Assessing the impact of charcoal production activities on the Shea Nut tree vegetation cover

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Abstract. Charcoal remains the main energy cooking source for urban dwellers in Uganda. The Shea Nut tree produces quality charcoal which is efficient and locally made. Therefore, it is facing increasing threats from the local communities so as to meet the mushrooming demand. The study analyses the state of the Shea Nut tree, drivers of charcoal production, predict Shea Nut tree vegetation coverage, and establish mechanisms for sustainable utilization and conservation of the Shea Nut trees in Kapelebyong District. Landsat images were classified using likelihood classification in ArcGIS and interviews were conducted whilst geospatial, Stata, and Nvivo tools were used for analysis. The findings reflect a sharp declining trend in the coverage of the Shea Nut trees by 2.3% and 6% from 2002-2012 and 2012-2022 respectively. The major drivers include high demand from urban areas, the need for income, and unemployment. As a result, it is predicted that by 2032, the coverage will have reduced to only 713 hectares (7.3%) from 1277 hectares (10.6%) in 2022. Therefore, charcoal production with other land uses has greatly resulted in Shea Nut tree deterioration. The study recommends the use of alternative energy sources, the provision of alternative income-generating activities for the local communities, Government of Uganda through NFA needs to enforce the ways through which Shea Nut trees are managed and utilized in order to minimize illegal cutting.

Keywords: Charcoal production; Shea Nut tree; drivers; prediction; and Mechanisms

1. Introduction

Over 60% of the World’s population use fuel wood especially charcoal as the main cooking energy source and as such, its demand is increasingly rising (Zulu & Richardson, 2013). It has in the recent years been highlighted to be one of the most easily reliable source of energy that can be produced locally by the without technological and capital investment (Zulu & Richardson, 2013). Moreover, its production has no gender, age or status restriction, instead it attracts ruralites and urbanites of all walks of life (Choung Nguekeng et al., 2021). The Shea butter tree (Sapotaceae, Vitellaria family) is one of the hardwood tree species spotted out to provide quality charcoal and this is commonly found in most semi-arid regions of sub-Saharan Africa notably from Senegal to Uganda (Siko et al., 2021). Charcoal production is not only shooting high due to its great usage as an energy for cooking but also as a major source of house hold income and a greater poverty reduction measure (Zulu & Richardson, 2013). All these have resulted to great pressure on the worlds tree species notably the Shea butter tree in the African continent (Mensah et al., 2022).

The Shea butter tree serves a variety of ecological and biological functions, making it valued in the places across the world where it grows (Buyinza & Bosco Lamoris, 2020). The tree produces a lot of domestically useful food oil as well as items with cosmetic and medicinal purposes (Branch & Martiniello, 2018). Jibreel et al., (2019) claim that the tree is frequently used in agricultural cultivation and agroforestry practices, which offer a variety of environmental services. The primary environmental ecological systems include maintaining biological systems, sequestering carbon, regulating temperature, supplying food and shelter for living things, and giving shade, in addition to making a major contribution to the economic livelihoods of rural communities (Mensah et al., 2022). In addition to providing numerous environmental benefits, the Shea Nut trees can help increase soil fertility (Hale et al., 2021).
In sub-Saharan Africa, approximately 80% of the people in town use charcoal as their prime cooking energy source, and the demand is predicted to immensely rise in the future (Nabukalu & Gieré, 2019). For the case of Uganda, fuelwood and charcoal production account for 92% of the energy demand nationwide whilst the annual energy consumption growth rate is predicted to rise by 2025 (Okullo, 2016). Uganda’s major capital, Kampala and other major newly created cities notably Mbarara, Fort portal, Mbale, Jinja, Soroti, Arua, Gulu, Lira, and Hoima, have considerable access to electricity, with more concentrated grid connections relative to other parts of the country. However, charcoal use has been on a boom (Buyinza & Bosco Lamoris, 2020). As a result, the rate of charcoal production in Kapelebyong district and other areas of Shea Nut trees is becoming more and more alarming in the recent years. The average production had risen to 11 million metric tonnes by 2007 and in 2008, 40% of households in the district were recorded to be engaged in charcoal production activities (Atalla, 2015).

