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Environmental Implications of Artisanal Fired Brick Manufacture in Kaélé and Yagoua, Far North Region of Cameroon

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Abstract: Currently, in the context of sustainable development, economic and environmental challenges drive the need to valorize local building materials. Unfortunately, population growth and the rapid development of the construction sector in sub-Saharan Africa and particularly in Cameroon are increasing the demand for this building material and consequently, its activities, hurting the environment. The present study focused on the environmental effects of the artisanal manufacturing of fired bricks in the Kaélé and Yagoua localities. Its objectives include a description of the traditional method of manufacturing fired brick and identifying its impacts on the environment. The method used to data collect is based on interviews conducted with workers in the survey areas. Data analysis shows that the high demand for fired bricks in these two localities involves the development of the activity in other villages and, in consequence, there is degradation, nutrient loss from the soil, socioeconomic problems, deforestation, and the disappearance of vegetable species. The manufacturing of that building material is done by craftsmen in unsafe conditions. Therefore, it is advised that to lessen citizens' exposure to environmental threats, government agencies, and other pertinent authorities promote community awareness and education.

1. Introduction

Earth is an ancient building material that has been used in many different ways around the world for thousands of years (Niroumanda, 2013). The first known shelters on Earth were outgrowths of transient, seasonal structures constructed of wood and bush and typically waterproofed with mud (Niroumanda, 2013). These initial shelters were known as pit huts. It was used effectively in various climatic zones, the application method depends on the type of soil, technical know-how, and tools as well as local traditions and customs of the community (Adam and Agib, 2001; Gramlich, 2013; Temga et al., 2015; Almssad *et al.,* 2022). With the rise of civilization, the adobe, a sun-dried mud-performed modular masonry unit, came into being (Niroumanda, 2013; Giamello *et al.,* 2016; Almssad *et al.,* 2022).

According to United Nations (2019) report, the world population is expected to rise to 9.7 billion by 2050, 2 billion more than the 7.7 billion in 2020. At present, a large part of the world's rural population still lives in earth buildings (FAO, 2006; 2019). This population growth, together with climate change, increases the pressure on housing demand. It is estimated that over 30% of the world's population still live in houses built using soil third-world which represents third- countries (Easton, 1996; Lynne *et al.,* 2000; McHenry, 2000; Minke, 2005; Rael, 2009; Rodríguez and Saroza, 2006).

Nowadays, in many regions of Sub-Saharan Africa and particularly in Cameroon, earth has long been used as the main raw material for the manufacture of crude and fired bricks because of their great abundance (Thibault and Le Berre, 1985; Tchamba *et al.,* 2012; Chaouki *et al.,* 2013; Frar *et al.,* 2014; Temga *et al.,* 2015; El Azhary *et al.,* 2017; Nzeukou *et al.,* 2013; El Ouahabi *et al.,* 2018; Mefire *et al.,* 2018; Yaboki *et al.,* 2021). The so-called modern materials such as concrete and steel are almost inaccessible for a large part of the population. This is due to the lack of their high costs. Then, raw earth construction made from these materials have not only low mechanical characteristics due to their physical property, but also because crude earth is often seen as a symbol of poverty and poor quality in contraposition to modern materials. In addition, they easily degrade in contact with water, causing major damage to soil structures and reducing construction durability (Temga *et al.,* 2013; 2015). According to Yaboki *et al.* (2021), the constructions made with earth material in these areas are permanently attacked by termites and are the subject of regular maintenance. To solve their housing problem, the population opted for fired earthen bricks which require high consumption of energy and accentuate deforestation (Yaboki *et al.,* 2021). However, it is well known that construction activity also contributes significantly to environmental pollution and global climate change.

In the Far North region of Cameroon, fired earthen bricks production has been done and often still is using archaic methods and rudimentary tools. Different techniques have been used for fired brick-making at the handicraft level in these areas. In general, they are very inefficient and energy-consuming. Moreover, these activities concern the majority of the population and their exploitation poses enormous environmental, economic, social, and even cultural problems. Specifically, in the rural communes of Kaélé and Yagoua, these environmental effects are often perceptible in the soil, water, and air on which human life depends. In addition, the studies linked to the environment are still in their early stages in this area. The only study that has been done thus far on the characterization of soils for use in agriculture or home construction (Yaboki *et al.,* 2021; Temga, 2013; Basga, 2015; Temga *et al.,* 2015; Basga *et al.,* 2018; 2020; Tiki, 2020). Additionally, we also note the work on the erodibility and degradation of soils carried out by Boli (1991), Seiny-Boukar (1992), Ibrahim *et al.* (2018), Souoré (2018), and Souoré et al. (2022). On the expansion of the fired brick activity in Kaélé and Yagoua localities, the current study was conducted to determine their effects on the environment.

