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Climate change and some adaptation measures in the Sudano-Sahelian zone of Cameroon

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Abstract. Cameroon aspires to emergence by 2035. Since 2009, it has drawn up reference documents such as the "Vision 2035" and the "Strategy Document for Growth and Employment", which include growth goals such as poverty reduction, economic development, industrialization, democracy and unity. In addition, in the document of the Intended Determined Contribution to the National Plan submitted to the United Nations, the country undertakes to reduce its greenhouse gas emissions up to 32% by 2035, with particular emphasis on renewable energy which will contribute 25% of total electricity production. The Sudano-Sahelian region of Cameroon is the region most threatened by climate change. For more than a decade, actions have been carried out both under government leadership and private initiatives to reduce the effects of global warming on the socio-economic development of the region. In our work, we will present some of the local action plans experienced both in the laboratory and in the field based on energy, agriculture, environmental techniques, and hydraulics and water control. **Keywords:** Global warming; Environmental techniques; Renewable Energy; Agriculture; Hydraulics and water management; Socio-economic development.

1 Introduction

The world is suffering the consequences of global changes following sudden climatic variations, strong demographic pressure, etc. This has the direct corollary of drought, rural exodus, urban saturation, increased poverty, food and nutritional insecurity, lack of energy and severe impoverishment. The most vulnerable populations are those in developing countries such as those in sub-Saharan Africa. Climate changes are unequivocal and are probably the major issues of our century [1-3]. They concern the international scientific community and countries around the world because of their potential and proven negative impacts on people and ecosystems. African populations are particularly exposed to the effects of climate change [4, 5]. This situation stems from their very strong dependence on the use of natural resources through agriculture, livestock, fishing and logging activities. Indeed, human activities have greatly contributed to modifying the ecological balance of the planet (fig. 1). This upheaval is reflected today in an amplification of climatic dynamics and an acceleration of climatic events such as cyclones and heat waves [5, 6]. In addition, trends towards global warming are already causing disruptions in the precipitation cycle which result in extreme phenomena such as floods or droughts which affect food production [7-11].

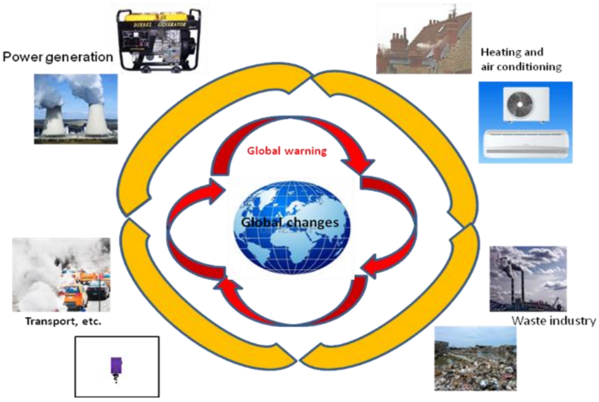

Figure 1 : Global changes of the planet

Cameroon is no exception, and is even particularly exposed due to its territories in the Sahelian zone, hard hit by desertification, and its territories in coastal areas, threatened by the rise in sea level. We are already faced with an abnormal recurrence of extreme climatic phenomena such as strong winds, high temperatures or heavy rainfall that endanger human communities, ecosystems and the services they provide. Due to the great agro-ecological diversity in Cameroon, the nature of climate change varies widely from one region to another and their impacts differ. Already, about 320,000 Cameroonians are affected by climate-related disasters [9]. The consequences of these climate changes could undermine Cameroon's efforts to reduce poverty, develop a strong, diversified and competitive economy,

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and strengthen national unity and the consolidation of the democratic process; and thus undermine the objective of the "vision 2035" to become an emerging country within twenty years.

Furthermore, it should be noted that wood energy will remain the main source of domestic energy in Cameroon for decades to come [12]. Despite the considerable efforts devoted to alternative energies and electrification, the number of people dependent on biomass energy continues to increase. It is estimated that in 2030, more than 2.7 billion people in the world will use this type of energy to cook their food [8]. In the Far North region of Cameroon, for example, household energy supply depends more than 95% on forest biomass [12]. This percentage shows that in this Sudano-Sahelian zone of Cameroon, wood is the most used source of cooking energy. To this end, the need for firewood is very high and is increasing at the rate of the population, while the supply does not evolve at the same rate, on the contrary, it tends to decrease [13]. This insufficiency will undoubtedly disturb the maintenance of the environmental balance in the short term given that the annual rates of reforestation and deforestation do not evolve at the same rate on the one hand and there remains a waste of wood following the use of traditional three-stone stoves [17].

To continue to survive in this unfavorable environment where the issue of energy is becoming increasingly problematic, local communities in the Sahel must resort to practices and technologies that consume less wood [4]. Therefore, to minimize this pressure on the forest perimeters, we must think about the increase in the efficiency of the use of wood that can be achieved with the use of improved stoves [18]. It is with this in mind that the Cameroonian government has initiated a project on improved stoves which is part of Operation Sahel Vert. The government, through the Ministry of the Environment, Nature Protection and Sustainable Development, has decided to distribute Bangui-type improved stoves each year, which is the most effective in terms of reducing wood consumption and reducing the time taken during cooking [19-23]. However, an evaluation carried out in 2014 shows that the shared stoves as part of the Sahel Vert operation to limit this phenomenon are ineffective for households. Indeed, the possession of an improved stove is not always an indicator that can testify to its use, most of the stoves offered free of charge to women are used very little or not at all [7].

