

Community acceptability of Eichhornia crassipes-based ecological charcoal production processes and impacts on households as cooking energy in the Lake Chad areas of Cameroon

Alexis Dzokom, Jules Balna, Léonnie Tchinda Dezeu, Benjamine Anguessin

▶ **To cite this version:**

Alexis Dzokom, Jules Balna, Léonnie Tchinda Dezeu, Benjamine Anguessin. Community acceptability of Eichhornia crassipes-based ecological charcoal production processes and impacts on households as cooking energy in the Lake Chad areas of Cameroon. Sahel Nature Consulting Revue, In press, Ecological charcoal production processes, 07 (02), pp.1-17. ⟨hal-05151665⟩

HAL Id: hal-05151665

https://hal.science/hal-05151665v1

Submitted on 8 Jul 2025

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY 4.0 - Attribution - International License

SAHEL NATURE CONSULTING
Cabinet office
Bassin du Mayo-Tsanaga
Mokolo/Extrême-nord/Cameroun
Tel : +237 693 306 877/ +237 674536870
Mail : sahelnatureco@gmail.com
« L'expertise au service du développement durable du sahel »

Sahel Nature Consulting Revue ISSN : 1401-0006



Community acceptability of *Eichhornia crassipes*-based ecological charcoal production processes and impacts on households as cooking energy in the Lake Chad areas of Cameroon

Scientific-Article Juillet 2025, Volume 07, Issue 02

Abstract

This work explores the acceptability of *Eichhornia crassipes* transformation processes into ecological charcoal in communities bordering Lake Chad. It assesses local perceptions, economic and environmental benefits, and the impact on households in terms of reduced energy costs and health effects. Community acceptability of ecological charcoal briquettes was gained by highlighting: the reduction of cooking time by 20-30%, the reduction of energy costs by 30-50% and the lower CO_2 emissions and preservation of forests. The 50% reduction in the amount of wood used for cooking shows a major positive impact on local forest resources while the 50% reduction in CO_2 emissions is a direct result of the decrease in wood consumption, which reduces deforestation and greenhouse gas emissions. Thus, these results highlight the importance of integrated natural resource management and sustainable ecosystem use strategies to reduce environmental pressures, enhance biodiversity and contribute to combating climate change. The adoption of green charcoal has significant economic, social and environmental benefits, with beneficial effects on households, local communities and the environment. The study reveals a growing acceptance linked to awareness and perceived effectiveness of the product, while identifying challenges in popularization. However, there is a need for longitudinal studies to monitor the impacts of green charcoal over an extended period.

Sahel Nature Consulting Revue (ISSN : 1401-0006 March 2025)

Dr. Eng. Dzokom Alexis, M.E., M.Rl., Ph.D.,

Chief Editor

Mrs. Yakadam Charlotte B., M.Sc (Maroua)

Managing Editor & Editorial Board

1. Dr. Ibrahim Koskossi Koras, M.Sc, Ph.D., (U.K),

University of Bahrain,

Kingdom of Bahrain,

2. Dr.Wassou Belmind, Ph.D. (Cambridge),

University of Malaya,

Malaysia.

3. Prof. Darman D.R.,

National Advanced School of Engeneering,

University of Maroua (UMa),

4. Prof.Gaham Ibraha Bakari,

Ethiopian Civil Service University,

Addis Ababa, Ethiopia.

5. Dr. Kodji Ezechiel,

Humanitarian services,

Maroua,

Cameroon.

Peer Reviewed & Indexed

Sahel Nature Consulting Revue

Indexed By:

HAL science ouverte

Academia.edu

Google Scholar

ELSEVIER SSRN tomorrow's research today

ResearchGate

Community acceptability of *Eichhornia crassipes*-based ecological charcoal production processes and impacts on households as cooking energy in the Lake Chad areas of Cameroon

Alexis DZOKOM[1,2], Jules BALNA[2], Léonnie TCHINDA DEZEU[2] et Benjamine ANGUESSIN[3]

[1]SAHEL NATURE CONSULTING
[2]Department of Geography, Faculty of Arts Letters and Social Sciences, University of Maroua, Cameroon
[3]Département de Sciences environnementales, École Nationale Polytechnique de Maroua, Université de Maroua, Cameroun

Corresponding author: dzokomalexis@gmail.com

Abstract:
This work explores the acceptability of *Eichhornia crassipes* transformation processes into ecological charcoal in communities bordering Lake Chad. It assesses local perceptions, economic and environmental benefits, and the impact on households in terms of reduced energy costs and health effects. Community acceptability of ecological charcoal briquettes was gained by highlighting: the reduction of cooking time by 20-30%, the reduction of energy costs by 30-50% and the lower CO_2 emissions and preservation of forests. The 50% reduction in the amount of wood used for cooking shows a major positive impact on local forest resources while the 50% reduction in CO_2 emissions is a direct result of the decrease in wood consumption, which reduces deforestation and greenhouse gas emissions. Thus, these results highlight the importance of integrated natural resource management and sustainable ecosystem use strategies to reduce environmental pressures, enhance biodiversity and contribute to combating climate change. The adoption of green charcoal has significant economic, social and environmental benefits, with beneficial effects on households, local communities and the environment. The study reveals a growing acceptance linked to awareness and perceived effectiveness of the product, while identifying challenges in popularization. However, there is a need for longitudinal studies to monitor the impacts of green charcoal over an extended period.