2. Site characteristics

The study area is located in the Far North of Cameroon (**Figure 1**), characterized by a long dry season from October to April and a short rainy season from May to September, with the maximum in the month of August. The dry season prolong for about seven to eight months and the short rainy season was only for about four to five months (Olivry, 1986). Annual Rainfall varies from 700 to 900 mm/year and the atmospheric temperature is situated between 25-43°C (Suchel, 1987; L'Hôte, 1999; 2000). Maximum temperatures are reached in April, while minimum temperatures are observed in August when precipitations are abundant. The hydrography of the area shows a dendritic network characterized by the existence of seasonal rivers. The natural vegetation is relatively homogenous in terms of forage quantity and quality. It is covered by savannah and steppes vegetation (Letouzey, 1968). The flora is characteristic of the thorny steppes, consisting of tree and shrub savannahs with a very irregular herbaceous cover. The tree species observed are mainly Balanites aegyptiaca, Ziziphus mauritiana, Faidherbia albida, Anogeissus leocarpus, Combretum culeatum, Dichrosta chyscinera, Tamarindus indica, Acacia hockey, and Bombax costatum (Letouzey, 1968; Wang-Bara *et al.,* 2021). The herbaceous layer was dominated mostly by perennials and annual plants of the family of Graminaceae mostly Andropogon spp, Loutedia oogenesis, and Schoenefel diagracili (Wang-Bara *et al.,* 2021). The Agroforestry town of the localities of Kaélé and Yagoua is composed of some plants of Neem (Azadirachta indica), Moringa oleifera, and Senna sp.

