Assessing the spatial availability and distribution of crop residues for energy production in Northern Uganda.

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Abstract

Northern Uganda generates considerable volumes of crop residues across the agricultural value chain, and converting these residues into energy offers a viable pathway for advancing the region's clean energy transition. However, sustainability is challenged by competing uses. This study assessed the availability and alternative uses of crop residues in Amuru District, Adjumani District using a cross-sectional design and mixed-method approach. Data were collected through Focused group Discussion, observations and in-depth interviews, identifying rice husks, maize cobs, groundnut shells, as the most prevalent residues. The findings revealed that these residues are predominantly utilised for livestock feeding and bedding, which significantly constrains their potential as feedstock for energy production. Although agricultural residues are abundant, their diversion to other uses limits the feasibility of residue-based energy solutions. Addressing this challenge requires strategic resource mapping to guide allocation, formulation of local policies for sustainable residue management, and community engagement to enhance awareness of clean energy benefits. Additionally, investment in infrastructure for efficient residue recovery and processing is essential to ensure consistent supply for energy conversion initiatives. Balancing these competing demands is critical to realising the full potential of agricultural residues as a sustainable energy resource in Northern Uganda.

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Introduction

Agricultural waste, a readily available biomass, is produced annually worldwide and is vastly underutilized (Biswas et al., 2017). Approximately 990 million tons of agricultural residues are produced annually commonly generated from six important crops globally: barley, maize, rice, soybean, sugar cane and wheat.(Saleem, 2022), (Allesina et al., 2018). The potential of agricultural biomass as a source of energy has been explored in many countries, including India, China, Denmark, Poland, and Nigeria (Saleem, 2022). Over the past 20 years, a number of studies have come with estimates of agricultural crop residues production for energy production, offering recognizable outcomes (Bentsen et al., 2014). The use of agricultural residues to generate electricity is becoming more common as it is deemed a sustainable energy source that could reduce on over reliance on fuelwood for household cooking (Lubwama & Yiga, 2017). In Uganda, large quantities of crop residues are generated throughout various stages of crop production value chains in many parts of the country which is predominantly agricultural based economy (Olupot et al., 2024)(Oteu et al., 2024). Underutilization of these abundant crop residues represents a missed opportunity for energy generation while exacerbating environmental problems deforestation and Land degradation. According to Peng et al., (2025), Agricultural wastes being produced annually is estimated at 1 billion tons globally. Assessing the spatial and temporal availability of crop residues is one of the most crucial stages in optimizing a biomass utilization as an alternative energy source, Usually Geographical Information Systems(GIS) tools are employed to analyze spatially referenced data enabling provision of useful information for decision makers (Zhang et al., 2021).

Northern Uganda generates substantial quantities of agricultural crop residues each season—such as maize stalks, rice husks, groundnut shells, and sorghum stalks—that remain underutilized despite their significant potential as alternative bioenergy resources. A systematic assessment of these residues is urgently needed to support the transition toward more sustainable and locally available energy sources. Several studies like Olupot et al., 2024 characterized Uganda's main Agri-Food value chain wastes for gasification. Also Mohamedeltayib., (2017) explored the availability, energy potential, and environmental benefits of using agricultural residues for biomass energy production in Uganda. Another study conducted at regional level include; Oteu et al., 2024 evaluated agricultural waste-based briquettes as an alternative biomass fuel in Mukono district in Uganda have examined Uganda's biomass energy sector at mostly national or regional level and lack spatially detailed information on where biomass resources are located and in what quantities in northern Uganda. In order to assess the spatial availability and distribution of crop residues for energy production, this study takes in to consideration crop production, residue production and alternative uses of crop residues.

Using geospatial techniques such as GIS tools facilitates an in-depth understanding of spatial patterns, relationships, and phenomena by providing high-resolution, location-specific insights that conventional statistical assessments cannot achieve (Bao et al., 2025). A geospatial assessment would therefore become an essential for identifying and evaluating the feasibility of crop residues as an alternative energy source.
Therefore the present study was conducted to assess the spatial availability and distribution of crop residues for energy production in Northern Uganda.

Materials and methods

Description of study area

The geographical location of this study constituted of Amuru District and Adjumani District situated in the Northern part of Uganda. This area was selected because given that charcoal and firewood which represents the bulk of domestic fuel in Uganda; 40% of it comes from Northern Uganda MEMD(2016). Amuru District is located between longitude 30-32 degrees East; latitude 02-4 degrees North which covers a total land area of 4,851.68sqKm.
Adjumani District is located in the North western region of Uganda, between latitudes 31^{0} 24” and 32^{0} 4” east of Greenwich line; and longitudes 2^{0} 53” and 3^{0} 37” north of the Equator. The total land area of the District is 3128 Sq.Kms, of which 46.8 Sq.Kms is covered by water. The area occupied by forest is estimated at 37.44 sq kms.

