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Research Article

Environment-Food-Energy Nexus Complexities in Zambia: A Case of Forest Exploitation in Mpande Community of Kafue District

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Abstract

Forests are important for sustaining life on Earth, they perform environmental functions such as soil management, biodiversity conservation and climate moderation. However, forests have been threatened with deforestation due to the need for income generation and forest clearance for agriculture purposes. The anticipated annual rate of deforestation in Zambia is between 250,000 and 300,000 hectares. Mpande community in Zambia's Kafue district has been faced with forest exploitation, which has resulted in intricate problems pertaining to the environment- food-energy nexus. Competition has arisen among food and energy resources due to the growing scarcity of environmental resources, coupled with population growth. This study explored the complex interrelationships among the environment, food and energy in Mpande community. Thus, this study aimed to explore the relationships among the environment, food and energy nexus with specific focus on the complexities arising from forest exploitation in Mpande community. Using a qualitative case study design, data was gathered through semi-structured interviews, focus group discussions, unstructured interviews and physical observation. Data was collected from a sample of 254 respondents that were purposively selected. The respondents comprised of members of Mpande community and key informants from Kafue Forestry department and Ministry of Agriculture. Thematic analysis was used to analyze data in order to recognize the linkages in the environment- food-energy nexus. The results of this study revealed that forest exploitation has led to loss of biodiversity, weakened soil fertility and reduced the availability of wild foods, thereby exacerbating food insecurity. Additionally, the community's dependence on charcoal and firewood which has been driven by lack of alternative energy sources had also accelerated forest exploitation. Therefore, this study highlighted the need for integrated community-based forest management, sustainable agricultural practices, promoting alternative energy sources and an increase in environmental literacy.

Keywords

Forest Exploitation, Food Security, Deforestation, Sustainable Energy, Environment-Food-Energy Nexus, Mpande Community, Zambia

1. Introduction

A forest is an extensive area composing of dense and tall species of trees and other biota in symbiotic relationships. Forests exist in all regions of the world capable of sustaining tree growth [1]. Forests perform environmental functions

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including but not limited to; biodiversity conservation, climate moderation, soil management and carbon sequestration [1]. Other functions of the forests are socio-cultural in nature, these include; food security, income generation and religious worship. However, forests have been threatened with deforestation which is the conversion of forest areas to non-forest areas; forest degradation, which is the reduction in the density or structure of the forest and forest fragmentation which is the conversion of a continuous forest area into patches of forest separated by non-forest lands [1].

The growing demand for food and energy poses great challenges to natural resources and environmental sustainability. The concept of the environment, food and energy nexus provides an opportunity for integrated management of these systems. With the increase in population, economic development and the rising living standards, the demand for food and energy will continue to grow which poses significant challenges to natural resources sustainability and environmental protection [2].

Deforestation is a global environmental issue. Globally, there is about 239 Mha (Million hectares) of gross deforestation recorded. In many parts of the world, deforestation can be attributed to the conversion of forest land to land for crop production, livestock production and logging. Additionally, within the overall impact of the agricultural sector on the forests, about 24 percent of the forests were cleared for cropland to meet the global demand for food, feed for livestock and fuelwood [3].

In Africa, the rate of deforestation is a serious issue with broad implications. Nearly 4 million hectares of forests in Africa are cleared annually, which is nearly twice as fast as the average rate of deforestation worldwide [4]. Between 2015 and 2020, this caused Africa to lose 4.4 million hectares of forest annually. Between 2000 and 2005, Africa saw an average yearly negative change rate of -0.62 percent and a net loss of 4 million hectares per year [5].

In Zambia, the anticipated annual rate of deforestation is between 250, 000 and 300,000 hectares. Zambia's tree cover changed by -2.87 Mha between 2000 and 2020 [4]. Wood fuel, increased agricultural production, mining, timber exploitation, charcoal production and development of infrastructure are the main causes of deforestation in Zambia [5]. In rural parts of Zambia, deforestation is pronounced as a large number of people rely on wood and charcoal for survival and income generation[1].

With the community's dependence on forest resources for food and energy, the depletion of these resources intensified. Additionally, the increasing population and high charcoal demand from nearby towns such as Kafue, Mazabuka and Lusaka, contributed to significant forest exploitation [6].

This has intensified the connection between the environmental, food and energy needs, which has undermined the community's food and energy security. Exploiting forest resources creates a vicious cycle were the community relies on forest resources for sustenance, thereby causing further degradation, which in turn also affects agricultural productivity. The lack of a comprehensive approach that considers the connections among the environment, food and systems further complicates the situation and causes conflicts of interest and unsustainable resource use [1].

The significance of this study lies in its ability to provide insights into the complex interplay of factors in the environment-food-energy nexus. The research addressed the critical issue of forest exploitation, which is often associated with deforestation and habitat loss. Analyzing how forest exploitation affects local food security can help in forming strategies to ensure a sustainable usage of these resources, additionally, investigating the impact of forest exploitation of energy availability is crucial for sustainable energy planning [7]. This study shed light on how forest exploitation affects local economies and suggested measures for minimizing forest exploitation. This study aimed at assessing the direct and indirect effects of forest depletion on food security, examining energy dynamics related to forest utilization and understanding the role of the community in forest management.

Mpande community is located approximately 30 kilometers south-east of Lusaka the capital of Zambia. Mpande is located in Chiefteness Nkomesha Mukamambo II, in Lukolongo ward under the Headman Keembe. Below is a map showing the location of Mpande community.

