

Research Article

Estimation of Pig Manure Energy Potential for Biogas Production in Forest Region in Guinea

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Abstract

Biogas production from animals' dejection is an important way to reduce energy shortages in non-developed countries. In this work we performed an estimation of pig manure energy potential for biogas production in forest region in Guinea. To achieve this objective, we first carried out a census of the pig herd in all the cities of the forest region. Then we evaluated the average daily production of pig manure per animal. At the end a physicochemical characterization of pig manure is done and an estimation of the pig manure energy potential is computed for all the cities of then forest region of Guinea. A comparison between modern and local pig manure in terms of energy potential is made. The mains results are: a) the pig herd in the cities of the forest region in Guinea are respectively: (333) for Beyla, (6 530) for Lola, (5387) for Queckedou, (23425) for Macenta, (62333) for Nz é ð kor é and (24313) for Youmou. The total pig herd is 122321. The average daily production of pig manure per animal (2.57 kg/day) for pig manure from modern breeding and 0.76 kg/day for those from local breeding. The parameters physicochemical parameters for modern pig manure are: humidity (50.59%), dry matter (49.4%), organic (99.4%) and carbon content (57.67%). For local pig manure the parameters; humidity (39.37%), dry matter (60.62%), organic (58.61%) and carbon content (33.99%). The maximum daily energy potential is 271.315,446094 kWh/d for Modern pig manure and 35.659,908391 Kwh/d. These values are for the Nz é ð kor é city.

Keywords

Pig Manure, Energy, Estimation, Biogas, Production, Forest Region, Guinea

1. Introduction

Biogas production from animal waste is a credible alternative for sustainable energy supply. It constitutes a sustainable environmental solution in the treatment and recycling of animal droppings and organic waste. Biogas is a source of renewable energy, similar to solar, wind, and geothermal energy [1]. It is a flammable gas produced by the anaerobic digestion of animal, plant, human, industrial and municipal waste and mainly composed of methane (50-70%), carbon dioxide (20-40%) and traces of other gases (Nitrogen, Hy-

drogen, Ammonia, Hydrogen sulfide, etc.) [2].

The pig manure is a good candidate for biogas production [3]. In addition to waste treatment and reducing fossil fuel consumption, biomethanization has additional benefits for households practicing agriculture and breeding. This is particularly the case in many rural communities in the Republic of Guinea [4-6]. This anaerobic digestion promotes the daily accessibility of local populations to clean energy and quality fertilizers for arable land [7].

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Environmental, cultural and socio-economic conditions favor pig breeding in Forest Guinea. This breeding produces a large quantity of droppings a manure every year, whose valuation remains a major problem [8]. Assessment of the energy potential of pig manure for the production of biogas in the N'Zérékoré city in Guinea has been recently done [9]. Comparison of physicochemical parameters between modern and local pig manure in N'Zérékoré city for biogas purpose was recently performed in [10].

This paper proposes an estimation of pig manure energy potential for biogas production in forest region in Guinea. For this end, we first carried out a census of the pig herd in all the cities of the forest region. Then we evaluated the daily average production of pig manure per animal. At the end a physicochemical characterization of pig manure is done and an estimation of the pig manure energy potential is computed for all of cities in forest region of Guinea. A comparison between modern and local pig manure in terms of energy potential is made.

2. Materials and Methods

2.1. Materials

2.1.1. Study Area

The forest regions of Guinea, covers an area of 37,658 km² or 18% of the national territory, its capital is Nzérékoré city and is the 3rd most populated region of Guinea, after Kankan and Conakry. This region is in the south-east of the Republic of Guinea, limited to the north by the natural region of Upper Guinea, to the south by the Republic of Liberia, to the east by the Republic of Côte d'Ivoire and to the west by the Republic