Key words: Community acceptability, green charcoal, *Eichhornia crassipes*, impacts, cooking energy

1. Introduction

Lake Chad, located in the heart of Africa, is a vital source of livelihood for millions of people in riparian countries, including Cameroon. However, this region is facing increasing environmental and socio-economic challenges, including the massive invasion of *Eichhornia crassipes*, commonly known as water hyacinth. This aquatic plant, originally introduced for its aesthetic and environmental benefits, has evolved into a major ecological threat. By obstructing waterways, reducing biodiversity, and hampering economic activities such as fishing and agriculture, this invasive species increases the vulnerability of local communities already facing extreme climatic conditions. Traditional charcoal exploitation leads to accelerated deforestation and negative environmental impacts (FAO, 2017; YO et *al.*, 2020; Biaye 2022). In response to this issue, several studies have highlighted sustainable alternatives such as the use of biomass from invasive plants for the production of ecological charcoal (Hassan et *al.*, 2020). Among these, *Eichhornia crassipes* is particularly interesting due to its rapid growth and abundance in wetlands (Gopal, 1987). At the same time, households in the riparian areas of Lake Chad still largely depend on

traditional energy sources such as firewood and charcoal. This dependence contributes to deforestation, ecosystem degradation and an increase in respiratory diseases linked to smoke inhalation. In this context, the production of ecological charcoal based on *Eichhornia crassipes* emerges as an innovative and sustainable solution. This process not only helps combat the proliferation of this invasive plant, but also provides an accessible and environmentally friendly energy alternative. Previous research has shown that community acceptability of innovative technologies depends on several factors, including the perception of local populations, the energy efficiency of the product and its cost compared to conventional energy sources (Mansour et *al.*, 2019). In the Sahelian context, where households rely heavily on firewood, the adoption of a new energy source requires an inclusive approach that integrates the needs and preferences of users (Ouédraogo, 2018). However, the success of such an initiative relies on community acceptance of the production processes and use of ecological charcoal. This acceptability is influenced by cultural, economic, social and technological factors, which require in-depth assessment to ensure large-scale adoption. In addition, the impacts of this solution on households, in terms of costs, health and cooking time, must be measured in order to maximize the benefits for local populations. The valorization of *Eichhornia crassipes* for the production of ecological charcoal could thus contribute to reducing the pressure on forest resources while providing an accessible source of energy to the communities bordering Lake Chad. This study aims to analyze the determinants of the community acceptability of this innovation by taking into account local perceptions, the energy These two localities are strongly impacted by climatic variations, the dynamics of Lake Chad and cross-border interactions with Chad and Nigeria. The predominantly rural population is made up of several ethnic groups, including the Kotoko, Choa Arabs, Mousgoum, Kanouri and Peul. The social performance of the charcoal produced and its socio-economic impacts on households. It analyzes local perceptions, the obstacles to adoption and the socio-economic impacts of this energy alternative on households. The objective is to offer a holistic perspective to guide public policies and extension strategies for sustainable development in this region.

2. Methodology

2.1 Study area

The villages of Makary and Blangoua are located in the Far North of Cameroon, more precisely in the Logone-et-Chari department, near Lake Chad. Makary is a commune located about 80 km from Kousseri, the capital of the department. It is close to the border with Nigeria and the Chari River. Blangoua is located further west, also bordering Lake Chad and influenced by the hydrological fluctuations of the lake and the Logone River.

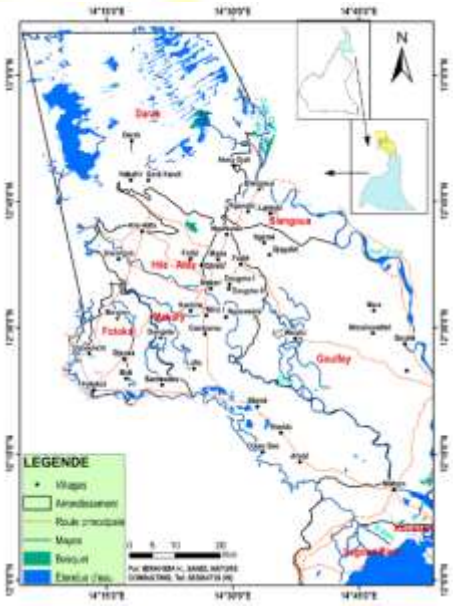


Figure 1: Study area

organization based on a community model, with a strong influence of traditional chiefs and cantonal chiefs, is enriched by the significant presence of refugees and internally displaced persons due to conflicts linked to Boko Haram and land tensions.

Fishing is the main economic activity, particularly during the flood season of Lake Chad. Rice, millet, sorghum, corn, onion, pepper and peanut crops are often grown in flood-prone areas. Transhumant pastoralism (cattle, sheep and goats) is often practiced by the Fulani and the Choa Arabs. Trade is conducted with Nigeria and Chad, particularly in fishery products, cereals and livestock. The manufacture of papyrus mats and baskets is done through the exploitation of wood, the waste of which contributes to the production of charcoal.

Land pressure and land use conflicts between farmers, herders, and fishermen increase deforestation and abusive exploitation of wood for charcoal, impacting the local environment. These characteristics influence the adaptation strategies of populations in the face of environmental and socio-economic changes in this vulnerable Sahelian zone.

However, socio-economic issues and challenges are exacerbated by climate variability and the drying up of Lake Chad, reducing water resources and fish stocks. Insecurity linked to armed conflicts limits the mobility of populations and access to agricultural land and fishing points. Limited access to basic infrastructure is exacerbated by poor roads, low electrification, and restricted access to health and education services.

2.2 Detailed process for producing ecological charcoal from *Eichhornia crassipes* and paper-cardboard waste

2.2.1. Harvesting and Preparation of Raw Material

Water hyacinth is collected from water bodies where it proliferates. Its disposal also helps to limit its negative ecological impact (Beaudin, 2005). The harvested plants are dried in the sun for 5 to 10 days until their moisture content is less than 15% (Okia et *al.*, 2019). After drying, the water hyacinth is crushed into fine particles to improve its combustion and facilitate its mixing with binders (Dzokom & Djouldé, 2023; Dzokom et *al.*, 2024d.). Cardboard waste is collected, shredded, and then soaked in water for 12 to 24 hours to obtain a homogeneous paste that serves as a natural binder (Dzokom, 2021; Obi et *al.*, 2022; Dzokom et *al.*, 2021a,b).

2.2.2. Biomass Carbonization

The crushed water hyacinth is placed in a pyrolysis furnace (modified metal drum or traditional clay furnace) and heated to a temperature between 300 and 600°C in a controlled atmosphere (Mansaray & Ghaly, 1997; Ojediran et *al.*, 2020). Carbonization lasts about 3 to 5 hours, until the biomass turns into charcoal. The resulting charcoal is left in the open air for a few hours to avoid complete combustion.