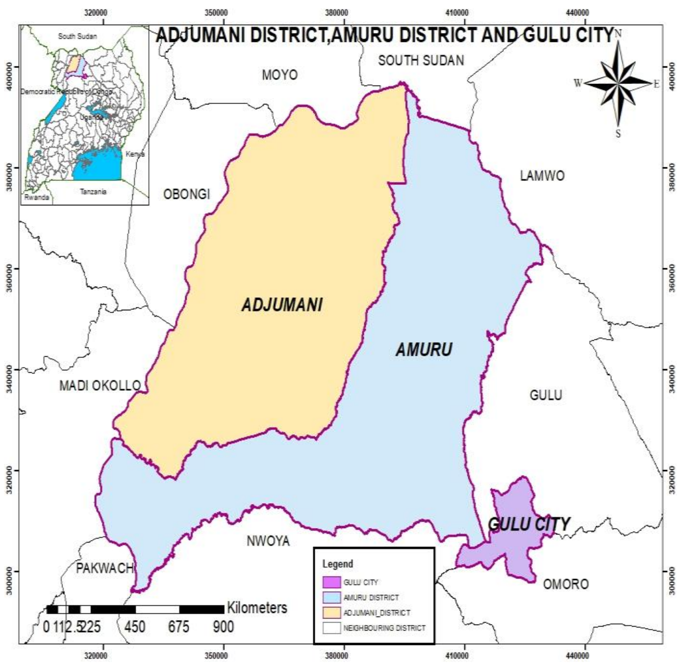


Fig.1 Map of the study area

Climate

The climate is categorized as tropical dry climate with both the dry and rainy seasons where it peaks twice a year from late march to late November.(JICA, 2011) with annual rainfall of 400–1600 mm of rain falling there each year specifically for Amuru having a mean annual rainfall of 1434 mm (Omara, 2021)

Topography
Adjumani District lies at an approximate altitude ranging from 900 to 1500 metres above sea level (Quality, 2020). It is principally gentle undulating land merging into rock outcrops. Amuru district's altitude ranges between 1,000 and 1,200 meters above sea level with notable feature like Kilak Hills in the northeastern part of the district.

Vegetation
Adjumani and Amuru Districts are predominantly savannah woodland and grassland with grasses ranging from 0.5-2.0 meters high and also endowed with other vegetation cover like the papyrus which notably occupy the River Nile bank (Quality, 2020)

Social economic activities
A big number of the population estimated to be one million derive their livelihood from the natural resources through activities such as agriculture and charcoal burning.

The methods adopted for conducting this study is explained below:
Determination of the spatial extent of the study area.
The target area was delineated using GIS tools by defining the boundaries of the areas of interest.
Preparation of the reference map for the overlay of field data.
A base map with known coordinates was aligned using common points and field data plotted onto the overlay using consistent symbols and clear labels.
Selection of the target participants.
The participants were selected purposively from the two districts, who included the Agriculture officers, the commercial officers, the environment officers whose input added value to the subsequent analyses.
Carrying out of the mapping through Participatory Geographical Information Systems. This was conducted through a focused group discussion and in depth interviews with the selected participants while plotting of the base map for the targeted areas.

Results
Characterizing of major Agricultural crops
From the mapping exercise with the participants, an inventory of the crops grown in the target area was developed as below.
Table 1. Inventory of crops grown in the two districts in each sub county and the different town councils was developed.

District	Subcounties	Crops grown	TC	Processing
Amuru	Amuru	Gnut	Amuru TC	G-nuts
	Atiak	Cassava, Pigeon peas, Shorgum	Atiak TC	Rice
	Guruguru	Gnut, ricce, Gnut processing (high)	Elegu TC	Rice
	Lakang	Maize (Commercial farms), soybeans, rice	Pabbo TC	Rice
	Lamogi	Gnut, maize		
	Layima	Maize (Commercial farms), soybeans, rice		
	Opara	Rice		
	Pabbo	Rice		
	Pogo	Rice, Gnut		
Adjumani	**SC**	**Crops**	**TC**	**Procesing**
	Adropi	Cassava	Adjumani TC	Maize
	Arinyapi	Simsim	Pakele TC	Maize
	Ciforo	Soybeans, Cassava, Rice		
	Dzaipi	Gnuts, cotton, simsim		
	Itrirkwa	Rice, Cassava, Soybeans		
	Ofua	Cassava		
	Pacara	Soybeans, Cassava, Rice		
	Pakele	Rice, soybeans		
	Ukusijoni	Simsim		