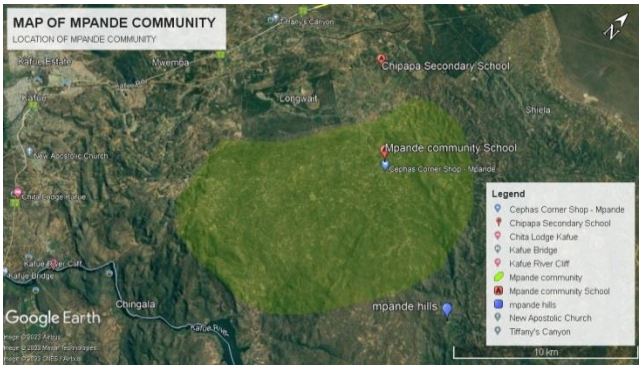

Figure 1. *Map of Mpande Community.*

2. Materials and Methods

The philosophical basis that was adopted for this study was interpretivism. Interpretivism is an epistemological position that requires the social scientist to grasp the subjective meaning of social action [8]. Interpretivism emphasizes the importance of understanding and interpreting subjective experiences and meanings of individuals within their social and cultural contexts [9].

Interpretivism allowed to gain a deep understanding of how

[1] In Kafue district of Zambia, forest exploitation in Mpande community has led to challenges related to the environment-food-energy nexus. The forest in Mpande is a protected forest which has been partially degazetted, however, the forest has been encroached and exploitation of forest resources has extended into the parts of the forest that have not been degazetted.

the community of Mpande perceives and interacts with the forest in terms of, food and energy resources. It also helped to reveal the interconnected relationship among forest exploitation, food access and energy needs from the perspective of Mpande community by taking into account the community's cultural, social and economic dynamics. Additionally, by embracing interpretivism, it helped in gaining insights into specific challenges and opportunities related to the environment, food, energy nexus in Mpande community. This understanding helped inform the development of more culturally and contextually relevant sustainable interventions, policies or community-based initiatives to address the complexities identified.

The approach used in this research was an inductive research approach, which asserts that theory is generated from the data collected. Inductive approach entails that theory is the outcome of research and is formed by drawing generalizable inferences out of observations [10]. Inductive research allowed to gather data and insights directly from Mpande community, taking into account their unique environmental circumstances. This was important for understanding the relationships and challenges related to forest exploitation. Inductive research approach also allowed for a more holistic understanding of the environment-food-energy nexus and the complexities surrounding forest exploitation in Mpande. By using an inductive approach, this research uncovered emergent themes and patterns that may not have been previously identified or acknowledged in the reviewed literature. This research took a qualitative approach, which allowed for a detailed exploration of the social, economic and cultural factors influencing the environment-food-energy nexus.

This study adopted a case study research design which took an exploratory approach. Exploratory approach was suitable for this study as it allowed for an in-depth exploration of the complexities and dynamics of forest exploitation in Mpande community, within the context of environment-food- energy nexus. This research design was ideal as it helped in providing context-specific insights that can be relevant for policy makers, local stakeholders and environmental efforts in Zambia [11].

The sampling method comprised selecting Mpande community as a study area. Sample selection is a process of selecting a group, event, behaviors or other elements that are representative of the population being studied [12]. The sampling method that was used in this research was non-probability sampling. Respondents were selected through purposive sampling to participate in interviews and focus group discussions. Purposive sampling is a form of non-probability sampling which the researcher aims to sample participants in a strategic way, so that those sampled are relevant to the research questions that are being posed [8].

The respondents included community members, community representatives and key informants from forestry and agriculture departments. The community members provided first-hand information on their experiences and observations on what they use the forest for in terms of energy needs and they also provided insights on how the food and energy activities impact the environment in their community. The community members also provided information on energy usage and historical patterns of forest exploitation within the community. Information on how the community relies on the forest for livelihoods, such as gathering food, obtaining energy sources and economic activities linked to forest resources was provided by the respondents from the community. Overall, by engaging with community members, comprehensive and contextual understanding of the complexities surrounding the environment-food-energy nexus in Mpande community was gained.

The key informants provided valuable insights into local practices, community perspectives, economic dynamics and environment impacts related to the interplay of the environment, food, energy and the environment. They also shared knowledge on forest utilization, community needs and potential challenges, offering a comprehensive understanding of the environment-food-energy nexus complexities in Mpande community.

Purposive sampling method was used to select a sample size of respondents from the 699 households in the study area [12]. A sample size is a number of subjects or participants recruited and consenting to take part in a study [13]. To calculate the sample size from 699 number of households, the formula $n=N/1+Ne^2$ was used. Where n=sample size, N=population size and e=significance level (0.05 at 95% confidence level) [14].

The sample size in this study consisted of 254 respondents, distributed as follows; From a total of about 699 households in the study area, 78 households were chosen based on their location where deforestation was more pronounced. In each of these 78 selected households, three household members were interviewed totaling to 234 respondents.

Additionally, four key informants were purposively selected- two from Kafue Forestry Department and two from the Ministry of Agriculture in Kafue. Furthermore, two focus group discussions were conducted, with each group comprising eight participants, resulting in a total of 16 participants.

To generate efficient information on the environment-food-energy nexus complexities, qualitative data collection methods were used in three categories. The first category was interviews with sample households in the study area. Household members who were interviewed were purposively sampled. The total number of households living in the study area is 669 of which 78 households were identified for the interview. Unstructured interviews were used to collect data from the community members through the use of interview guides to gain information on the environment-food-energy nexus [15]. Unstructured interviews allowed participants to express themselves on the perspectives of the complexities of forest exploitation in Mpande community. A list of topics to be covered were made into an in-

terview guide which was an informal way of data collection. The phrasing and sequencing of questions varied from interview to interview [8]. This approach enabled a deeper exploration of local insights and individual experiences, contributing to a richer understanding of the interconnections among the environment, food and energy nexus [15].