In this work, we will present some of the local action plans experienced both in the laboratory and in the field based on energy, agriculture, environmental techniques, hydraulics and water control.

2. Effects of climate change in Cameroon

2.1. Presentation of Cameroon

Cameroon is located in Central Africa. It extends from the Gulf of Guinea to Lake Chad, between 2° and 13° North latitude, then 8° 30' and 16° 10' East longitude (fig. 2). The country has an area of 475,650 km^2 with a long coastline of 402 km. Triangular in shape, its length from North to South is 1,400 km and its width from East to West is approximately 800 km at most. It is bordered to the south by Congo, Gabon, Equatorial Guinea and the Atlantic Ocean, to the west by Nigeria, to the north by Lake Chad, to the east by Chad and the Central African Republic. Cameroon is 63% mountainous [24]. Its hydrographic network is divided into 5 large groups: 1) the Sanaga basin with the Sanaga river and its tributaries Djerem, Noun, Mbam, Lom and Pangar. 2) The coastal river basin with the Cross River, Mungo, Wouri, Dibamba, Nyong, Lokoundjé, Kienke, Lobé and Ntem rivers. 3) The Congo basin with the Sangha, Dja, Boumba and Ngoko rivers, and Kadei 4) The Niger basin with the Benue river and the Katsina Ala, Donga, Faro, Kébbi, Menchum, Gordi rivers. 5) The Lake Chad basin with the Chari and Logone rivers as well

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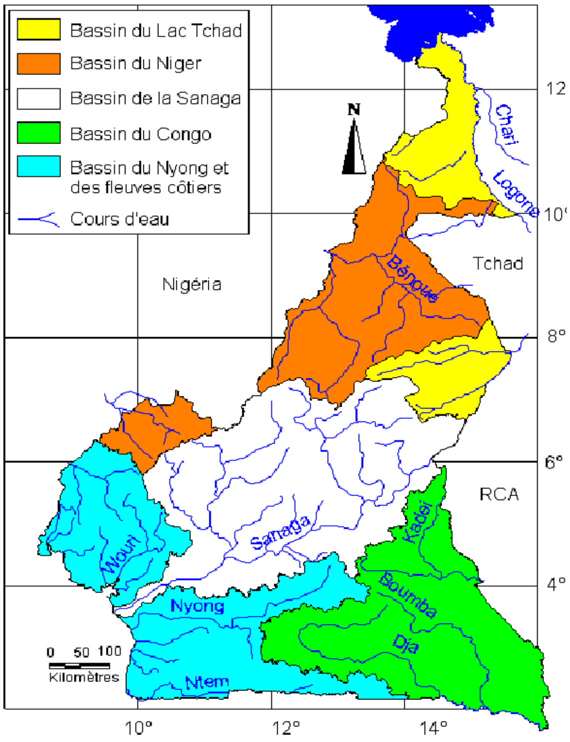

Figure 2 : Cameroon map [24, 22]

The country has five major agro-ecological zones (ZAE) which are presented in Table 1.

Table 1: Major agro-ecological zones of Cameroon **[25].**

	Zone	Region	Area (km²)
I	Sudano Sahelian	North and Far North	10 0 353
II	High savannas	Adamawa and departments of Mbam and Lom and Djerem	12 3 077
III	Highlands	West and North West	31 192
IV	Rainforests with monomodal rainfall	Littoral and South West	45 658
V	Bimodal rainfall forests	Centre, South and East	16 5 770
TOTAL			46 6 050

Cameroon's economy is one of the most diversified in Africa. Although the secondary (22% of GDP) and tertiary (45%) sectors are well developed, the economy is nevertheless mainly based on production sectors: agriculture, livestock, fishing and aquaculture, forestry and forestry. Agriculture employs nearly 60% of the population and remains the predominant sector of the national economy both in terms of its contribution to GDP (23%) and the knock-on effects on other sectors of activity. The main cash crops are cocoa, coffee, tobacco, cotton, bananas and pepper (PNACC) [24].

2.2. Climate changes observed in Cameroon over the past 50 years

The climatic changes observed in Cameroon during the last 50 years include among [24]:

- a decline in precipitation since 1960 of -2.2% on average per decade. This decrease in rainfall concerns in particular the ZAE of the high plateaus, and especially the Sudano-Sahelian ZAE.
- an increase in the average annual temperature of +0.7°C from 1960 to 2007. The agro-ecological zones most affected by this rise in temperature are the forest ZAE with bimodal rainfall and the ZAE of the high Guinean savannahs.
- a resurgence of extreme events throughout the country: droughts, especially in the Sudano-Sahelian ZAE and the high Guinean savannah ZAE, more frequent and more violent storms, floods and mass movements, i.e. landslides, mudslides, falling rocks, landslides, etc. caused by heavy rainfall.

2.3. Climate changes expected in the future in Cameroon

According to Cameroon's National Climate Change Adaptation Plan, we would expect in the future to:

- Future precipitation: a drier climate in the North and hotter and wetter in the South, with however high variability over the whole of Cameroon.
- Future temperatures : the scenarios predict a warmer climate throughout the country, but particularly in the North.