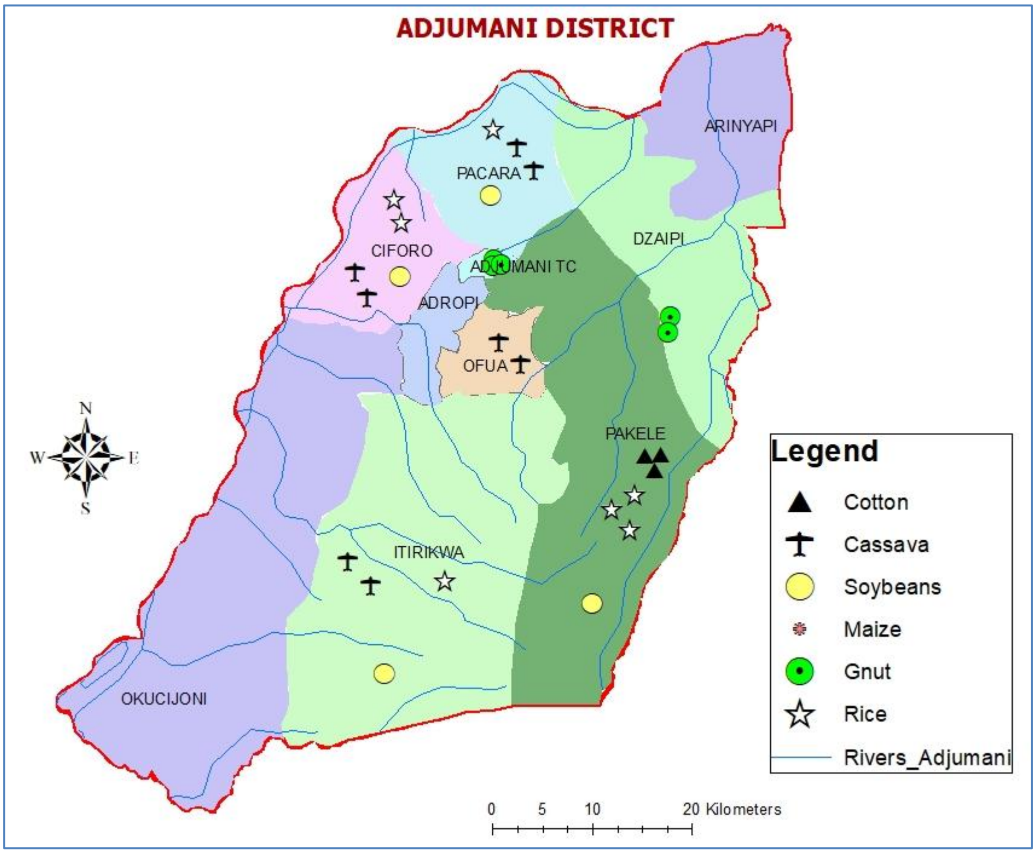
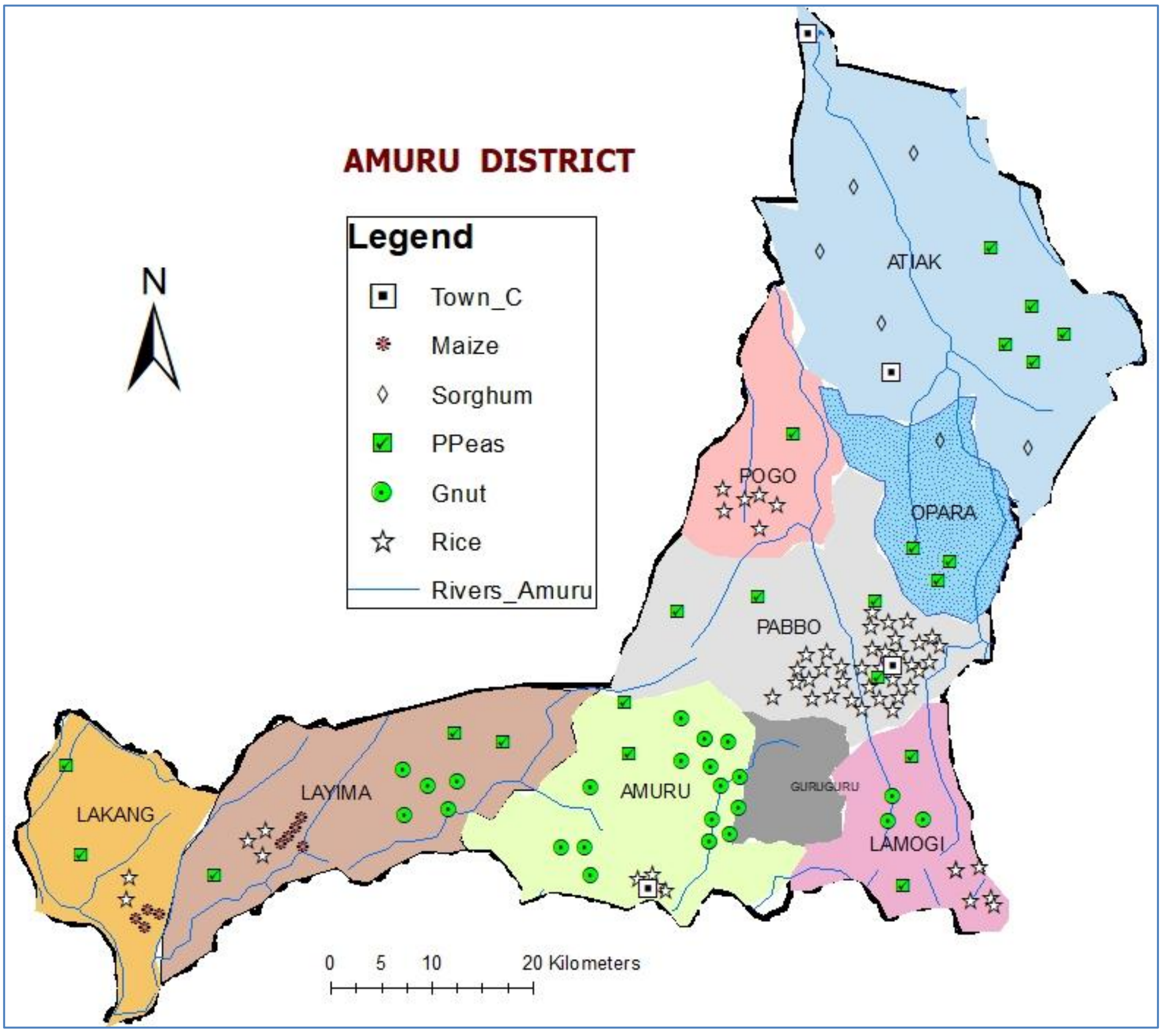


