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Neo-Vernacular Architecture in Nawdéba Country in Northern Togo: Analysis of Elements of Sustainability, Vulnerability to Climatic Hazards and Thermal Comfort of a Social Hall at CIDAP (Centre International de Développement Agro-Pastoral)

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Abstract

Due to rapid urbanization, climate and socio-economic change, vernacular architecture in the Kara region of Togo is now facing mutations that threaten its existence. In the Kara region, new forms of housing, inspired by ancestral building practices and green technologies, are emerging as neo-vernacular architecture. This study aims to evaluate the overall performance of the CIDAP social hall, which is considered a model of neo-vernacular architecture. Through a series of both qualitative and quantitative tools, including the VerSus tool, the PTVA method and the calculation of the temperature difference ratio (TDR), the CIDAP social hall was analyzed regarding the criteria of durability, vulnerability to climatic hazards and thermal comfort. This work indicates that this building achieves a sustainability score of 88.33%. In terms of vulnerability to climatic hazards, the vulnerability index is around 0.392 for heavy rainfall, 0.389 for high heat and 0.309 for strong wind hazard. For thermal behavior, the TDR is of the order of 0.634. All these results reveal a satisfactory performance of the CIDAP social hall in terms of durability, vulnerability and thermal comfort.

Keywords: vernacular architecture; physical vulnerability; thermal performance; sustainable architecture; resilient architecture

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1. Introduction

1.1. Context and Problem Statement

According to data published by Togo's national meteorological authority ANAMET (Agence Nationale de Météorologie du Togo), the Kara region, along with several other regions of the country, has been experiencing pronounced climate change phenomena in recent decades. Over the period spanning 1990 to 2023, ANAMET records indicate a discernible upward trend in mean annual temperatures, rising from approximately

27 °C during the 1990–1999 decade to 28 °C over the 2000–2023 period. With regard to precipitation patterns, while the overall trend points to a gradual decline in annual rainfall, the region is increasingly subject to episodes of intense precipitation concentrated within short temporal intervals, which have resulted in recurrent flooding across the territory [1]. These climatic phenomena have resulted in considerable material damage, as well as numerous injuries and loss of life. Over the course of this period, a significant number of school buildings have also sustained substantial structural damage, most notably the detachment of metal roofing elements [2]. Apart from climate change, the demographic projections produced in Togo also indicate a population growing at an accelerated pace. In November 2022, the 5th RGPH (Recensement Général de la Population et de l'Habitat) estimated the Togolese population at 8.09 million inhabitants [3]. According to the National Institute of Statistics and Economic and Demographic Studies (INSEED), the urbanization rate will evolve from 42.9% in 2022 to reach 50% by 2026 [4]. The 5th General Population and Housing Census (RGPH) also raised concerns about the population growth in secondary cities. In certain cities, like the city of Kara, the population has almost doubled; estimated at 94,900 inhabitants in 2010, the population of Kara in 2022 was 158,090 inhabitants [3]. In the face of the escalating climate emergency and accelerating urbanization, informal construction is proliferating at an uncontrolled rate. These emerging forms of housing are characterized by a progressive abandonment of traditional construction methods and techniques [5]. In Africa, informal constructions represent a significant portion of 50 to 75% of the built environment [6]. They are mostly made of concrete walls and metal roofs. Choices made during construction can lead to thermal discomfort inside buildings, particularly in rural areas where air conditioning equipment is absent. In a hot-climate environment, the roof of a building can contribute up to 50% of the building's thermal loads depending on the material used for its construction [7]. Modern constructions tend to exhibit greater thermal sensitivity to intense heat, rendering them increasingly difficult to inhabit in the absence of energy-intensive air conditioning systems [8]. In urban areas, although air conditioning devices are present (fan, split), they require a significant amount of electrical energy that existing power plants struggle to support due to their limited production capacity [6]. Over the past fifty years, energy considerations have been neglected in the design of buildings in Africa [6].

Togolese architecture, which for a long time resisted external influences, is now confronted with profound transformations that increasingly threaten to erode its cultural values. The visible changes spanning socio-economic, cultural, and technological dimensions reflect a deep-seated upheaval within Togolese society. Concrete and imported manufactured materials dominate modern architecture in Togo, making it completely "deterritorialized." The built space has completely severed its connection with the environment, raising increasing questions about its relevance. "Reterritorializing architecture" to make it harmonious with its immediate environment is one of the crucial challenges of the 21st century and will allow for better understanding of the future [9]. In this perspective, actors in the construction sector are attempting to reintroduce elements of vernacular architecture in order to achieve thermal comfort and sustainability [10,11]. Vernacular architecture is defined as architecture inspired by popular traditions that develops its own characteristics in a specific region, using local materials, construction techniques, and traditional forms of that region [12]. It is worth noting that traditional architecture is subordinate to vernacular architecture. While the concept of "vernacular" pertains to a specific region and its associated social group, the notion of "traditional" relates primarily to the temporal dimension. Consequently, the term "vernacular architecture" is more encompassing in scope, subsuming within it the characteristics and elements of traditional architecture. Vernacular architecture may thus be understood as the traditional and natural means by which communities shape their habitat

in response to their specific needs [13]. It uses simple methods (organic shapes, materials with high thermal inertia, integration of green spaces, and green roofs) to improve thermal comfort and prevent overheating. The architect Bernard Rudofsky is one of the pioneers in theorizing vernacular architecture. Through his landmark photographic exhibition Architecture Without Architects, held at the Museum of Modern Art (MoMA) in New York in 1964, Rudofsky brought to light qualities of vernacular built environment production that had hitherto remained largely unrecognized within architectural discourse [14]. Building upon Rudofsky's pioneering work, Paul Oliver, in his seminal contribution "The Need for a New Approach" (1969), demonstrated that vernacular architecture constitutes a rich repository of knowledge and a valuable source of inspiration for architectural practice. He advocates for a structuralist approach to building that must be contextualized within society, as spatial practices vary across cultures [15]. In 1972, Amos Rapoport established the vernacular conceptual framework and analyzed the determining elements of habitat. For Amos Rapoport, vernacular architecture is the direct and unconscious translation of a culture into material form, reflecting its needs and values as well as the desires, dreams, and passions of a people [16]. Through vernacular constructions, humans sought a state of balance with nature instead of dominating it [16]. It is thus a response to the need for balance between the different uses of its inhabitants. It can be applied in both urban and rural areas through public or private construction projects.

1.2. Theoretical Foundations of Vernacular Architecture and Critical Regionalism

The renewed interest in vernacular architecture, while particularly prominent in contemporary discourse, is by no means a recent development. It constitutes, in fact, the conceptual foundation of one of the most significant theoretical frameworks in modern architecture: critical regionalism. Critical regionalism advocates for an architectural approach that is attuned to the cultural, climatic, and topographical specificities of each given territory. In doing so, it draws upon the legacy of vernacular architectural traditions while simultaneously integrating contemporary construction techniques and methods. In 1981, architect Alexander Tzonis and historian Liane Lefaivre, through an article titled "The Grid and the Pathway: Architecture in Greece," introduced the term "critical regionalism" to offer a dialogue between traditional local architecture and the realities of universal architecture to achieve an appropriate regional architecture [17]. Kenneth Frampton theorized critical regionalism and summarized this approach in six points [18]. First, K. Frampton criticizes the current capitalist world, where economic and high-tech production govern construction at the expense of culture. Secondly, K. Frampton opposes postmodernism, which he considers a simulacrum of art that only feeds a mass culture by proposing reactionary architecture. In the third point, like A. Tzonis and L. Lefaivre, K. Frampton advocates for a backward-looking regionalism that questions and draws inspiration from the vernacular architectures of the past rather than copying them exactly. He argues that critical regionalism must cautiously adopt new technologies with great restraint. Fourth, K. Frampton puts forward the idea that the regionalist must integrate the characteristics of a place that represents a space defined by presence and allows humans to identify and orient themselves. In the fifth point, K. Frampton advocates for a balance between the environment and cultural heritage. K. Frampton opposes the use of air conditioning, which he considers a form of domination by a universal technique that does not respect the unique climate of a region. Finally, regionalism, according to K. Frampton, must complement the notion of perception, which until now has been limited to the visual, with the notion of tactile as a plurality of human perceptions. Humans experience tactile value through these five senses. It is a set of sensory perceptions, such as the intensity of light, darkness, heat and cold, the sensation of humidity, the smell of materials... For K. Frampton, considering

the notion of tactility is a way to restore the proximity of humans to their environment. The six points of the critical regionalism approach, according to K. Frampton, provide clear strategies that explain an architecture inspired by the past that carefully integrates modern techniques to create meaningful places where humans come closer to their environment. This approach has led to the emergence of several initiatives for virtuous and environmentally respectful architecture. It has fostered a renewed interest in vernacular architecture, which advocates respect for the place or environment of the project.

