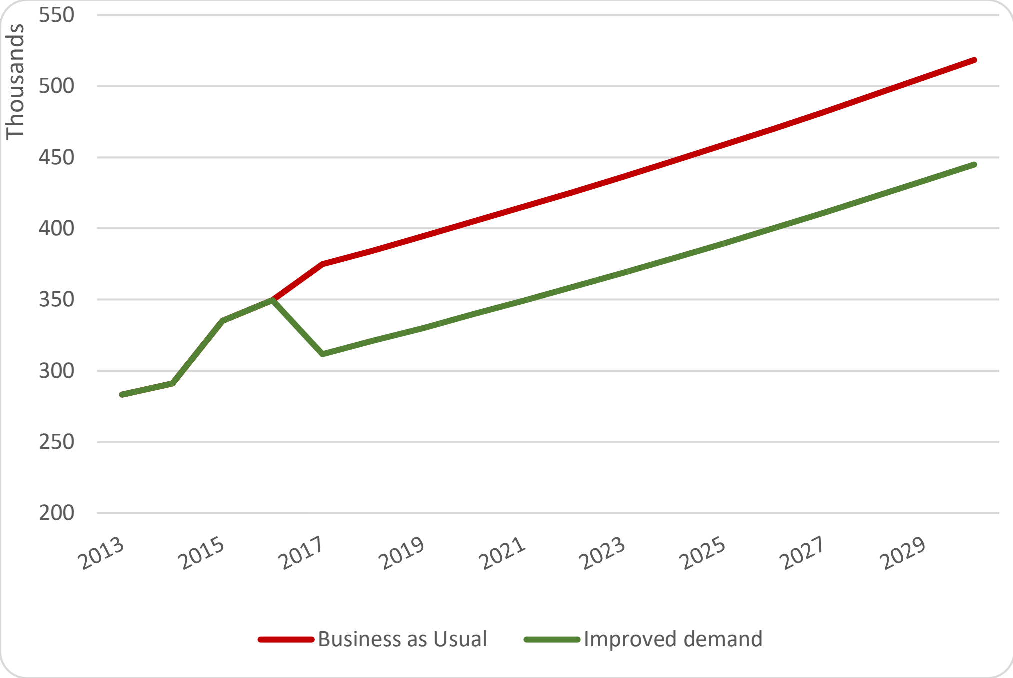

Figure 43 – Woodfuel consumption under the Business-as-Usual scenario compared with the improved demand scenario (Source: data collected).

Scenario with tree plantations

Plantations for the production of woodfuel in tropics have typically a short rotation length, ranging from 3 to 15 years (FAO, 2001). For the eco-climatic region of the area of interest[8], the Intergovernmental Panel on Climate (IPCC) provides default values of aboveground living biomass at maturity of 20 t/ha, for broadleaves plantations, and of 15 t/ha, for young pine plantations (IPCC, 2006, pp. 4.54, table 4.8). Thus, to fulfil the entire annual demand of woodfuel of the 4 sites for the year 2020 (329 196 t/yr, under a BAU scenario), it would be necessary to harvest 16 459 hectares of mature broadleaf plantations every year. These areas correspond to approximately one quarter of all the area of interest object of the study. For comparison purpose, it is worthy to notice that the total area of forest plantation in Nigeria in 2010 is reported to be 382 000 ha (data from the FAO Forest Resources Assessment country report 2015[9]). That is, the area that would need to be harvested to fulfil the estimated annual woodfuel demand would be about 4 percent of the total planted area of the country.

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[8] The sites fall into the ecological zone of tropical shrub land, according to the FAO global ecological zone classification 2010.

[9] http://www.fao.org/3/a-az293e.pdf

Assuming a rotation length of 6 years, planting 1000 ha of broadleaf plantations every year for the next 6 years would ensure at maturity (that is, after 6 years) an annual production of woodfuel approximately equal to the 5 percent of the demand for the period 2024–2030 (392 388 t/year on average, under a BAU scenario). This would correspond to convert to forest plantations a total of 6 000 ha of land. In the case only 100 ha per year are allotted for broadleaf plantation, the production will be roughly 0.5 percent of the total demand in the period 2024–2030. If instead 10 000 ha are planted annually the production might cover about the 50 percent of the demand. The three scenarios are presented in Table 22.

Table 22. Potential aboveground biomass production of broadleaf plantation planted every year for 6 years in the AOI under different scenarios.