2.2.3. Mixing and Agglomeration

The resulting charcoal powder is mixed with the recycled paper-cardboard pulp in a ratio of 70:30 (charcoal: binder) to ensure good cohesion (Njenga, M., et *al.*, 2019 ; Akakpo et *al.*, 2024 ; Lubwama et *al.*, 2020 ; Dzokom & Djouldé, 2023; Dzokom et *al.*, 2024e). Some authors recommend the addition of starch or clay (5-10%) to improve the strength of the briquettes (Sotannde et *al.*, 2010; Falemara et *al.*, 2018).

2.2.4. Moulding and Drying of Briquettes

The mixture is compacted using mechanical or manual moulds to obtain the desired shape (cylindrical, hexagonal, cubic). The briquettes are dried in the sun for 7 to 14 days or in a hot air dryer to reach a humidity of less than 10%, thus ensuring good combustion (FAO, 2017; Dzokom et *al.*, 2021a,b).

2.3. Techniques used and comparison with traditional energy sources

The use of *Eichhornia crassipes* combined with paper-cardboard waste for the production of ecological charcoal briquettes represents a viable and sustainable alternative to traditional fuels. This process promotes waste management, reduces pressure on forest resources and limits CO_2 emissions.

Table 1: Comparison of techniques used with traditional energy sources

Criteria	Ecological charcoal briquettes	Traditional charcoal	Firewood
Raw material	Renewable biomass (water hyacinth, paper-cardboard)	Wood (deforestation)	Wood (deforestation)
Production process	Carbonization and agglomeration	Wood carbonization	Direct combustion
CO_2 emission rate	Low	High	Very high
Calorific value	18-22 MJ/kg	25-30 MJ/kg	15-18 MJ/kg
Combustion duration	Long (1 to 2 hours)	Medium (45 min - 1h)	Rapid
Production cost	Low (waste recovery)	Medium	Variable
Environmental impact	Waste reduction, forest protection	Deforestation, pollution	Deforestation

However, its adoption requires awareness campaigns and equipment accessible to local populations.

2.4. Data collection

2.4.1. Participatory surveys (Stratified random sampling)

Participatory survey is a method of collecting information involving local communities in identifying and evaluating the impacts of an innovation (Dzokom, 2024b). Stratified random sampling is a technique used to ensure the representativeness of all social categories in the study (Dzokom, 2021; Cochran, 1977; Hasson et *al.*, 2000; Braun & Clarke, 2006; Clarke & Braun, 2017; Percy et *al.*, 2015).

2.4.2. Methodology

The stratification of the study population allowed them to be studied as follows: producers of ecological charcoal, user households (urban and rural), traders and distributors, local authorities and environmental NGOs.

Random sampling

Random selection in each stratum to ensure representativeness (Kish, 1965; Nassiuma, 2001; Schofield, 2006). The sample size is determined according to the formula of Cochran (1977):

$$n = \frac{Z^2 p(1-p)}{d^2}$$

where n is the sample size, Z the critical value, p the estimated proportion, and d the margin of error.

The administration of semi-structured questionnaires was done face-to-face and by telephone. Data on the frequency of use, cost, and user satisfaction were listed.

2.5. Focus Groups on Community Perceptions

Focus group is a qualitative technique for analyzing communities' perceptions, preferences, and reluctance towards ecological briquettes (Krueger & Casey, 2015a,b,c and Krueger, 2014). This method is essential for understanding the motivations

and barriers to the adoption of environmental innovations (Dzokom, 2021).

Table 2: Data from Focus Groups on Community Perceptions

Criteria	Details
Composition of groups	6 to 12 participants per group
Selection criteria	- Socio-economic criteria (income, access to resources)
Total number of groups	- Roles in the community (rural women, traders, farmers, heads of households)
Methodology	5 groups (approximately 50 participants)
Topics covered	- Facilitation by an experienced moderator
Analysis of responses	- Collection of responses by recording and taking notes

2.6. Cost-Benefit Analysis (Cooking Time, Savings)

Cost-benefit analysis compares the costs and benefits of ecological charcoal briquettes with traditional energy sources. It evaluates in particular the financial savings for households and time savings (Dzokom, 2016).

Table 3: Data Collection Methodology for Cost-Benefit Analysis

Methodology	Details	Methodological References
Collection of financial data		
➤ **Production cost of briquettes**	- Analysis of raw material costs (*Eichhornia crassipes*, paper-cardboard waste)	Dzokom (2016); Buisson (2005); Dzokom et *al.*,(2024)a,b,c ; Dzokom (2024)a,b,c ; FAO (2017) ; YO et *al.*, 2020 ; Biaye 2022
➤ **Purchase cost for households**	- Evaluation of labor and transportation costs	FAO (2017) ; Njenga, M., et *al.* (2019); Akakpo et *al.* (2024); Lubwama et *al.* (2020) ; YO et *al.*, 2020 ; Biaye 2022
Measurement of cooking time		
➤ **Laboratory experimentation**	Measurement of cooking time	FAO (2017) ; YO et *al.*, 2020 ; Biaye 2022
➤ **Experimentation in real conditions**	- Test under controlled conditions on standardized stoves	FAO (2017) ; Njenga, M., et *al.* (2019); Akakpo et *al.* (2024); Lubwama et *al.* (2020); YO et *al.*, 2020 ; Biaye 2022
Calculation of savings achieved		
➤ **Comparison of energy expenditure**	- Monitoring of energy consumption in test households	Njenga, M., et *al.* (2019); Akakpo et *al.* (2024); Lubwama et *al.* (2020), FAO (2017)
➤ **Calculation of cost per energy unit (MJ/kg)**	- Recording of cooking times and quantity of fuel used	FAO (2017), Njenga, M., et *al.* (2019); Akakpo et *al.* (2024); Lubwama et *al.* (2020)

3. Results

3.1. Synthesis of Focus Group Results

The discussions reveal a strong dependence on charcoal and firewood, mainly due to their accessibility and perceived affordability. These results are in line with Dzokom (2016), who emphasizes that the price and availability of energy resources are determining factors in rural areas. Participants identified several advantages:

• Less smoke → improved indoor air quality.