1.3. Vernacular and Neo-Vernacular Research in Sub-Saharan Africa

The Egyptian architect Hassan Fathy, a key figure in African architecture, has been among the most influential advocates of vernacular architecture on the continent. In his view, every region of the world possesses its own distinctive local architectural forms and details, and the built heritage of each territory represents the remarkable outcome of a harmonious interplay between the collective imagination of its people and the inherent demands of the natural landscape [19]. The works of H. Fathy highlight the ingenuity of ancestral construction techniques using natural materials that are found in most African societies. In the West African sub-region, the research work of Thierry Joffroy on the royal courtyard of Tiébélé, a major site of Kassena heritage in Ghana, provides rich documentation on a model of vernacular architecture with defensive characteristics and highly symbolic wall paintings or decorations [20]. In Burkina Faso, architect Basile Kéré, through his research on architecture and constructive cultures, demonstrates that traditional housing is not just a shelter but a vector of constructive knowledge [21]. This knowledge manifests through a great architectural variety, a technical mastery of local resources (materials, workforce, energy), and an intelligent adaptation of populations to their environment and historical past. B. Kéré denounces the impact of accelerated urbanization and the widespread use of imported materials, which primarily lead to the loss of diversity in vernacular housing and the standardization of construction methods [21]. Just like B. Kéré, Maria Aguilar-Sanchez et al. have also conducted studies on vernacular architecture in Burkina Faso [22]. These authors analyzed Burkinabé vernacular architecture in terms of thermal performance. Their study revealed that contemporary vernacular architecture is a complete failure in terms of thermal comfort. The use of imported materials, such as metal sheets, causes overheating of interior spaces, with temperatures exceeding outdoor temperatures by 1 to 3 °C. For Maria Aguilar-Sanchez, contemporary vernacular architecture inspired by the Western model neglects the importance of the bioclimatic principles of traditional vernacular architecture [22]. This reflection is also shared by María Lidón de Miguel, whose research has revealed that traditional Burkinabé architecture is undergoing a major cultural and technical depreciation [23]. Local populations in Burkina unjustly perceive earth material as "non-permanent" and precarious. The impact of colonization conveys the idea that traditional housing, with its decorations, is primitive housing, leading to this negative perception [23]. Madina Yasmine Adjibade also studied the characteristics of vernacular housing in the Bissa region of Burkina Faso [24]. She demonstrated the durability of traditional vernacular architecture and compared, using the VerSus tool, the durability of contemporary popular architecture to that of a new vernacular architecture created by the Burkinabé architect Francis Kéré, 2022 Pritzker Prize winner (the most coveted award for renowned architects). It emerges from this study that the new vernacular architecture, specifically the teachers' houses in the Gando school complex, presents a durability score of 64% compared to 38% for contemporary popular architecture [24]. Although it is the evolution of traditional vernacular architecture and the preferred choice of the populations, contemporary popular architecture presents flaws in terms of thermal comfort and cultural adaptation [24]. In Northern Togo, the work of Sébastien Moriset et al. on the conservation

practices of the Sikien (fortified dwellings of the Batammariba people) also highlighted a model of sustainable architecture rich in a system of material and immaterial values [25]. The architect Atsou Fiéfonou Akouété has proven that postcolonial architecture in Togo is not bioclimatic, in stark contrast to precolonial and colonial architecture, which is [5]. According to the work of Y. Modeste Awoussi and E.K.A. Domtse, the vernacular habitat in the Kara region is sustainable at a rate of 85% for habitats in the Nawdéba area and 83.33% for habitats in the Kabiyè area [26].

In practice, within the construction sector, several notable projects, among them the works of architect Francis Kéré in northern Togo, have demonstrated that the accumulated wisdom embedded in traditional construction solutions can effectively supplant the need for contemporary mechanical air conditioning systems. Through these built works, Kéré illustrates that an architecture firmly grounded in its local context has the capacity to serve as a genuine source of innovation, yielding appropriate and contextually responsive solutions for both the Global North and the Global South [27]. He uses locally available materials to create buildings that offer artisanal solutions adapted to the local context. By combining traditional construction practices with new technologies, he designs culturally rooted projects while remaining contemporary. F. Kéré believes in designing buildings modestly, conceiving them locally, and implementing them socially. This perspective is equally shared by local organizations such as the Nubian Vault Association, which advocates for an architectural approach that is both ecologically respectful and less demanding in terms of resource consumption [28]. While considerable progress has been made in the implementation of vernacular architectural practices across the continent, the overarching objective of adequately addressing the pressing socio-economic and environmental challenges confronting local populations has yet to be fully realized [24]. In most cases, issues such as economic inaccessibility, difficulty of reproduction, lack of adaptability, and architectural pastiche hinder the popularization of vernacular solutions [29]. These challenges call into question the viability of vernacular architectural solutions, raising critical concerns regarding their long-term sustainability and their capacity to adequately respond to the lived realities and practical needs of contemporary populations.

"Reterritorializing architecture" does not simply mean promoting ancestral construction practices. It is therefore not about fully copying these practices, but rather about drawing inspiration from them and adapting them to the needs of new generations. Faced with contemporary constraints of comfort, solidity, and aesthetics, it has become urgent to revisit this vernacular construction knowledge using technologies that prioritize respect and environmental protection. It is therefore time to think about a new vernacular architecture in line with the current socio-economic and environmental dynamics of populations. This new vernacular architecture, referred to as 'neo-vernacular' in this research, must be at the crossroads of the social, cultural, economic, and environmental realities of these populations. Examples of this form of neo-vernacular architecture exist in the Kara region. The observation is that research on these forms of habitats in the region mostly focuses on descriptive aspects (construction methods, lifestyle, culture) and elements of sustainability. Researchers have poorly documented the aspects related to vulnerability to climatic phenomena and thermal comfort. It is important to focus on these aspects to guide local populations and public authorities towards architectural models adapted to their context.

1.4. Definition and Positioning of Neo-Vernacular Architecture

Variously referred to as new vernacular or vernacular modernism [30], neo-vernacular architecture adopts an approach that consciously incorporates the techniques, materials, and formal vocabulary of vernacular architecture within the context of the contemporary built environment. It is, however, conceptually distinct from vernacular architecture

in a fundamental respect: whereas vernacular architecture emerges organically from a community's accumulated and time-tested responses to its local context over successive generations [16], neo-vernacular architecture is an intentional and reflexive act of professional architectural design. In this regard, neo-vernacular architecture pursues sustainability as a core objective, drawing upon locally sourced materials and design principles derived from the vernacular architectural tradition. Neo-vernacular architecture shares with critical regionalism a common contestation of the neutrality, uniformity, and rootlessness of the International Style, as well as a shared awareness of the importance of place-specific peculiarities in architectural production [31]. Nevertheless, the two approaches differ fundamentally in their methods and theoretical ambitions. Critical regionalism seeks to ground modern architecture in the experiential specificity of place through the mediation of light, material texture, topography, and tectonic culture while maintaining a critical and objective distance from the very traditions it evokes. Neo-vernacular architecture, by contrast, aims to recover and reinterpret the visible formal language of regional architectural cultures, drawing more directly upon their aesthetic and material heritage.

Among the architects who most compellingly reconcile these two approaches is Hassan Fathy, whose practice embodies principles central to both neo-vernacular architecture and critical regionalism. On the one hand, Fathy revived and reinterpreted traditional Nubian construction methods to address contemporary needs; on the other, rather than merely replicating historical forms, he critically adapted them to the specific physical and climatic conditions of each project. In the contemporary African architectural landscape, Mariam Kamara and Nzinga Mboup equally stand as significant figures within the neo-vernacular movement, continuing and expanding this tradition of contextually grounded and culturally responsive design.

The CIDAP center, located in the Kara region of Togo, exemplifies a number of architectural interventions that draw directly upon the vernacular building practices of the region. Among the most salient characteristics of the local vernacular tradition that informed the design of the center are the circular morphology of traditional huts and enclosures, as well as the use of locally sourced construction materials, including stone, earth, and straw. The center valorizes indigenous resources and actively promotes vernacular architectural practices while simultaneously seeking to enhance and refine them in response to contemporary requirements. The underlying design intent extends beyond the mere integration of buildings within the topography and climatic conditions of the site; it encompasses a deliberate commitment to bringing to light and critically updating traditional construction knowledge for application within a modern architectural context. It is precisely these qualities, the conscious reinterpretation and elevation of vernacular building traditions within a contemporary architectural framework, that justify the classification of the CIDAP center's Social Hall as neo-vernacular within the scope of this article.

1.5. Aim and Structure of the Paper

The present article aims to examine the elements of sustainability, vulnerability, and thermal comfort inherent in neo-vernacular architectural work, namely the CIDAP social hall. The research holds both scientific and practical significance: on the one hand, it seeks to generate empirical data that highlight the merits and best practices embedded in ancestral construction traditions; on the other, it proposes concrete solutions for the adaptation of such practices to the current socio-economic and environmental realities confronting contemporary populations. This article is structured around four principal stages. First, we will present the characteristics of the study area. Second, a detailed description of the social hall of the CIDAP center will be presented. In the third step, a series of scientific tools will be implemented to analyze the elements of sustainability,

vulnerability, and thermal comfort of the social hall at CIDAP. These include the VerSus tool for sustainability, the PTVA method for vulnerability, and the calculation of the temperature difference ratio (TDR) for thermal comfort. Finally, the last phase will be dedicated to solution approaches to guide local authorities in designing architecture that is in harmony with the local environment.

2. Materials and Methods

The methodology deployed in this research is a combination of tools based on the work of M.Y.Adjibadé [24], Papathoma-Köhle [32], and Givoni [33] which focus, respectively, on the evaluation of the sustainability of vernacular architecture, the evaluation of the vulnerability of buildings to climatic hazards, and the evaluation of the thermal performance of traditional buildings. This methodology is both qualitative and quantitative and can be broken down into four fundamental steps, namely:

- Step 1: General characteristics of the study area.