of Sierra Leone [11]. The climate is that of the Guinean ridge, generally of the Equatorial Guinean type. It is a variant of the Guinean subequatorial climate and brings the harmattan which is more rigorous in Beyla [12]. There are two seasons: a rainy season from March to November and a dry season from December to February. Due to this climate, the region has many important agricultural production areas. Despite its rugged terrain, the region's rivers follow the seasonal rhythm of the rains. The average annual rainfall in the region is 1600 to 2000 mm and its vegetation cover is characterized by dense forest in the south and savannah-type vegetation in the north. The N'Zérékoré region, which has a very rugged relief, is dominated by two large mountain ranges: the Daro massif in Guékédou, whose highest point is the Mount Konossou (1345 m), and the Nimba massif (1752 m) in the Lola city with an extension of the Simandou chain in Beyla (1656 m). The flora is varied and constituted of wooded savannahs and forest islands in the north in the city of Beyla and Guékédou and dense forests in the south in Macenta (Ziama Classified Forest), N'Zérékoré, Yomou (Diéké Classified Forest) and Lola (Déké Classified Forest). With an estimated population of 1,689,799 inhabitants in 2016 [13], the N'zérékoré region has an average annual population growth rate of 3.7%. With a population of 870,847 women represent 51.62% of the population. The region includes six (6) cities (Beyla, Lola, Macenta, Guékédou, N'Zérékoré and Yomou), 60 sub-prefectures, 6 urban communes, 60 rural communes, 774 districts, 104 neighborhoods and 2,550 sectors. The existence of hydro-agricultural potential and a large herd of cattle, sheep and goats favors pig breeding in this region. Figure 1 shows the map of the forest region with the six cities.

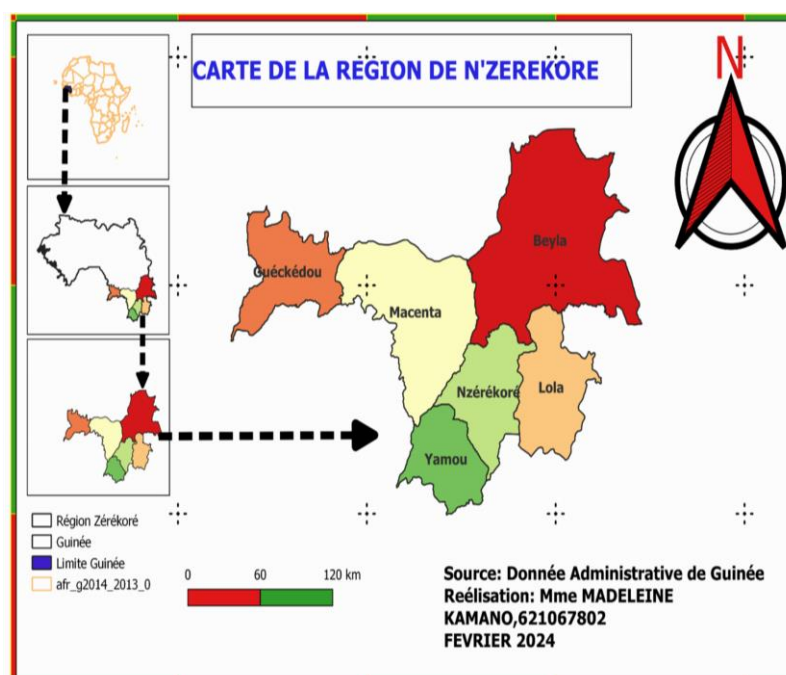


Figure 1. Map of the forest region (N'zerekore region).

2.1.2. Materials Used

The mains materials used are:

- 1) pig farm to collected pig manure;
- 2) sampling for physicochemical parameters determination (plastic bottles, cooler, gloves, boots, muffle oven, oven, desiccator, incinerator, electronic balance, analytical balance and containers graduated in centiliter);
- 3) energy potential estimation tools (census sheets, polyethylene bags, markers, survey sheets, shovels, buckets, boots, gloves, nose guards, wheelbarrows and hook scales).

Figures 2 and 3 show respectively modern and local pig farm in which we collected pig manure.



Figure 2. Modern pig Farm in Nzérékoré city.



Figure 3. Local pig Farm in Nzérékoré city.

2.2. Methods

2.2.1. Daily Production of Pig Manure Per Animal Assessment

After the field survey on pig herds in the forest region (Nzérékoré region), we determined the daily production of manure per animal. Daily pig manure production was computed by measuring the mass of pig manure produced per day by a given number of animals, using a 100 kg scale. The daily quantity of pig manure from a given animal population is calculated as follows:

$$Q_j = P_{mj} * N_a \quad (1)$$

where,

Q_j represents the daily quantity of pig manure in (kg/d);

P_{mj} is the average daily pig manure production (kg/head/day);

N_a is animal population (pig population).