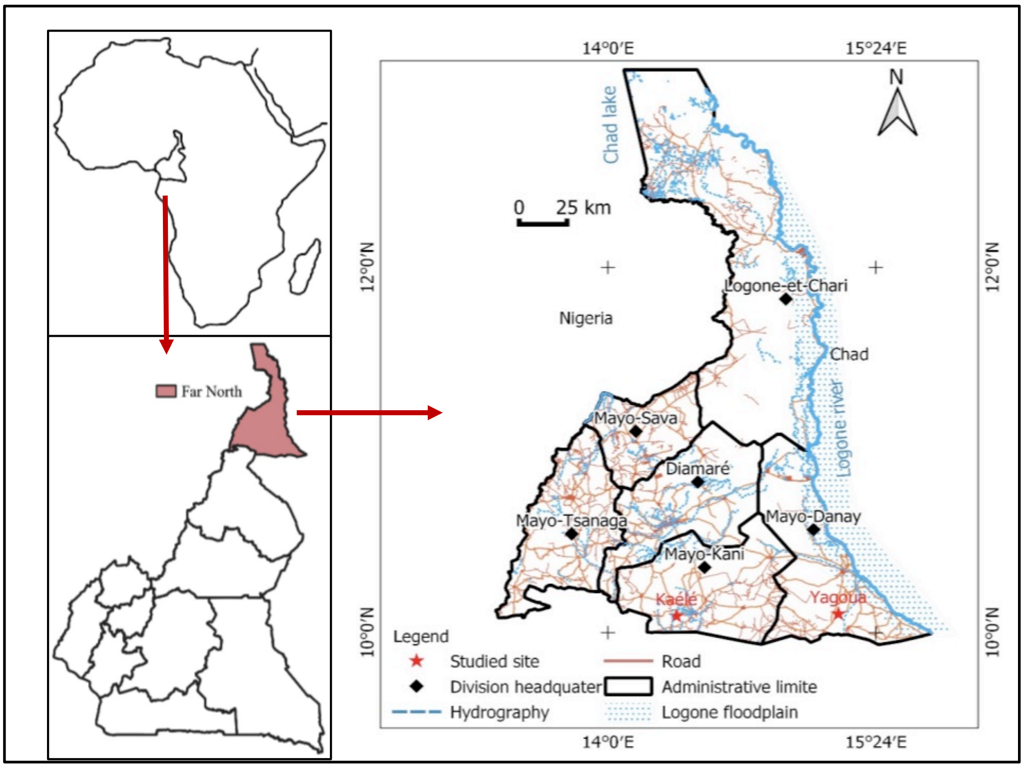

Figure 1. Location of the study area

The population of these localities is made up of a mosaic of peoples composed of sedentary and transhumant, and the anthropic factors due to human activities also influence the zone. The activities are centered on agriculture livestock farming and fishery. During the past 10 years, this area has been transformed into one of the most important Common pool grazing lands in the dry season for Arab and Fulbe pastoralists from Chad, Nigeria, Niger, and Cameroon. Climatic conditions and relief forms are favorable for the cultivation of cotton (Gossypium barbadense), rice (Oryza sativa), millet (Pennisetum glaucum), Sorghum (Sorghum bicolor), maize (Zea mays), Peanut (Arachis hypogea), Onion (Allium cepa), Gombo (Albelmoschus esculentus), Tomato (Lycopersicum esculentum) and Lettuce (Lactuca sativa), fruit trees (Seignobos and Moukouri, 2000; Mawouma *et al.,* 2022). The superficial formations are constituted of poorly tropical ferruginous soils, hydromorphic soils, holomorphic soils, lithosoils, and vertisols (Brabant et Gavaud, 1985; Seignobos and Moukouri ,2000; Basga, 2015; Basga *et al.,* 2020; Tiki, 2020). Geological formations include granite, quartzite, and pegmatite gneiss. Specifically, the study was carried out in the two localities, Kaélé and Yagoua districts.

3. Research methods

Being aware of the environmental problems, this study was approached in a methodical and multidisciplinary way. This research was also started based on cooperation with craftsmen who provided us with valuable information and insight into the real problems. The methodological approach consists of three main steps: choice of localities, data collection, and data analysis.

3.1. Choice of localities

The choice was made in areas where the practice of fired bricks activities has been constant for several years, with relatively intense brick-making activities. The survey was carried out in two municipalities of the region, distributed into two divisions as follows: Kaélé in the Mayo Kani division and Yagoua in the Mayo Danay division. In addition, almost all fired brick used in the Capital city (Maroua) and neighboring towns (Kaélé and Yagoua) come from these two localities.

3.2.Data collection methods

In the context of this work, the methods used to collect data included:

- Interviews of craftsmen, guided by questionnaires and semi-structured interviews on general perceptions of the impacts of artisanal fired earthen bricks activities on the environment in their locality. 50 craftsmen were randomly chosen in the localities surveyed for this study. The conditions were residence in the localities surveyed, permanent and nonpermanent handicraft producers including loaders and truck drivers.
- Consultation regarding unpublished reports of the Ministry of Environment, Nature Protection, and Sustainable Development.

3.3. Data analysis

Several difficulties were faced; the majority of divers were illiterates who had difficulty expressing themselves in French and the reluctance to communicate with the population surveyed. The local handicraft producers suspected that the investigators could be members of the government. Data collected were recorded on a table of Excel de Microsoft 2017. The ODK-Collect software on smartphones was used to collect the answer of peasants during the investigation.

4. Results and Discussion

4.1 Description of the handcraft method of fired brick activity

During the field investigation, several manufacturers of crude and fired bricks visited in Kaélé and Yagoua subdivisions. Brick production in this case was segmented into two main processes. In general, the first phase of earthen brick production is the same between the crude and fired ones. It employed readily available resources and needed little planning or preparation of the materials to be used. The production process adopted by artisans begins with a manual raw material preparation during which the clay soil is ground using a wooden stick (**Figure 2a**), followed by the addition of water gradually (**Figure 2b**), vegetable fibers (**Figure 2c**) and mixing using feet to obtain a homogeneous water distribution in the paste (**Figure 2d**). The proportion of different constituents (vegetable fiber, water, and sand) varies according to local soil characteristics, material availability, and manufacturer's experience. Thereafter, the dough is formed through the wooden mold, giving the typical brick shape

(**Figure 2e**), and sun-dried for two weeks (**Figure 2f**). The dimension of the mold is also considered to achieve the desired shape and size. Globally, the size of the bricks varies from one locality to another, with thicknesses ranging from 100 to 150 mm, widths from 150 to 200 mm, and lengths from 350 to 400 mm.

