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Thermal comfort and energy consumption in modern versus traditional buildings in Cameroon: A questionnaire-based statistical study

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HIGHLIGHTS

- Traditional buildings are more comfortable during the two seasons.
- In modern habitats, inhabitants want "more air".
- More than 80% energy used came from biomass and oil.

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ABSTRACT

The present article reports the results of a questionnaire-based statistical study of subjective answers by inhabitants regarding thermal comfort and energy consumption in their area of residence. This study was conducted in five towns of four Cameroon regions with different climatic conditions (center, littoral, west, and east). The questionnaires were distributed in more than 500 modern and traditional buildings during two seasons: a long rainy season (mid-March to mid-November) and a short dry season (mid-November to mid-March). The physical measurements of air temperature, relative humidity, and wind speed were performed simultaneously. The results showed that the traditional buildings were more comfortable during the two seasons. The data revealed that 51% of the occupants in traditional buildings voted for "no change" versus 37.6% in modern buildings. On the other hand, 73.4% of the occupants of modern buildings desired greater humidity versus 28% of traditional buildings. Overall, the inhabitants of modern habitats desired "more air," while those of traditional habitats preferred no change in their environment.

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1. Introduction

Thermal comfort can be defined as the situation in which a person feels neither cold nor warm in a given atmosphere. Thermal comfort in a living environment is very important not only for good health but also for factors like productivity of an individual or an occupant. It depends on the subjective parameters such as age, sex, health, origin of an individual, and clothing. It has been proven that, within an environment with the same characteristics and climate, the thermal sensation and preferences for the same differs among individuals [1]. This preference always varies according to the place of study and its climatic condition. Thermal comfort is very important not only for health but also for the productivity of the occupants. In fact, thermal comfort greatly affects the efficiency of work by an individual as well as the production and social costs. Consequently, the conditions for comfort should be appropriate for the well-being, productivity, and work efficiency of the inhabitants [2]. Thermal comfort heavily depends not only on environmental factors but also on physical, physiological, and psychological aspects. Satisfaction with the thermal environment is a complex topic, and the subjective responses are extremely variable. The main purpose of a building is to offer a comfortable and healthy indoor environment to its occupants during two important seasons of this region. This condition is essential for the occupant's daily productivity [3]. In addition to the resistance offered by the clothing and human activity, air temperature, relative humidity, and air movement also play an important role in the indoor thermal comfort. Researchers worldwide are presently focusing on the energy efficiency of buildings. Thus, international norms imply varieties of ranges of comfort. In the sub-Saharan region, the climatic study of the environment and local materials are not always considered by the architects during the designing of buildings, because of which, most modern buildings are not comfortable.

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The passive methods ensure the thermal comfort of the indoor environment by providing a healthy and sufficient energy [4,5]. Some occupants are obliged to depend on the ventilation systems that consume high energy to control the indoor air quality. Nowadays, various climatic regions seek comfort parameters suitable to their environment. This topic has been widely studied in continents like Europe, America, Asia, and Africa, but very few studies address the residential environment in the sub-Saharan region [6–10]. Energy efficiency is important for the use of energy in the residential sector. The different techniques of energy savings however remain unknown in most modern residences in Africa. The consumption of energy for cooling or heating is an important factor to be considered in the total residential consumption of energy. Green house gas reduction can be achieved by using traditional buildings techniques that consider the type of building material, particularly the locally available construction materials. The energy demand increases as the population increases in a particular region. African policy in the domain of energy is not yet well-defined, particularly in the domain of renewable energy. In Cameroon, which is the second-most forest occupied region in Africa with an area of about 21 million hectares (as estimated in 2006 [11]), 98% of the poor households still use firewood as their main source of energy [12]. With energy consumption between 0.29 and 0.32 tep/hab, more than 80 ktep electricity is consumed in the residential area of this region [13]. This rate remains slow in consideration of the increasing demand.

The present statistical study was conducted using subjective answers on the thermal comfort and energy consumption in traditional and modern buildings in the equatorial area of Cameroon, comprising of five towns from four regions of Cameroon with different climatic conditions. In order to compare the subjective answers of the questionnaires with the physical estimations, we employed the adaptive approach by distributing questionnaires and simultaneously measuring the air temperature, wind speed, and relative humidity of the study area.

