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(RESEARCH ARTICLE)

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Inventory of biodigesters for the biogas project in the Prefecture of Macenta, Republic of Guinea

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Abstract

This research is part of the environmental and energy impact assessment of the biodigesters of the Biogas 2016 Project in Macenta. The methodological approach consists of conducting a survey of biodigester owners. The data collected using the "Kobo-collecte" software were processed using QSIS 3.24 and SPSS software, yielding the following results: Of the 114 biodigester owners, 87.72% are men and 12.28% are women, with 4.39% of biodigesters being functional and 95.61% non-functional. Biodigester malfunctions are due to cracks causing water ingress in 52 out of 109 biodigesters (47.71%), soil structure issues, a lack of animal manure in 29 biodigesters (27.52%), and odors. 15 users of biodigesters suffered from a lack of protective equipment and were exposed to odor pollution (17.43%), while those of 9 biodigesters were experiencing a labor shortage (7.34%). During the project, the fuels used were as follows: biogas and charcoal (60.53%), biogas (17.54%), firewood (13.17%), and biogas and firewood (8.77%). During the project, 67% of biodigester owners transformed the digestate into compost, while only 4% transformed these residues into biopesticides, and 29% did not use any method of recovery. After the project, the abandonment of biodigesters led to a return to the excessive use of firewood (54.39%), followed by charcoal (27.19%), firewood and charcoal (14.04%), and finally biogas and charcoal (4.39%). Following the project, of the 62 owners of biodigesters using only firewood as cooking fuel, 40 were women and 22 were men, representing 64.52% and 35.48% respectively.

Keywords: Inventory; Biodigester; Project; Biogas

1. Introduction

Energy production is a major challenge for the coming years; the energy needs of populations and industrialized societies are constantly increasing, particularly for developing countries, most of which lack safe, suitable, and affordable energy sources [1-3].

Populations seeking economic income and energy sources are engaging in the overexploitation of forest ecosystems, even though these play an important role in mitigating climate change [4-6].

Furthermore, modern economic development stemming from industrialization relies on non-renewable mineral resources (fossil fuels). This fossil fuel-based development model facilitated the demographic, scientific, and technological explosion of the 20th century. Currently, this model faces three constraints: strong demographic and economic growth, environmental degradation, and disruptions to the biosphere's climate system [7-10].

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Globally, the concentration of carbon dioxide (CO2) emissions from fossil fuels in the atmosphere has increased from 280 parts per million (ppm) in the pre-industrial era to 413 ppm in 2021 [11].

The African continent is rich in energy potential and raw materials. Unfortunately, obstacles to development are also present. Energy, agriculture, natural resource exploitation, and sanitation are central to Africa's challenges. Half of African countries have an electrification rate of less than 20% [12,13].

Thus, in many African countries, access to electricity and modern cooking fuels remains a challenge for residential and commercial activities. Households in sub-Saharan Africa constitute the majority of the 2.7 billion people worldwide who primarily use traditional biomass for cooking [14-16].

Guinea has immense energy potential, with 612,000 tonnes of oil equivalent (toe) of biomass, 6,000 MW of hydroelectric power, and an average solar irradiance of 4.8 kWh/m^2, but electricity generation capacity remains insufficient to meet national needs and accelerate growth objectives. Per capita energy consumption is 0.5 toe/year, representing an energy access rate of 7% [17].

Currently, the main primary energy sources in Guinea's energy mix are biomass and oil, while electricity is primarily generated from hydroelectric and fossil fuel power plants. Biomass (mainly wood and charcoal) accounts for 77% of primary energy consumption. Over 84% of households have access to biomass, and this widespread use of biomass contributes to the rapid depletion of the country's forest resources, exacerbating deforestation [18, 19].

Furthermore, livestock farming, after agriculture, is the second largest activity in rural Guinea. It is a sector with significant growth potential that contributes substantially to food security and poverty reduction. However, this sector also produces more than 10 million tons of animal manure each year [20]. With very little use in the energy and agricultural sectors, this waste poses a public health and environmental problem. To meet energy needs and significantly reduce pollution and greenhouse gas emissions, and to preserve the environment, the exploration and development of new energy sources have been undertaken, including the idea of creating a market for the development and use of biogas resources in Guinea. This idea was transformed into a project called the Guinea Biogas Project, funded by the Global Environment Facility (GEF), initiated on August 15, 2013, and approved on May 26, 2015. It falls within the framework of environmental protection and natural resource management, primarily through the reduction of greenhouse gas (GHG) emissions related to domestic energy consumption [18].