Figure 2. Methods of handcrafting adobes in the Far North region of Cameroon: (a) and (b) clay soil is ground using a wooden stick with the addition of water gradually, (b and c) the addition of vegetable fibers and mixing using feet, (e) brick casting, and (f) drying of bricks in the open air or sun drying

The second phase begins after sun drying, they are ready to use as crude bricks; in the case of firing, they are stacked in a typical scove kiln structure (**Figure 3a**), with channels in the bottom region to be filled by a solid fuel (**Figure 3b**) another fuel employed is also poured in the gaps between the bricks in the interior stack part, while the gaps are filled by dough in the exterior part to reduce heat dispersion. The firing phase usually lasts several hours (18-24h), (**Figure 3c**) and the fired bricks are left to cool down for several days before they are offloaded (**Figure 3d**).

During the firing phase, according to the location and accessibility, many solid fuels or wood (**Figure 4a, 4b**) used to integrate combustion included local tree nuts (**Figure 4c**), animal dejections and charcoal. Previous studies were done by International Labour Office (1984), on the brick kiln's performance assessment. These studies indicate that the wood consumption of the scove kiln can be estimated, which is about 0.16 kg of wood for 1 kg of fired bricks.

Figure 3. Phase of firing bricks (a) and (b) Stalking of bricks for firing, (c) kiln firing in progress, and (d) Offloading of fired bricks

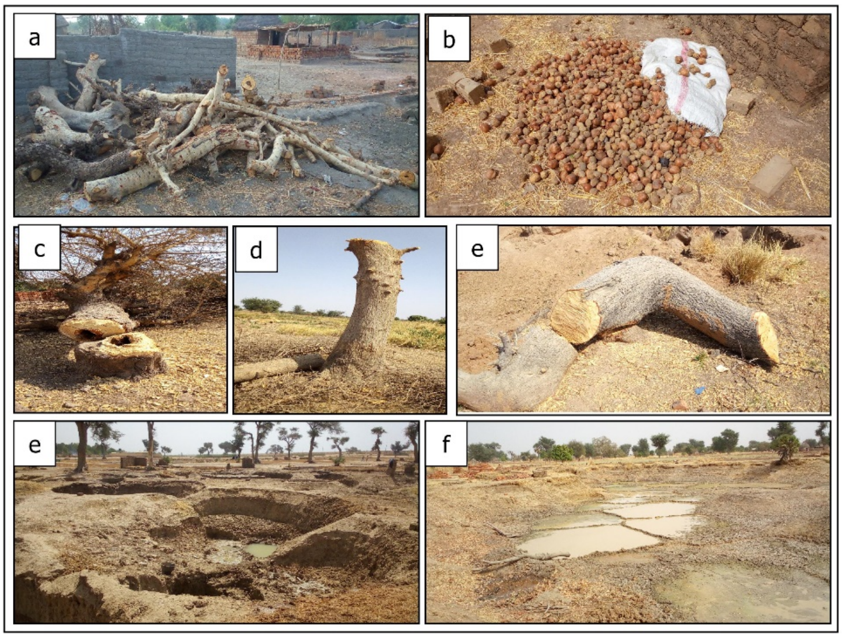

Figure 4. Solid fuels used for firing brick: (a) wood, (b) local tree nuts, (c, d, and e) trees cutting for firing bricks; and (f, g) soil degradation caused by clay extraction.