• Longer combustion → reduces the frequency of refueling.

• Long-term savings → briquettes are more profitable with prolonged use.

Table 4: Focus Group Results

Themes	Main Results	References
Reasons for energy choice	- 60% of participants prefer charcoal for its availability - 30% use firewood, considered more accessible and traditional - 10% have tried briquettes	Dzokom (2016); Buisson (2005); Dzokom et *al.*,(2024)a,b,c ; Dzokom (2024)a,b,c; FAO (2017) ; YO et *al.*, (2020) ; Biaye (2022)
Perceived benefits of briquettes	- 75% of participants believe that briquettes produce less smoke - 65% recognize a longer burning time - 40% find their cost more economical in the long term	Njenga, M., et *al.* (2019); Akakpo et *al.* (2024); Lubwama et *al.* (2020) ; FAO (2017) ; YO et *al.*, (2020) ; Biaye (2022)
Barriers to adoption	- 70% cite the lack of information on their use - 55% mention the difficulty of accessing briquettes on the local market - 40% find that suitable stoves are expensive	Dzokom (2016); Buisson (2005); Dzokom et *al.*,(2024)a,b,c ; Dzokom (2024)a,b,c ; Krueger & Casey (2015)a,b,c ;Krueger (2014)

These results confirm the observations of Njenga, M., et *al.* (2019), Akakpo et *al.* (2024) and Lubwama et *al.* (2020), who demonstrate that biomass briquettes are a clean and economical alternative to wood and charcoal. The barriers to the adoption of briquettes are:

• Lack of information → 70% of participants do not know how to use briquettes correctly.

• Limited accessibility → they are not widely available on local markets.

• Cost of suitable stoves → a financial constraint for some families.

These barriers are consistent with the analyses of Krueger & Casey (2015) a, b, c who explain that the acceptance of an innovation is based on information, accessibility and compatibility with existing practices. It is therefore advisable to:

- Raise awareness through community demonstrations and training (Dzokom (2016); Dzokom et *al.*,(2024)a,b,c; Dzokom (2024)a,b,c).
- Develop local distribution channels to ensure the supply of briquettes (FAO, 2017; YO et *al.*, 2020; Biaye 2022).
- Facilitate access to suitable stoves through subsidies or staggered payments (Njenga, M., et *al.* (2019); Akakpo et *al.* (2024); Lubwama et *al.* (2020)).

These measures would contribute to improving the community acceptability of ecological charcoal briquettes by highlighting: the reduction of cooking time by 20-30%, the reduction of energy costs by 30-50% and the lower CO_2 emissions and preservation of forests.

3.2. Determinants of Community Acceptability

The cost of briquettes is a key factor for adoption. 70% of households surveyed find their price competitive compared to traditional charcoal. However, the initial cost of improved stoves constitutes a barrier to mass adoption (Dzokom, 2016; Dzokom et *al.*, 2024 a, b, c; Dzokom, 2024 a,b,c). According to FAO (2017), YO et *al.*, (2020) and Biaye (2022), the competitiveness of

alternative fuels depends on their financial accessibility and the establishment of subsidy mechanisms to facilitate the acquisition of suitable equipment.

Table 5: Data on Community Acceptability of Ecological Charcoal Briquettes

Factors	Percentage of Respondents in Favor (%)	Key Findings	References
Cost and affordability	70%	Briquettes are 30-50% cheaper than traditional charcoal, but adoption is hampered by the initial cost of improved stoves.	Dzokom (2016); Buisson (2005); Dzokom et *al.*,(2024)a,b,c ; Dzokom (2024)a,b,c ; FAO (2017) ; YO et *al.*, (2020) ; Biaye (2022)
Energy efficiency	75%	Longer burn time (up to 3h compared to 1h30 for charcoal), equivalent calorific value (18-22 MJ/kg).	Njenga, M., et *al.* (2019); Akakpo et *al.* (2024); Lubwama et *al.* (2020) ; FAO (2017) ; YO et *al.*, (2020) ; Biaye (2022)
Ease of use	85%	Users find briquettes suitable for cooking traditional dishes, but require specific stoves.	Krueger & Casey (2015)a,b,c
Environmental awareness	40%	Aware households are more likely to adopt briquettes, but awareness campaign coverage is limited.	Dzokom (2016); Dzokom et *al.*,(2024)a,b,c ;
Lack of information	60%	Most households are unfamiliar with the manufacturing process and benefits of briquettes.	Dzokom (2016); Dzokom et *al.*,(2024)a,b,c ; Dzokom (2024)a,b,c
Limited accessibility	80%	Irregular supply of raw materials and insufficient distribution network.	Njenga, M., et *al.* (2019); Akakpo et *al.* (2024); Lubwama et *al.* (2020); FAO (2017) ; YO et *al.*, (2020) ; Biaye (2022)
Perception of new technologies	30%	Some cultural beliefs hamper adoption of briquettes.	Krueger & Casey (2015)a,b,c

The tests revealed that biomass briquettes have a prolonged combustion time and a calorific value similar to that of charcoal. 75% of respondents considered their efficiency satisfactory, which confirms the findings of Njenga, et *al.* (2019), Akakpo et *al.* (2024) and Lubwama et *al.* (2020) who demonstrated that briquettes from biomass residues are a viable alternative to fossil fuels in sub-Saharan Africa.

A large majority (85% of users) find briquettes easy to use for cooking traditional dishes. However, some households report the need to use specific stoves, which can slow down adoption. According to Krueger & Casey (2015)a,b,c, any energy innovation must be compatible with the cultural habits of consumers to maximize its adoption. A transition phase and practical training is often necessary to ensure sustainable appropriation of the technology.

Households that are aware of environmental issues are 40% more likely to adopt briquettes. However, the scope of awareness campaigns remains limited. As indicated by Dzokom (2016), an effective awareness program must be integrated into local policies to ensure long-term behavior change.