The main objective of this study is to conduct an inventory of the biogas project's biodigesters in order to assess the project's energy and environmental impacts in the Macenta prefecture.

2. Materials and Methods

2.1. Presentation of the Magenta Prefecture (Study Area)

The Macenta Prefecture is an administrative subdivision of the N'Zérékoré Region, located in the southeast of the Republic of Guinea, 700 km from the capital, Conakry. Macenta lies between latitude 8°32'37'' N and longitude 9°28'22'' W, with an average altitude of 609 m. It covers an area of 2724 m^2. According to the 2016 General Population and Housing Census, the prefecture had 297,779 inhabitants, nearly 70% of whom live in rural areas. It is bordered to the East by the prefecture of Beyla, to the North by that of Kérouané, to the Northwest by the prefecture of Kissidougou, to the West by the prefecture of Guéckédou, to the Southwest by Liberia and to the South by the prefecture of Yomou. The landscape of Macenta is entirely dominated by the Guinean Ridge. Its climate is sub-equatorial, characterized by two seasons of unequal length: a dry season (3 months) from December to February and a rainy season (9 months) from March to November, with an average annual rainfall of 1085 mm. The average annual temperature hovers around 25°C, with northeasterly winds averaging 0.6 m/s and an average humidity of 60% [21]. The prefecture of Macenta is subdivided into 14 sub-prefectures plus the urban commune, namely: Balizia, Bindikala, Bofossou, Daro, Fassankoni, Kouankan, Koyamay, Macenta Centre, N'Zebela, Orémai, Panziazou, Semgbedou, Sérédou, Vasérédou, and Watanka.

In the Biogas project's background document, Macenta is one of the 5 prefectures in the forest region that were affected by the project. (See figure 1).

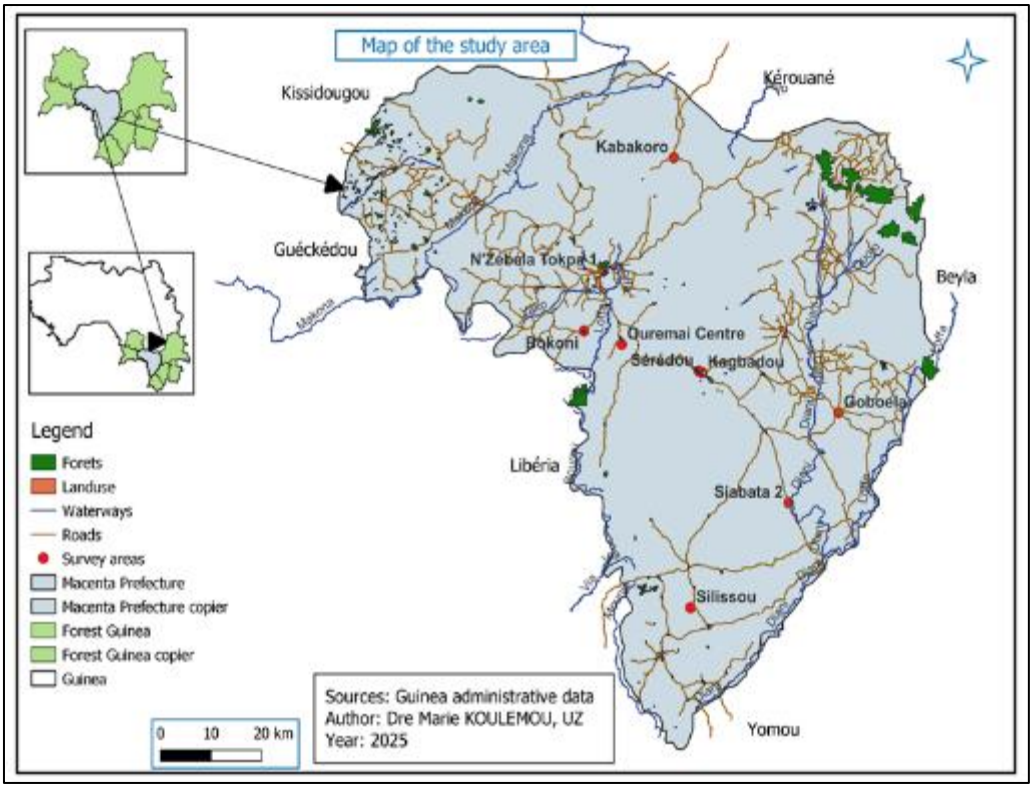

Figure 1 Map of the study area

2.2. Survey Materials

Several materials were used during our survey activities. First, we designed a questionnaire for biodigester owners. This questionnaire was entered into the Kobo-collected software, which includes GPS for georeferencing the biodigesters. Then, using QSIS 3.24 software, we mapped the areas where we located the biodigesters (see Table 1).