This step provides an overview of the study area. This presentation includes the climatic, geographical, demographic, and economic aspects of the study area.

- Step 2: Presentation of a typology of neo-vernacular architecture

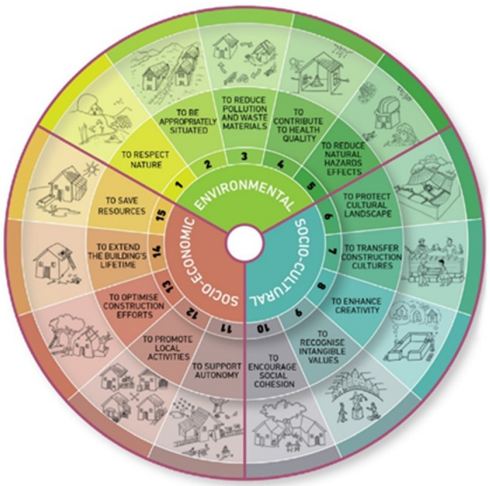
This stage is devoted to the detailed presentation of the CIDAP social hall building as a model of neo-vernacular architecture.

- Step 3: Evaluation of the Neo-Vernacular Architecture Model

This step is dedicated to the evaluation of the social hall at CIDAP. Regarding the VerSus method, the PTVA method, and the hygrometric data collection method, the CIDAP social hall was evaluated, respectively, in terms of durability, vulnerability, and thermal comfort.

In terms of sustainability assessment, several standards and certifications, such as LEED (Leadership in Energy and Environmental Design) in the USA, BREEAM (Building Research Establishment Environmental Assessment Method) in the United Kingdom, and DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) in Germany, can be used to determine the sustainability of buildings. The research conducted by Felicioni [34] reveals that the majority of these assessment tools fail to address, in an equitable manner, the three fundamental dimensions of sustainable development, namely the environmental, the social, and the economic. In practice, environmental impacts are afforded considerably greater priority than their social and economic counterparts. In 2014, the VerSus project developed a methodological tool in the form of a wheel with 15 indicators [35]. These 15 indicators are divided into groups of 5, each of which corresponds to a dimension of sustainable development. This tool comprehensively brings together the environmental, socio-cultural, and socio-economic dimensions of sustainable architecture [35]. In the framework of this study, the indicators of the VerSus tool were consolidated by the economic criteria drawn from the SEPRA (Sustainable Habitat Evaluation Rating and Participative Approach) tool [36]. These are the criteria for the affordability of buildings integrated into indicators 13 and 15 of the VerSus tool. According to research by Awoussi et al. [26], the use of the VerSus tool (Figure 1) to study sustainability requires scoring from surveys, including focus groups with manufacturers, as well as observations from the research field. A numerical scale graduated from 0 to 3 will make it possible to quantify the qualitative response to the criterion under consideration. A score of zero signifies the absence of performance, as it doesn't meet any aspects of the criterion. A score of 1 signifies the meeting of at least one-third of the criterion's constituent aspects, indicating underperformance. A score of 2 indicates that two-thirds of the elements of the criterion have been met, which corresponds to satisfactory performance. A score of 3 signifies excellent performance, as it meets most

of the criterion's aspects. Despite the existence of an element of subjectivity, each notation is preceded by reasoning based on factual elements observable in situ. This approach encourages participants to justify their answers unanimously to minimize potential errors.



ENVIRONMENTAL Principles

The habitat is a result of its integration into natural environment

1. TO RESPECT NATURE
2. TO BE APPROPRIATELY SITUATED
3. TO REDUCE POLLUTION AND WASTE MATERIALS
4. TO CONTRIBUTE TO HEALTH QUALITY
5. TO REDUCE NATURAL HAZARDS EFFECTS

SOCIO-CULTURAL Principles

The habitat helps to preserve and transfer inherited values

6. TO PROTECT CULTURAL LANDSCAPE
7. TO TRANSFER CONSTRUCTION CULTURES
8. TO ENHANCE CREATIVITY
9. TO RECOGNISE INTANGIBLE VALUES
10. TO ENCOURAGE SOCIAL COHESION

SOCIO-ECONOMIC Principles

The habitat empowers communities and optimizes local resources

11. TO SUPPORT AUTONOMY
12. TO PROMOTE LOCAL ACTIVITIES
13. TO OPTIMISE CONSTRUCTION EFFORTS
14. TO EXTEND THE BUILDING'S LIFETIME
15. TO SAVE RESOURCES

ENVIRONMENTAL PRINCIPLES	**1. RESPECTING NATURE** **The habitat integrates seamlessly with the other elements of the local ecosystem** INTEGRATION HARMONY BIODIVERSITY SENSE OF PLACE MINIMAL INTERVENTION REINSTATEMENT UNALTERED MORPHOLOGY REDUCED FOOTPRINT	**2. ESTABLISHING YOURSELF WELL** **The habitat benefits from the bioclimatic characteristics of the site** TOPOGRAPHY GEOLOGY ORIENTATION THERMAL INERTIA OF THE SITE WIND PROTECTION CLIMATE ADAPTATION ADAPTATION TO THE WATERCOURSE CONSIDERATION OF THE WATER LEVEL	**3. REDUCE POLLUTION AND WASTE** **Housing optimizes resources so as not to pollute the place that hosts it** REUSE RECOVERY REHABILITATION RECYCLING LOCAL MATERIALS MINIMALLY PROCESSED MATERIALS LESS USE OF MACHINERY REDUCED TRANSPORTATION	**4. PRESERVING HEALTH** **The habitat allows the inhabitants of the place to develop in healthy atmospheres** HEALTHY MATERIALS HYGROTHERMAL REGULATION THERMAL INSULATION COMFORT FEATURES NATURAL VENTILATION NATURAL LIGHT PLANT SHADE BUFFER SPACES	**5. MITIGATING THE EFFECTS OF NATURAL HAZARDS** **Housing offers security and safety to inhabitants of the place** AERODYNAMICS REDUCING THE EFFECTS OF FLOODING TALUS TORRENT CHANNELING SEISMIC ELEMENTS ENHANCED STABILITY WINDBREAKS BREAKWATER
SOCIO-CULTURAL PRINCIPLES	6. PROTECTING THE CULTURAL LANDSCAPE **Landscapes shaped over time are preserved** TERRACED FARMING CULTIVATED VALLEYS ENCLOSURE WALLS PROTECTIVE WALLS CHANNELS PONDS SALT MARSHES AND PORTS	7. TRANSMITTING CONSTRUCTIVE CULTURES **The habitat reuses the knowledge and know-how observed on traditional habitats** IDENTITY KNOW-HOW EXPRESSION OF THE PROFESSION CULTURE MAINTENANCE CONSTRUCTIVE MEMORY ADAPTATION TO LOCAL RESOURCES MEETING NEEDS EVOLUTION	8. SEDUCING CREATIVITY **Housing encourages innovative solutions and creative expressions** INTELLIGENCE COLLECTIVE EXPERIMENTATION INGENICITY DEXTERITE MISCELLANEOUS SOLUTIONS WEALTH PRETTYNESS / BEAUTY UNIQUENESS	9. RECOGNIZING INTANGIBLE VALUES **Housing enhances the identity of the territory resulting from accumulated experience** COLLECTIVE MEMORY CULTURAL IDENTITY ATTACHMENT TO PLACE SYMBOLIC REPRESENTATION SACRED CUSTOMARY MEETING PLACES PEACE AND WELL-BEING HISTORY AND MYTHOLOGY	10. PROMOTING SOCIAL COHESION **Housing facilitates exchange to nurture collective intelligence** PEDESTRIAN SPACES ARCADES INTEGRATION INTO THE NEIGHBOURHOOD CO-RESPONSIBLE INTERVIEW SPACES OF CONVIVIALITY DEVELOPMENT OF PUBLIC SPACES MUTUAL AID SHARED FACILITIES
SOCIO-ECONOMIC PRINCIPLES	11. ENCOURAGING AUTONOMY **Housing reinforces the self-sufficiency of the Community** INTEGRATED HOUSING AND PRODUCTION AUTOCONSTRUCTION INTEGRATED VEGETABLE GARDENS DOMESTIC BREEDING PROCESSING SYSTEMS ACCESS TO WATER CONSERVATION SPACES COLLECTION AND STORAGE	12. STIMULATING LOCAL ACTIVITY **Housing promotes local production, processing and trade** LOCAL PRODUCTION LOCAL ENERGY FOR LOCAL INDUSTRY LOCAL PROCESSING SKILLED WORKFORCE PRODUCTS OF RECOGNIZED QUALITY CIRCUITS COURTS PARATRANSIT LOCAL CONSTRUCTION	13. OPTIMIZE CONSTRUCTION EFFORTS **Housing optimizes the energy used to build** TAILLE ADEQUATE TECHNICAL SIMPLICITY OPTIMIZED USE REDUCED NUMBER OF MATERIALS SHARED USES MINIMALLY PROCESSED MATERIALS PLANNING IN STAGES SCALABLE HOUSING	14. EXTENDING THE USEFUL LIFE OF BUILDINGS **The habitat guarantees its good durability over time and is long-term** PROTECTION INTERVIEW STABILISATION REINFORCEMENT OF WEAK POINTS REPLACEABLE ELEMENTS DURABLE MATERIALS ADAPTABILITY EXTENSION POSSIBLE	15. SAVING RESOURCES **Housing makes measured use of local resources, limits losses and avoids waste** COMPACITE NETWORK SHARING POOLING OF ASSETS SOBRIETY RENEWABLE ENERGY LESS EMBODIED ENERGY REDUCED ENERGY LOSSES PASSIVE SYSTEMS

Figure 1. Map showing the indicators of the VerSus tool [35].