Table 2: Summary of climate change expected by

Variables / Climate hazards	**Sudan-Sahel**	**Guinean high savannahs**	**Highlands**	**Bimodal rainfall**	**Single-mode pluviometry**
Temperature	↑	↑	↑	↑	↑
heat waves	+++++	++	++	+++	++
Dust storms	++++	nc	nc	nc	nc
Rainfall	↓	↓	↓	↓	↓
Amount of rain	+	++	++	++	++++

Rainfall variability	++	++	++	++	+++
strong wind	++	++	++	+	+++
Extreme events	↑	↑	↑	↑	↑
drought	++++	++	+	+	NA
loods	+++	++	++	+++	+++
ground movements	++	+++	+++	++	+
Land erosion and coastal erosion	+++	++	++	++	+++
Sea level rise	nc	nc	nc	nc	nc

Legend : ↑ increase ; ↓ decrease → stability ; NC not concerned

- Future extreme events: climate projections in Cameroon show an increase in the frequency and amplitude of: droughts, particularly in the Sudano-Sahelian ZAE; erosion particularly in the coastal ZAE; flooding in the Sudano-Sahelian, coastal and forest ZAEs with bimodal rainfall, landslides in all the ZAEs.
- Sea level rise, the projections give a rise between 9 and 38 cm in 2050 then 86 cm in 2100.

2.4. National action plan to combat climate change in Cameroon

The frequency of extreme climatic events, the false starts of the rainy seasons, the recent floods, the recurrent droughts of which Cameroon is increasingly a victim, prove that climate change has ceased to be a strictly scientific question concerning a distant future. of the planet to become a real and significant problem for our society. Aware of this reality, the State of Cameroon has adhered to the United Nations Framework Convention on Climate Change (UNFCCC) and regularly participates in international climate negotiations. Since the COP in Bali in 2007, it has now been established that in the face of climate change, we must combine two types of action: the reduction of our greenhouse gas emissions to contain the rate of global warming; the adaptation of our societies to the now inevitable changes in the climate to limit its damage [24].

Although Cameroon does not contribute to the emission of greenhouse gases, climate change is perceptible, the climate there is increasingly unstable. Faced with these observed effects, the Cameroonian government is not indifferent and it is thus [26-28]:

- A climate change observatory is being implemented;
- Civil society has always led debates on the issue for the benefit of grassroots populations;
- The ongoing relaunch of the "green sahel operation";
- The creation within the National Assembly of a thematic group of parliamentarians and a network of parliamentary actions on the issue of climate change and sustainable forest management;
- The creation of two specialized ministries on the issue of environmental protection (MINEPDED (Ministry of the Environment, Nature Protection and Sustainable Development) and MINFOF (Ministry of Forests and Wildlife));
- The implementation of the framework law on the environment and sustainable development in charge of the education of actors (state, large social groups, households, etc.); etc

3. Effects of climate change in the Sudano-Sahelian zone of Cameroon

The Sudano-Sahelian zone is between 8th and 13th degrees north latitude (fig. 3). It includes the Monts-Mandara, the plains of the Far North and the Bénoué Valley. It extends over 102,680 km² and experiences climatic annual rainfall of 400 to 900 mm concentrated over 4 months (July to October). The average temperatures are close to 28°C, with very significant temperature differences (7.7°C annual average). The soils are generally vertic, clayey-sandy or halomorphic (hardés).

Figure 3: Sudano-Sahelian zone of Cameroon

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It is bordered to the west by Nigeria and to the east by Chad and the Central African Republic, and to the north by the Lake Chad basin (endangered) (fig. 4)

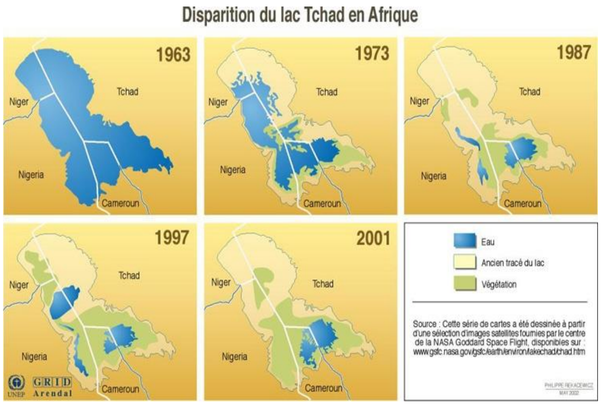

Figure 4 : Disappearance of Lake Chad [22]

Despite an unfavorable natural environment, the area has an average population density of around 37 inhabitants per km² with peaks of around 320 inhabitants/km² in the Mandara Mountains. Cultivable land represents 23% of the total area and about half of it is effectively developed. There are three main types of agriculture:

- traditional low-productivity agriculture where cereals (millet and maize), groundnuts and other plants such as okra or beans are grown around homes;

- improved rain-fed agriculture which has mainly developed around cotton cultivation, with the use of inputs (fertilizers, pesticides, and more recently herbicides) and animal traction which has led to a strong increase in maize soil;

- an intensive agriculture with a commercial vocation which uses irrigation and concerns rice cultivation in the hydro-agricultural developments of the Logone valley and the cultivation of onions and other market gardening products.

High demographic pressure is the major problem in the Sudano-Sahelian zone. The average cultivable area per rural inhabitant should drop from 0.3 ha in 1995 to 0.2 ha in 2020 in the Far North region. In the Mandara Mountains, with saturation thresholds exceeded under current conditions of use, this demographic pressure leads to many problems in the management of village land (increased conflicts between farmers and herders in the use of rural space; overexploitation resources leading to soil and woody cover degradation; precariousness of rural activities and incomes aggravated by frequent rainfall deficits and poor rainfall distribution) [28].
The degradation of natural resources and the precariousness of the living conditions of the populations constitute the main constraints in this area.