Table 1. Some prices for crude, fired and sand-cement brick in Kaélé and Yagoua (2022-2023)

Locality	Price of crude brick		Price of fired brick		Price of sand-cement brick	
	CFA	EUR	CFA	EUR	CFA	EUR
Kaélé	15-25	0.025- 0.04	50-150	0.075-0.23	200	0.32
Yagoua	25	0.04	150	0.23	250	0.4

Data analysis showed that the production of fired brick in Kaélé and Yagoua increase progressively. This trend is not only because fired bricks are more resistant to deterioration by atmospheric agents, but because it is perceived as a symbol of modern materials (Steyn and Bosman, 2010). In the same way, (United Nations Habitat, 2022; National Institute of Statistics, 2019) stated that the phenomenon of urban sprawl has increased the demand for building material in general and fired brick in particular. This explains the up-growing of Kaélé and Yagoua fired brick demand. Additionally, the manufacturing costs of fired bricks are low compared with those of sand-cement bricks (**Table 1**). Concerning production cost and selling price, different data were found according to the location and brick typology (**Table 1**).

4.2 Analysis of the environmental effects of fired bricks making

The present section was mostly focused on the analysis of the environmental implications of fired brick-making in the Kaélé and Yagoua areas. In this, area, the majority of handicrafts workers believe that soil, water, and wood used in firing brick production are infinite resources. The notion of infinite resources held by most handcraft in this area is more justifiable when one considers that about 70% of them stated they were producing more now than 5-15 years ago. Handicrafts were asked for their perceptions of the relationship between their activity and the natural environment in addition to how they felt about manufacturing trends.

About 60% of respondents believed that fired brick production had no negative effects on the environment. This can be related to a basic ignorance of what constitutes environmental consequences, or it might be motivated by a fear of being charged with a crime. When handcraft was questioned if they engage in any livelihood activities other than fired brick production, 80% and 90% declared at least one other source of income. In Kaélé and Yagoua area over 95% of artisan workers do not use any protective equipment. In most cases, handcrafts take no precaution other than to trust in God as their protector. According to **Table 2**, the environmental impact of fired brick activities takes place in two phases, notably during the mud brick production phase and the firing phase. During the mud brick production phase, the main impacts are land degradation; suppression of arable land; depletion of the diversity of plant species fertilizing the soil; open pits causing animal traps including acting as mosquito breeding grounds due to stagnant water collection after being abandoned by handicraft (**Table 2**). Other environmental impacts include competition among water users and risk of work-related accidents. During this phase, non-biodegradable plastic waste such as adulterated whisky packets, bottles, fragments of nylon cloth used to wet the mold, leather goods, and pieces of metal from damaged equipment are left on the production sites. Most of this waste is non easily biodegradable and therefore has long-term persistence in ecosystems, on the other hand, some of it, such as plastic and textile fragments is consumed by animals, and in turn, humans consume animals.

Table 2. Environmental impacts of firing brick activity

Activity phase	Sources of impacts	Component of the environment affected	Environmental impacts
Production of mud bricks phase	extraction of clay soil	soil/flora/fauna	nutrient loss from the soil
			depletion of the diversity of plant species fertilizing the soil
			suppression of arable land
		landscape	land degradation
			open pits causing health hazards
		water	competition among water users
		socio-economic	risk of work-related accidents
			delinquency and precocious abandon of studies
			alcohol consumption and conflicts among workers
			open pits causing animal traps including acting as mosquito breeding grounds due to stagnant water collection after being abandoned by handicraft
Conditioning the mud bricks for firing	brick firing process	soil	soil degradation/ denuded soil
		atmosphere	air pollution resulting from co_2 emissions and acute respiratory infection caused by smoke
		water	risk of groundwater contamination
		vegetation	destruction of vegetation/desertification
		socio-economic	conflicts among workers

The majority of these wastes contain chemical substances like copper, iron, zinc, lead, mercury, cyanides, cadmium, aluminum, acids and alkalies, etc. which reach the soil indirectly through air or directly with groundwater (Covelli *et al.,* 2021; Sethi and Gupta, 2021; Protano *et al.,* 2023). Several research has revealed that land affected by contamination could be risky to humans, ecological receptors like flora and fauna, and water quality (Bone *et al.,* 2010; Kumari and Mishra, 2021; Sethi and Gupta, 2021; Essien *et al.,* 2023). According to Fonge *et al.* (2011) and Wei *et al* (2010), these wastes left on the production site are responsible for soil contamination and poor water quality. They reduce soil biodiversity, deplete soil fertility, and disturb the biological equilibrium of the soil (Varjani *et al.,* 2016; Essien *et al.,* 2023). Wei *et al. (*2010) and Duong and Lee (2011) have shown that soils around the urban, and industrial areas, have relatively high concentrations of heavy metals and other toxic elements, linked to anthropogenic and industrial activities. The excessive extraction of clay material and the removal of topsoil have resulted in an enormous depletion of virgin clay (**Table 2)**. Therefore, soils constitute part of the vital environmental, ecological, and agricultural resources that must be protected for sustainable development and future generations.