The assessment of the physical vulnerability of the built environment is frequently based on three distinct methods, namely, vulnerability curves, damage matrices, and vulnerability indicators. The works of Kappes M.S. et al. [37] and S. Menoni [38] have identified significant shortcomings in the assessment of physical vulnerability through the use of vulnerability curves and damage matrices. Indeed, both methods account for only a limited number of the parameters that bear upon physical vulnerability, and neither provides meaningful guidance with respect to risk reduction strategies. In contrast, the vulnerability indicator method is an approach that considers all climate risks in a specific region, as well as various parameters that influence the vulnerability of the element exposed to these risks. Researchers in the socio-economic sector, such as Cutter et al. [39] and Collins et al. [40], have adopted this approach to assess spatial vulnerability using biophysical and social indicators. Research by Granger et al. [41] and by Puissant et al. [42] demonstrates the use of vulnerability indicators to highlight the physical characteristics of buildings, as well as their respective vulnerability to climatic hazards. Another well-known example of vulnerability indicators is the PTVA method [43]. This method, originally developed to assess the vulnerability of buildings in coastal areas prone to tsunamis, was later adapted to apply to floods in mountainous areas [44]. It has also been adjusted to allow the assessment of the vulnerability of buildings to forest fires [45]. Papathoma-Köhle et al. [32] have recently implemented this approach to assess the vulnerability of buildings to weather

hazards such as high winds, heavy rain, and hail. The PTVA tool was implemented in this research to assess the physical vulnerability of CIDAP's social hall to the climatic hazards that predominate in the region. Referring to the work of Awoussi et al. [46], these climatic hazards concern heavy rainfall, strong winds, and high temperatures. In addition, Awoussi et al. revealed the indicators that influence the physical vulnerability of vernacular constructions in the Kara region to climatic hazards. The calculation of the Physical Vulnerability Index (PVI) is based on expert judgment to score the indicators. It is also based on the Analytic Hierarchy Process (AHP), developed by R.W. Saaty [47], to carry out the weighting of these same indicators. The AHP method involves the use of criteria that allow the binary comparison of decisions to determine the weight of the different factors. To mitigate the inherent subjectivity in the evaluation of the indicators, two successive series of interviews were conducted. The first involved local builders and trainers from the local chambers of trades, while the second engaged architects registered with the ONAT (Ordre National des Architectes du Togo) and agents of the local civil protection services. During these interviews, the participating experts were invited to assess and substantiate the relevance of each indicator with respect to building vulnerability. The Physical Vulnerability Index (PVI) is determined at the end by aggregating the indicators according to the following formula:

$$\mathrm{PVI} = \sum_{1}^{m} w_m \cdot I_m s_n$$

PVI: The Physical Vulnerability Index

w_m: risk of wind

$I_m s_n$: the rating of each indicator

PVI (Figure 2) does not relate to the intensity of the danger but more precisely reflects the relative vulnerability of the building to climatic hazards.

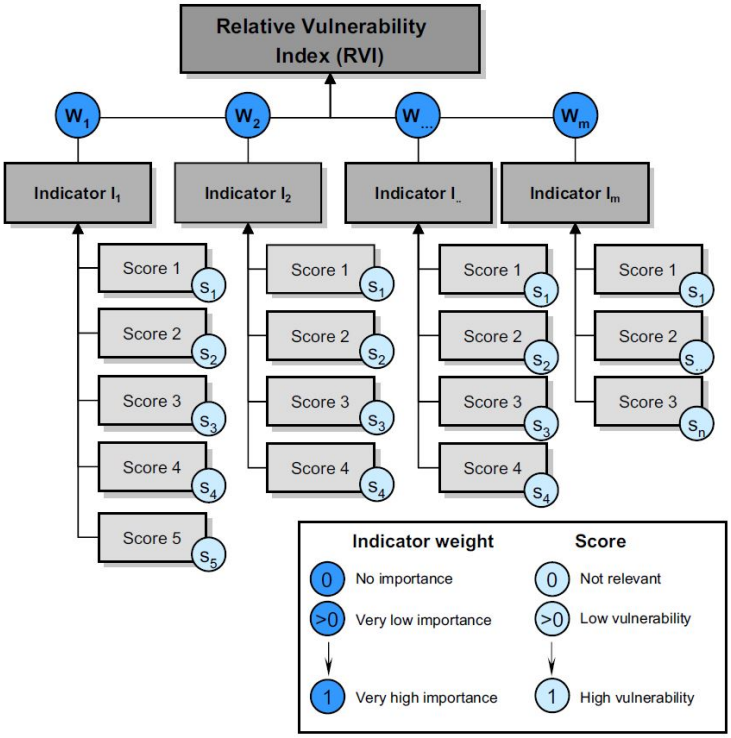


Figure 2. Framework for calculating the vulnerability index.

Thermal comfort is a subject that animates scientific debates today. In the context of increasingly intense heat phenomena, the question of thermal comfort within the interior environment of buildings is assuming growing significance in both research and professional practice. As defined by ASHRAE Standard 55 [48], thermal comfort refers to a state of mind expressing satisfaction with the thermal environment and is inherently subjective in its evaluation. In the assessment of thermal comfort within buildings, two principal methodological approaches are commonly employed. The analytical model proposed by Fanger [49] is relevant for environments regulated by HVAC (heating, ventilation, and air conditioning) systems, while the adaptive thermal comfort model applies to homes with natural ventilation and no HVAC systems [50–52]. The adaptive approach takes into account various factors, including environmental elements (air temperature, relative humidity, radiant temperature, and wind speed); human factors (metabolism and clothing); and the culture and characteristics of the building [53]. The standardization of the adaptive approach has led to the development of the ASHRAE-55/2023. It should also be noted that the method of collecting hygrothermal data (temperature and relative humidity), as well as their analysis through the calculation of the TDR (temperature difference ratio), is an essential step in the evaluation of the thermal performance of vernacular buildings [33]. This method, used in recent work [22,54,55], was developed by B.Givoni [56] and allows you to compare different passive cooling systems. The calculation of the Temperature Difference Ratio (TDR) was used in our work to evaluate the thermal performance of the CIDAP social hall. It involves a series of hygrometric data collections inside the social hall and in its environment. In this research, the data were collected during the period from December to January, during which significant variations in temperature and relative humidity can be observed [46]. The Onset sensor models, MX 1101, MX2301A, and MX100 (Onset Computer Corporation, Bourne, MA, USA), shown in Table 1, were installed in the field from 5 to 10 January 2025 in the areas where heat exchanges are most significant, in accordance with the recommendations of experts, in particular those of the International Energy Agency. Temperature and relative humidity data were recorded at five-minute intervals under normal operating conditions in the absence of modern air conditioning systems, insulation, or materials with high thermal resistance. Inside the building, the sensor (Onset MX 100 model) was installed close to the roof (30 to 40 cm from it) to avoid heat transmission to the collectors. The sensor (Onset MX 1101 model) is positioned 1 m above the ground to collect data at ground level. The sensor (Onset MX 100 model) is positioned close to the ground (30 to 40 cm above the ground) to avoid floor surfaces that are likely to present thermal anomalies. For external data, the sensor (Onset MX model 2301A) was suspended from a plant support (stem or tree) in a ventilated and obstacle-free area. The analysis of the data is performed through calculation of the TDR, which establishes the relationship between the maximum outdoor and indoor temperature difference and the thermal amplitude:

$$\text{TDR} = \frac{Tmax\ out - Tmax\ ins}{Tmax\ out - Tmin\ out}$$

where $Tmax\ out$ is the maximum temperature measured outdoors (°C); $Tmax\ ins$ represents the maximum temperature recorded indoors (°C); and $Tmin\ out$ corresponds to the minimum temperature observed outdoors (°C). These values are not determined by means of an average but rather correspond, respectively, to the maximum and minimum values collected in the different spaces. A high TDR value indicates that there is a significant temperature difference between the outside and the inside, which implies a considerable cooling potential.

Table 1. Technical specifications of the collectors used.

Characteristics of the Collectors Used					
Sensor Models		**Operating Range**		**Degree of precision**	
		Temperature	**Relative Humidity**	**Temperature**	**Relative Humidity**
Indoor sensor	Onset MX 1101	−20° to 70 °C	1% to 90%	±0.21 °C from 0° to 50 °C	±2% from 20% to 80%
	Onset MX 100	−30° to 70 °C	_	±1.0 °C from −30° to −5 °C ±0.5 °C from −5° to 50 °C ±1.0 °C from 50° to 70 °C	_
Outdoor sensor	Onset MX 2301A	−40 to 70 °C	0% to 100%	±0.25 °C from −40 to 0 °C and ±0.2 °C from 0 to 70 °C	±2.5% from 10% to 90%, Less than 10% and greater than 90% RH ±5%

- Step 4: Potential for application of the research

At this stage, the present research proposes a series of solution-oriented approaches intended to guide local authorities and communities in the design and implementation of neo-vernacular architecture. The methodological framework underpinning this research is illustrated in Figure 3. The subsequent paragraphs provide a detailed account of each step of the process.