Year	Demand (t) BAU	Scenario 1 100 ha of plantation		Scenario 2 1 000 ha of plantation		Scenario 3 10 000 ha of plantation	
		Production (t)	% of the demand	Production (t)	% of the demand	Production (t)	% of the demand
2018	384 520	0	0	0	0	0	0
2019	394 506	0	0	0	0	0	0
2020	404 695	0	0	0	0	0	0
2021	415 088	0	0	0	0	0	0
2022	425 684	0	0	0	0	0	0
2023	436 489	0	0	0	0	0	0
2024	447 511	2 000	0.45%	20 000	4.47%	200 000	44.69%
2025	458 757	2 000	0.44%	20 000	4.36%	200 000	43.60%
2026	470 228	2 000	0.43%	20 000	4.25%	200 000	42.53%
2027	481 924	2 000	0.42%	20 000	4.15%	200 000	41.50%
2028	493 849	2 000	0.40%	20 000	4.05%	200 000	40.50%
2029	506 003	2 000	0.40%	20 000	3.95%	200 000	39.53%
2030	518 386	2 000	0.39%	20 000	3.86%	200 000	38.58%

It is worth reminding that the figures presented in Table 22 are based on average default values for the macro-ecological region and for the general class of broad-leaved species. The actual production of such plantations will depend on a complex set of factors, including, among others, management practise, ecological conditions and species selection. One of the factors to take into consideration is land access due to security. If the security situation does not improve plantations may not be possible and access to land will remain difficult in some locations.

Fuel wood species for arid and semiarid region, which may be suitable for the area of interest, may include *Acacia Nilotica Ssp. Adstringens*, *Annogeisus Leiocarpus* and *Azadirachta Indica*. The latter seems to be well adapted to the region as it was inventoried in 8 of the 14 field inventory plots of Dusuman. *Acacia Nilotica Ssp. Adstringens* and

Annogeisus Leiocarpus are native species whereas *Azadirachta Indica* (Neem tree) was largely introduced in the areas from the Indian sub-continent. Despite energy, the three species present specific characteristics which makes them particularly suitable for the area:

- *Acacia Nilotica Ssp. Adstringens* can be used for its gum, as fodder and for tanning and dyeing
- *Annogeisus Leiocarpus* is planted along river banks for soil maintenance and in association with legumes in agroforestry systems
- *Azadirachta Indica* is common in arid climate and is used as a medicinal plant, insect repellent and fertilizer (Rafiu, 2012)

Estimates of standing biomass of *Acacia Nilotica Ssp. Adstringens* is 36 t/ha for 5-year-old plantations in Haryana (India) (PROTA, 2018). Early studies on the cultivation for industrial fuel of Acacia Nilotica in Sudan reports that rotation varies from 20 to 30 years (National Research Council, 1980). The *Leiocarpus Leguminosae* open woodlands are reported in areas with annual rainfall of 600 to 900 mm per year (similar to the local conditions of northeast Nigeria) (FAO, 2000). *Annogeisus Leiocarpus* is mostly used for soil maintenance of river banks benefiting from moister conditions. Plantation of *Annogeisus Leiocarpus* is not reported in the literature. Fragmented information demonstrates that average height growth is more than 70 cm/year, stem growth more than 4 cm/year and basal area 5.6 m^2/ha in iron-rich tropical soils with pH 6 and average precipitation of 1 200 mm/year (Ouattara, 1990). Cultivation trials carried out in the sixties in Samaru (northern Nigeria) showed that the yield of 8-year-old neem ranged from 19 to 169 m^3 per ha (Gravsholt, 1967). In Ghana, the first rotation yield of Neem in a short rotation plantation was reported to be 108-137 m^3 of fuelwood per ha (National Research Council, 1980).

Recommendations

If the different users manage natural resources in an integrated way, the environment should be able to supply the total woodfuel demand of all users. Reducing demand should be part of the intervention. This could be achieved by supporting the adoption of efficient cookstoves (obtaining 6 percent decrease in demand) and, where viable, briquettes from agricultural residues.

The integration of supply and demand information tends to demonstrate that biomass losses could be attributed to woodfuel consumption but at different scales in the three areas: 61.5 percent in the Auno & Dusuman area, 7.5 percent in Gwoza whereas the estimated biomass consumption for energy accounts for 36 percent of the yearly biomass available in Ngala. Therefore, efforts should be concentrated on the Auno & Dusuman and Gwoza areas. Given the impact of woodfuel consumption on the local resources, any alternative to woodfuel should be assessed for the two areas with the highest biomass losses attributed to woodfuel (Auno & Dusuman and Gwoza). Possible alternative fuels include briquettes made from crop residues, ethanol and liquefied petroleum gas. The area around Gwoza is of particular concern since the local communities cannot cross the city boundaries to access woodfuel. Therefore, existing woodfuel distributions should be complemented by a reflexion on local energy sources (briquetting from crop residues, biogas production if livestock is available, solar off-grid systems with induction stoves and woodlots plantation of energy, other uses and land restoration).