Table 1 Surveyed Areas

Surveyed Areas	Number of biodigesters surveyed
Magenta Centre	40
Bokoni	6
Sardou	7
Kaba Koro	9
Sabata 2	8
Silicon	9
Nebel	10
Agbada	8
Oromia	8
Gobel	9
Total	114

2.3. Data Collection and Processing

Data was collected through semi-structured interviews with biodigester owners, literature reviews, and field observations. Finally, SPSS 21 software was used to process and analyze our data.

3. Results and Discussion

3.1. Gender of Biodigester Owners in the Magenta Prefecture

From this figure, we observe that of the 114 biodigester owners interviewed, 100 are men (87.72%), while women represent 12.28%. This low percentage of female biodigester owners is explained by the fact that men are the heads of households. The women who own biodigesters are widows, single women, or divorcees (see Figure 2).

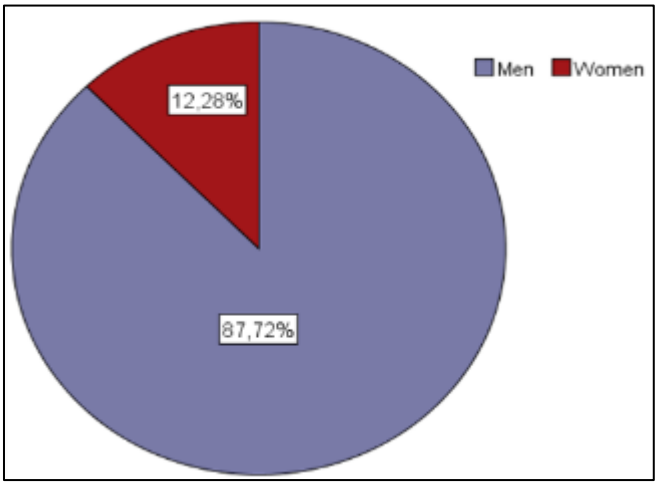

Figure 2 Types of biodigester owners in Magenta prefecture

3.2. State of biodigesters during the Magenta project

This figure shows that 100 out of 114 biodigesters surveyed in the Macenta prefecture were functional, representing 87.7%. However, our respondents revealed that the lifespan of these biodigesters was short due to several factors, such as abundant rainfall and soil structure. See Figure 3.

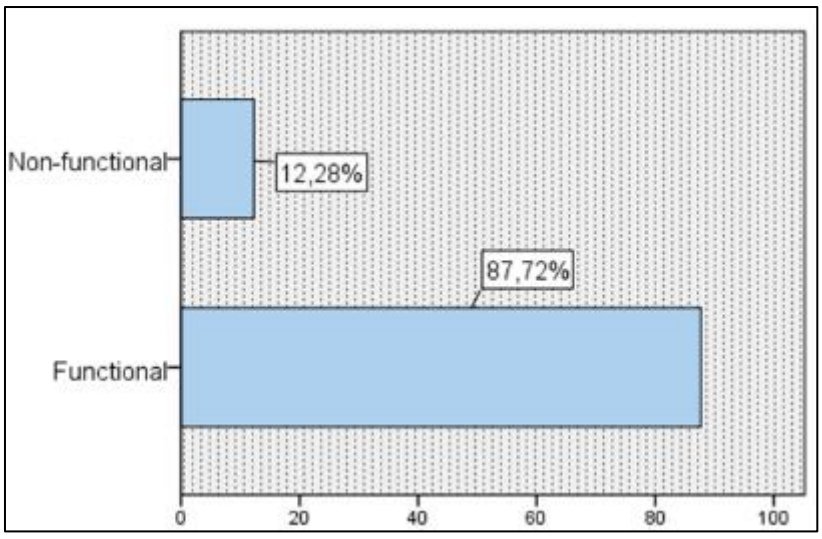

Figure 3 Status of biodigesters during the project

3.3. State of functionality of biodigesters after the project

From this figure, only 5 biodigesters are functional in the prefecture of magenta and 109 are non-functional, with values of 4.39% and 95.61% respectively, see figure 4.