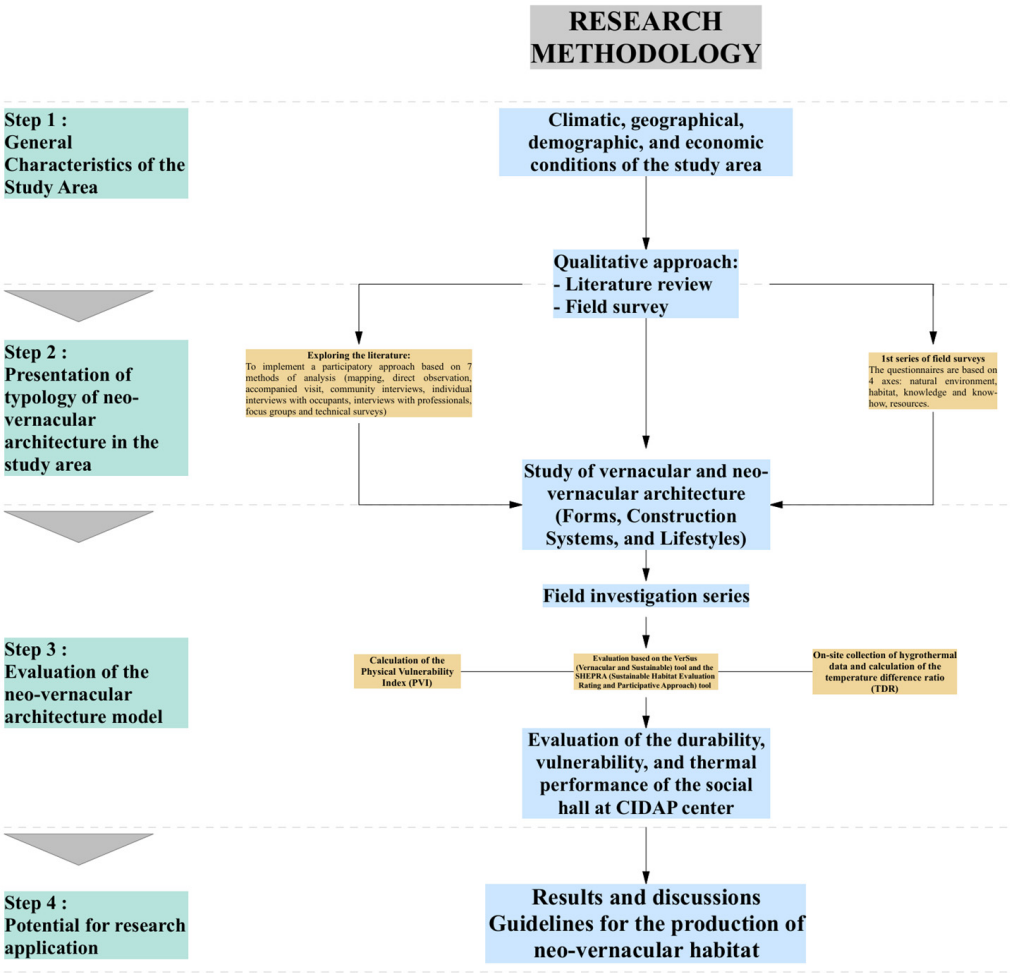


Figure 3. Research methodology structure.

2.1. Characteristics of the Study Area

The CIDAP center, which constitutes the subject of the present study, is situated in the canton of Baga, within the prefecture of Doufelgou, one of the seven prefectures comprising

the Kara region in northern Togo (Figure 4). The canton of Baga is located more precisely within the commune of Doufelgou 1, the administrative capital of which is Niamtougou (Figures 5 and 6). It is made up of six villages, including Samaragou, where the CIDAP center is located. The canton of Baga has an area of about 69 km^2 for a population of 5905 inhabitants, or about 7% of the total population of the prefecture of Doufelgou. It has a density of about 94 inhabitants/km^2 and is one of the most urbanized cantons of the Doufelgou prefecture. The cantons of Defalé and Kpaha border the canton of Baga to the north. It borders Aloum to the west, Niamtougou and Koka to the south, and Tenega to the east. From a climatic point of view, the prefecture of Doufelgou, like the rest of the Kara region, benefits from a tropical Sudanian-type climate with a unimodal regime, marked by a dry season from November to April and a rainy season the rest of the year. Rainfall extends from May to October, reaching its peak in August. The average annual rainfall varies between 1200 and 1400 mm. The average annual temperature is 28 °C. The geomorphological aspect of the Doufelgou prefecture is dominated by the Atakora range, locally called the Defale Mountains, which have altitudes that vary between 400 and 800 m. It is a mountainous area where most of the rocks observed are white quartzites. In the prefecture, the soil is mainly ferruginous and is highly prized by farmers because of its fertility compared to the cultivation of maize or sorghum [57]. There are also some areas of clayey and ferralitic depression in the prefecture. Savannahs and forests distinguish the vegetation cover. In addition to this natural vegetation, it is worth including anthropogenic formations, which are composed of néré and palm groves. These anthropogenic formations are the centerpiece of the actions carried out by the CIDAP center.

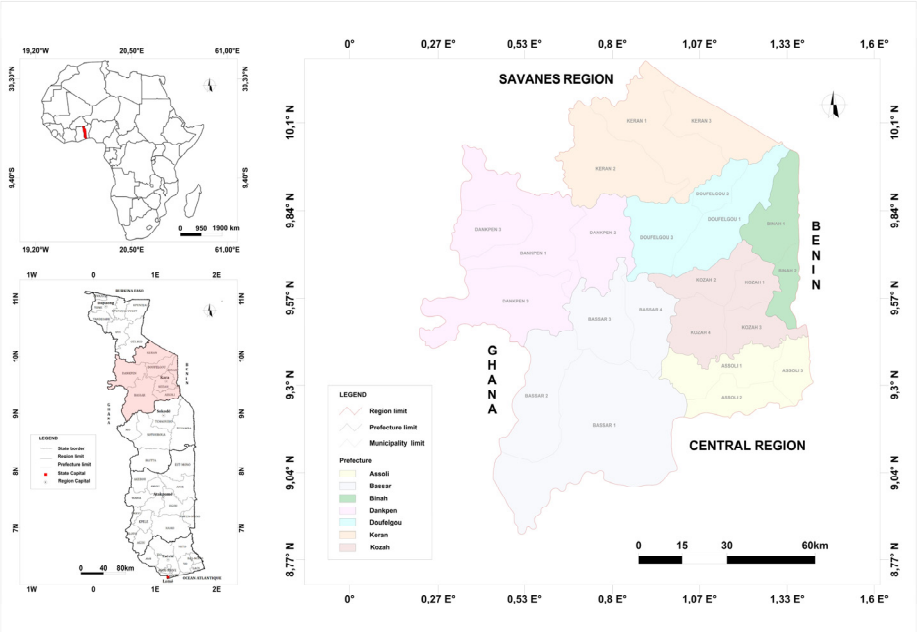


Figure 4. Map of the Kara region.

The prefecture of Doufelgou is mainly occupied by the Nawdeba people, who live on the Defale range and on the Kabyè mountains. The presence of the Lamba peoples, often assimilated to the Kabyè tem group, is also remarkable in the prefecture. This presence dates back to the 12th century [58]. Agriculture (cultivation of sorghum, maize, yams, beans), livestock (goats, sheep, and poultry), crafts (pottery, soap making), and basketry represent the main economic activities of the prefecture [59].

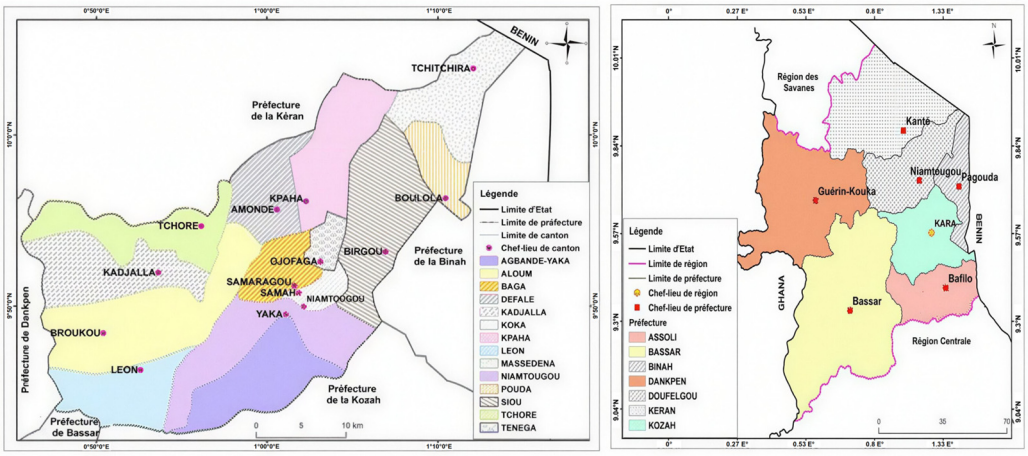


Figure 5. Doufelgou prefecture and its cantons [59].