Fuel-efficient cookstove promotion

Raising awareness on efficient cookstoves and their advantages for reducing fuel needs of the local population and other benefits, such as reducing wood collection time and burden, protection risks and the prevalence of respiratory diseases, is fundamental. It is important to have a common understanding of what a fuel-efficient cookstove is, in terms of firewood/charcoal savings, materials used, etc. Furthermore, cookstove programs should be carefully planned to address the needs of the population in terms of design, functionality, heating type and cooking time. Promotion should be part of the delivery model, together with effective and timely customer service and satisfaction. Adoption of fuel-efficient stoves is not ensured by distribution from humanitarian actors. Therefore, it is recommended to implement delivery models taking into account the role of existing private actors and the willingness to pay of local beneficiaries (4 530 NGN or 12.44 USD per household). This will ensure a more profound impact of fuel-efficient cookstove promotion in the longer term.

An additional advantage of fuel-efficient cookstove promotion is the opportunity to work on alternative and sustainable livelihoods, through the production of fuel-efficient cookstoves. When people, who depend on the collection and selling of firewood, are included in such programmes, they should receive training and expertise in a more sustainable and safer livelihood, increasing their resilience. This approach requires a longer-term engagement and continued support, and can form the basis for an intervention supporting non-governmental and private actors to establish local stove production centres.

The demand for fuel-efficient stoves should be addressed by raising local awareness of the impact of inefficient cooking technologies on the environment and associated challenges (protection, nutrition, health, safety and tensions over natural resources). Addressing this demand for efficient technologies can use innovative humanitarian delivery models such as cash transfer or energy vouchers. Providing cash to affected populations has been proven to be more cost effective than distribution of food and non-food items (Harvey, 2005). The side effect being the stimulation of the local economy. In northeast Nigeria, there are currently two obstacles to cash transfers for the adoption of fuel-efficient stoves and associated fuels: food insecurity remains high and cash transfer would be dedicated to food purchase rather than energy; the offer of fuel-efficient stoves is limited in the northeast and clients may not find the appropriate stove model on local markets. Therefore, it is recommended to support stoves and/or fuel vouchers where beneficiaries could exchange the vouchers against a fuel-efficient stove or for fuels from traders, at distribution outlets, markets or special relief shops. This could stimulate local markets and the import of fuel-efficient stoves from other parts of the country to the northeast. The practical implementation of these modalities remain under the responsibility of the local energy and environmental working group.

The promotion of efficient cooking solutions should remain the core pillar of SAFE programming in the area together with devices, which could improve the protection of crisis-affected populations when searching for firewood such as solar lanterns. A realistic intervention of supporting the diffusion of 32 450 fuel-efficient stoves with a conservation efficiency of minus 40 percent of biomass consumed could lead to an average decrease of 6.2 percent of the total annual woodfuel consumption compared to the BaU scenario. Less conservative scenarios such as increasing the percentage of fuel-efficient stoves adopted to 50 percent of the population could lead to an average reduction of 19 percent with the greater results in Auno & Dusuman (-29.5 percent) and Ngala (-18.3 percent) compared to Gwoza (-14.1 percent).

Beside fuel-efficient stoves support, training on fuel-saving cooking practices can also be supported (FAO, 2018). These practices are related to fuel and stove, food and cooking materials and utensils. Cutting and splitting fuelwood will ensure a more complete burning process while keeping the same heat output. Using dry fuelwood (2 months is the optimal period) will improve the combustion process. Shielding stoves from wind will prevent the acceleration of the burning process. Putting out fire promptly could induce energy savings of 15 to 20 percent. By restricting the amount of fuel in the initial heating phase, when the stove is absorbing heat from the fire, the total amount of fuel needed will decrease. Once the stove is hot, it will not take heat away from the fire and the heat will go directly to the cooking pot.

The use of fresh food, pre-soaking, milling or pounding hard foods, cutting food in smaller pieces and tendering food (salt, bicarbonate or papaya juice) have all the potential to reduce cooking time. Simmering food instead of boiling will reduce the fuel quantity needed for cooking but will also ensure that more nutritional value is retained in the food. Finally, ensuring that all ingredients are within reach of the cook will decrease the time used for cooking and the stove heating in the absence of food to be cooked. Metal pots are very well suited for boiling water, whereas clay pots will retain heat much longer and are better for preparing meals which require extensive simmering. Loss of energy can be prevented by using tight-fitting lids on cooking pots as well as pot skirt which encloses the pot and forces the flame and hot gases to cook its sides (SET4Food, 2018). Certain types of partly cooked food can be transferred to a fireless cooker or 'haybasket'. This is an insulated container, where food continues to cook without external heating source.