With the objectives of this study being, mapping, examining drivers of charcoal burning, predicting the future coverage of the Shea butter tree and establishing the possible mechanisms for sustainable charcoal production, this undertaken study will serve as a yard stick to understanding charcoal production and Shea Nut tree trend dynamics so as to enhance its sustainable utilization and conservation.

2. Materials and Method

2.1. Study Area

The study was conducted in Kapelebyong district located in Teso sub-region, Eastern Uganda in the East African region. The geographical coordinates are 2° 17' 36" North, 33° 49' 51" East and its original name (with diacritics) is Kapelebyong. It is a boarder district that divides Teso land and Karamoja land (OPM, 2020). The district is bordered by Katakwi from the East, Amuria in the South, Otuke in the North, and Napak in the North East. It consists of one single constituency of Kapelebyong, 6 sub counties, 55 parish units and 327 villages. The District Headquarters is Kapelebyong town council located 81Kms from Soroti via Amuria road.

![Figure 1. Location of the study Area](image-url)
2.2 Materials

2.2.1 Land cover change of the Shea butter tree between 2002 and 2022

The study mainly utilized satellite images for three different periods that is 2002, 2012, and 2022 for Landsat 7, 5 and 8 respectively with 30 by 30m grain size from USGS portal (http://glovis.usgs.gov/web-link). The images were corrected by projection techniques in ArcGIS 10.8 to WGS 1984 UTM zone 36N coordinate system. The downloaded images were pre-processed by obtaining composite samples notably 4-3-2 bands for Landsat 5 and 7 while 3-2-1 were used for 8 to depict natural colours (Red, Green, and Blue). This criterion was used because it covers the entire area and the high reflectance ability to generate clear and accurate output land use/land cover maps. To map specific areas of the Shea Nut tree occurrence and differentiate it from other tree types, 400 sample coordinates points of Shea Nut trees were obtained in 6 Sub Counties using Garmin GPS (Figure 2).

![Figure 2. Shea Nut sample points used in creating training samples for image analysis](image)

2.2.2 Underlying drivers of charcoal production in Kapelebyong District

Simple random sampling was employed for the local communities and as such, 10 charcoal burning points were randomly selected from each sub county at that time and direct interviews were used. An interview guide consisting of closed ended questions was used to obtain the reasons for engagement of the local communities in charcoal production business. Only ten respondents were considered in each sub county rather than a parish because there is a possibility of not finding charcoal production in some small parishes and thus, a total of 60 respondents were interviewed in the 6 SubCounties.

2.2.3 Predicting the future Shea butter tree coverage by 2032 in Kapelebyong district

The prediction of the vegetation cover change of the shea butter mainly due to charcoal production between 2022 to 2032 was based on shea Nut wood tree vegetation change detection for the period 2012 – 2022 using Methods of Land
Use Change Evaluation (MOLUCE), a plugin in built in Quantum GIS purposely for detecting land cover/land use change overtime. The model utilizes output maps of the previous years to detect and estimate future trends (Ferreira et al., 2019). A map depicting Shea Nut tree, land use and land cover transitions was obtained as an out from MOLUSE model which was later used as a basis for predicting Shea Nut tree cover changes between 2022 and 2032.

2.2.4. Mechanisms for sustainable charcoal production to enhance Shea Nut tree conservation.

The sample size for mechanisms on sustainable charcoal production consisted of 4 respondents at the district level. These include Senior Environment Assessment Officer, Senior Environment officer, Natural Resources officer and District Forest Officer. These were selected following purposive sampling procedures. Key informant interviews were conducted for the 4 purposively selected stakeholders known to be involved in the district environmental management programs and as such, key informant interview guide was used, direct questions posed to the respondents to obtain their views on the strategies of ensuring sustainable charcoal production and reduce the massive loss of the Shea Nut trees in the region. The selection of key informants was informed by technical expertise and knowledge, such that their fields of jurisdiction made them considered for environmental degradation, which was central to this study.