2.2.2. Theoretical Production of Biogas

The biogas and methane productivity of waste depends on the dry matter (DM), organic matter (OM) rates and the specific biogas and methane production for an animal waste source. The daily quantity of organic matter is calculated by equation (2), while the daily biogas and methane productivities per OM are determined by equation (3) and (4).

$$OM = N_a * Q_j * \%OM \quad (2)$$

$$P_{biog} = OM * (\%biog / OM) \quad (3)$$

$$P_{CH_4} = P_{biog} * \%CH_4 \quad (4)$$

where,

OM is the organic matter available per day (m^3/d) or (kg/d);

N_a is the Number of animals according to categories;

Q_j is the quantity of animal waste produced per day in (m^3/d);

$\%OM$ represents the rate of organic matter per dry matter;

Daily- P_{biog} is the biogas production in cubic meters per day (m^3/d);

$\%biogz/OM$ represents the average biogas content per organic matter (m^3/kg OM);

P_{CH_4} is the daily methane production (m^3/j);

$\%CH_4$ is the rate of methane contained in the biogas.

2.2.3. Energy Potential

The energy potential animal waste depends on the methane level content in the biogas, on its lower calorific Value and the average efficiency of a gas turbine or biogas engine, which is 30% [14]. The PCI of methane is 9.94 kWh/ Nm^3 or 35784 kJ/ Nm^3 . Also, 1 m^3 of biogas with 50% of methane is equivalent in average to 4.58 kWh of electricity or 16488 kJ [15]. The daily energy potential of animal waste is determined by equation (5).

$$P_{Energ} = P_{CH_4} * PCl_{CH_4} \quad (5)$$

where

P_{Energ} represents the daily energy production from biogas (kJ/d);

PCl_{CH_4} is the lower calorific value of methane (kJ/ m^3).

2.2.4. Pig Manure Physicochemical Parameters Characterization

The samples were collected in all the cities of forest region and transported in airtight polypropylene bottles to the laboratories of the Guinean Society of Oil Palms and Rubber Trees of Diéké. These samples consist of pig manure (modern and local breeding). The gravimetric method was used to determine the following physicochemical parameters: The humidity rate H (%), the dry matter rate DM (%), the organic matter rate OM (%) and finally the organic carbon rate C (%).

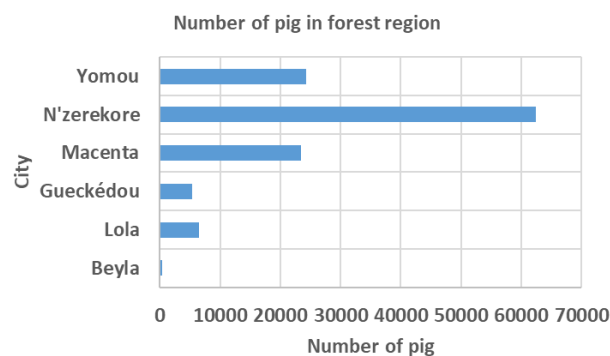


Figure 4. Number of pigs in the cities of forest region.

3. Results

3.1. Pig Herds Census Result

The field survey for the census of pig herds in all the cities allowed to determine the number of pigs as indicated in Figure 4. It appears clearly that Nzérékore city has highest number of pigs followed by Yomou city.

3.2. Pig Manure Physicochemical Parameters

Figure 5 gives the average values of the physico-chemical parameters of the two types of pig manure (modern and local pig manure). The result illustrates the modern pig manure contains high level of organic matter and carbon content than the local pig manure.

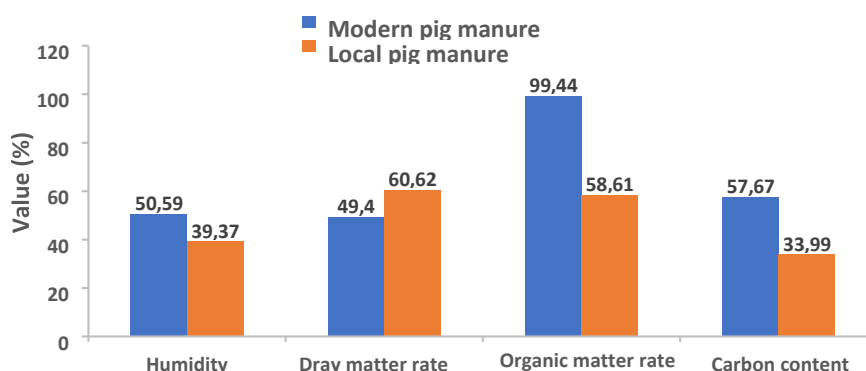


Figure 5. Physico-chemical parameters of Modern pig manure (blue color) and local pig manure (red color).