Briquette manufacturing

Briquette production can have three advantages: replacing a significant amount of unsustainably sourced woodfuel, constituting a livelihood activity for woodfuel collectors (cash for work activity) and provide access to modern and clean energy to local communities. However, it is recommended to perform a techno-economic analysis at field level to define where the residues are the most accessible, the cost of collection, the preferred technical process involved, the size of the market and the marketing strategy to replace a certain amount of the woodfuel consumed.

Innovative energy solutions

Beyond cookstoves and briquette production, developing access to clean and sustainable energy services should remain the goal of any interventions. The diffusion of solar lighting in the IDP camps could increase protection, safety and productivity of conflict-affected people. Off-grid solar systems can improve energy access in both IDP camps and host communities. Finally, existing initiatives related to fuel-efficient stoves using ethanol could also represent an alternative to the use of woody solid biomass (Project Gaia, 2018). To replace traditional cooking fuels, ethanol can be produced from sugar cane, corn, sorghum or cassava.

Off-grid solar systems can improve energy access in both IDP camps and host communities for cooking but also for productive uses. These interventions require a profound understanding of the local context as well as renewable energy and clean cooking business-models. When taking on an integrated approach to food-energy production, traditional food processing methods can be upgraded such as fish drying, cereal milling and food conservation (SET4Food, 2015).

Afforestation and reforestation measures

Tree planting interventions have a great potential. Starting from existing structures of environmental management, such efforts should be supported by technical expertise and the provision of inputs. Community-based approaches to sustainable forest management can be used, involving host community members, IDPs and returnees. Environment committees can be established or supported on initiatives such as tree nurseries and communal woodlots. Regional, national and state-level afforestation programmes should also be supported. Based on FAO experience in promoting and monitoring forestry programs, the technical support to existing nurseries and the development of new nurseries could be envisaged in collaboration with the local forestry department and agents.

On average, 1 000 ha of tree plantation for woodfuel production can cover 4 percent of the woodfuel consumption based on the BaU scenario. Combined with demand-side measures, 1 000 ha of tree plantation could cover 5 percent of the woodfuel consumption. The three species presented in this study (*Acacia Nilotica Ssp. Adstringens*, *Annogeisus Leiocarpus* and *Azadirachta Indica*) have all the potential to be used for energy purpose but could also bring higher livelihood benefits. For instance, the collection and sale of Acacia gum (*Acacia Nilotica Ssp. Adstringens*) can support the resilience of local communities (FAO, 2018). Establishing local processing and value-addition measures can help producer countries realize an increased market share of this lucrative trade (FAO, 2011). Legumes associated with *Annogeisus Leiocarpus* close to riverbeds or ponds could also bring extra-benefits for nutrition and livelihood support to crisis-affected populations. Neem trees (*Azadirachta Indica*) are well adapted to the region as it was inventoried in 8 of the 14 field inventory plots of Dusuman. The associated benefits are also well documented. The current support provided by FAO to local tree nurseries and reforestation efforts should be scale-up to reach a larger reforestation area. Despite the importance of technical considerations for forest plantation (site identification, choice of species, and number of seedling needed…), there is also a clear need to define a community-based forest plantation management plan grounded on the needs and preferences of all communities (host, IDPs and returnee) (FAO & UNHCR, 2018).

The afforestation and reforestation activities need to be performed under the broader umbrella of integrated land use and natural resources management. This could include activities such as the development of a local soil management plan, raising awareness of farmers on soil conservation and the detrimental effects of slash and burn practices, training of farmers on soil management and integrated fertilization techniques, and the designation of land plots for agroforestry activities.

Tensions over natural resources can be aggravated in situations of prolonged conflict, especially when large displaced populations come into a certain host community. Interventions related to enhancing energy access for conflict-affected populations should therefore be conflict sensitive and peaceful management of natural resources should be mainstreamed. A good example is involving host communities, IDPs and returnees in tree planting campaigns, ensuring good understanding between all parties. Training in environmental management and conflict resolution might take on an instrumental role in building trust.

Awareness raising

Energy access is intrinsically linked to local values and norms. Therefore, it is essential to contextualize and adopt a culturally sensitive perspective. For example, the collection of woodfuel and cooking on three stones fires are very widespread practices in Borno State and are strongly interlinked with gender roles (SAFE Working Group in northeast Nigeria, 2018). Awareness raising activities on the multiple challenges and risks related to an unsustainable and unsafe energy access should accompany any energy-related intervention, touching on issues such as food insecurity, protection risks including gender-based violence (GBV) and protection from sexual exploitation and abuse (PSEA), women's work burden, climate change and safety hazards. A possible entry point could be the combination of nutrition sensitization with training on fuel-efficient stove use. Given the concentrated demand for fuel (notably in Gwoza and in insecure areas), efforts should also ease the pressure on forests and woodlands by promoting improved pruning techniques for the selective collection of firewood as well as community mapping of woodfuel resources and a community-based approach for their management including displaced, returning and host communities.