Uncontrolled emigration, the expansion of the agricultural front and transhumance areas towards the less densely populated and better watered areas of the North region constitute a threat to the parks and wildlife reserves which represent 9% of the total area of the area and about 40% of that of the latter region. This crucially raises the question of a reorganization of land use in this region.
Although all the agro-ecological zones of Cameroon are affected by the effects of climate change, the Sudano-Sahelian zone, the subject of our study, is the one most affected by the phenomenon. We can cite among others:

i) Difficult access to drinking water

Access to safe water remains low for the populations of the Sudano-Sahelian zone (North region: 35.4%); Far North region: 37.8%). People in most mostly rural localities are often called upon to get up early or travel long distances to access water (fig. 5).

Figure 5 : Difficult access to water

ii) Drought, arid or semi-arid, infertile lands with scarcity of rainfall

The scarcity of rains hampers agricultural development in the region, leading to drought, food insecurity, famine and poverty (fig. 6). In recent years, we have seen barely 2-3 rains.

Figure 6 : arid soil

iii) Recurrent flooding and silting of waterways

Floods are more and more recurrent (figs. 7 and 8) and several rivers have lost their surface area due to their silting up (fig. 9).

Figure 7: Flooding in Zina, October 2020

Figure 8: Flooding of roads in Maroua, October 2020

Figure 9: Siltation of the logone, March 2019

iv) Increased deforestation

Between 1990 and 2005, it was attributed to the collection of firewood, the main cause of the loss of 64 million ha of forest in Africa. [9]. Africa consumes about 89% of wood from forests or green spaces. In Cameroon, firewood is the most widely used fuel. Its consumption represents 77% of the national energy balance. In the Far North region in particular, firewood is the only source of energy accessible to more than 80% of rural and urban households. Energy supply households in the Far North region of Cameroon are more than 95% dependent on forest biomass. The level of consumption in the city of Maroua is more than 125,000 tonnes per year (Aboubakari, 2014). 15.3% of the Cameroonian population has access to cooking gas and in the far north 0.5% [18].

56.3% of the rural population of the Far North live in poverty. This situation has contributed to the increase in anthropogenic pressure on the vegetation cover. The uncontrolled exploitation of wood energy largely contributes to the progressive destruction of natural resources.

To this should be added the climate of insecurity that reigns in the region due in particular to the attacks perpetrated by Boko Haram (fig. 10)..

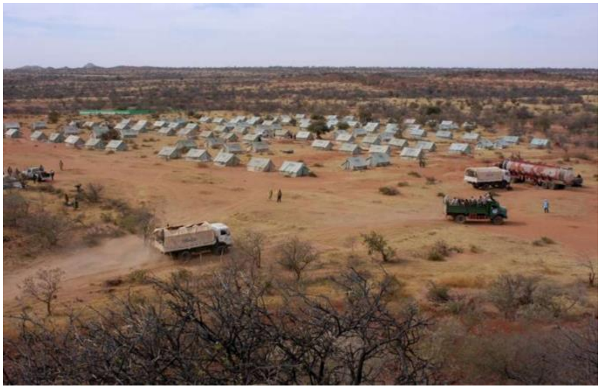

Figure 10: Refugee camp victims of Boko Haram

4. Adaptation measures

The government has put in place a set of programs including Operation Sahel Vert, which initially consists of slowing down the phenomenon of desertification through: reforestation and the installation of improved stoves (Bangui type); Then to improve the living environment of rural populations in order to fight against poverty. In our laboratory, we have carried out a series of works aimed at combating climate change. In this section we present some of the obtained results.

4.1. Use of jatropha curcas (pourghere)

Etymologically, Jatropha, from the Greek, iatros (doctor) and trophê (food), in reference to the medicinal use of the seeds, is a species of dicotyledonous shrub of the Euphorbiaceae family, native to Mexico in the neighboring regions of Central and South America, and, reaching 8 m in height. This perennial, drought-resistant plant with a longevity ranging from 30 to 50 years, can grow in marginal soils. In Europe, it is called pinion d'inde or pourghère (in French) or physicnut (in English). It is called “Madjidirnadé” or “colcoladjé” in the Fulfulde Fulani language of the Far North of Cameroon [29]. Jatrophacurcas seeds are ellipsoidal, 1-2 cm long, mottled black and coarsely pitted. The whole fruit contains 25% oil and the seeds 37%. Shelled seeds (almonds) contain per 100 g: water 3 to 6 g, energy 3100 to 3300 kJ, proteins 23 to 29 g, lipids 53 to 70 g, neutral

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detergent fiber 4g, acid detergent fiber 0.1-0.2g, ash 3.8g. The lipid content of whole seeds is 32-45%, with the seed coat accounting for 35-40% of the total seed weight [29].

Figure 11: (a) Stages of evolution in the ripening of seeds of Jatropha curcas Jatropha bud at the top, from left to right we have: the flower, the green fruit, the yellow fruit, the rotten fruit, the dry and black fruit, the seeds of a fruit and kernels of a fruit of Jatropha curcas.

i) Erosion control

When Jatropha is planted in living hedges, it helps to fight against soil erosion. The roots of the plant grow very close to the surface of the soil, fixing it like miniature dikes or clods of earth. These dikes slow down water runoff, allowing more water to penetrate the ground. In fact, the developed root system of Jatropha allows it to mobilize the elements of the deep layers of the soil. This root system, thanks to its rapid growth and its strong branching, seems interesting to fight against erosion. The association of crops with Jatropha is possible and would thus protect crops against wind and runoff water. [29] (fig. 12).