The second category was four key informant interviews comprising of two field officers from the Forestry department and two extension officers from Ministry of Agriculture who were purposively selected. Data from key informants was collected through semi-structured interviews with the use of interview guides. The interview guides were developed with the objective of obtaining meaningful information on the interconnections of the environment, food and energy nexus in Mpande community.

The third category were focus group discussions. Focus group discussions were used to collect data from the community members through the use of interview guides to gain information on the environment-food-energy nexus [15]. A total of two focus group discussions were conducted with the use of focus group interview guides. Each focus group had eight members comprising of farmers, charcoal sellers, small business owners and community leaders. Focus groups aim to obtain data from a purposely selected group of individuals rather than from a statistically representative sample of a broader population [16]. The focus group discussions allowed for the collection of diverse opinions and perspectives from various community members, facilitating a comprehensive understanding of the complex interrelationships in the environment-food-energy nexus. In the focus group discussions, participants engaged in interactive discussions, building upon each other's insights and experiences [17]. This dynamic exchange uncovered subtle nuances and generated in-depth information about the community's perceptions and practices related to the environment-food-energy nexus.

Participant observation was also used as a data collection method as it helped in gaining first-hand insights into the activities related to the environment-food-energy nexus. Participant observation also allowed to observe and document practices related and associated with forest exploitation [8]. This method provided a holistic view of how the community interacts with the environment and utilizes resources for food and energy. Additionally, secondary data was collected by a way of systematic reviewing of secondary data materials related to the research topic such as journals, publications, books and research reports.

Thematic analysis was used in analysing the data that was collected. Thematic analysis is a term used in connection with the analysis of qualitative data to refer to the extraction of key themes in one's data. It is an approach with few generally agreed principles for defining core themes in data [8]. In qualitative data analysis, data analysis often involves identifying themes within it. This is done by breaking down the data into component parts and giving those parts labels or codes [9].

Thematic analysis was done by identifying key themes related to environmental impacts, food security and energy sources. The data that was analysed was qualitative data which was collected from participant interviews, key informants and focus group discussions. Thematic analysis was used to identify, describe and interpret key patterns. Thematic analysis involved systematically organizing and identifying patterns or themes across the dataset to generate new knowledge. Thematic analysis enabled to explore relationships and potential solutions of the environment, food and energy dynamics in Mpande community. Additionally, simple descriptive statistics for variables such as age, marital status and level of education was analysed in order to understand the demographic profile of the respondents.

Ethical obligations were important in this study. The study was approved by The University of Zambia Natural and Applied Sciences Research Ethics Committee (NASREC). Confidentiality and protection of participants' rights was maintained by anonymizing the data and ensuring that participants' identities are not revealed. Consent was obtained from each participant before administering the data collection tools and the respondents were assured that the information provided was for academic purposes only. This research was conducted according to the Declaration of Helsinki (1964).

Below is the summary of the methods and materials.

Table 1. *Summary of methods and materials.*

Component	Description
Research Approach	Inductive
Research Design	Qualitative
Study Area	Mpande Community, Kafue, Zambia
Target Population	Local leaders, farmers, policy makers, community members and charcoal producers
Sampling Method	Non-probability Sampling
Sample Size	254 respondents
Data Collection Methods	Unstructured Interviews, Semi-Structured Interviews and Focus Group Discussions

Data Collection Tools	Primary Sources: interview guides, Focus Group Interview Guides and participant observation. Secondary Sources: Journals, Publications, Books and Research Reports
Data Analysis Techniques	Thematic analysis
Ethical Consideration	Informed consent, Anonymity, confidentiality and Ethical Approval from NASREC

3. Results

The results are organized around the key themes that emerged from interviews, focus group discussions and direct observations conducted. This study aimed at capturing the local's perceptions on forest exploitation and how it intersects with food security, energy needs and environmental sustainability.

In this study, the participants comprised of 254 individuals who were purposively selected. Their demographic characteristics such as gender, age, educational level and marital status were collected. Most of the participants (56 percent) were between the ages of 30 and 39, while the smallest group (12 percent) was aged 50 and above. The larger number of participants were female (59 percent) compared to male (41 percent). Most of the participants were married (46 percent), with the single (33 percent) and the divorced/widowed (21percent). In terms of education, 44 percent of the respondents had completed primary school, 38 percent had completed secondary school, 16 percent had no formal education and only eight percent had received tertiary education. The demographic overview of the participants provided an insight into the diverse backgrounds represented in this study. The differences in age, gender, education and marital status helped shape the differing perspectives on forest exploitation, food security and energy use in Mpande community, contributing to a rich understanding of the environment-food-energy nexus.

3.1. Forest-based Environmental Services and the Impacts of Deforestation

In the past years, the forest in Mpande played an important role in providing environmental services such as improving soil fertility and supporting biodiversity. However, there is a decline in these services due to accelerating deforestation. Over the past 10 years, Mpande community has seen notable degradation in the environmental services provided by the forest. The forest in the past helped to preserve soil fertility and supported biodiversity important for agricultural activities. According to the interviews, there were some droughts in 2015/16 and 2018/19 before the recent 2023/24. These droughts and erratic rainfall patterns with the loss of environmental services have made the community more vulnerable.

The demographic information indicates that various age groups were affected by these changes, with the majority (56 percent) aged between 30 to 39. This age group forms the active workforce which heavily depend on forest services for agriculture and sustenance. Women representing 59 percent of the population, during focus group discussions mentioned that they rely on the forest for firewood which is the main source of cooking fuel.

Mpande community gets a number of environmental services from the forest, which are vital for their energy needs, food security and livelihoods. A male key informant stated that only some portions of the forest have been degazetted. However, the forest has been encroached with much of the encroachment being forest clearance for cultivation and rearing animals, which have affected the services from the forest. This issue is exacerbated by the low education levels among the population, with 60 percent having either no formal or primary education as they have limited environmental awareness, which has contributed to unsustainable forest use and further degradation.