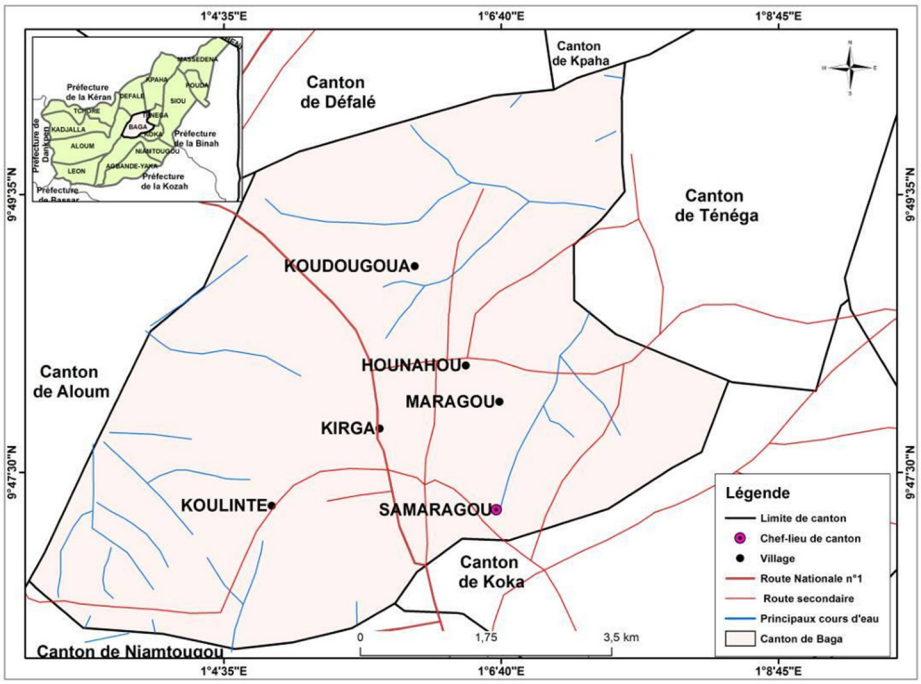


Figure 6. Canton of Baga, geographical location [59].

Challenges Related to the Creation of the CIDAP Center

Recently in the Doufelgou prefecture, the phenomenon of desertification, caused by much longer dry seasons as well as soil erosion due to poor agricultural practices (chemical fertilizers and pesticides) [58], has led to significant crop losses. According to Lamouroux [57], agricultural techniques in Nawdeba country are contrary to the values of agroecology and deplete the soils in less than three years, forcing farmers to abandon them for a minimum of five years. In response to this progressive soil depletion, the prefecture has been experiencing a sustained wave of emigration among the Nawdéba and Lamba peoples towards rural areas in the central and southwestern parts of the country [58]. Togo's agricultural policy aims to transform the Kara region into a competitive hub based on traditional agricultural knowledge. The observation is that this policy does not take into account the resurgence of environmental issues that are essential for the survival of communities, particularly those considered the most disadvantaged [59]. Indeed, local actors and ecosystem services are only partially integrated [59]. Moreover, the agricultural training provided does not enable young people to effectively engage in favor of sustainable

development in rural areas. The CIDAP center was founded in the Baga district to reverse the trend. It was created in 1984 by the couple Séda and Tiyéda Bawiena with the ambition of establishing a farm to promote family-based subsistence agriculture in rural areas [60]. The center also aims to promote agropastoralism and agroecology to improve the living conditions of local populations through self-promotion and local development. It has an educational farm with facilities spread across two sites: the Baga site, developed on 17 hectares, and the Natoun-Ténéga site, developed on 8 hectares (Figures 7–12). With a staff consisting of agronomists and economists, it offers agricultural training aimed at a diverse audience (youth, adults, men, women, and children). After 42 years of existence, a genuine impetus has been given to territorial development and the empowerment of local populations [60].



Figure 7. Aerial view of the housing CIDAP center, Baga site, Kara region, Togo.



Figure 8. Reception Hall of CIDAP center, Baga site, Kara region, Togo.



Figure 9. View of the housing at CIDAP center, Baga site, Kara region, Togo.



Figure 10. View of administration at CIDAP center, Baga site, Kara region, Togo.



Figure 11. Building with sloped roof at CIDAP center, Natoun-Ténéga site, Kara region, Togo.



Figure 12. Building with slab roof at CIDAP center, Natoun-Ténéga site, Kara region, Togo.

The CIDAP center has achieved significant national and international recognition, attracting the attention of public officials at both levels [61]. In 2021, the center received funding through the German–Togolese cooperation framework, specifically via the PAFPE (Programme de Formation Technique et Professionnelle et Emploi des Jeunes)—Phase II—N°201467364, established by the METFPA (Ministère de l'Enseignement Technique, de la Formation Professionnelle et de l'Apprentissage), with the FNAFPP (Fonds National d'Apprentissage, de Formation et de Perfectionnement Professionnels) serving as its implementing agency [62]. This investment was directed towards strengthening the center's institutional capacities through targeted training, the construction of new infrastructure, the rehabilitation of existing buildings, and the provision of equipment. In alignment with the overarching policy of promoting local traditional values, the CIDAP center and the PAFPE program jointly undertook the development of several architectural interventions (Figures 13–16). Some of them highlight a form of neo-vernacular inspired by traditional and contemporary practices to create places in harmony with the local context. The building that perfectly embodies this approach is the social hall designed to make the most of the traditional and the contemporary (Figure 15).



Figure 13. New constructions at CIDAP center, Baga site, Kara region, Togo.



Figure 14. Dormitory buildings at CIDAP center, Baga site, Kara region, Togo (A).



Figure 15. Social Hall at CIDAP center, Baga site, Kara region, Togo.



Figure 16. Dormitory buildings at CIDAP center, Baga site, Kara region, Togo (B).

2.2. Presentation of a Typology of Neo-Vernacular Architecture

The findings of Awoussi et al. [26,46] reveal that the Kara region is dominated by two housing models associated with the Kabiyè and Nawdéba ethnic groups that mainly populate the region. These are identified as vernacular architecture among the Kabiyè (KVA) and vernacular architecture among the Nawdéba (NVA). Both housing typologies are characterized by circular or organic enclosures organized around a central open-air space and are distinguished by their harmonious integration within their immediate natural surroundings. The buildings of the CIDAP center perpetuate and reinforce the values inherent in these circular and organic enclosure traditions. By adhering to this policy, the PAFPE program has followed in the footsteps of the builders of the CIDAP center to rehabilitate and construct buildings following the logic of valorization of local resources.

2.2.1. Project Program

According to the CIDAP center, in addition to capacity-building training, the PAFPE program has financed the construction, rehabilitation, and equipment of fifteen buildings (Figures 17–19). These include the rehabilitation of 24 housing huts and their outdoor toilets; the construction of a computer room (65 m^2), a borehole (150 m deep) with a solar pump, a soil analysis laboratory (28 m^2), a phytosanitary analysis laboratory (32 m^2), a composting station (45 m^2), an infirmary (65 m^2), a dormitory with sanitary facilities in R+1 (340 m^2 spread over two levels), a cheese factory (35 m^2), a canteen (45 m^2), three classrooms (200 m^2), and a social hall (40 m^2) for the student community. The total cost of the investment is 231,111,885 CFA francs, including tax, i.e., € 352,328 [62]. With the view of participating in the development of the local economy, the program has opted for materials and construction techniques mastered by local communities. For example, the rehabilitation of the 24 housing huts involved the reinforcement of the wooden framework of the roof and the replacement of the straw roof with similar new materials. Therefore, the company chosen to perform the work is a local firm. The entire construction work officially began on 1 September 2021 and was completed on 12 June 2023. Among the multitude of buildings built, the social hall building, the subject of this article, stands out particularly for its shape and structure, inspired by the local context.



Figure 17. Site plan of the CIDAP center, Baga site, Kara region, Togo.

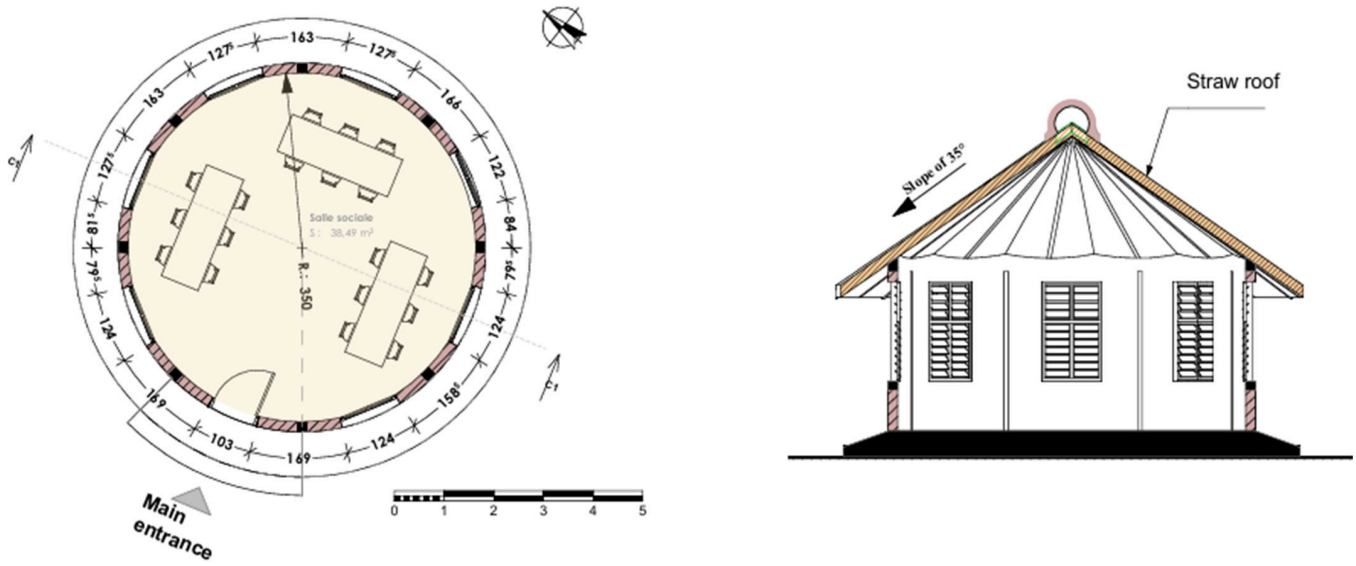


Figure 18. Plan and section of social hall at Baga site, Kara region, Togo.