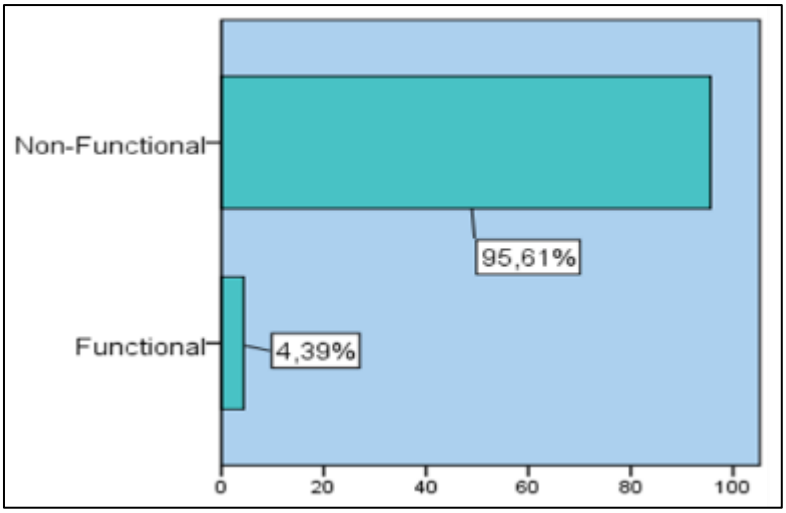

Figure 4 Status of biodigesters after the project

3.4. Reasons for Biodigester Malfunction

As in the other prefectures studied, several reasons were cited by the owners for the abundance of biodigesters in the Macenta prefecture.

From this data, we observe that the most common reason given by our respondents for biodigester malfunctions in the Macenta prefecture concerns cracks causing water to rise in the biodigesters, affecting 52 out of 109 biodigesters. This represents 47.71%. This result is understandable given the area's abundant rainfall and soil structure. The second reason is a lack of animal manure to serve as feed for the biodigesters, accounting for 27.52% (30 biodigesters).

The third reason is related to odors during the mixing of animal waste to fill the biodigesters. This means that users, due to a lack of protective equipment, were exposed to odor pollution in 17.43% (19 biodigesters) and finally the lack of manpower for biodigester activities amounts to 7.34% (8 biodigesters), see figure 5.

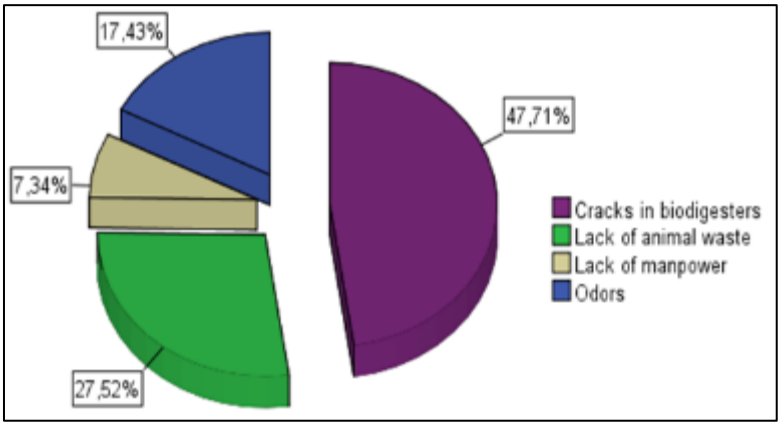

Figure 5 Reasons for biodigester failure

3.5. Impacts of the use of biodigesters in the prefecture of Magenta

3.5.1. Fuels used during the project

Figure 6 below shows that in the prefecture of Magenta during the project, biogas and charcoal were the most used fuels by households with biodigesters, representing 69 cases (60.53%), followed by biogas (20 cases, 17.54%), firewood (15 cases, 13.17%), and finally, biogas and firewood together (10 cases, 8.77%).