3. Result and Discussion

3.1 Land cover change of the Shea Nut tree between 2002 and 2022

The results signify that for the past 20 years, the vegetation cover of the shea Nut trees has rapidly reduced. The results in figure 3 clearly show that it covered 18.9%, 16.6% and 10.6% in 2002, 2012, and 2022 respectively. This implies that the shea Nut trees reduced by 2.3% from 2002-2012 and by 6% from 2012-2022. Therefore, the results depict a sharp declining trend in the coverage of the shea Nut trees which has also influenced other cover types. This change was attributed to population explosion in the country which increased demand for charcoal energy for cooking processes and unemployment leading to poverty and as such, the local communities in the area resort to charcoal production as a quick source of income.

![Figure 3. Spatial variation of the Shea Nut tree coverage from 2002-2022](image-url)
The shea Nut trees rapidly declined in coverage compared to other land use types with increasing trends especially farmlands. The study revealed a decline in grasslands and wetland area lost especially farmlands (Figure 3). According to the data obtained from the locals engaged in charcoal production, the 1960s and 1970s were the good old times of low population, high soil productivity and immense coverage of the area with the Shea Nut trees. However, with the increasing population over time, woodland areas of the Shea Nut trees were cut off for charcoal production to fulfill the high demand of the growing population in the country. This is in line with (Mensah et al., 2022), who noted that the ever mushrooming growing demand for cooking charcoal mostly in towns and cities has seen a rise in indiscriminate exploitation of the Shea Nut trees especially in Northern and Eastern Uganda.

Given this kind of reduction rate, Shea Nut trees and grasslands may completely disappear due to pressure from the ever-growing and increasing land use activities. Farming is on the rise at the expense of grasslands and Shea Nut trees which are cleared for charcoal production and other land uses. The results are in agreement with Majaliwa et al. (2018) who assessed the historical and future land use dynamics in Uganda and noted that farmlands and grazing areas often expand while wetlands shrink as they are cleared off for crop cultivation. This corresponds to findings by Tun et al. (2023) who noted that, Land use types expand in response to the ever mushrooming population and land cover shrinks due to land use types.

3.2. Drivers of charcoal production in Kapelebyong District

The study findings reveal that regardless of the multiple drivers of charcoal production in the area, it is driven by three major factors, that is income, unemployment and high demand in Uganda’s major urban and city centres while need for charcoal for cooking by the local people and culture account for a small percentage (Table 1). The study therefore reveals that charcoal production is mainly caused by the need for income among the rural poor due to limited viable income generating economic activities worsened by the mushrooming unemployment rates which has pushed people to charcoal production with clean quick income to meet their needs.

<table>
<thead>
<tr>
<th>Reason</th>
<th>Frequency</th>
<th>Percentage (%)</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>High demand</td>
<td>38</td>
<td>26</td>
<td>63</td>
</tr>
<tr>
<td>Unemployment</td>
<td>42</td>
<td>29</td>
<td>70</td>
</tr>
<tr>
<td>culture</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Income</td>
<td>59</td>
<td>41</td>
<td>98</td>
</tr>
<tr>
<td>charcoal for Cooking</td>
<td>4</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
<td>100.0</td>
<td>240.0</td>
</tr>
</tbody>
</table>

The study findings confirmed that, this results from population explosion causing unemployment, ever increasing demand whilst the poor ruralites resort to charcoal burning to obtain income hence massive cutting down of the shea nut tree. This trend is likely to continue to account for decline of this valuable tree not only in Kapelebyong District but other Shea Nut areas in Uganda and the African continent at large. This rhyme with the findings by Doggart & Meshack, (2017) who noted that Population growth and migration has seen a sharp increase in the demand for charcoal as the major energy for cooking in most cities and towns of the country.