Figure 12: Roots of a young Jatropha curcas plant (left) and live hedge of the COPRESSA field, Maroua par le Jatropha (right)

ii) cooking fuel

Laboratory work has proven that raw Jatropha oil can be directly used as cooking fuel. Figure 13 shows the traditional Jatropha curcas oil extraction steps carried out in the Far North region of Cameroon. You can also use a Bielenberg press.

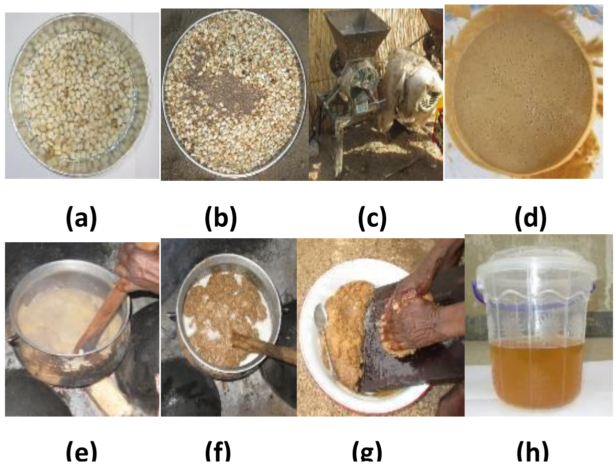


Figure 13: Traditional oil extraction steps from Jatropha curcas. (a). Dried Jatropha almonds; (b). Jatropha almonds roasted for 2 minutes in preheated sand; (c). Trituration of roasted almonds by a motorized machine; (d). Jatropha paste obtained (56° C.); (e). Mix paste + boiling water in a pot under low heat; (f). Dough cooked after 30 minutes and the supernatant oil in the pot; (g). Hand pressing of the cooked dough in 10 min; (h). Filtered Jatropha oil (a little dark).

Figure 14 gives a description of the mechanical extraction process using a Bielenberg press.

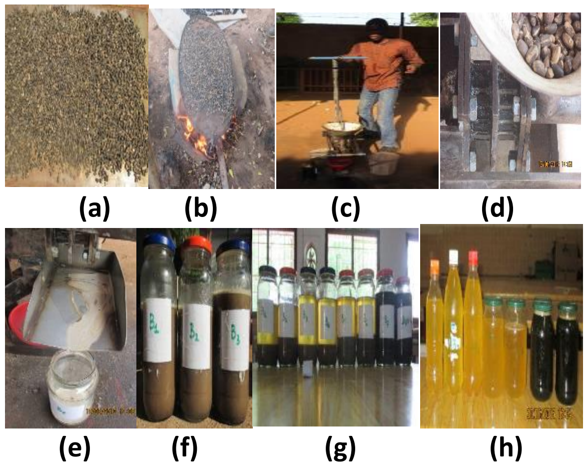
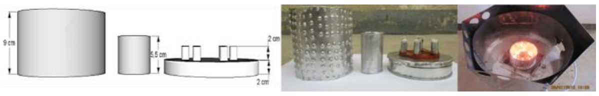
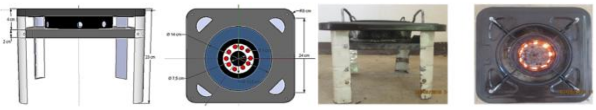


Figure 14: Étapes d'obtention d'HVPJ par extraction à la presse Bielenberg (a). drying the seeds in the sun; (b). heating the seeds in a fire; (c). pressing of the seeds (dried or heated) by the Bielenberg press (movement (return or cycle) exerted by the operator by means of the lever); (d). oil escaping (in the form of a white foam) between the interstices of the filter; (e). first raw Jatropha oil flowing into the receptacle towards the jar; (f). Crude oil laden with sediment; (g). Jatropha crude oil decanted for 10 days (visible separation of sediment from oil); (h). filtered and decanted oil (HVPJ).

However, for the latter to be competitive with wood, it should cost an average of 125 CFA francs per litre; the government could, for example, subsidize this sector. Jatropha crude oil can be directly used as cooking fuel in suitable stoves (fig. 15).



(a)



(b)

Fig 15:(a). 6-tube stove designed and built (3D model on the left) (b). 10-tube stove designed and built (3D model on the left)

iii) Soil amendment and livestock feed

After the oil has been industrially extracted, Jatropha cake (fig. 16) still contains about 20% oil (the seed contains 35 to 40%) and 55 to 64% protein. This protein and mineral richness potentially makes the meal a food supplement for breeding and an organic fertilizer.

Note that Jatropha oil can also undergo transesterification to obtain biodiesel. It can also be used to make household soap.

Figure.16: Jatropha cakes after mechanical (left) and traditional (right) pressing

4.2. Use of ecological dumplings from dead neem leaves (azadirachtaindica) and rice husks

Rice husk (fig. 17) is an important residue from rice mill hulling units. Depending on the variety, the percentage of hulls extracted during hulling by millstones or roller hullers is between 20 and 25%. rice husks are rich in cellulose and ash, particularly silica (SiO2 content evaluated at 20%). But rice husks have a low digestibility rate, which explains why they will not be used for livestock feed. The most important productions are located several kilometers from the town of Maroua, for example in Yagoua in the department of mayo-danay with a plot of 5300 ha irrigated each year and, in Maga in the same department with 6400 ha per year and of which production is around 55,000 tons, and the UNVDA produces 7,508 tons [30]. The share that is produced in the surrounding area is not negligible [14].