A conflict-sensitive approach should be incorporated in any energy access mechanisms (FAO, 2018). Depending on the local context and power/conflict dynamics, there are a few examples of programmes that could be used to support objectives around social cohesion and conflict prevention over natural resources: the Joint Community Peace Committees, the Dimitra Clubs or cross-border dialogue mechanisms. Capacity building and institutional strengthening of local governments to create an enabling environment for inter-communal dialogue is key in this regard.

Communities require a secure environment in which to move around and to manage natural resource sustainably and in a cohesive manner. Local initiatives, particularly those with women as central actors in reconciliation and confidence-building activities, are instrumental in this endeavor. Capacity building of local governments and planning of energy interventions between local and humanitarian actors have an important leverage effect. In this regard, the Energy and Environment working group for northeast Nigeria embedded in the humanitarian cluster system has a key role to play in terms of information sharing and training. Finally, initiatives such as *the Lake Chad Basin Governors' Forum for Regional Cooperation on Stabilization, Peacebuilding and Sustainable Development in the region affected by Boko Haram* should be welcomed since they "promote dialogue and cross-border design and exchange of information and crisis response solutions" related not only to security measures but also to sustainable development (UNDP, 2018). The environment domain could include improved energy access as a crisis-response solution since this problematic is common to local authorities from Cameroon, Chad, Niger and Nigeria participating to the forum.

By providing an alternative technology and by demonstrating its usefulness in this way, the interventions mentioned above will be more sustainable in the longer term.

Conclusion

The conflict in northeast Nigeria has considerably impacted the local population, especially in Borno State. Livelihoods of host communities, IDPs and returnees have been disrupted, increasing their vulnerability to the negative impacts of climate change. The lack of access to sustainable and safe energy resources leads to unsustainable management of wood resources and increases vulnerabilities linked to food insecurity, exposure to protection risks, safety and health hazards. If adequately managed, the natural resources in the area beyond the security perimeters are sufficient to meet the needs of the local community.

The integration of woodfuel supply and demand information provided evidence that major biomass losses are not only the result of woodfuel consumption in the selected LGAs (Auno, Dusuman and Ngala). Other factors which might contribute to loss of biomass are the rapidly increasing urban population in Maiduguri (requiring high amounts of charcoal for energy and wood resources for multiple purposes) and the negative consequences of climate change (soil erosion, desert encroachment, etc.). In the Gwoza AOI, a different situation presented itself with a woodfuel consumption which is significantly higher than the yearly biomass loss. The explanation for this can be found in the unstable security situation, limiting access for people to collect woodfuel in the immediate environment around the town.

The energy supply and demand measures proposed in this assessment will be most successful in combination with efforts to raise community awareness, improve land management and increase conflict sensitivity. Throughout these processes, it is important to contextualize and start from local norms and values in order to achieve a long-term impact.

Sustainable natural resource management implies a drastic reduction of the woodfuel demand (combined measures could reduce it by 15 percent) as well as major restoration efforts with multi-purpose tree plantations (10 000 ha could cover 49 percent of the demand). However, due to the local environment, the natural base only cannot sustainably support the energy needs of the local communities using traditional fuel and cooking technologies. Therefore, the deployment of alternative energy sources (non-woody biomass, ethanol, fossil fuels or improved electricity access) should also be pursued. It is also recommended to support innovative humanitarian delivery models shifting from energy items or fuel distribution to energy vouchers in stable areas. In unsecure areas, distribution of lightweight fuel efficient stoves and solar lanterns to reduce protection risks would remain the short-term norm.

To mitigate the pressure of human activities, it is essential to monitor natural resources in a continuous and participatory manner. Local authorities with the support of technical partners should lead replantation, restauration and afforestation efforts as well as their monitoring. These efforts must include local communities (displaced, returned and host) for mapping of natural resources and for their management in a view to reduce tensions.