The data collected showed that the community gets intangible and tangible benefits from the forest. A dominant theme that emerged in the interviews and focus group discussions was the provisioning services that are obtained from the forest. All the respondents across all demographic categories identified essential forest resources that sustain their daily needs. For example, 12 percent of respondents aged 50 and above equivalent to 30 respondents mentioned that, some medicinal plants that are used in households to treat common illnesses were available within the forest. An older male respondent said that '*the forest was a major source of medicinal plants, some illnesses such as colds and stomach pains were easily treated. He continued and stated that most medicinal plants are no longer found in the forest due to deforestation, making it difficult to treat illnesses.*'

Another recurring theme was how the forest helps with timber and poles that are used to build houses, fences, livestock enclosures and shelters locally known as "insakas." Additionally, grass is also harvested which is used to thatch houses and make brooms. These forest products are also sold to nearby places to earn an additional stream of income. Married individuals (46 percent) and those aged between 30 and 39 are the majority of the ones at the forefront of utilizing these forest products.

A total of 229 respondents equivalent to 90 percent of the total respondents expressed the role of the forest in being shields from strong winds, providing shelter to wildlife and provision of shade to people. These participants noted that

deforestation attributed to the change in local weather patterns. A total of 178 respondents equivalent to 70 percent of the total respondents who are farmers stated that, the cutting down of trees had also contributed to the drought that is being faced. They stated that in the past years when deforestation was not prominent, drought was not experienced. As such, they felt deforestation also contributed to the drought. A female participant stated that '*there is less shade and the winds feel stronger than when there were more trees*.'

Mpande forest had some dambos that were used by animals and the community members. They also mentioned that forests protected the dambos from drying up as they are water recharge areas. However, they expressed concerns that deforestation had led to reduced water availability as the dambos have dried up. '*The dambos have now dried up and we do not see most of the animals anymore because they ran away as there is no water for them to drink*' noted one of the male respondents. Additionally, all the respondents mentioned that they are no longer seeing the animals that were there before as there is habitat destruction due to deforestation.

3.2. Impacts of Forest Exploitation on Food Security

Food security has been negatively impacted by forest exploitation in Mpande community. A total of 66 households equivalent to 85 percent of the total number of households that are reliant on forest products for additional nutrition stated that the availability of wild fruits and game meat had diminished. A recurring theme in the interviews was how it was hard to access these food sources which have decreased over the last 10 years. Additionally, deforestation quickened soil degradation, reducing soil fertility, which has led to reduced agricultural yields. Farmers mentioned that the role of the trees in preventing soil erosion weakened and this has caused crop failures.

The married respondents representing 46 percent of respondents, produce more maize as their households are benefiting from having more family members working the land. On the other hand, single or widowed households which comprise of 33 percent and 21 percent of respondents respectively, are not producing a lot of maize due to limited labour resources.

A total of 178 respondents equivalent to 70 percent of the total respondents are into subsistence farming with the major crop being maize, 51 respondents equivalent to 20 percent of the total respondents grow vegetables for consumption and 25 respondents equivalent to 10 percent of the total respondents do not farm. According to the data collected, in the previous years, each household that farms on average would harvest about 300(50kg) bags of maize. The maize was sold to the Food Reserve Agency (FRA) and markets to generate income and the crop was also used for home consumption.

On average a family of 6 keeps 24(50 Kg) bags of maize for consumption each farming season and sells the rest to FRA. FRA on average buys 50 Kg bags of maize at K350 each, entailing that each household would sell about 270 (50 Kg) bags of maize, giving an income of about K 96, 600. Currently, about 70(50 Kg) bags of maize are harvested per household due to the 2023/24 drought. After 24(50 Kg) bags of maize are reserved for consumption for a family of 6, only about 46 (50 Kg) bags of maize are being sold to FRA, which brings the income to about K 16,100 which is significantly lower than the previous years. A male farmer stated that '*the trees used to hold the soil together but now it is harder to grow enough food for the family as the fields are drying up faster*.' Due to reduced agricultural productivity, families resorted to relying more on forest resources for income generation, which further increased forest exploitation and food insecurity. All the respondents highlighted that with the increase in crop failure and the reduction in the availability of forest products such as fruits, edible roots and game meat, this has a strain on their food security.

Female-headed households, which represented a significant portion of the population, are particularly vulnerable as women (59 percent of respondents) often bear the burden of securing food for their families and collecting forest resources are most affected by food insecurity. These responsibilities become even more challenging as forest products, like firewood and edible roots become scarce. Similarly, large families face a lot of pressure, as their greater food needs are harder to meet with the declining maize yields. Additionally, lower-education households, comprising 60 percent of respondents, lacked the resources or knowledge to implement sustainable agricultural practices or diversify their income sources, further deepening their vulnerability to food insecurity.

All the respondents indicated that most of the food from the forest was gathered during the rainy season. Foods such as mushrooms and edible roots locally known as "*busala*" and local fruits such as "*Masuku*." The respondents also mentioned that the forest is important as it helps to supplement their diet and helps to cope with food scarcity. However, all the respondents mentioned that they do not get much from the forest as they used to in the years back, attributing this change to deforestation.

All the respondents also mentioned that more food was accessible in the forest before deforestation was prominent. Previously, they used to also harvest a lot of honey, edible bush rats locally known as "Mbeba" edible caterpillars locally known as "vinkubala", monkeys, impalas, birds and rabbits. However, due to habitat loss, most of the animals are not found in the forest anymore which has affected the availability of food that the forest used to provide.