Multiplicity of Uganda’s urban dwellers use charcoal as the main source of energy for cooking. This high demand has directly created an opportunity for income generation with minimal investment. This is in line with (Alfaro & Jones, 2018), who noted that charcoal industry, which is prevalent in rural settings due to its affordability and accessibility to the poor, could contribute to poverty reduction through alternative income-generation opportunities. Moreover, some business people do buy charcoal from the local communities and sell it expensively to the urban dwellers. This implies that not only are the local poor communities engaged in charcoal production but the rich business men as well due to quick cash obtained with ease of buying from the locals, transport and deliver to different urban markets. Worse still, the market venders sell to the final user more expensively. This trend has therefore accounted for massive exploitation of the Shea Nut tree, a threat to environmental conservation. Threats to vegetation cover across the universe is just like that of the precious non-renewable resources which is in most cases invisible (Yonas et al., 2022). For charcoal production in Kapelebyong, the drivers are equally not visible but manifested by remnants of Shea Nut tree trunks (Figure 4).
Figure 4. Evidence of charcoal burning in Kapelebyong District
(1, 3, 4) Cut Shea Nut tree waiting to be buried for charcoal burning
(2) Remain of Shea Nut tree trunk cut four years ago
(5) Ongoing charcoal burning
(6, 7, 8) Piles of soil and broken charcoal left behind after charcoal burning

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3.3. Prediction the future Shea Nut tree coverage by 2032.

The results show that by 2032, the coverage of the Shea Nut tree will have reduced to only 713 hectares (7.3%) from 1277 hectares (10.6%) of 2022. This means that approximately 564 hectares of the Shea Nut trees will be lost between 2022-2032 which indicates a negative change.

Therefore, the trend of Vegetation deterioration is more likely going to increase over time and as such this valuable tree will exist only in small patches of Kapelebyong district and other parts of Uganda. The results also show that other land use and cover types will change in the next 10 years notably; burnt vegetation will have reduced to 212 hectares, wetland to only 439 hectares, built up area to 109 hectares, farmland will have increased to 6846 hectares and grassland will have reduced to 1233 hectares’ coverage.

Table 2. Predicted vegetation cover change of the Shea Nut trees in Kapelebyong between 2022 and 2032

<table>
<thead>
<tr>
<th>LULC Class</th>
<th>2022 (Hectares)</th>
<th>%</th>
<th>2032 (Hectares)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shea Nut Trees</td>
<td>1277</td>
<td>10.6</td>
<td>713</td>
<td>7.3</td>
</tr>
<tr>
<td>Burnt Vegetation</td>
<td>582</td>
<td>4.8</td>
<td>212</td>
<td>2.2</td>
</tr>
<tr>
<td>Wetland</td>
<td>1747</td>
<td>14.6</td>
<td>439</td>
<td>4.6</td>
</tr>
<tr>
<td>Built up Area</td>
<td>425</td>
<td>3.5</td>
<td>109</td>
<td>1.1</td>
</tr>
<tr>
<td>Farmland</td>
<td>6363</td>
<td>53.0</td>
<td>6846</td>
<td>71.7</td>
</tr>
<tr>
<td>Grassland</td>
<td>1613</td>
<td>13.4</td>
<td>1233</td>
<td>12.9</td>
</tr>
</tbody>
</table>

Figure 5. Predicted vegetation cover change of the Shea Nut trees from 2022-2032
Predicted results reveal that the Shea Nut trees will lose land area to grassland, wetlands and grasslands will lose much of the land area to farmlands for crop cultivation (Figure 4). Besides, some the Shea Nut tree area will also be lost to farmlands and built up areas. Moreover, some patches of the wetlands will lose land to grasslands and grasslands to burnt vegetation. Therefore, the prediction indicates the pattern of decline of the Shea Nut trees, burnt vegetation, grassland and built up areas. However, it also depicts a pattern of gain to farming activities in the area. The farmlands are likely to extend to most grassland areas, wetlands and Shea Nut vegetated areas. The pattern of settlement in the area is poor in that the settled area seems to be reducing and this is attributed to remoteness and political instability in the district.

Therefore, the prediction indicates the pattern of decline of the Shea Nut trees, burnt vegetation, grassland and built up areas. However, it also depicts a pattern of gain to farming activities in the area. These results agree with (Charvet et al., 2022) who traced the fact that by 2040, predictions show that farming areas in Uganda will most likely increase by about 1%.