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Annexes

Annex 1 – Energy demand household survey questionnaire

Survey information	
State:	Local Government Area:
IDP Camp:	Village/Community:
Partner:	Name of Field Enumerator:
Date:	

1. HOUSEHOLD INFORMATION	
Household Name (Optional):	Interviewee Name (Optional):
Interviewee age:	Interviewee relation to head of household (husband, wife, child, etc.):
Head of household gender: 1-☐ Male 2-☐ Female	Interviewee gender: 1-☐ Male 2-☐ Female
Total household members:	Number of income earners in the household:

Number of children (<15 years)		Number of youths in the household (15-24 years)		Number of adults (>24 years)	
Male	Female	Male	Female	Male	Female

Livelihood category						Status of household		
Agriculture	Agro-pastoral	Pastoral	Petty Trade	Fishing	Handcraft	IDP	Returnee	Host

What are the main sources of household income?					
Selling or exchanging food	Selling fuelwood	Remittances	Cash for labour	No income	Other
If other, please specify income source and income earner:					

2. CURRENT SOURCES OF FUEL FOR COOKING	
What is the main source of fuel for cooking and heating water for the household?	
1. Firewood	
2. Charcoal	
3. Agricultural residues	
4. Animal dung	
5. Non-organic waste (plastic bags/bottles, etc.)	
6. Gas/Liquefied Petroleum Gas (LPG)	
7. Kerosene	
8. Solar power	
9. Other	
If other, please specify:	

What is the main source of fuel you would prefer for cooking and heating water for the household?	
1. Firewood	
2. Charcoal	
3. Agricultural residues	
4. Animal dung	
5. Non-organic waste (plastic bags/bottles, etc.)	
6. Gas/Liquefied Petroleum Gas (LPG)	
7. Kerosene	
8. Solar power	
9. Other	
10. If other, please specify:	

What is the average quantity of fuel you consume per month for cooking? **Unit needs to be specified.**		
Fuel Type	Unit (**bundle, kg or litres**)	# of units **per week**
Firewood		
Charcoal		
Agr. residues		
Animal dung		
Non-organic waste		
Gas/Liquified Petroleum Gas (LPG)		
Kerosene		
Solar power		
Other		
If 'Other' was selected, please **specify unit** and the **number of units per week**		

Is the average quantity of fuel you consume per week for cooking sufficient to cover all your energy needs for cooking?	
Yes	No

Where do you source your fuel? Tick all boxes that apply				
Collection from bush	Collection from forest	Received from NGO/UN org.	Buying from market	Other
If 'Others' was selected, please specify the source and amount of fuel:				

Which means does your household use to transport fuel?					
Carry on back	Donkey cart	Bicycle	Motorized vehicle	Delivered at home	Other
If 'Other' was selected, please specify:					

If you collect fuelwood, how many fuelwood collection trips do you undertake per week?					
0	1	2-3	4-5	6	7 or more

Who within your household is primarily responsible for collecting fuel?					
Male adult (>24 years)	Female adult (>24 years)	Female youth (15-24 years)	Male youth (15-24 years)	Female child (<15 years)	Male child (<15 years)
If 'Other' was selected, please specify:					

What is currently the **average time in hours** for one collection trip (go out, collect, come back)?	
What was the **average time in hours** for one collection trip one year ago (go out, collect, come back)?	
What is currently the **average distance in km** for one collection trip (go out, collect, come back)?	
What was the **average distance in km** for one collection trip one year ago (go out, collect, come back)?	

What **type of wood** to use as fuel do you collect OR buy? Tick all boxes that apply								
Dead wood	Complete living tree	Big branches from living tree	Small branches from living tree	Branches from living shrubs	Complete living shrubs	Roots	Bark	Other
If other, please specify:								

What **species of tree or shrub** to use as fuel do you collect OR buy? Tick all boxes that apply						
Annona	Acacia	Neem	Prosopis	Leucaena	Eucalyptus	Others
If other, please specify:						

Which species of tree or bush **is most available** in your immediate environment? Tick all boxes that apply						
Annona	Acacia	Neem	Prosopis	Leucaena	Eucalyptus	Others
If other, please specify:						

What species of tree or bush to use as fuel would **you prefer**?						
Annona	Acacia	Neem	Prosopis	Leucaena	Eucalyptus	Others
If other, please specify:						

3. TECHNOLOGIES FOR COOKING	
What is **the main type of stove/technology that you currently use** for cooking and heating water?	
1. Three stone fire/open fire	
2. Mud stove	
3. Metal stove	
4. Gas stove	
5. Kerosene stove	
6. Solar cooker	
7. Other	
If other, please specify:	
What are the **problems/challenges** you are experiencing with this stove/technology? Tick all that apply.	
1. Food undercooked	
2. Stove heats up too fast	
3. Stove heats up too slow	
4. Temperature is hard to control	
5. Stove produces too much smoke	
6. Stove requires too much fuel	
7. Too expensive because of high fuel costs	
8. Type of fuel not available	
9. Fire in house/camp/community	
10. People get burned while cooking	
11. Lack of appropriate cooking pots/utensils	
12. Stove not durable/breaks easily	
13. Stove requires a lot of maintenance	
14. Stove is not stable enough/falls over	
15. Stove is too light	
16. Stove is too heavy	
17. Stove is not easy to transport	
18. Other	
If other, please specify:	
What is the **main type of stove/technology** that you used for cooking and heating water **before the crisis**?	
1. Three stone fire/open fire	
2. Mud stove	
3. Metal stove	
4. Gas stove	
5. Kerosene stove	
6. Solar cooker	
7. Other	
If other, please specify:	