3.3. Daily Production of Pig Manure

The average daily quantity of produced modern pig manure is in Table 1. The pig species are:

- 1) pigs, with average weight of 12 kg;
- 2) sows with average weight of 50 kg to 95 kg and the veras, with average weight of 75 kg to 130 kg.

Table 1. Average daily production of modern pig manure.

No.	Collection date	Days	Pig number				Pig manure (Kg)	Average (Kg/d)
			Pigs	Sows	Veras	Total		
1	12/07/2023	1	05	06	02	13	34,00	2,62
2	13/07/2023	2	01	01	01	03	6,20	2,10
3	14/07/2023	3	02	02	02	06	13,50	2,25
4	15/07/2023	4	10	08	06	24	70,00	2,92

No.	Collection date	Days	Pig number				Pig manure (Kg)	Average (Kg/d)
			Pigs	Sows	Veras	Total		
5	16/07/2023	5	07	10	08	25	68,20	2,73
6	17/07/2023	6	06	07	10	23	64,00	2,78
7	18/07/2023	7	04	05	03	12	28,60	2,38
8	19/07/2023	8	03	04	07	16	44,00	2,75
9	20/07/2023	9	08	04	09	21	59,05	2,81
10	21/07/2023	10	09	03	05	17	40,00	2,35
Average								2,57

For the local pig manure, the average daily quantity produced is in following [Table 2](#).

Table 2. Average daily production of local pig manure.

No.	Collection date	Days	Pig manure			Pig manure (Kg)	Average (Kg/d)
			Males	Females	Total		
1	17/07/2023	1	01	01	02	1,50	0,75
2	18/07/2023	2	03	02	05	4,00	0,80
3	19/07/2023	3	02	04	06	5,20	0,87
4	20/07/2023	4	05	03	08	6,20	0,78
5	21/07/2023	5	04	07	11	8,60	0,78
6	22/07/2023	6	06	08	14	10,00	0,71
7	23/07/2023	7	08	05	13	9,50	0,73
8	24/07/2023	8	07	09	16	11,50	0,72
9	25/07/2023	9	09	06	15	12,00	0,80
10	26/07/2023	10	10	10	20	14,00	0,70
Average							0,76

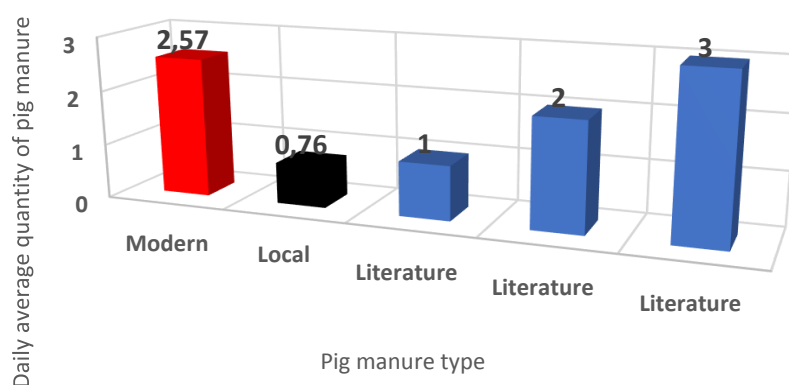


Figure 6. Average daily production of pig manure: comparison between the two types of pig manure (modern and local) to the literature results.

Figure 6 illustrates the comparison of the average daily production of modern and local pig manure to the results from the literature. We note that the result of modern pig manure, 2.57 Kg/d well includes in the range of the literature results which is equal to 1 to 3 [16, 17]. On the other hand, the result of the average daily production of local pig manure, 0.76 Kg/d not includes in the range of the literature. This could be explained by the fact that the literature results mainly concern

modern pig manure.

3.4. Daily Energy Potential of Pig Manure

Tables 3 and 4 give the estimated values of the energy potential calculated by equation (1-5) respectively for modern and local pig manure for all the cities of the forest region.

Table 3. Daily energy potential of modern pig manure.