Figure 17: rice hull

Neem or margousier in french (fig. 18) is a tree native to India, belonging to the Meliaceae family, which are hardwood trees or shrubs. Neem is adapted to poor soils and has a tolerance to high temperatures and low [1]. It is found in arid and semi can be pl-arid areas of Africa, tropical Asia and in humid areas. Neem anted on sandy, stony land. It grows easily in soils with a pH of 6.2 to 7. Neem can be 20m or 30m in height and a circumference of more than 2m. Neem is a species rich in active substances that inhibit the activity of several microorganisms. Nimbrin and azadirachtin are the two major substances. It has a vertically cracked and brown bark, easy to dry wood and red-brown in color. Its leaves are grouped near the end of the branches and carry 5 to 8 pairs of toothed leaflets, opposite to the pointed tip. Its flowers are small with white petals. The fruits characterize the species. These fruits are about 18mm in length and are green to greenish yellow in color [1, 5]. Inside these fruits, there is a sweet pulp surrounding a seed. Dead leaves of neem trees cover the ground in households and roadsides, almost everywhere these trees are planted. Throughout the dry season, these trees lose their leaves, which constitute the bulk of household waste. Sometimes, they constitute thick layers preventing any regeneration because the seeds which fall do not reach the ground and do not manage to germinate. These trees, adapted to the tropical climate, are found everywhere in the Far North region of Cameroon, in North Cameroon and in other parts of the country. Given the availability of these leaves, it is possible to consider new uses as fuel [20].

(a)

(b)

(c) (d)

Figure. 18 : Neem (a) Neem leaves, (b) Neem flowers, (c) Neem fruits, (d) Neem seeds [31]

The use of fuels from dead neem leaves (azadirachta indica) and rice hulls contributes (figs. 19-22) to the fight against the energy crisis, deforestation, environmental degradation, and to the emission of greenhouse gases during the biological degradation of these biomasses.

Figure 19 : mixing and molding dumplings made from rice hulls

Figure 20 : mixing and molding dumplings made from dead neem leaves

Figure 21 : Improved pellet-type stoves

Figure 22 : Use of dumplings

4.3. Use of biochar from dead neem leaves (azadirachta indica), sawdust and rice husks

The production of biochar takes place in a pyrolyzer (fig. 23a). The biochar produced (fig. 23b) can be used as cooking fuel using an appropriate hearth (figs. 24-25) or as a soil amendment (table 3, figs. 26-29).

(a) (b)

Figure 23: (a) : Pyrolyzer, (b) : Biochar

Table 3: Elemental composition of biochar produced

Element	**Unit**	**Biochar from neem**	**Biochar from rice hulls**	**Biochar from sawdust**
pH	-	9.8(H_2O)	9 ($CaCl_2$)	9.2 (H_2O)
$C_{org.}$	%	48	44	23.61
C_{total}	%	48	44	-
N_{total}	%	5.46	1.1	1.06
O.M	%	-	-	40.71
P_{total}	%	45.97	-	0.684
Ca	%	0.65	4.6	30.49
Mg	%	0.56	0.49	3.68
Na	%	4.05	0.060	6
K	%	2.24	1.9	1.27
Fe	Mg/Kg	713.0	290.0	5469.58
Cu	mg/Kg	13.00	7.2	0
Zn	mg/Kg	185.30	71	93.83
Pb	mg/Kg	0.19	4.6	0
Cd	mg/Kg	-	<0.3	0
Cr	mg/Kg	0.03	8.9	0
Ni	mg/Kg	40.33	2.8	47.12
Mn	mg/Kg	175.16	120	0
S	%	-	0.12	-

Molybdenum	mg/Kg	-	0.43	-
Boron	mg/Kg	-	52	-
Arsenic	mg/Kg	-	<5	-
Aluminium	%	-	0.36	-

O.M= Organic material

i) As cooking fuel

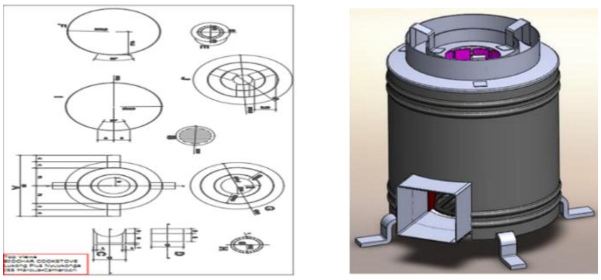


Figure 24: Biochar type cooker

Figure 25: Using biochar for cooking

ii) To amend the soil

(a) (b)

Figure. 26: (a) Onion field with biochar (on degraded soil - Maroua) (b) Onion field without biochar

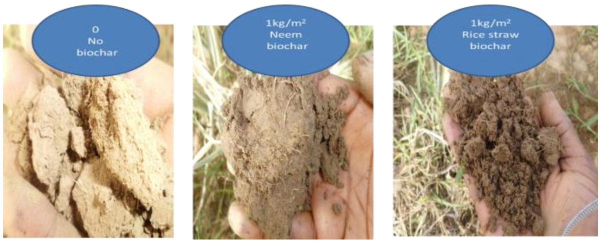


Figure 27. Soil moisture after two weeks of watering [32, 33]