A female key respondent mentioned that '*the forest is not significant source of food for the community currently due to deforestation as most of the trees remaining in the forest are due to secondary regeneration*.' The female key informant further mentioned that parts of the forest have been cleared to create land for farming maize, rear goats and cattle. The forest

had some dambos where animals were taken to drink water. Unfortunately, these dambos dried up due to the drought causing the farmers in the area to have challenges in accessing water.

The community's reliance on forest resources has created a feedback loop, where reduced agricultural productivity forces families to exploit the forest further, worsening deforestation and food insecurity. This dependency is also intensified by low education levels, with 60 percent of respondents having only primary or no formal education, potentially limiting awareness of sustainable agricultural and conservation practices.

3.3. Energy Needs and Forest Dependency

Mpande's dependence on charcoal and firewood has intensified over the past 10 years. As the demand for charcoal went up in the surrounding towns such as Kafue town, Lusaka and Mazabuka. This demand caused charcoal production to become a livelihood in Mpande, causing a high rate of trees being cut in the forest. Mpande community is faced with a challenge in access to alternative energy sources as they are not connected the electricity national grid. Therefore, the forest plays a vital role in supplying firewood and charcoal which is used in the households and sold for income generation. A total of 190 respondents equivalent to 75 percent of the total participants from several households indicated that collection of firewood was mostly a daily activity as it is a necessity in cooking and heating. Gathering firewood was mostly the responsibility for women, many of whom acknowledged that firewood served as the main source of energy.

Demographic data showed the extent of this dependence, with 75 percent (190 respondents) reporting that collecting firewood is a daily necessity, primarily for cooking and heating. Women, who constituted 59 percent of the population, bear the primary responsibility for gathering firewood, as emphasized during focus group discussions. A female respondent mentioned; '*If we do not get firewood and charcoal from the forest, that means we will not have any means of preparing food. We do not have electricity here and we cannot afford to buy gas stoves.*' Another female respondent stated that *'a lot of big trees have been cut already for charcoal production. Charcoal is not being produced as it was in the past years because only small trees are remaining in the forest. As at present, we are only getting firewood from the forest.'* A total of 229 respondents equivalent to 90 percent of the total respondents said at present, they only collect firewood from the forest and the other 25 respondents equivalent to 10 percent of the total respondents still cut down trees for charcoal production.

The demographic data highlighted the critical role of women in energy collection and production. Among the respondents, 59 percent are women, who bear the primary responsibility for gathering firewood, a task carried out daily by 75 percent (190 respondents) of the community. Although charcoal production has declined due to tree depletion, 25 respondents (10 percent of the total), of which 6 are women continue to cut down trees for charcoal as a means of income generation. This activity, while important for livelihood, is placing additional pressure on the forest's already diminishing resources.

A male key informant stated that in 2014 Mpande community produced about 2000 (50 Kg) bags of charcoal per month. Charcoal production dropped to about 1000 bags per month in 2019, which indicated that a significant number of trees were cut. In 2024, charcoal production reduced to just 50 (50 Kg) bags per month which is as a result of continued deforestation.

3.4. Community Role in Forest Management

The findings revealed that while the community depends on the forest for environmental services, food and energy, there is not much involvement in managing the forest. From the data collected, it was evident that community members were aware of the dangers of deforestation, but still had no role in managing the forest. All the respondents indicated that there are no community-based initiatives that can help the community to regulate the forest and also bring about initiatives for tree planting.

A female respondent said '*we know that deforestation is bad, but we do not have any organisation to help us with tree planting efforts. We can want to preserve some seeds from some of the indigenous trees for replanting, but we have water challenges here as we only have one borehole. Additionally, there is drought, so even if we decide to re-plant trees, the seedlings will dry up because there is no rainfall.*' All the respondents echoed the need for government and non-government organisations' collaborative efforts for reforestation to occur. During courtesy call by the researcher to Headman Keembe, the Headman also stressed the need for organizations to help the community with initiatives on how to preserve what is left of the forest and also how the forest can be regenerated.

On the other hand, one of the male key informants mentioned that '*there has not been much engagement in Mpande community because they have encroached in the protected forest. The community members are actually encouraged to move out but it has been a challenge. Maybe an alternative is engaging them and taking initiatives that will enable them to protect the forest.*'

Below is the summarized table of the findings from this research.

Table 2. Summary of research findings.

Key Theme	Findings
Forest Based Environmental Services and the Impacts of Deforestation	-Deforestation has led to biodiversity loss, drying up of dambos and soil degradation. -Forest encroachment for settlement and farming has reduced forest cover. -Decline in medicinal plants and habitat for wildlife -Decline in availability of wild foods (game meat, fruits, edible roots and mushrooms).
Impacts of Forest Exploitation on Food Security	-Reduction in agricultural productivity due to the change in local climate and loss of soil fertility. -Increased food insecurity. -Households resort to further forest exploitation to supplement income, further worsening deforestation
Energy Needs and Forest Dependency	-High reliance on firewood and charcoal for heating and cooking. -Demand for charcoal in the nearby towns (Kafue, Lusaka and Mazabuka) has increased forest exploitation for income generation. -Charcoal production has declined over the years due to tree depletion, causing households to rely more on firewood.
Community Role in Forest Management	-There is a lack of community-based forest management initiatives. -Need for government and non-government organisations interventions to support tree planting and conservation efforts. -The community is aware of the negative effects of deforestation, but there are no efforts to mitigate them.

4. Discussion

The results revealed significant environmental degradation, with deforestation reducing biodiversity, affecting the availability of wild foods, affecting soil fertility and the availability of water resources. Food security has been affected as there is a reduction in forest services and reduced agricultural productivity, which have left households vulnerable. Additionally, the community's reliance on firewood and charcoal, has increased forest exploitation. It was also noted that, the community lacks forest management initiatives, thereby threatening sustainability.