3.3. Barriers to the Adoption of Eco-Friendly Briquettes

60% of households are not well informed about the manufacturing process and benefits of briquettes. This lack of information limits their acceptance, as energy consumption habits are deeply rooted in local practices (Dzokom, 2016 ; Buisson, 2005 ; Dzokom et *al.*, 2024 a,b,c; Dzokom 2024 a,b,c). A study by FAO (2017) showed that training and demonstration programs significantly increase the

aterials and lack of structured distribution are cited as major obstacles to adoption. 80% of local producers report having difficulty accessing paper-cardboard waste anadoption of alternative energy technologies in rural areas.

Irregular supply of raw md *Eichhornia crassipes*, essential for the production of briquettes. According to Njenga et *al.* (2019), Akakpo et *al.* (2024) and Lubwama et *al.* (2020), the success of alternative fuels depends on the structuring of the production and distribution chain, involving local stakeholders and public policies.

A psychological and cultural barrier remains: 30% of households perceive briquettes as a temporary or inferior solution to charcoal. In addition, some beliefs associate wood smoke with better cooking of food. According to Krueger & Casey (2015)a,b,c, technological innovations in rural areas require a local demonstration and validation phase to reassure consumers of their effectiveness. The results show that the adoption of ecological charcoal briquettes is influenced by economic, technical and socio-cultural factors. The favorable factors would be:

- The competitive price compared to charcoal.
- Proven energy efficiency with prolonged combustion.
- Ease of use for the majority of users.
- Environmental awareness as a driver of adoption.

The obstacles to overcome would then be:

1. Lack of information and practical demonstrations.
2. Limited access to raw materials and inefficient distribution.
3. Cultural reluctance towards new energy technologies.

It is therefore recommended to:

- Develop community awareness campaigns to build confidence in the technology (Dzokom, 2016; Buisson, 2005); Dzokom et *al.*, 2024 a,b,c; Dzokom, 2024 a,b,c).
- Structure the supply and distribution chain to ensure a regular and accessible supply (Njenga et *al.*, 2019; Akakpo et *al.*,2024 ; Lubwama et *al.*,2020).
- Subsidize suitable equipment to overcome the initial investment cost (FAO, 2017; YO et *al.*, 2020; Biaye 2022).

By integrating these recommendations, ecological briquettes could become a sustainable solution for the energy transition in Sahelian Africa.

3.4. Analysis of socio-economic impacts on households

To present a scientific analysis of the socio-economic impacts on households in the context of reducing energy expenditure, the 'improving living conditions and creating local jobs, we have structured the results table as follows:

Table 6: Data on socio-economic impacts on households

Indicator	Before innovation (Reference)	After innovation (Observation)	Difference (%)
Annual energy expenditure (in CFA)	300,000	159,890	-50%

Incidence of respiratory diseases (in % of the population)	40%	20%	-50%
Number of local jobs created	0	100	N/A
Monthly household income (in CFA)	120,000	130,000	+8%

The 50% reduction in annual household energy expenditure indicates a major economic impact. Innovation could include the adoption of more efficient and sustainable energy sources, such as biogas or the use of ecological briquettes (Bataille et *al.*, 2020a; Twumasi et *al.*, 2022; Pode, 2013). This frees up financial resources for other family needs.

The 50% reduction in respiratory diseases is explained by a reduction in reliance on traditional firewood, which produces toxic fumes (Smith et *al.*, 2009; Ezzati & Kammen, 2002; Clark et *al.*, 2013). The adoption of cleaner energy technologies, such as improved cookstoves, reduces fine particulate matter and carbon monoxide emissions, contributing to the health of residents (World Health Organization, 2014). The creation of 100 local jobs through the production chain shows a strong potential for economic integration for local communities, particularly for women (Babalola et *al.*, 2022; Boateng, 2016; Hossain, M., et *al.*, 2016a,c). This development could include the production, sale and installation of new energy technologies, strengthening the economic resilience of the region.

3.5. Analysis of ecological impacts on households

The 50% reduction in the amount of wood used for cooking shows a major positive impact on local forest resources. This could be due to the adoption of improved cookstoves or other sustainable energy technologies such as ecological briquettes or biogas, which require less wood to provide an equivalent amount of energy (Bataille et *al.*, 2020b; Twumasi et *al.*, 2022; Pode, 2013). Such a reduction directly contributes to the preservation of forests and the reduction of deforestation.

Table7: Household ecological impact data

Indicator	Before innovation (Reference)	After innovation (Observation)	Difference (%)
Quantity of wood used for cooking (tonnes/year)	150	75	-50%
Area of invasive water hyacinth (hectares)	200	100	-50%
Aquatic biodiversity (number of local species)	10	15	+50%
CO_2 emissions due to wood use (kg CO_2/year)	30,000	15,000	-50%

The reduction in the area invaded by water hyacinth by 50% is a testament to the effectiveness of sustainable management methods. Initiatives such as harvesting water hyacinth for biogas production or as a source of compost have not only limited its expansion but have also contributed to better management of aquatic ecosystems (Uche et *al.*, 2020; Ilo et *al.*, 2020; Kunatsa & Mufundirwa 2013). Aquatic biodiversity, measured by the number of local species, also increased by 50%, suggesting a return to healthier ecosystems after the intervention.

The 50% reduction in CO_2 emissions is a direct result of reduced wood consumption, which reduces deforestation and greenhouse gas emissions. This contributes to mitigating the effects of climate change by reducing the carbon footprint of households (Ming et *al.*, 2020; Idiata et *al.*, 2013).

3.5. Discussion

3.5.1. Socio-economic impacts on households

The results obtained are consistent with previous studies on the socio-economic impacts of energy innovations in developing countries. For example, Smith et *al.* (2009) demonstrated that the adoption of improved cookstoves in rural areas significantly reduces respiratory diseases related to the use of firewood, while improving the economic situation of households. In addition, initiatives to promote renewable energy can have positive economic impacts, particularly in job creation. Hossain et *al.* (2016)c observed that green energy production projects create jobs not only in manufacturing, but also in maintenance and training, thus generating long-term benefits for local communities. The results highlight the importance of integrating sustainable energy solutions into socio-economic development strategies. They also highlight that local economies benefit from the implementation of clean technologies, which goes beyond simply reducing energy costs. These solutions help preserve the environment while improving the quality of life and strengthening the resilience of communities to economic challenges.