Did you experience any **problems/challenges** with this stove/technology **before the crisis**?	
1. Food undercooked	
2. Stove heats up too fast	
3. Stove heats up too slow	
4. Temperature is hard to control	
5. Stove produces too much smoke	
6. Stove requires too much fuel	
7. Too expensive because of high fuel costs	
8. Type of fuel not available	
9. Fire in house/camp/community	
10. People get burned while cooking	
11. Lack of appropriate cooking pots/utensils	
12. Stove not durable/breaks easily	
13. Stove requires a lot of maintenance	
14. Stove is not stable enough/falls over	
15. Stove is too light	
16. Stove is too heavy	
17. Stove is not easy to transport	
18. Other	
If other, please specify:	
If you had a choice, what type of stove/technology would you **prefer** to use for cooking?	
1. Three stone fire/open fire	
2. Mud stove	
3. Metal stove	
4. Gas stove	
5. Kerosone stove	
6. Solar cooker	
7. Other	
If other, please specify:	

What are the **most important characteristics for you when selecting a stove to use for cooking**? Tick all boxes that apply:	
1. Time saving during cooking	
2. Durable/doesn't break easily	
3. Low in maintenance	
4. Weight/not too heavy or not heavy enough	
5. Mobility/hand grips	
6. Fuel type used in stove (charcoal, firewood, gas, etc.)	
7. Material of the stove (clay, metal, etc.)	
8. Stable/doesn't fall over	
9. Dimension/not too big or small	
10. Compatibility with cooking pots/utensils	
11. Reduced smoke/particles	
12. Safer/less burns and fires in house	
13. Easy to control the temperature	
14. Other	
If other, please specify:	

What is the **maximum price** for such a stove that you would be willing to pay? **(in Naira)**

How frequently do you use **your current stove/technology per day?** (please specify the number of **times/day**)				
1	2	3	4	>4

Where did you get your current stove/technology?				
Produced yourself	Relatives	Market	NGO/UN org.	Other
If other, please specify:				

Is the cooking stove you use an **improved/more efficient** cooking stove (i.e. a stove which improves upon the performance of traditional stoves in the specific location)?	
Yes	No

If you currently have an improved stove, since when has your HH been using it for cooking? (please specify the year):

What are the **three main types of food cooked** in your household and what is the average cooking time for each of these?	
Type of food (text freely)	Average cooking time (in minutes)
1.	
2.	
3.	

If you receive food through food assistance, is your current cooking technology/stove **appropriate for the food distributed**?		
Yes	No	No food assistance
If no, please specify the main problem:		

3. MULTI-SECTORAL CHALLENGES

Do people in your community face **protection risks** when they collect firewood? Please specify by ticking the boxes that apply.

Harassment	Assault	Rape	Abduction	Other	None

If 'Other' was selected, please specify:

Did you notice **a change in availability of woodfuel resources** in the surrounding environment comparing with one year ago?

Decrease in woodfuel resources	Increase in woodfuel resources	No change

What **other uses** do you have for wood resources?

Construction (shelter, storage)	Medicinal use	Shade for people and livestock	Livestock feed	Fences	Other

If other, please specify:

Are **sufficient wood resources** available for these other uses?

Yes	No

Are you aware of **any problems/tensions between** IDPs, returnees and host communities related to the collection of woodfuel resources?

Yes	No

If yes what kind of problems:

Are you aware of **any rules/agreements between** IDPs, returnees and host communities regarding the collection of fuelwood in the surrounding environment?

Yes	No

If yes what kind of rules/agreements:

Are you aware of **any commercial relationship between** IDPs, returnees and host communities regarding the collection or selling of energy sources (firewood, charcoal, animal dung, etc.)?