4.1. Forest Exploitation and Forest-Based Environmental Services

The results of this study highlighted the important role that Mpande forest has played in providing essential environmental services. The function of the forest depends on the daily needs and livelihood of the people accessing it. For example, most rural populations depend on forests for income, health and cultural aesthetic benefit as stated by Chomba, Tembo, Mutandi, Mtongo and Makano [18]. The findings also correlated with a related study conducted by Olagunju [1], who states that the forest provides ecological resources, income, food as well as physical facilities like building materials. Additional functions of the forest are soil erosion prevention and provision of essential habitat for wildlife to survive [1]. However, the forest services are being threatened by deforestation which is caused by land clearing for agriculture, harvesting trees for fuelwood and land clearing for settlements.

The research findings revealed that, deforestation has reduced the ability of the forest to regulate local water cycles and protect against soil erosion. Deforestation greatly disrupts the local hydrological cycle, which is the continuous movement of water through evaporation, transpiration, condensation and precipitation [19]. Wang [20] reported similar findings where deforestation has disrupted local hydrological cycles, which has led to reduced streamflow and increased vulnerability to droughts, aligning with the acknowledgement in this study that forest loss is a critical driver of climate variability, affecting agricultural productivity and local water resources.

Despite Zambia's Forest Act of 2015, which seeks to regulate forest use and promote sustainable practices, from this study it was noted that enforcing this act still remains weak. The findings also revealed that charcoal production and forest encroachment remain unchecked, leading to further deforestation. Similarly, Kalaba, Quinn, Dougill and Vinya [21], notes that weak policy enforcement weakens the efforts to preserve environmental services.

The disruption of forest based environmental services is concerning in Mpande community as the community depends on these resources for their livelihood. Forest ecosystems are home to a variety of plant and animal species. These disruptions can come from various factors such as deforestation, climate change and fragmentation according to Thom and Seidl [22]. The results of this study showed that there is loss of

biodiversity as some of the animal and plant species that were seen in previous years are no longer available. These findings also matched with the findings of FAO [4], who contends that disrupting these environments often times leads to biodiversity loss due to habitat destruction and fragmentation. Forest fragmentation is a process that converts a continuous forest area into patches of forest separated by non-forest lands. Some species that require large territories or specific habitats may struggle to survive and are at risk of becoming extinct [22].

This study showed that local communities that depend on forests for their livelihoods often face severe consequences when environmental services are disrupted. Forest exploitation reduces access to resources such as medicinal plants, fuel wood and food. The research findings stated that most of the medicinal plants can no longer be found in the forest due to deforestation, posing a challenge when trying to treat ailments that were easily treated in the past years. This correlates with the findings of Lambin [23] who states that disrupting environmental services in forest ecosystems leads to negative effects that impact biodiversity, water quality, soil health and climate stability.

Olagunju [1] also notes the important role that forests play in providing ecosystem services such as biodiversity conservation and water regulation. The research findings agreed with these insights as respondents linked deforestation to reduced soil fertility, biodiversity loss and drying dambos. The difference with the results of this study is that existing literature does not adequately explain how local socio-economic dynamics, such as the community's dependence on forest resources like building materials worsen deforestation. This study revealed the compounded challenges faced by the communities experiencing both environmental degradation and socio-economic challenges such as low education levels and poverty.

4.2. The Impact of Forest Exploitation on Food Security

The findings of this study highlighted how deforestation disrupts soil quality, reduces water availability and consequently diminishes agricultural productivity. The research findings are supported by Chidumayo and Gumbo [24], who stresses that forests provide a variety of ecosystem services that support agricultural productivity and food security. These ecosystem services include preserving soil fertility, regulating the water cycle and providing habitats for wildlife, which are all important for agricultural productivity. The research findings indicated that in the previous years when deforestation was not prominent, there was a variety of biodiversity in the forest. A similar study was conducted by Chidumayo and Gumbo [24], who state that forests are a source of non-timber forest products such as edible plants, nuts and fruits, which contribute to dietary.

In this study, it has been noted that deforestation disrupts these processes, which leads to reduced soil quality, increased vulnerability to climate variability leading to decreased agricultural yields. It was noted that with the increase in forest exploitation, the availability of wild food resources has declined, worsening the nutritional challenges in the community.

The conversion of forests to agricultural use in Mpande community correlates with the findings of Chaudhary, Pfister and Hellweg [25], who stresses that usually, conversion of forests to agricultural use provides short-term economic benefits but leads to long-term soil degradation. Deforestation reduces the land's natural fertility by making it less productive over time. This study showed that due to the conversion of the forest into agricultural land, there has been a decline in productivity which has resulted in crop failures and lower agricultural outputs, exacerbating food insecurity within the community.

Gbetnkom [26] states that forests play a vital role in contributing to food security of a large portion in Africa. Foods from forests constitute a significant component of household food supply. The foods include a wide variety of plant and animal products found in markets of urban and rural areas. In many small towns and villages, the contribution of forests to food supply is essential for food security, as they provide a number of important dietary elements that the normal agricultural produce does not provide adequately. The results of this study indicated that the forest is a source of wild fruits, mushrooms and game meat. A similar study conducted in Cameroon by Gbetnkom [26], which correlates with the research findings, shows that there are many different kinds of foods that are gathered from forests, such as roots, tubers, rhizomes, termite larvae, mushrooms and leaves. Forests also provide the habitat for many commonly consumed wild animals. Trapped and hunted wild animals provide supplementary income. In some instances, forest food is smoked, dried or fermented, making it available over extended periods of time.