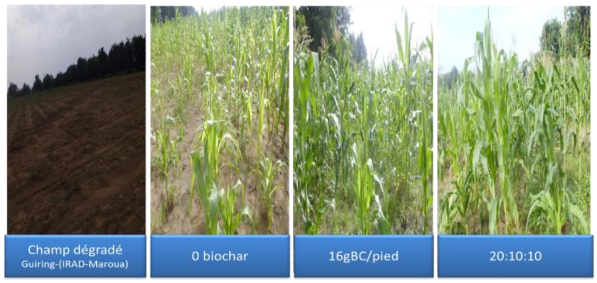


Figure 28: Use of biochar in a maize field, Maroua, [33]

4.4. Biodigester unit using neem leaves and cow dung as substrate

We have carried out conclusive tests in the laboratory in two biodigester units (cylindrical and fixed dome) (fig. 29-30) of one cubic meter using the mixture in a certain ratio of cow dung and pretreated neem leaves.

Figure 29 : Construction of an experimental cylindrical biodigester unit using dead neem leaves [32]

Figure 30: Construction of an experimental fixed dome biodigester unit using dead neem leaves ([32]

4.5. Experienced improved cookstoves

We have made modifications to conventional bangui-type stoves by using clay as thermal insulation (figs 31-34). We have also experimented with pellet

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and ecological coal type fireplaces (fig. 35), biochar type (fig. 36) as well as vegetable oil stoves (fig. 37)

i) Modified bangui type

Figure 31: Bangui-type improved stoves [32]

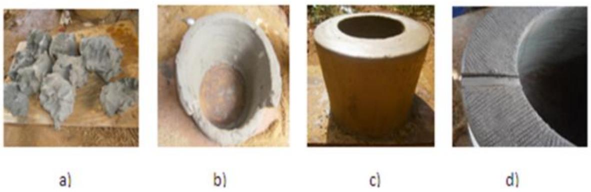

Figure 32: Steps in the manufacture of models for the removable load a) the banco, b) modeling of the hearth, c) obtaining a complete hearth, d) cutting of the hearth

Figure 33: Emission of smoke from the different types of stove a) the unloaded Bangui type improved stove, b) the loaded Bangui type improved stove, the F3P stove, d) the prototype

Figure 34: the level of soiling of the pots and the ground for the prototype and FABCM. a) soiling of the pot with the hearth loaded in a MINEPDED way. b) deposit of the ashes on the ground with the hearth loaded in a MINEPDED way, c) cleanliness of the pot used with the prototype, d) cleanliness of the ground with the use of the prototype.

ii) Pellet type fireplaces and ecological coals

Figure 35: Improved stoves such as pellets and ecological charcoal [32]

iii) Biochar type hearth

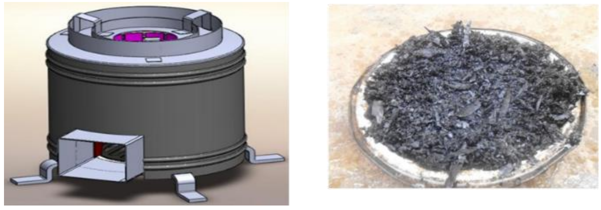

Figure 36: Biochar-type hearth [32]

iv) Vegetable oil fireplace

Figure 37: Vegetable oil cooker [33]

4.6. Photoirrigation

Solar irradiation in the Sudano-Sahelian region of Cameroon is very favorable (5 kWh/m2/day) for solar pumping projects to irrigate fields (photoirrigation). Several projects in this direction have emerged (fig. 38-41). Some organize themselves into a common interest group (CIG) for better profitability [34-39].

Figure 38. Photoirrigation system

Figure 39. Okra irrigation, Yagoua, [16]

Figure 40. Rice irrigation, Yagoua, , [16]

Figure 41 : Onion irrigation, Mora, , [29]

4.7. Valorization of slaughterhouse waste for energy and agriculture

We have carried out work to recover slaughterhouse waste into cooking energy (figs 42-44) or to improve the soil (figs. 45-46).