The brick-firing phase mostly leads to deforestation, soil and groundwater contamination, and air pollution resulting from CO_2 and other gas emissions. The FAO (2006) report states that agriculture, in particular the expansion of crops and livestock ranching, constitutes one of the main sources of deforestation in Cameroon. In addition, firing bricks activities and charcoal production also plays a crucial role in deforestation in the Sudano-Sahelian area. However, forests are a crucial factor in preserving the vitality of the environment and human life. They are the main means of storing carbon, protecting from climate change impacts, preserving biodiversity (FAO, 2006; 2019; Garcia-Carreras and Parker, 2011), and serving as a reservoir of resources in the form of food, medicinal plants, and wood (Gbetnkom 2005). So, it would seem that policymakers in Cameroon should be concerned about deforestation since it poses a long-term threat to ecological sustainability and socioeconomic development. Soil is crucial for human survival on Earth. But, when waste is deposited on soil, it can accumulate heavy metal, trace elements, and organic contamination (hydrocarbons) causing the soil to become contaminated. These three types of pollutants are particularly toxic and difficult to degrade (Gao *et al.,* 2019). Any chemical substance or toxic chemical (pollutant) present in the soil in a higher quantity than usual hurts unintended organisms or poses a threat to the environment and/or human health (Sethi and Gupta, 2021).

Due to inadequate control of human activities, the main causes of groundwater contamination have been linked to anthropogenic activities such as discharging of untreated effluents (Akhtar *et al.,* 2020) and waste disposal. Acid rain that penetrates the soil and dangerous substances that release heavy metals are probable to end up in streams, rivers, lakes, and groundwater. Groundwater contamination, however, constitutes an important risk to the ecosystem and has a direct impact on human health, animals, plants, and socio-economic development (Kumari and Mishra, 2021; Li *et al.,* 2021; Chukwuma *et al.,* 2023).

According to Shakir and Mohammed (2013), atmospheric emission as SO_2, CO_2, NOX, VOC, CH_4, and particulates are generated in all steps of the firing bricks process. High temperature in the kiln is responsible to produce thermal NOX as well as fuel NOX (Shakir and Mohammed, 2013). Jeorge *et al.* (1998) stated that pollutant gasses originated from the raw material emitted from the brick kiln as well as the energy consumption in Canadian brick plants. According to his investigation, the pollutant emissions include fluorine (0.7- 4) ppm in stack gasses as well as SO_2 and CO_2. The environmental impacts of fluorine and chlorine are responsible for acid precipitation, and the possible resulting acidification of surface water as well as tree and crop damage (Jeorge *et al.,* 1998). Syed *et al* (2009) investigated the role of the fired bricks-making industry on deforestation and greenhouse gas emissions in Sudan. He stated that the energy consumption in the annual deforestation associated with the fired bricks making for the whole of Sudan is 508.4×103 m^3 of wood biomass, including 267.6×103 m^3 of round wood and 240.8×103 m^3 branches and small trees.

Conclusion

Based on the intensive and comprehensive study which has been conducted by the authors of this work on the fired brick production in Kaélé and Yagoua localities, the following conclusions can be drawn: Data collected in the field showed that the production of fired brick increased gradually and they are affordable and accessible, most appropriate for house construction. This explains why the population of the neighboring towns is highly interested in using this product. The system adopted by the handcraft for fired brick production has brought about environmental problems such as land degradation, nutrient loss from the soil, deforestation, socioeconomic problems, etc.

This paper suggests that, to make craftsmen aware of the consequences of the activity of fired bricks on their health and on the environment. It will be required to suggest the adoption of appropriate procedures for the defense and restoration of the soil after the works to prevent the deterioration and loss of soil nutrients. It is also recommended to seek an alternative fuel and promote the usage of renewable energy for the firing brick. In this context, green building practices have been recognized as a promising approach to reduce the negative environmental effects of construction activities.

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