This study outlined the intricate relationship between forest exploitation and food security in Mpande. Deforestation intensifies soil erosion, disrupts local climate patterns and depletes the availability of non-timber forest products which supplement local diets. Over the past decade, soil degradation has negatively affected agricultural productivity, which has led to reduced crop yields. The findings of Costa, Botta and Cardille [27] are similar with the findings of this study, stating that reduction in agricultural productivity due to soil degradation has led many households to turn into charcoal production and other forest related activities to meet their livelihood needs. Therefore, this study found that this recurring relationship between forest loss and food insecurity creates a feedback loop where natural resources degradation leads to further reliance on the same diminishing resources.

This study found that in Mpande community, the erosion of soil quality has forced some households to increase their reliance on forest exploitation, particularly for charcoal production and firewood, as a coping strategy. This forms a vi-

cious cycle, were deforestation contributes to food insecurity, which in turn drives further environmental degradation, as observed in Mpande community. The study conducted by Elias [28] states that the ongoing struggle to balance the need for food with the necessity of preserving the forest highlights the complexities of achieving sustainable development in forest-dependent communities. The findings in this study are consistent with the findings of Elias [28], who further highlights how deforestation intensifies food insecurity by reducing agricultural productivity. This was noted by the decrease in crop production over the years. This study further showed that forest exploitation was both a cause and consequence of food insecurity in Mpande community.

This study also revealed that forest resources are frequently used by households in Mpande community as a coping mechanism against poverty. One of the causes of forest exploitation in the area is cutting trees for fuel wood and charcoal production. This provides short-term financial relief but damages the natural environment that is necessary for farming and food gathering in the long run. Kalaba, Quinn, Dougill and Vinya [21], conducted a study in a similar context in Zambia and have noted that exploiting forests for income frequently leads to a cycle of poverty and environmental degradation, further endangering food systems.

Fraint, Ayambem, Alobi, Ifebueme, Otukpa, Orgar, Alawa, Goldberg, Jacka and Rothman [29], emphasizes the direct relationship between forest degradation and food insecurity through the depletion of wild foods and the degradation of agricultural soils. The findings align with these insights as households reported a reduction in crop yields due to soil erosion and reduced access to wild fruits and game meat. This study provides new insights on additional feedback loops where reduced agricultural productivity drives increased forest exploitation for income, further worsening food insecurity.

4.3. Energy Dependence and Forest Exploitation

The findings showed that over reliance on charcoal and firewood is a main driver of forest exploitation. A similar study conducted by Phiri [30], contends that Zambia loses approximately 250, 000 to 300, 000 hectares of forests yearly, as a result of charcoal production. Phiri [30] further states that many Zambians engage in charcoal production as a coping mechanism due to recurring droughts that have an impact on crop yields. These findings correlate with this study's results which indicated that the economic reliance on charcoal and firewood often leads to overharvesting and depletion of forest resources. The results indicated that Mpande community is not connected to the electricity grid and community members are not able to afford alternative sources of energy such as gas because it is expensive, this has become a driver of forest exploitation coupled with the need to generate income. Furthermore, the study indicated that firewood and charcoal are the primary sources for heating and cooking in the community. Zambia's National Energy Policy highlights renewable energy promotion but has limited implementation in rural areas. Increasing access to affordable alternatives, such as solar cookers and biogas systems could reduce reliance on forest biomass. Gonz âlez-Eguino [31] also emphasizes that affordability and accessibility are critical to the adoption of cleaner energy solutions.

The findings indicated that over the last 10 years, the growing demand for charcoal and firewood has led to unsustainable levels of forest exploitation. The findings also indicated that the growing demand of charcoal in the nearby towns such as Kafue, Lusaka and Mazabuka has been a major diver of forest exploitation in Mpande community, as this was seen as an opportunity for income generation. In Zambia, charcoal production is a significant driver of deforestation exacerbated by urbanization and climate change-induced droughts. In most rural areas, about 90 percent of Zambian households rely on wood fuel for energy, with charcoal being the largest source due to its affordability and availability as stated by Kalaba, Quinn and Vinya [21].

The research findings corresponded with the findings of Gonz âlez-Eguino [31], who states that energy poverty remains a persistent issue in rural communities globally, as over two billion people depend on biomass for energy needs. This study's findings reflected this dependency in the 75% of households that collect firewood daily, with women being the ones mostly responsible for collecting firewood. These findings also agree with the findings from the study conducted by Kalaba, Quinn, Dougill and Vinya [21], who links energy poverty to forest degradation, as households exploit forest resources to meet basic energy demands.

The research findings also indicated that low education levels limits awareness and adoption of sustainable energy practices. Charcoal production has been a major source of income for households in Mpande community, this however, has declined due to the reduction of large trees in the forest, leaving firewood as the primary source of energy. Similarly, Kalaba, Quinn, Dougill and Vinya [21] states that in rural areas, charcoal production contributes significantly to income generation but intensifies deforestation.

This study also revealed that tree cutting for charcoal and firewood has quickened deforestation, which has led to biodiversity loss and soil erosion. The removal of tree cover has also worsened water scarcity, since trees play an important role in maintaining water cycles and protecting dambos, which have dried up. Studies conducted by Costa, Botta and Cardille [27] also confirm that, deforestation disrupts local hydrological systems, reduces rainfall infiltration and intensifies soil degradation, further compounding environmental challenges.

Existing literature, such as a study conducted by Kalaba, Quinn, Dougill and Vinya [21], identifies the role of forests in providing energy resources like firewood and charcoal. However, the findings from Mpande show a growing dependency on the forest which is insufficient to meet energy

needs. This study adds depth to literature by showcasing how the lack of access to alternative energy sources and the declining in availability of large trees for charcoal production have left communities reliant on firewood, further escalating deforestation.