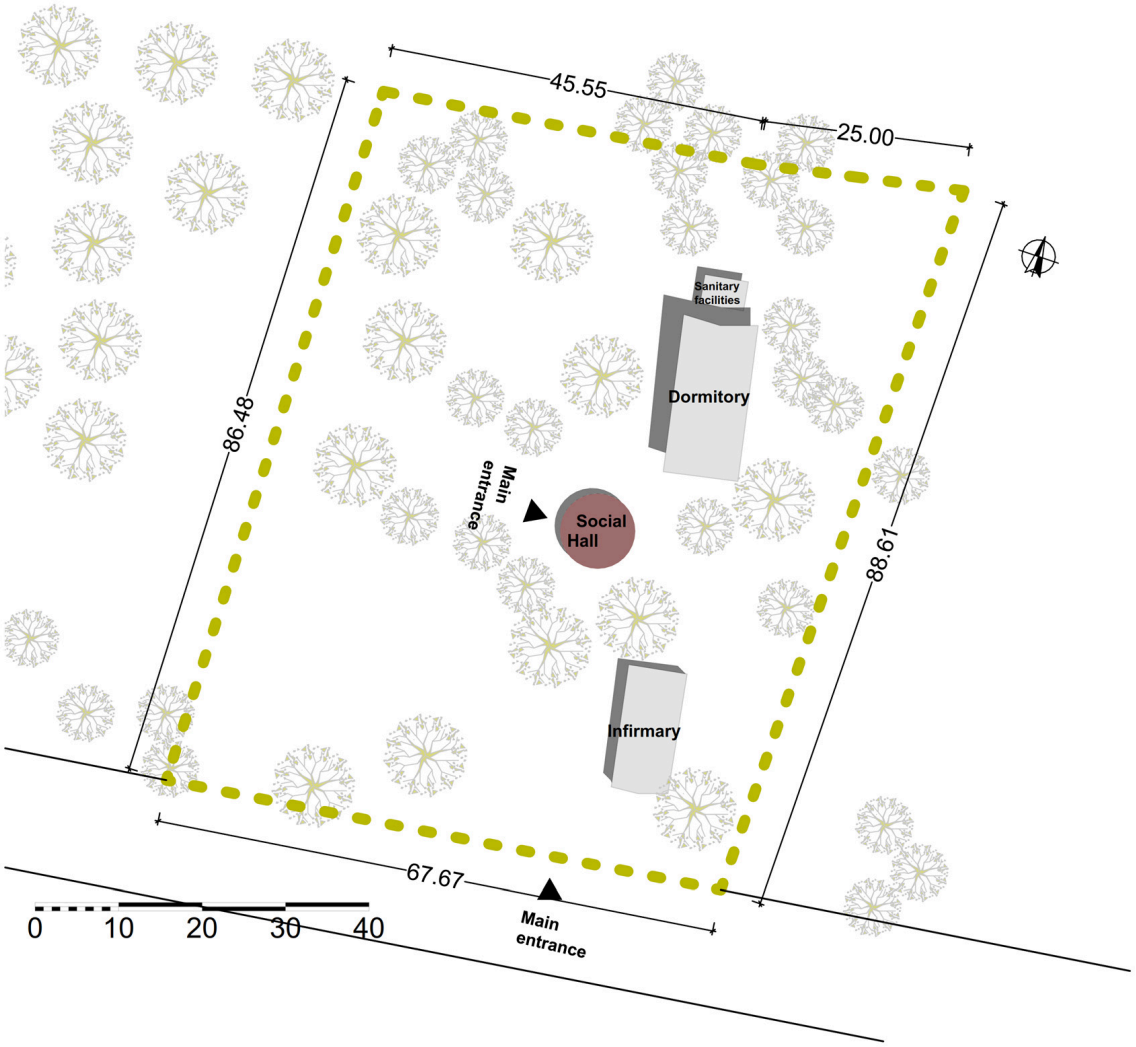


Figure 19. Site plan, PAFPE interventions, Baga secondary site, Kara region, Togo.

2.2.2. Description of the Social Hall

Situated on an ancillary plot of land approximately 500 m from the main CIDAP site, the Social Hall (Figures 20 and 21) functions as a dedicated meeting and discussion space for the center's students. Located in proximity to the student dormitories, the building has been conceived to serve as a place of communal exchange, evoking the symbolic role of the palaver tree or the central thatched hut within the spatial organization of traditional habitation. With its west-facing entrance, a disposition consistent with local traditional housing conventions, the Social Hall demonstrates a deliberate adherence to the cultural values and spatial practices of the surrounding communities.



Figure 20. Social Hall, main façade, Baga secondary site, Kara region, Togo.



Figure 21. Social Hall, rear façade, Baga secondary site, Kara region, Togo.

- Foundations, structures, and walls

The foundation of the building is made of insulated footings and reinforced concrete columns (Figures 22–27). The building is elevated above natural ground level as a preventive measure against moisture ingress resulting from capillary action. To this end, a gravel sub-base layer was installed prior to the pouring of the floor slab. The interior floor level of the building is raised by 50 cm above natural ground level, thereby ensuring effective protection against surface water runoff. The walls are made of compressed and stabilized earth brick (BTCS) with dimensions L = 29.5 cm, W = 14 cm, and D = 9.5 cm. The bricks formed of raw earth were stabilized by compression with a little cement (on average 8% cement in the composition). This composition reduces their sensitivity to water and increases erosion resistance while maintaining the thermal properties of the earth material [63–65]. Brick walls rest on a masonry wall to provide effective protection against soil moisture. For the structure, the load-bearing frame construction method (columns,

beams) with infill was adopted. The entire structure was dimensioned according to BAEL reinforced concrete design standards.



Figure 22. View of the foundations, Social Hall, Kara region, Togo.



Figure 23. Preparation of the floor slabs, Social Hall, Kara region, Togo.



Figure 24. View of the paving stones, Social Hall, Kara region, Togo.



Figure 25. Elevation of structural elements, Social Hall, Kara region, Togo.



Figure 26. Construction of walls in BTCS, Social Hall, Kara region.



Figure 27. Aerial view of the BTCS walls under construction, Social Hall, Kara region, Togo.

- Roof

One of the particularities of this building is its exclusively green roof (Figures 28–31). It consists of a wooden framework assembled and arranged in a circular fashion on which a straw roof rests. This roof carries a clay pot (pot) that joins the straw twigs together. Although straw is becoming increasingly scarce in the region because of the phenomenon of transhumance [26], the architects of the project wanted this option to participate in the development of the local economy. Thus, the work on the wooden framework and the installation of the straw roof were carried out by local craftsmen. In the region, the most common type of straw is *Andropogon* Sp., locally known as Kavloum. This species was used in the project.



Figure 28. Straw material used for the roof, Social Hall, Kara region, Togo.



Figure 29. Roof construction, Social Hall, Kara region, Togo.



Figure 30. Roof in progress, Social Hall, Kara region, Togo.



Figure 31. View of the wooden frame supporting the thatched roof, Social Hall, Kara region, Togo.

- Openings

The considerable fluctuations in temperature and relative humidity recorded in the prefecture constitute a significant constraint on the use of timber as a material for doors and window frames. The use of metal has consequently become an increasingly favored option at the local level, owing to the historically remarkable development of metallurgical activities in the region [66]. For this reason, the doors of the social hall are made of metal, and the windows are Naco type, with glazed slats housed in a frame and aluminum profiles (Figures 32 and 33). In the dry season, this type of window with the openwork slats promotes excellent natural ventilation of the interior spaces. The front door is protected by a 5 cm high threshold to prevent rainwater from entering.



Figure 32. Naco-type window with glazed slats and aluminum frame, Social Hall, Kara region.

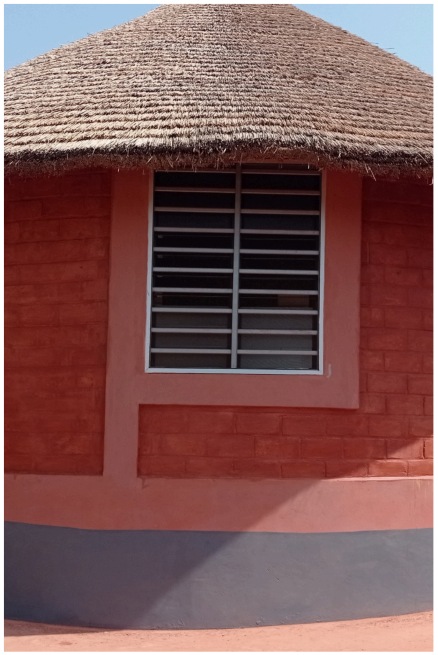


Figure 33. View of the Naco-type window, Social Hall, Kara region, Togo.