No.	City	Number of pig	Daily pig manure quantity (Kg/d)	MS (Kg/d)	MO (Kg/d)	Daily Biogaz quantity (m ³ /d)	Energy (KWh/d)
1	BEYLA	333	765.9	378.423531	376.304359	31.647196	144.944158
2	LOLA	6530	15019.0	7420.73771	7379.181579	6205.891708	28422.984023
3	GUECKEDOU	5387	12390.1	6121.824509	6087.542292	5119.62307	23447.873661
4	MACENTA	23425	53877.5	26620.333975	26471.26010	22262.32974	101961.47020
5	N'ZEREKORE	62333	143365.9	70835.657531	70438.977848	59239.180370	271315.446094
6	YOMOU	24313	55919.9	27629.463391	27474.738396	23106.254991	105826.647858
TOTAUX		122321	281338.3	139006.440647	138228.004579	116249.751850	532423.863473

For the local pig manure, the average daily quantity produced is in following Table 4.

Table 4. Daily energy potential of local pig manure.

No.	City	Number	Daily pig manure quantity (Kg/d)	MS (Kg/d)	MO (Kg/d)	Daily Biogaz quantity (m ³ /d)	Energy (KWh/d)
1	BEYLA	183	139.08	84.311806	49.415149	41.558140	190.336281
2	LOLA	3592	2729.92	1655.024919	970.010105	815.778498	3736.265520
3	GUECKEDOU	2963	2251.88	1365.211257	800.150318	672.926417	3082.002989
4	MACENTA	12884	9791.84	5936.342167	3479.290144	2926.083011	13401.460190
5	N'ZEREKORE	34283	26055.08	15795.996470	9258.033531	7786.006199	35659.908391
6	YOMOU	13372	10162.72	6161.189650	3611.073254	3036.912606	13909.059735
TOTAUX		67277	51130.52	30998.082272	18167.976020	15279.267832	69979.046670

From Tables 3-4 above, Figures 7-8 illustrate respectively the daily energy potential of modern and local pig manure for the different cities of N'zerekore region.

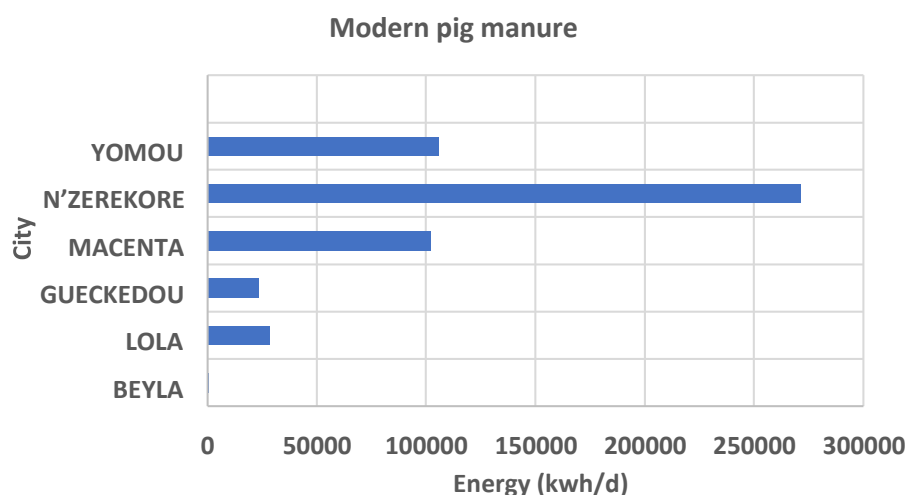


Figure 7. Daily energy potential of modern pig manure: comparison between the cities of Nzerekore region.

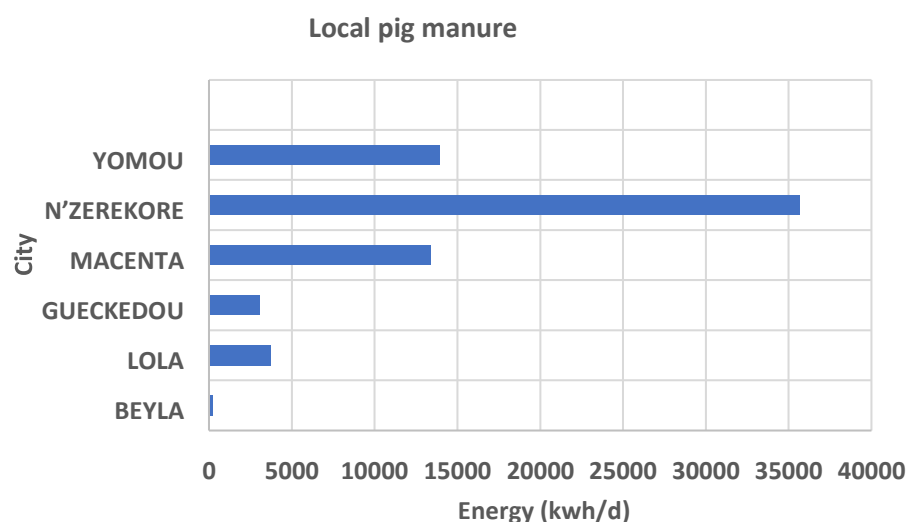


Figure 8. Daily energy potential local pig manure: comparison between the cities of Nzérékoré region.