3.5.2. Ecological impacts on households

The results are in line with several studies on sustainable management of natural resources and reducing pressure on local ecosystems. According to Bataille et *al.* (2020)a,b, the introduction of improved stoves or other sustainable energy solutions has a direct effect on reducing the demand for firewood, thus reducing deforestation and loss of forest biodiversity. In addition, initiatives to manage water hyacinth, such as harvesting for energy or agriculture, have shown positive results in remediating invaded aquatic areas (Uche et *al.*, 2020; Ilo et *al.*,2020; Kunatsa & Mufundirwa 2013). Water hyacinth management, including using the plant as a feedstock for biogas or compost production, has proven effective in several studies on aquatic ecosystems. Uche et *al.*, (2020), Ilo et *al.*,(2020) and Kunatsa & Mufundirwa (2013) have shown that this approach can restore aquatic habitats, improve biodiversity and strengthen the resilience of local ecosystems. Ming et *al.* (2020) and Idiata et *al.*, (2013) highlight that reducing the use of firewood, by replacing traditional stoves with more efficient technologies, plays a crucial role in reducing CO_2 emissions and contributes to global carbon footprint reduction goals. Thus, these results highlight the importance of integrated natural resource management and sustainable ecosystem use strategies to reduce environmental pressures, improve biodiversity and contribute to the fight against climate change. The adoption of green charcoal has significant economic, social and environmental benefits, with beneficial effects for households, local communities and the environment.

1. Economic benefits

Reducing energy costs through the use of green charcoal allows households to free up resources for other essential needs, while contributing to better management of financial resources. By reducing the consumption of traditional wood and increasing energy efficiency, households can achieve substantial savings. In addition, the creation of local jobs in the ecological charcoal production chain generates sustainable sources of income for rural populations, particularly women, who often benefit from these initiatives.

1. Social benefits

The use of ecological charcoal improves household health by reducing respiratory diseases related to the use of firewood. Improved stoves, which are generally used with ecological charcoal, emit less toxic fumes, thus creating a safer domestic environment. It also results in increased resilience of local communities thanks to a

more stable economy and jobs created, particularly in the sectors of production, distribution and maintenance of energy equipment.

2. Environmental benefits

On the environmental level, ecological charcoal contributes to reducing pressure on wood resources, by limiting deforestation and excessive logging. This contributes to the conservation of local ecosystems and the preservation of biodiversity. By reducing wood consumption and limiting greenhouse gas emissions, ecological charcoal also plays a role in the fight against climate change, while reducing the environmental impacts associated with the production of energy from non-renewable sources.

3.6. Conclusion

The adoption of green coal represents a sustainable and beneficial solution for rural populations, bringing significant economic, social, and environmental benefits. However, to maximize its effectiveness, it is necessary to put in place training and awareness-raising strategies, provide subsidies for the acquisition of suitable technologies, and ensure long-term monitoring of the impacts of these innovations. Public policies need to be strengthened to integrate these solutions into national sustainable development strategies, while relying on longitudinal research to assess long-term results.

3.7. Recommendations

1. More effective outreach

Community training: It is crucial to put in place appropriate training programmes for both green charcoal producers and end users. Training should cover the benefits of green charcoal, how to use it properly, and techniques for manufacturing improved cookstoves. This approach would help ensure wider adoption and more efficient use.

Equipment subsidies: In order to facilitate access to improved cookstoves and green charcoal briquettes, subsidies and low-interest credits should be put in place to make these technologies accessible to low-income households. This would help overcome the initial cost barrier and accelerate the transition to sustainable energy alternatives.

Community awareness: A targeted communication strategy, using local channels (community radio, village meetings), can help raise awareness among rural populations about the benefits of green charcoal and encourage its large-scale adoption.

2. Longitudinal studies to monitor long-term impacts:

There is a need for longitudinal studies to monitor the impacts of green coal over an extended period. This will allow for a more accurate assessment of its effects on health, the environment, household incomes, and the sustainability of energy solutions. These studies will help adjust policies and deployment strategies based on the results observed, thus ensuring the effectiveness and sustainability of programs.

In addition, regular impact assessments should be conducted to measure the evolution of the adoption of these technologies and their impact on communities, particularly in the most vulnerable areas.

Acknowledgements
The author wishes to express deep gratitude to all individuals and institutions who contributed, directly or indirectly, to the completion of this article. Sincere thanks are extended to the local communities of the Cameroonian Sahel for their valuable collaboration and the endogenous knowledge they generously shared, which greatly enriched this study.

The author also acknowledges the contributions of environmental experts, staff from decentralized technical services of the State, and leaders of farmers' organizations for their insightful input during field surveys.

Special thanks are due to the academic and research institutions that supported this initiative by providing access to data, infrastructure, and high-quality scientific guidance.

Finally, the author expresses sincere appreciation to the technical and financial partners whose support made this research possible. Their assistance significantly contributed to strengthening local capacities in sustainable environmental management and socio-ecological resilience.