3.4. Mechanisms for sustainable charcoal production to enhance Shea butter Tree conservation.

The study highlights multiplicity of mechanisms to ensure sustainable production of charcoal so as to conserve the Shea Nut trees notably Income generating activities, Licensing charcoal burners, Alternative energy, replacing cut shea nut trees, law enforcement, sensitization, increase charges, electrification, monitoring of charcoal burning activities, use of energy saving/efficient stoves, and implementation of environment awareness programs (Figure 5). Strategies established for conservation of green cover ought to be given priority by government through ensuring timely implementation.

The government environmental agencies must also be supported in boosting awareness and implementation of laws and regulations that entail charcoal production. Inter-sectoral, multi-stakeholder dialogues across the entire charcoal value chain should be encouraged, to discuss coordinated options for reducing massive destruction of Shea Nut trees.

Replanting cut trees through replacement is very key in reducing the disappearance of this valuable tree. The NFA and NEMA should strictly implement the tree replanting policy applicable to the whole country such that “cut 1 tree, plant 10” to replace it. Ironically, the charcoal production industry could save the environment that it now threatens only if communities and private practitioners grew and replaced Shea Nut and other trees for charcoal as well as harvested trees sustainably through operating according to proper formulated management plans. Mensah et al., (2022) noted that, there is potential to improve Shea Nut tree cover and produce charcoal, through adoption of short rotational agro forestry systems.

The tree and forest act Ministerial directive, Judiciary restrictions and Police enforcements are vital in minimizing over cutting down of this tree in Kapelebyong district and other areas having the Shea Nut tree in Uganda. Some of these mechanisms for Shea Nut tree conservation through sustainable charcoal production exist but have continued to fade out due to inadequate implementation and corruption tendencies. Strategies established for conservation of green cover ought to be given priority by government through ensuring timely implementation. This resonance with (Buyinza & Bosco Lamoris, 2020) who in their study emphasized that, the tree and forest act Ministerial directive, Judiciary restrictions and Police enforcements are vital in minimizing over cutting down of this tree in Kapelebyong district and other areas having the shea nut tree as well as The existing laws like forest, NEMA acts be implemented and enforced in these areas where exploitation is high.

Sensitization programs are very key in ensuring that the local communities are availed with relevant information about the value of the shea nut tree and the dangers of over cutting them for charcoal production. This can be done through implementing advisory services aiming at providing the status of the shea nut tree and how its degradation will affect the communities and future generation. Sensitization of the local charcoal burning communities on the dangers of over exploitation of the shea nut tree for charcoal production and how it is greatly affecting sustainability of this great tree mainly through outreach programs and project work, replacing cut trees in every point where exploitation and charcoal burning processes are being carried out all over the district and other distant areas of the country, region, continent and globe at large (Jibreel et al., 2019).
4. Conclusion

Shea Nut tree vegetation cover is rapidly declining due to charcoal production, farming, and house construction. There was declining cover of the Shea Nut trees from 2002-2022 as well as negative predicted change between 2022 and 2032. Wetlands, burnt vegetation, grasslands and built up areas experienced negative changes. Farmlands covered the largest land cover at the expense of wetlands and grasslands. Income, high urban demand and unemployment are the main drivers of charcoal production in the area due to population explosion in the country, there has been a sharp rise in the demand for charcoal for cooking purposes making charcoal very expensive. Losses and deterioration of the Shea Nut vegetation cover will most likely increase in magnitude given the ever increasing population, unemployment and demand for charcoal such that by 2032 of about 713 hectares (7.3%). Implementable mechanisms for sustainable charcoal production are pertinent in regulating the rate at which the Shea Nut tree is utilized. The study concludes that Income generating activities, Licensing charcoal burners, Alternative energy, replacing cut shea nut trees, law enforcement, sensitization, increase charges, electrification, monitoring of charcoal burning activities, use of energy saving/efficient stoves, and implementation of environment awareness programs are key in ensuring sustainable utilization of the Shea Nut tree.

Figure 5. Mechanisms for sustainable charcoal production
References