Yes	No

Did you face any of the **following challenges** (related to food security and nutrition) as a result of an insufficient access to energy resources? Tick all boxes that apply:

Undercooking of food	Skipping meals	Exchanging or selling food for fuel	Switching to food with shorter cooking time	Insufficient boiling of water	Other

If other, please specify:

Where does the cooking in your household happen?				
Inside, enclosed space (without window)	Inside, ventilated space (with window)	Outside, open air	Communal cooking, not in/around household living space	Other
If other, please specify:				

How many people are tasked with cooking and attending to the cooking fire/stove in your household? Please specify the number of household members (disaggregated by age and gender)					
Male adult (>24 years)	Female adult (>24 years)	Male youth (15-24 years)	Female youth (15-24 years)	Male child (<15 years)	Female child (<15 years)

Did you or somebody in your household experience any **respiratory illness/disease/chronic coughing/asthma/problems with lungs** in the past year?	
Yes	No

Did you or somebody in your household experienced **cooking-related burns** in the past month?	
Yes	No

What is the main source of **energy/technology** your household use for **lighting** purposes?					
No energy for lighting	Wood energy (open fire)	Kerosene lamp	Solar lantern	Torchlight (battery)	Other
If other, please specify:					

What are, according to you, the **3 most significant risks and challenges** related to energy and **energy access in the community**? Rank them from most significant to less significant.

1. No challenge
2. Protection risks (harassment, assault, abduction, …)
3. Health risks (lung problems, itchy eyes, …)
4. Deforestation
5. Food security and nutrition risks (skipping meals, …)
6. Tension/conflict over energy resources

Comments/Observations:

Annex 2. SMALL-SCALE FOREST INVENTORY: BIOMETRIC FORM

Location:____________________________ GPS Ref(N)______________________ Plot No: ________

GPS Ref(E)_______________________

Date: _____________________________________ Enumerators: ____________________

Species	Height (m)	Diameter (cm)	Stump (cm)	Bole (m)	Canopy (m)	Plot/Tree condition

Annex 3

Species	Relative dominance	Relative density(%)	Relative frequency	IVI
Auno				
Acacia ataxacantha	1.07	8.06	10.1	19.23
Acacia seyal	0.33	4.84	6.1	11.27
Adansonia digitata	2.48	0.81	1.0	4.29
Anogeisus leiocarpus	0.02	0.81	1.0	1.83
Balanites aegytiaca	1.42	2.42	1.0	4.84
Boscia senegalensis	0.05	10.48	3.0	13.53
Capparis corymbosa	0.04	0.81	1.0	1.85
Cassia singuena	2.77	0.81	1.0	4.58
Diospyrus mesepiliform	4.45	7.26	6.1	17.81
Gueria senegalensis	0.01	6.45	1.0	7.46
Mitragyna inermis	0.13	9.68	11.1	20.91
Piliostigma reticulatum	9.07	40.32	50.5	99.89
Piliostigma thoningii	3.56	3.23	2.0	8.79
Scelerocarya birrea	8.52	0.80	1.0	10.33
Steculia setigera	14.08	0.80	1.0	15.89
Tamarindus indica	11.96	1.61	2.0	15.57
Ziziphus mucronata	0.01	0.81	1.0	1.82
		100		

Dusuman				
Acacia nilotica	0.001	0.76	0.8	1.56
Acacia seyal	0.18	4.58	4.6	9.36
Acacia siberiana	4.05	0.76	0.8	5.61
Adansonia digitata	10.43	2.29	2.3	15.02
Azadirachta indica	56.15	48.85	48.9	153.9
Balanites aegytiaca	13.75	9.92	9.9	33.57
Boscia senegalensis	0.02	1.53	1.5	3.05
Combretum aculeatum	0.38	4.58	4.6	9.56
Dichrostachys cinerea	0.06	3.05	3.1	6.21
Diospyrus mesepiliform	1.99	0.76	0.8	3.55
Faidherbia albida	3.77	2.29	2.3	8.36
Hyphene thebaica	3.44	2.29	2.3	8.03
Mangifera indica	1.69	8.40	8.4	18.49
Piliostigma thoningii	0.01	1.53	1.5	3.04
Ziziphus mauritania	4.08	8.40	8.4	20.88
		100		

Relative dominance = Total basal area of a species/total basal area for all species x 100

Relative density = Number of a species per plot/ number of all species per plot x 100

Relative frequency = Number of time a species occur/ total number of occurrence of all species x 100

Important Value Index (IVI) = Sum of Relative dominance + relative density + relative frequency

The error matrix is a cross-tabulation of the class labels allocated by map and reference data.

Usually the map classes are represented in rows and the reference classes in columns. The diagonal of the matrix contains the correctly classified data points, whereas the cells off the diagonal show commission and omission errors. Omission error is complementary measure of producer accuracy (FAO, 2016)[10].

Table 23 Error Matrix Auno & Dusuman

		Reference Class	
	Class Name	Loss	No-Loss
Map Reference	Loss	10	30
	No Loss	21	218
	Total	**31**	**248**

Table 24 Error Matrix Gwoza

		Reference Class	
	Class Name	Loss	No-Loss
Map Reference	Loss	18	21
	No Loss	21	233
	Total	**39**	**254**

[10] http://www.fao.org/3/a-i5601e.pdf

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