i) Eco-friendly charcoal

Dry digestate pyrolysis oven match water binder press

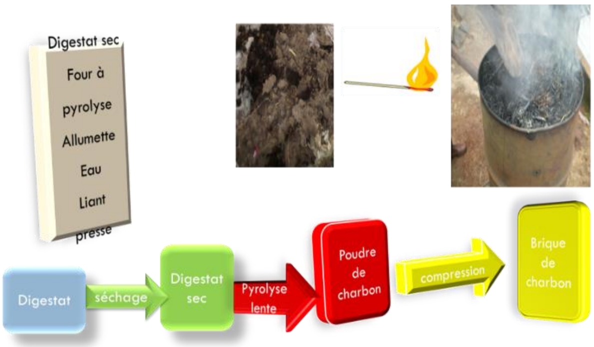

Figure 42: Production of ecological charcoal from slaughterhouse waste

Figure 43: Ecological charcoal obtained from slaughterhouse waste

ii) Biogas

Figure 44: Production of biogas from slaughterhouse waste

iii) **Soil amendment: Compost**

Figure 45: Production of compost from slaughterhouse waste

iv) Soil Amendment: Biochar

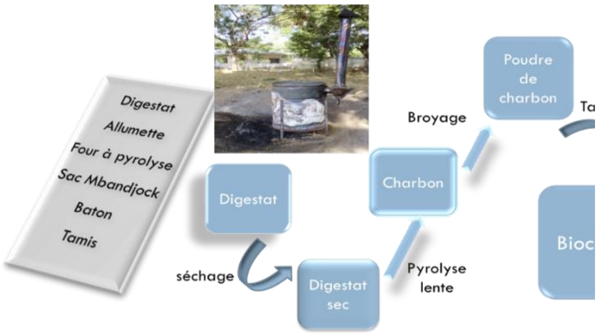

Figure 46: Production of biochar from slaughterhouse waste to amend the soil

5. Conclusion

In this work devoted to the multisectoral study of the impact of climate change and adaptation measures in the Sudano-Sahelian zone of Cameroon, we have some of the local action plans experienced both in the laboratory and in the field based on cooking energy, irrigated agriculture, environmental techniques (anti-erosion, soil amendment), hydraulics and water control. All these techniques are for some in the experimental phases and others in the mass diffusion phase.

References

1. A. Atikou. Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua (2014).
2. B. Edouard, Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua (2014).
3. C. Kapseu, N. Djongyang, G. E. Nkeng, M. Petsoko, D. A. M. Egbe. Harmattan. ISBN: 978-2-296-99102-6 (2012).
4. C. T. Sall, M. Fall, A. F. B. Mbow, B. Gueye. Support Fund for Local Adaptation Strategies (FSSA)" IED Afrique. (2011).
5. C. Babé, D. Kaoga Kidmo, A. Tom, R. R. Ngono Mvondo, B. Kola, N. Djongyang. Energy Reports 7-686-698. (2021)
6. D. Kidmo Kaoga, N. Djongyang, S. Y. Doka, D. Raïdandi. International Journal of Basic and Applied Sciences, 3 (1): 38-46. (2014)
7. F. Hamadou. Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua. (2015)
8. H. Bakari. Engineer's thesis, University of Maroua. HERA - GTZ Domestic Energy Program (2014).
9. I. Mamate Abakaka. Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua. (2015).
10. J. Domra Kana, N. Djongyang, A. Zakari, N. Kasi, D. Raïdandi, P. N. Nouck, W. T. Assastsé, T. C. Tabod , Geo-Energy and Geo-Resources, 7, 94. (2021).
11. J. Levy, A. Hickendorff, M. Niasse. Gestion des connaissances et adaptation aux changements climatiques en Afrique : manuel sur la capitalisation des expériences. PAA, PNUD. (2012)
12. N. Djongyang, A. A. Bouba, A. Nana, Kodji Deli, J. Domra Kana, A. Ombolo, Madi Ali. Harmattan. ISBN: 978-2-343-18071-7. (2019).
13. MINEPDED. Plan National d'Adaptation aux Changements climatiques du Cameroun (PNACC). (2020)
14. D. Kouamou. Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua. (2015)
15. R. E. Kouatchoua. Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua. (2015)
16. Lukong Pius Nyuykonge. Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua. (2014)
17. Lukong Pius Nyuykonge, N. Djongyang, V. Lendzemo Wirnkar, J. Fagbenro. Adeneyi International Journal of Energy and Power Engineering 4(2): 65-70. (2015).
18. M. do Livramento Medina SILVA, S. H. Barros Martins. (2009)
19. Mahi. Thesis of Renewable Energy Works Engineer, Higher Institute of the Sahel, University of Maroua. (2014).
20. G. Mai-Yanpa Gaodandi. Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua. (2014).
21. M. do Livramento Medina SILVA, S. H. Barros Martins. (2009)
22. Mekok Me Lande, D. Ulrich. Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua. (2014).
23. MINEPDED. Technical sheet on Central African-type improved stoves distributed in the Far North region. (2013).
24. MINEPDED. National Plan for Adaptation to Climate Change in Cameroon (PNACC). (2020)
25. National Action Plan to Combat Desertification (PAN/LCD), (2007).
26. MINEPDED. Conference on World Environment Day. (2015)
27. MINEPDED-PNUD. Consolidation of available information on risks and vulnerabilities in the North and Far North regions of Cameroon.117p. (2013)
28. http://www.alternativesdurables.org/informations/effets-du-changement-climatique-au-cameroun, march (2021)
29. Y. Bébé. Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua. (2015)
30. Ministry of Agriculture of Cameroon, April (2006)
31. www.toptropical.com

32. B. Moffo Dagueho Bertrand. Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua. (2015).
33. P. Nkapepouo. *Promotion de la vente du gaz domestique dans la ville de Maroua, une autre solution contre la déforestation dans la région de l'Extrême-Nord. (*2014).
34. N. Djongyang. Book review: C. (2012).
35. N. Djongyang.. Lambert Academic Publishing. ISBN: 978-3-659-64354-5. (2014).
36. R. Zieba Falama, M. Dawoua Kaoutoing, F. Kwefeu Mbakop, V. Dumbrava, S. Makloufi, N. Djongyang, C. Ben Salah, S. Yamigno Doka. Energy Conversion and Management 251 -114935. (2022)
37. R. Zieba Falama, F. Ngangoum Welaji, A. Dadjé, V. Dumbrava, N. Djongyang, C. Ben Salah, S. Yamigno Doka. Energies (ISSN 1996-1073), (2021).
38. M. Sinbai. Thesis of Design Engineer in Renewable Energies, Higher Institute of the Sahel, University of Maroua. (2015).
39. Yanimbock Mbekeli Hulda. Dissertation of Renewable Energy Works Engineer, Higher Institute of the Sahel, University of Maroua. (2013)