4.4. Community's Role in Forest Management

This study highlighted the important role that governance plays in managing forest resources, however, the results of the study showed that enforcement of sustainable practices still remains weak. This finding is consistent with the study conducted by Mwapamba, Ghilardi, Sande and Chaix [32] on forest governance in sub Saharan Africa, where enforcement of environmental policies is often hindered by inadequate institutional support.

The findings suggested that, the demand for charcoal and firewood in Mpande community and the need for income generation continues to drive unsustainable forest exploitation. The findings correlated with the study conducted by Kalaba, Quinn and Vinya [21], which states that the pressure from local economic needs and external markets complicates efforts to manage forest resources sustainably, which reflects the wider challenges facing rural communities in Zambia.

The study's findings suggested that while literature outlines the importance of community participation in sustainable forest management as stated by Chomba, Tembo, Mutandi, Mtongo and Makano [19], it often assumes that such participation is already established or viable. This study highlighted the absence of organized community-based initiatives in Mpande community, making it hard to conserve forest resources. The findings also revealed significant barriers, including water scarcity for tree planting efforts and limited engagement from external stakeholders.

4.5. The Nexus of Forest Exploitation, Food Security and Energy Dependence

This study demonstrated how closely food security and energy dependence are related to forest exploitation in Mpande. This is consistent with the findings of Prevedello, Winck, Weber, Nichols and Sinervo [3], who states that forests and other natural resources are essential to maintaining agricultural livelihoods and supplying people with energy. The results showed that the community's reliance on wood for fuelwood and charcoal is an indication of a larger problem of energy poverty in rural Zambia, as there is still limited access to alternative energy sources.

According to this study, the dependence on forest-based energy is driven by economic constraints, as most of the households are not able to afford gas and the community is not connected to the electricity grid. This reflects the findings of Arnold, Köhlin, Persson and Shepherd, Zulu and Richardson [33, 34], who state that rural communities in sub Saharan Africa often rely on biomass energy due to the high cost and limited availability of modern energy. The findings showed that in Mpande, this reliance does not only perpetuate forest exploitation but contributes to environmental degradation also.

The cycle of deforestation leading to soil erosion and reduced agricultural productivity reinforces the feedback loop described by Meyfroidt, Rudel and Lambin [35], where environmental degradation limits the capacity for sustainable livelihoods, driving further resource extraction. The loss of soil fertility reported by farmers in Mpande community directly affects crop yields, forcing households into a vicious cycle of relying more on forest exploitation when agricultural production fails.

This study enhances existing literature by providing a localized understanding of the environment-food-energy nexus complexities with a specific focus on Mpande community. While prior literature generally addresses the impacts of deforestation on biodiversity, soil fertility and climate, this study has highlighted the nuanced interconnected challenges faced by the community's reliance on the forest for both livelihood and sustenance. This research also captured specific demographic and socio-economic factors, such as education levels that shape forest dependency in Mpande

5. Conclusions

This study explored the complexities of the environment-food-energy nexus in Mpande community, focusing on the impacts of forest exploitation. The research findings highlighted the interrelationships that exists in Mpande community among environmental exploitation, food security and energy requirements. The findings revealed that forest exploitation in Mpande is driven by many factors, including dependency on charcoal production for income generation, harvesting firewood, need for agricultural land and limited access to alternative energy sources. The study revealed insights into how deforestation disrupts the interconnected systems of environmental services, food security and energy needs. Mpande community largely depends on the forest for livelihood, including food, income generation and firewood. Although forest resources are vital for sustaining livelihoods, environmental degradation and food insecurity are being worsened by forest exploitation. Due to forest degradation, water cycles are disrupted, there is decline in soil fertility and agricultural productivity is affected, causing the community to be in cycle of unsustainable forest use.

Deforestation has impacted food security by reducing the availability of wild food, lowering agricultural yields and degrading soil fertility. Due to the community's increased reliance on firewood and charcoal for energy, as well as meeting the charcoal demand from the surrounding towns such as Kafue, Lusaka and Mazabuka, forest exploitation has increased, creating a feedback loop that worsens resource depletion. Additionally, without the presence of community-

based forest management initiatives, this has left the forest vulnerable to unregulated exploitation. The community members observed changes in local climate patterns, including a decrease in rainfall and droughts, which have further put a strain on agricultural and water resources.

Overall, this study has shown the interrelationships among forest exploitation, food security and energy dependence in Mpande community. It revealed that deforestation has significantly impacted the community by reducing biodiversity, water resources and soil fertility, leading to decreased agricultural productivity and food insecurity. Forest degradation has been worsened due to the community's reliance on firewood and charcoal, as they do not have alternative access to energy sources. The study also highlighted the lack of community-based initiatives and the lack of implementation of sustainable forest management methods. The results showed the pressing need for integrated solutions that support sustainable forest management and alternative energy sources. Navigating the environment-food -energy nexus in Mpande will require community involvement, improved governance and focused initiatives that also take a socioeconomic approach. This cycle of environmental degradation and socio-economic challenges underlines the complexities of the environment-food-energy nexus in rural Zambia. The results of this study revealed that forest exploitation has led to loss of biodiversity, weakened soil fertility and reduced the availability of wild foods, thereby exacerbating food insecurity. Additionally, the community's dependence on charcoal and firewood which has been driven by lack of alternative energy sources has also accelerated forest exploitation. It was noted that forest exploitation in Mpande was driven by many factors, including dependency on charcoal production for income generation, harvesting firewood, need for agricultural land and limited access to alternative energy sources. The study revealed insights into how deforestation disrupts the interconnected systems of environmental services, food security and energy needs.

Abbreviations

Kgs	Kilograms
Mha	Million Hectares
NASREC	The University of Zambia Natural and Applied Sciences Research Ethics Committee

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Author Contributions

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Gear Mumena Kajoba: Supervision, Validation

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Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

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