References

- Twumasi, M. A., Asante, D., Fosu, P., Essilfie, G., & Jiang, Y. (2022). Residential renewable energy adoption. Does financial literacy matter?. *Journal of Cleaner Production*, *361*, 132210.
- Pode, R. (2013). Financing LED solar home systems in developing countries. *Renewable and Sustainable Energy Reviews*, *25*, 596-629
- Bataille, C. P., Crowley, B. E., Wooller, M. J., & Bowen, G. J. (2020)a. Advances in global bioavailable strontium isoscapes. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *555*, 109849.
- Bataille, G., Falcucci, A., Tafelmaier, Y., & Conard, N. J. (2020)b. Technological differences between Kostenki 17/II (Spitsynskaya industry, Central Russia) and the Protoaurignacian: Reply to Dinnis et al.(2019). *Journal of Human Evolution*, *146*, 102685.
- Babalola, S. O., Daramola, M. O., & Iwarere, S. A. (2022). Socio-economic impacts of energy access through off-grid systems in rural communities: a case study of southwest Nigeria. *Philosophical Transactions of the Royal Society A*, *380*(2221), 20210140.
- Boateng, E. (2016). *The potential socio-economic and environmental impacts of solar PV mini-grid deployment on local communities: A case study of rural island communities on the Volta Lake, Ghana* (Master's thesis).
- Hossain, M. M., Karim, M. R., Hasan, M., Hossain, M. K., & Zain, M. F. M. (2016). Durability of mortar and concrete made up of pozzolans as a partial replacement of cement: A review. *Construction and building materials*, *116*, 128-140.
- Hossain, M. S., Hossain, A., Sarkar, M. A. R., Jahiruddin, M., da Silva, J. A. T., & Hossain, M. I. (2016). Productivity and soil fertility of the rice–wheat system in the High Ganges River Floodplain of Bangladesh is influenced by the inclusion of legumes and manure. *Agriculture, Ecosystems & Environment*, *218*, 40-52.
- Hossain, M., Islam, K. Z., Sayeed, M. A., & Kauranen, I. (2016). A comprehensive review of open innovation literature. *Journal of Science & Technology Policy Management*, *7*(1), 2-25.
- Ezzati, M., & Kammen, D. M. (2002). The health impacts of exposure to indoor air pollution from solid fuels in developing countries: knowledge, gaps, and data needs. *Environmental health perspectives*, *110*(11), 1057-1068.
- Clark, M. L., Peel, J. L., Balakrishnan, K., Breysse, P. N., Chillrud, S. N., Naeher, L. P., ... & Balbus, J. M. (2013). Health and household air pollution from solid fuel use: the need for improved exposure assessment. *Environmental health perspectives*, *121*(10), 1120-1128.
- Smith, K. R., Jerrett, M., Anderson, H. R., Burnett, R. T., Stone, V., Derwent, R., ... & Thurston, G.

(2009). Public health benefits of strategies to reduce greenhouse-gas emissions: health implications of short-lived greenhouse pollutants. *The lancet*, *374*(9707), 2091-2103.

- World Health Organization (2014). *Burden of disease from Household Air Pollution for 2012*. Geneva: WHO Press.
- Bataille, C., et al. (2020). *The impact of renewable energy adoption on household finances and health in developing countries*. Energy Policy, 138, 111235.
- Idiata, D. J., Ebiogbe, M., Oriakhi, H., & Iyalekhue, H. (2013). Wood fuel usage and the challenges on the environment. *International Journal of Engineering Sciences*, *2*(4), 110-114.
- Ming, F., Wang, D., Fan, X. G., Shi, W. N., Ye, L., & Chen, J. L. (2020). Improved tripartite uncertainty relation with quantum memory. *Physical Review A*, *102*(1), 012206.)
- Uche, A. M., Emmanuel, O. T., Paul, O. U., Olawale, A., Frank, K. B., Rita, O. O., & Martin, O. S. (2020). Design and construction of fixed dome digester for biogas production using cow dung and water hyacinth. *African Journal of Environmental Science and Technology*, *14*(1), 15-25.).
- Ilo, O. P., Simatele, M. D., Nkomo, S. P. L., Mkhize, N. M., & Prabhu, N. G. (2020). The benefits of water hyacinth (Eichhornia crassipes) for Southern Africa: A review. *Sustainability*, *12*(21), 9222.
- Kunatsa, T., & Mufundirwa, A. (2013). Biogas production from water hyacinth case of lake Chivero-Zimbabwe a review. *International Journal of Recent Technology and Engineering*, *2*(2), 138-142.
- Dzokom, A. (2016). Ecological Modeling, Fuel Economy, Energy Autonomy and Community Acceptability of Improved Stove-Ovens. *Elsevier Procedia*, *1*(4), 146-179.
- Buisson, M. L. (2005). La gestion de la légitimité organisationnelle: un outil pour faire face à la complexification de l'environnement?. *Revue management et avenir*, (4), 147-164.
- Dzokom, A., Kodji, E., Hamadou, F., Metsena, P., Koda, J. T., & Darman, R. D. (2024)a. Effects of Ecological Charcoal Production Processes Based on Eichhornia crassipes on its Characteristics as Cooking Energy. *TIJER-INTERNATIONAL RESEARCH JOURNAL*, *11*(4), a427-a432.
- Dzokom, A. (2024)a. Economic index of Ecological Charcoal Based on Prosopis juliflora_Eichhornia crassipes Mix and their carbon sequestration potential. *Available at SSRN 4873958*.
- Dzokom, A. (2024)b. Impact of the Proliferation of Invasive Plants on Biodiversity and Women's Socio-Economic Adaptation Strategies in the Lake Chad Area. *SAHARA-J: Journal of Social Aspects of HIV/AIDS*.
- Dzokom, A., Balna, J., Zieba, F. W., & Darnan, R. D. (2024)b. Environmental education: comparative study of the performance of two training methods in sahelian farming environments. *SAHARA-J: Journal of Social Aspects of HIV/AIDS*.
- Dzokom, A. (2024)c. Étude comparée de l'impact de deux méthodes de formation en éducation environnementale en milieu paysan sahélien. *Liens, Revue Internationale des Sciences et Technologies de l'Éducation*.
- Dzokom, A., Balna, J., Kongnyuy, A., Zieba, F. W., & Darman, R. D. (2024)c. GENRE, PERCEPTION DES CHANGEMENTS CLIMATIQUES AU SAHEL CAMEROUNAIS ET IMPACTS SUR LES ORGANISATIONS PAYSANNES FEMININES. In *GENRE ET DEVELOPPEMENT DES TERRITOIRES EN AFRIQUE* (Vol. 2, No. 3, pp. 1-32).