Figure 5. Cropping pattern in Adjumani district as per the updated PGIS with the concentration of symbols for each crops showing relative abundance



Characterizing of Agricultural crop residues

In the present study, the production of Agricultural residues were characterized from the major crops grown identified in the districts of Amuru and Adjumani in the different subcounties and town councils. From the major crops identified processed based residues and field based residues were catergorised.

Types of crop residues	Name of crop	Category
Stalks	Maize, Shorgum, cotton Pigeon peas, Sim sim	Field Based
Straws	Rice	Field Based

Cobs	**Maize**	**Processed**
Husks	**Rice**	**Processed**
Shells	**Ground nuts**	**Processed**
Baggase	**Sugar Cane**	**Processed**

Crop residue availability
"After harvesting maize, there is usually plenty of cobs, and during the rice season, husks are everywhere around the mills. Groundnut shells are common at the end of the season, but they are only abundant for a short time." Mostly maize cobs are used for cooking when firewood is scarce. Rice husks are spread in animal kraals as bedding, and some people use them to make mud bricks. Groundnut shells are mixed into the soil to improve fertility."
Rice husks are concentrated around milling centers. Maize cobs are more widely spread across villages after harvest, while groundnut shells are seasonal." Residues are critical for livestock farmers; they use them as bedding and feed. Others sell residues for income or use them in brick making. These uses compete with energy production."

Conclusion
The districts of Amuru and Adjumani have plenty of agricultural crop production which can argument crop residues availability for energy production and any other alternative uses. Residue-to-energy projects could create jobs and reduce deforestation caused by charcoal burning. But the challenges are poor infrastructure, lack of storage facilities, and low community awareness. Furthermore, Government should provide guidelines, support private investors, and work with farmers' cooperatives to manage residues. Partnerships with NGOs could also help." There are also no specific residue management policies. We need clear guidelines and integration into district energy and agriculture plans

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