As we can see in Figures 7 and 8, the city of Nzérékoré has the greatest energy potential for biogas production from pig manure, followed by Macenta city.

4. Conclusions

In this work we first carried out the physicochemical characterization of the two types of pig manure (modern and local pig manure). A comparison of the physicochemical parameters (Humidity, dry matter, organic matter and carbon content) between modern pig manure and local pig manure was made. It was found that modern pig manure has the highest humidity level (50.59%) against (39.37%) for local breeding pig manure. However, local pig manure has the highest dry matter content (60.62%) against (49.4%) for the modern type.

We also compared the values of organic matter and carbon content for the two types of pig manure (modern and local

pig manure). The result indicates that modern pig manure has a higher level of carbon content (57.67%) and organic matter (99.4%) than local pig manure (33.99%) and (58.61%). This can be due to some factors such as the location, monitoring food and the animal breed.

Finally, we estimated the energy potential for pig manure from modern and local breeding for the Nzérékoré region. For this, we first compared the average daily production of modern and local pig manure with the results from the literature. We found the result of modern pig manure (2.57 Kg/day) is well includes in the range of the literature results which is from 1 to 3 kg/day. On the other hand, the result of the average daily production of local pig manure (0.76 Kg/day) is not the range of the literature. This could be explained by the fact that the results obtained in the literature mainly concern modern pig manure. Using this daily production of pig manure, we calculated the daily potential energy of modern and local pig manure for the different cities of the Nzérékoré region. It was found shown the N'zérékoré city

has the greatest energy potential for biogas production from pig manure.

Abbreviations

DM	Dry Matter
OM	Organic Matter Available Per Day (m^3/d) or (kg/d)
Q_j	Daily Quantity of Pig Manure in (kg/d)
P_{mj}	Average Daily Pig Manure Production ($\text{kg}/\text{head}/\text{day}$)
N_a	Animal Population (Pig Population)
P_{CH_4}	Daily Methane Production (m^3/j)
$P_{\text{Ener}g}$	Daily Energy Production from Biogas (kJ/d)
$P_{Cl_{CH_4}}$	Lower Calorific Value of Methane (kJ/m^3)
$\%CH_4$	Rate of Methane Contained in the Biogas
$\%biogz/OM$	Average Biogas Content Per Organic Matter ($\text{m}^3/\text{kg OM}$)
Daily- P_{biog}	Biogas Production in (m^3/d)

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Author Contributions

Oumar Keita: Conceptualization, Formal Analysis, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Madeleine Kamano: Data curation, Methodology, Investigation

Noukpo Medard Agbazo: Formal Analysis, Software, Investigation

Data Availability Statement

The data is available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



Oumar Keita is Professor in the Department of Hydrology at the University of Nzérékoré in Guinea. He completed his PhD in Engineer Sciences, Geomechanics fields, from Brussels School of Polytechnic, Free University of Brussels (ULB). Belgium. He holds three master's degrees, the first in Modelling and Experimentation in Solids

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Madeleine Kamano is a teaching Assistant at N'zerekore University, Department of physic. She completed his PhD in Energy Systems and Environment from Gamal Abdel Nasser University in 2025, and his Master of Energy Systems and Environment from the same institution in 2020.



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Research Field

Oumar Keita: Solar panels performance analyzes under environmental conditions, Biogaz production (from animal dejection), Ecological charcoal production (from agriculture waste, animal dejection), Hydro energy modeling, Wind Energy modeling, Thermal energy modeling.

Madeleine Kamano: Biogaz production (from animal dejection), Ecological charcoal production (animal dejection).

Noukpo Medard Agbazo: Hydrological modeling and forecasting, Chaos and fractal theories in applied physics, statistical post-processing of climate simulations, climate physics and multifractal statistics, Hydrological forecasting with machine learning model.