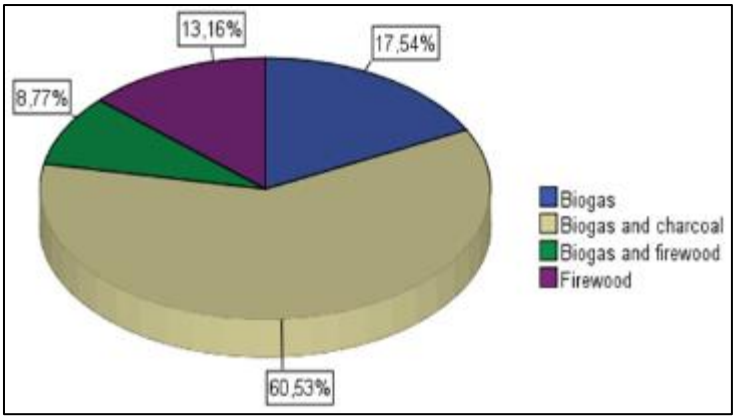

Figure 6 Fuels used in cooking during

3.6. Combustibles utilize après le ProJet

From the figure below, we observe that in the Magenta prefecture, as in the other two prefectures, firewood and charcoal remain the most widely used fuels. According to responses obtained during the field survey, of the 114 non-functional biodigesters, after the project, the owners abandoned them, which hindered the use of biogas in households. This abandonment is reflected in the return to the excessive use of firewood (62 units, representing 54.39%), followed by charcoal (31 units, representing 27.19%), a combination of firewood and charcoal (16 units, representing 14.04%), and finally, biogas and charcoal (5 units, representing 4.39%) (see Figure 7).

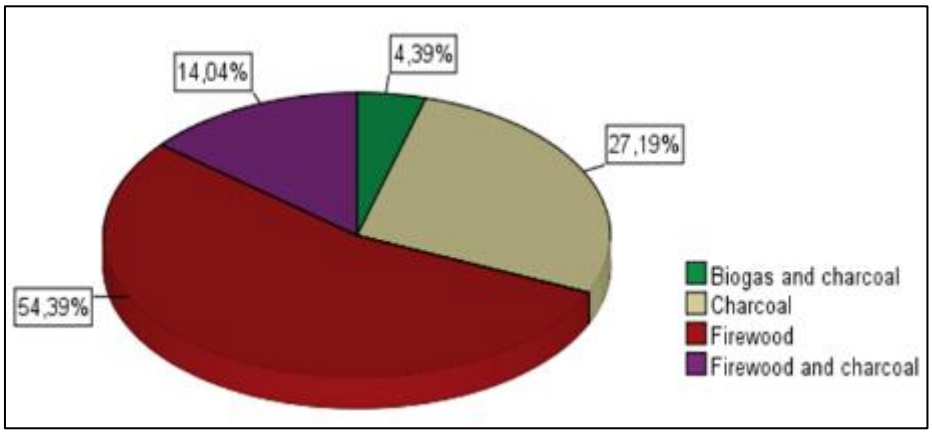

Figure 7 Fuels used in cooking after the project

3.7. Wood collectors in households

From this figure, we observe that of the 62 owners of biodigesters using only firewood as cooking fuel in households after the project, 40 women collect cooking wood compared to 22 men, representing 64.52% and 35.48% respectively, see figure 8.

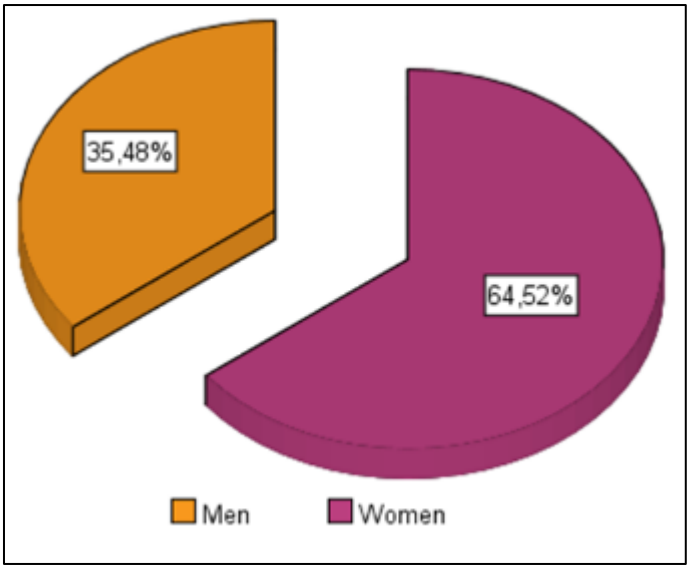

Figure 8 Household wood

3.8. Management and Use of Biomethane Digestate

In the Magenta prefecture, of the 100 biodigesters operating during the project, 67% of owners transformed the digestate from biogas production into compost used as soil fertilizer for vegetable crops, while only 4% transformed these residues into biopesticides used to control crop pests.