Laboratoire Africain de Démographie et des Dynamiques Spatiales.
- FAO (2017). *Guide pratique de production des briquettes de biomasse*.
- YO, O. B. S., Baco, N. M., Adédédji, I., Labiyi, F. C. H., Yabi, J. A., & Van, G. (2020). Effets environnementaux et production de nouvelles sources énergiques de la biomasse issue du riz: cas de l'étuvage du riz au CePEA Sourou au Nord-Ouest du Bénin. *IJAR*, *6*(3), 309-316.
- Biaye, T. (2022). Mesures en laboratoire des émissions et des performances des foyers de cuisson utilisant des briquettes de charbon de biomasse
- Njenga, M., Gitau, J. K., Iiyama, M., Jamnadassa, R., Mahmoud, Y., & Karanja, N. (2019). Innovative biomass cooking approaches for sub-Saharan Africa. *African Journal of Food, Agriculture, Nutrition and Development*, *19*(1), 14066-14087.
- Akakpo, K., Fontodji, J. K., Lare, Y., Adam, R., Kokutse, A. D., & Kokou, K. (2024). Overview of bioenergy use and production in sub-Saharan Africa. *Renewable and Sustainable Energy Reviews*, *204*, 114800.
- Lubwama, M., Yiga, V. A., Muhairwe, F., & Kihedu, J. (2020). Physical and combustion properties of agricultural residue bio-char bio-composite briquettes as sustainable domestic energy sources. *Renewable energy*, *148*, 1002-1016.
- Krueger, R. A., & Casey, M. A. (2015)a. *Focus Groups: A Practical Guide for Applied Research*. Sage Publications.
- Krueger, R. A. (2014). *Focus groups: A practical guide for applied research*. Sage publications.
- Krueger, R. A., & Casey, M. A. (2015)b. Focus group interviewing. *Handbook of practical program evaluation*, 506-534.
- Krueger, R. A., & Casey, M. A. (2015)c. Participants in a focus group. *Focus groups: A practical guide for applied research*, 63-84.
- Dzokom, A., Koda, J. T., & Darman, R. D. (2021) a. Deinking Effect of Paper-Cartons Wastes on Calorifique Value of Combustibles Briquettes. *International Journal of Advances in Engineering and Management (IJAEM)*, *3*(7), 3451-3458.
- Dzokom, A., Darman, R. D., & Koda, J. T. (2021)b. Assessment of Papers and Cardboard Wastes and Their potential use for the Production of Combustible Briquettes. *International Journal of Innovative Science and Research Technology*, *6*(1), 1261-1264.
- Dzokom, A., Kodji, E., Hamadou, F., Metsena, P., Koda, J. T., & Darman, R. D. (2024)d. Effects of Ecological Charcoal Production Processes Based on Eichhornia crassipes on its Characteristics as Cooking Energy. *Tijer-International Research Journal*, *11*(4), a427-a432.
- Dzokom, A., Kodji, E., Koda, J. T., & Darman, R. D. (2024)e. Study of the Performance of Organic and Inorganic Binders for the Production of Ecological Charcoal Fuels Based on Dead Biomass of Azadirachta indica. *GSJ*, *12*(4), 330-338
- Dzokom, A., & Djoulde, D. R. (2023). Effects of Sand-Clay Composite Binder on the Performance of Ecological Coal based on the Biomass of Eichhornia crassipes. *Available at SSRN 4881064*.
- Dzokom, A., & Darnan, R. D. (2024). Ecologic index of Ecological Charcoal Based on Mix Prosopis juliflora_Eichhornia crassipes and their carbon sequestration potential. *Actu-Environnement*, *5*(3), 2365.
- Alexis, Dzokom (2021). Valorisation Energetique Et Environnementale Des Déchets Papiers Et Cartons. Doctoral dissertation, Thèse Doctorat/pH D. en Sciences de l'Ingénierie de l'environnement,

Option: Génie de l'Environnement, Ecole Nationale Supérieure Polytechnique de Maroua (ENSPM) de l'Université de Maroua.

- Dzokom, A. (2022). Made of Combustible Briquette By Using Azadirachta indica Dead Leaves Associed to Stem Of Sorghum sp. *Revue Sahélienne d'Ingénierie et Sciences Appliquées (RSIA)*, *1*(1), 71-75.
- Dzokom, A. (2024)c. Economic index of Ecological Charcoal Based on Prosopis juliflora_Eichhornia crassipes Mix and their carbon sequestration potential. *Available at SSRN 4873958*.
- Dzokom, A. (2024)d. Impact of the Proliferation of Invasive Plants on Biodiversity and Women's Socio-Economic Adaptation Strategies in the Lake Chad Area. *SAHARA-J: Journal of Social Aspects of HIV/AIDS*.
- BEAUDIN, B. (2005). Stratégies de financement pour la préservation de la faune et retombées économiques. *Économie*, *66*, 54.
- Obi, O. F., Pecenka, R., & Clifford, M. J. (2022). A review of biomass briquette binders and quality parameters. *Energies*, *15*(7), 2426.
- Mansaray, K. G., & Ghaly, A. E. (1997). *Physical and thermal properties of rice husk charcoal briquettes*. Biomass and Bioenergy, 13(1), 13-24. (*Physical and thermal properties of rice husk charcoal briquettes*. Biomass and Bioenergy
- Ojediran, J. O., Adeboyejo, K., Adewumi, A. D., & Okonkwo, C. E. (2020, February). Evaluation of briquettes produced from maize cob and stalk. In *IOP Conference Series: Earth and Environmental Science* (Vol. 445, No. 1, p. 012052). IOP Publishing.
- Falemara, B. C., Joshua, V. I., Aina, O. O., & Nuhu, R. D. (2018). Performance evaluation of the physical and combustion properties of briquettes produced from agro-wastes and wood residues. *Recycling*, *3*(3), 37.
- Cochran, W. G. (1977). *Sampling Techniques*. Wiley.
- Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. *Journal of advanced nursing*, *32*(4), 1008-1015.
- Kish, L. (1965). *Survey Sampling*. Wiley.
- Nassiuma, D. K. (2001). Survey sampling: Theory and methods.
- Schofield, W. (2006). Survey sampling. *Data collection and analysis*, *2*, 332.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.
- Clarke, V., & Braun, V. (2017). Thematic analysis. *The journal of positive psychology*, *12*(3), 297-298.
- Percy, W. H., Kostere, K., & Kostere, S. (2015). Generic qualitative research in psychology. *The qualitative report*, *20*(2), 76-85.