2. Methodology

2.1. The study areas

Cameroon is divided into three climatic zones, namely, the Sudanese, the sudano-Sahelian, and the equatorial regions. Cameroon is characterized by an equatorial climate with two main seasons of equal amplitudes: a long rainy season from mid-March to mid-November (8 months) and a short dry season from mid-November to mid-March (4 months). The study was conducted in the equatorial cities of Nkongsamba (litoral region), Douala (coastal region), Bafang (western region), Yaoundé (central region), and Bertoua (eastern region).

The city of Nkongsamgba is located in the Moungo division, which is about 140 km from Douala, the economic capital of Cameroon. Nkongsamgba is located on the western slopes of the Manengouba mountain (2396 m) and at the foothills of the Nlonako mountain (1822 m). This city has a long dry season (from November to March) and a long rainy season (from July to October).

Douala is the main business center and one of the largest cities in the country. The climate of Douala is equatorial, with heavy precipitation, especially during the rainy season from June to October. In the dry season, from October to May, the air is very dry.

The city of Bafang is located in the western region, particularly in the Haut NKam division. Its population was estimated to be approximately 29,300 in 2010. The climate of this city is of subequatorial monsoon type with two seasons, including a rainy season from March to October and a dry season from November to February. There are two different micro-climates depending on the altitude. These micro-climates are warm and humid in lowland, but moist, cool, and attenuated.

The Yaounde city is built on several hills and has a picturesque setting with a relatively "fresh" climate. Yaounde is the capital of the central region and also the political capital of Cameroon. This city is located approximately at 300 km from the Atlantic coast and has a temperate sub-equatorial climate with four seasons, including a large dry season (mid-November to late-March), a short rainy season (April to mid-June), a short dry season (mid-June to mid-August), and a long rainy season (mid-August to mid-November). It is built on seven hills and had a population of about 2.5 million in 2011. Since the early 90s, the population increased with a growth rate of 7% per year.

Bertoua is located in the eastern region, within the Lom-et-Djérem subdivision. This town is located at 350 km from Yaoundé; it is the biggest forest region of Cameroon and the main development center of the region. It is supplied from the northern to the southern region by the Djadombe river. It is characterized by a subtropical climate with four seasons: a long dry season from December to mid-March, a short rainy season from mid-March to mid-May, and a long rainy season from mid-September to November. The rains in this region is relatively heavy (1500–2000 mm of rains per year). The Bertoua population is increasing due to the immigration of population from other villages and towns in Cameroon as well as other regions of the country and the neighboring country (Chad, RCA, Congo-Brazzaville, Nigeria). The active population of Bertoua majorly includes young people who work in the informal sector, particularly the transport sector, which is actually a privilege. Because of poverty, the access to education and health here is low.

Detailed characteristics of the different study areas is given in Table 1.

2.2. Instrumentation and field measurements

In this study, the indoor air velocity, relative humidity, CO_2 level, temperature, and the light intensity of the study areas were measured by thermo-anemometers (C.A1226; CO_2 Monitor model $CO_2$00, and a Light Meter IM-1308, respectively). Simultaneously, the outdoor temperature, wind speed, and relative humidity values were obtained from the Weather Station System of the five cities. The main characteristics of the measurement system used in this study are depicted in Table 2. All the equipments were calibrated before each experiment to ensure reliability and accuracy in the readings taken during the field studies.

Measurements were taken every 10 min at a height of 1.5 m from the ground level in strict accordance with the prescriptions of the ASHRAE Standard 55 and ISO 7730 Standard [14]. The

Table 1
Some characteristics of different cities.

City	Douala	Nkongsamba	Bafang	Yaounde	Bertoua
Latitude	4.067N	4.983N	5.167N	3.850N	4.58N
Longitude	9.717E	9.883E	10.083E	11.517E	13.68N
Altitude (m)	10	900	800–1100	600–800	650–680
Temperature (°C)					
Maximum	34	32	30	33	30
Minimum	18	16	14	15	14
Relative humidity (%)					
Maximum	100	97	95	98	99
Minimum	49	38	40	55	60
Wind speed (m/s)					
Maximum	1.2	2.5	1.9	3.5	2.8
Minimum	0.8	1.4	0.6	1.1	0.9
Area (km^2)	210	340	80	180	100