These methods of utilizing these residues contribute to reducing the use of chemical fertilizers. Furthermore, the use of compost has also allowed these households to save money on the purchase of these chemical fertilizers. From an environmental perspective, the use of these biofertilizers reduces the negative impacts of chemical pesticides on the environment and on human health.

However, 29% of biodigester owners did not apply any method of valorizing these residues before releasing them into the atmosphere, which could be the cause of another source of pollution (See figure 9).

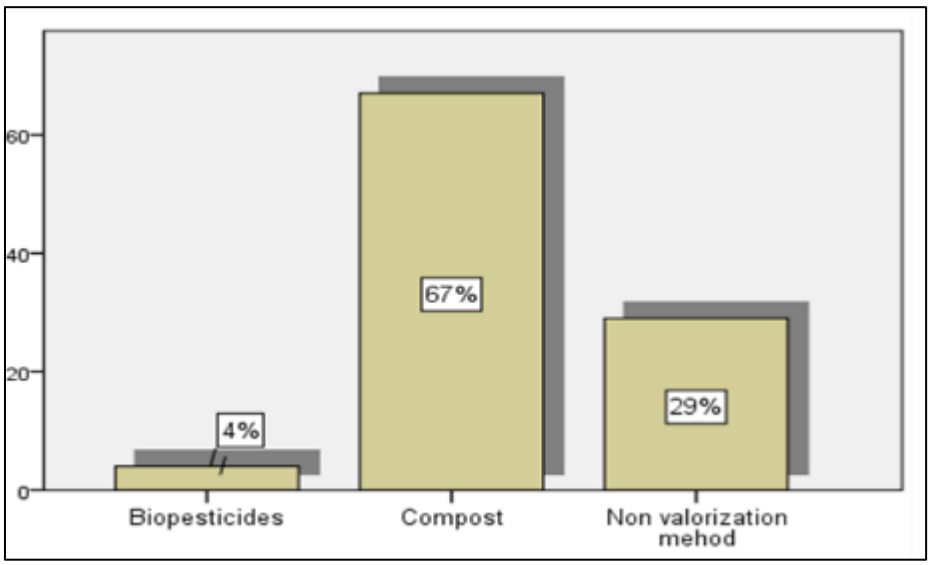

Figure 9 Management and use of

4. Conclusion

- At the end of this study, we obtained the following results:
  - Of the 114 biodigester owners, 87.72% were men and 12.28% were women, with 4.39% of biodigesters being functional and 95.61% non-functional.
  - Biodigester malfunctions were due to
- Cracks causing water to rise in 52 out of 109 biodigesters (47.71%), and soil structure.
- A lack of animal manure in 29 biodigesters (27.52%), and
- Odors during the mixing of animal waste to fill the biodigesters.
  - 15 users of biodigesters suffered from a lack of protective equipment and were exposed to olfactory pollution, i.e. 17.43%, while those of 9 biodigesters were lacking manpower, i.e. 7.34%.
  - During the project, the fuels used were as follows: biogas and charcoal (60.53%), biogas (17.54%), firewood (13.17%), and biogas and firewood (8.77%).
  - During the project, 67% of biodigester owners transformed the digestate from biogas production into compost, while only 4% transformed these residues into biopesticides, and 29% did not use any method of recovery.
  - After the project, the abandonment of biodigesters led to a return to the excessive use of firewood (54.39%), followed by charcoal (27.19%), firewood and charcoal (14.04%), and finally biogas and charcoal (4.39%).
  - After the project, of the 62 owners of biodigesters using only firewood as cooking fuel, 40 were women and 22 were men, representing 64.52% and 35.48% respectively.
  - Biodigester technology should therefore be included among the Sustainable Development Goals.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there are no conflicts of interest. Compliance with Ethical Standards: This article does not contain any studies involving human or animal subjects.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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