- Coatings

The concrete foundations were finished with a layer of earth and cement plaster, upon which a coat of paint was subsequently applied. The inner faces of the walls have been left untreated, preserving their natural material appearance. The exterior wall surfaces, by contrast, were treated with a quicklime-based plaster render to provide additional protection against moisture ingress. The exposed surfaces of the concrete structural elements, comprising columns and beams, were likewise coated with a clay-red pigment. The interior floor level of the building is raised by 50 cm above natural ground level.

2.3. Evaluation of the CIDAP Social Hall

This phase is dedicated to the evaluation of durability, vulnerability, and thermal behavior of the CIDAP social hall. Research published in 2025 by Awoussi et al. [26,46] on the assessment of the sustainability and vulnerability of vernacular buildings to climatic hazards has been exploited in this research.

2.3.1. Analysis of Sustainability Elements According to VerSus Tool

The evaluation based on the VerSus criteria was carried out by independent evaluators. Following a process of systematic field observations and surveys, selection of relevant evaluators was undertaken. To this end, focus groups of twelve participants were organized in collaboration with local builders, trainers from the local chambers of trades, and technical representatives from the national civil protection agency, enabling the rating of all VerSus criteria on a scale of 0 to 3. The exact number of participants, the method of selecting participants, the formation of discussion groups, the schedule of discussions, and the consensus method are presented in Table 2. While a degree of subjectivity is inherent to this process, each rating assigned reflects a reasoned assessment grounded in observable field evidence. The process requires respondents to justify their evaluations through unanimous consensus, thereby mitigating the risk of error attributable to subjective judgment.

Table 2. Details of the organization of focus groups for sustainability assessment.

Method of Selecting Participants	Stage	Participant	Number	Consensus Method	Period
Selection by reasoned choice to question individuals capable of providing relevant answers.	Evaluator's judgments according to the VerSus tool.	local builders, trainers from the local chambers of trades and the technical services of the national civil protection agency	12	Each rating given is the result of reasoning based on observable facts in the field. The process leads the respondents to justify their answer unanimously to limit the risk of errors due to the element of subjectivity	15–20 July 2024

Tables 3 and 4 and Figure 34 present the results from the analysis of the sustainability elements of the CIDAP social hall.

Table 3. Evaluation of sustainability elements of the CIDAP social hall according to the VerSus tool.

	NV	1. Respect for Nature	NV	2. Adaptation to the Site	NV	3. Pollution and Waste Reduction	NV	4. Contribution to the Improvement of Health, Well-Being and Comfort	NV	5. Contribution to the Improvement of Health, Well-Being and Comfort	NV
Environmental pillar		Integration (building and green spaces that follow the topography)	☑	Topography (adapt to the terrain)	☑	Recovery of parts of the structure	☑	Good quality sound materials	☑	Aerodynamics in the shape of the elements of the frame	☑
		Harmony (Materials that integrate the environment/architecture integrates its environment)	☑	Geology (Presence of troglodyte construction)	☒	Reuse of materials	☑	Hygrothermal control through the choice of materials	☑	Reduced flood consequences (High threshold gate, stilt construction)	☑
		Biodiversity (Taking into account natural elements in favour of fauna and flora)	☑	Orientation (Advantage of the place to protect the building)	☑	Recycling (limit losses in modifications)	☑	Thermal insulation through the choice of materials	☑	Embankment or water filtration system and protection of groundwater resources (presence of topsoil to filter water before it reaches rivers)	☑
		Sense of place (building in a protected area)	☑	Thermal inertia of the ground (Presence of subsoil)	☒	Rehabilitation (facilitated by materials)	☑	Devices to improve comfort (on windows or in walls)	☑	Channelling of torrents (for field work)	☑
		Minimal intervention (simplicity in the use of materials)	☑	Presence of wind protection device (orientation or presence of trees)	☑	Local materials (local availability of materials)	☑	Natural ventilation	☑	Seismic elements	☒
		Reintegration (materials used can return to nature at the end of the cycle)	☑	Adaptation of materials to climate	☑	Use of natural materials with little or no processing	☑	Natural lighting	☑	Enhanced stability	☑
		Unaltered morphology (building integrated into the natural element, habitat in the tree or in a cave)	☒	Presence of watercourse adaptation device (Gate with high threshold, construction on stilts)	☒	Reduced use of machinery in material work	☒	Plant shade	☑	Windbreaks	☑
		Minimal impact (Footprint reduced by occupying space)	☑	Taking into account the water table through humidity control devices (Use of waterproof products)	☑	Reduced transport	☒	Buffer spaces (presence of terraces, passageways, illuminated corridors, etc.)	☒	Breakwater (Wave Protection)	☒
Notation/15	**11,625 or 77.5%**		**2625**		**1875**		**2.25**		**2625**		**2.25**

Table 3. *Cont.*

		6. Protection of the cultural landscape	NV	7. Transfer of constructive cultures	NV	8. Promotion and stimulation of creativity	NV	9. Recognition and enhancement of intangible values	NV	10. Promotion of social cohesion	NV
Socio-cultural pillar		Terrace culture	☑	Identity	☑	Intelligence collective	☑	Collective memory	☑	Pedestrian spaces	☑
		Salt marshes	☒	Know-how	☑	Experimentation (use of materials)	☑	Cultural identity	☑	Arcades	☒
		Enclosures	☑	Expression of the profession	☑	Ingenuity	☑	Attachment to place	☑	Integration into the neighbourhood	☑
		Protective walls for crops	☑	Maintaining culture	☑	Dexterity (ease of execution, less pressure)	☑	Symbolic representation	☑	Co-responsible interview	☑
		Canals (for field work)	☑	Constructive memory	☑	Diversified solutions (material mixing)	☑	Sanctity	☑	Convivial spaces	☑
		Ponds (depending on the morphology of the site)	☑	Adaptation to local resources	☑	Wealth	☑	Meeting Spaces for the Community	☑	Design of public spaces	☑
		Valleys of Cultures	☑	Responding to the social needs and aspirations of targeted groups	☑	Beauty	☑	Peace and well-being	☑	Mutual aid	☑
		Dikes and harbour	☒	Evolution	☑	Uniqueness	☑	History and mythology	☑	Shared equipment	☑
Notation/15	**13,875**		**2.25**		**3**		**3**		**3**		**2625**
	or 92.5%										
		11. Empowering local people	**NV**	**12. Promotion of local activities**	**NV**	**13. Optimization of construction efforts**	**NV**	**14. Extending the life of buildings**	**NV**	**15. Saving and Safeguarding Resources**	**NV**
Socio-economic pillar		Auto-contruction	☑	Local production	☑	Appropriate intervention scale corresponding to the needs (optimal use of space or presence of multi-purpose space)	☑	Effectiveness of habitat protection systems (gutters; plasters; etc.)	☑	Compacted organization of habitats on the territory	☒
		Integrated housing and production	☑	Local processing	☑	Optimised use of materials (use of materials such as those from nature)	☑	Simplify the service and maintenance process	☑	Shared property and buildings in the community	☑

Table 3. *Cont.*

		11. Empowering local people	NV	12. Promotion of local activities	NV	13. Optimization of construction efforts	NV	14. Extending the life of buildings	NV	15. Saving and Safeguarding Resources	NV
Socio-economic pillar		Collection and storage	☑	Skilled labour from the community for local construction work	☑	Technical simplicity of construction (affordability)	☑	Use of solids with increased strength	☑	Sober construction (low cost and long-term viability of the project)	☑
		Conservation areas	☑	Products of recognized quality	☑	Presence of common areas shared by several members of the community	☑	Use of easily replaceable elements	☑	Use of renewable energies	☑
		Domestic breeding	☑	Use of locally produced energy with respect to industries involved in construction	☒	Reduction in the amount of building materials	☑	Scalable construction	☑	Use of energy loss reduction systems	☑
		Integrated vegetable gardens	☑	Short circuits favoured	☑	Use of minimally processed natural materials	☑	Extension possible	☑	Use of passive systems	☑
		Accessibility and availability of water (Presence of watercourses or boreholes)	☑	Local construction	☑	Construction progressive	☑	Adaptability of the parts of the structure	☑	Network Sharing	☑
		Transformation system	☑	Adapted transport	☑	Construction in phases	☑	Strengthening of fragile elements	☑	Embodied energy reduction	☑
Notation/15	**14.25**		**3**		**2625**		**3**		**3**		**2625**
	or 95%										
General score/45	**39.75**										
	or 88.33%										

Table 4. Summary of evaluators' judgments.

		Score	Summary of Evaluators' Judgments
Environmental pillar	1. Respect for nature	2625	Good performance due to the use of natural materials, the integration of green spaces and respect for local vernacular practices.
	2. Adaptation to the site	1875	Average performance. The implementation of the project required a slight levelling of the site.
	3. Pollution and waste reduction	2.25	Good performance due to the use of recyclable materials that are available locally.
	4. Contribution to the improvement of health, well-being and comfort	2625	Good performance due to the use of natural materials and the optimization of natural ventilation.
	5. Reduced effects of natural hazards	2.25	Good performance because of the reinforced concrete structure. In addition, BTCS stabilized with cement to reduce vulnerability to climatic hazards.
	Notation/15	11,625 soit 77.5%	Good performance
Socio-cultural pillar	6. Protection of the cultural landscape	2.25	Good performance due to the integration of agricultural areas close to concessions.
	7. Transfer of constructive cultures	3	The excellent performance is due to the respect for cultural elements and local know-how reflected in the materials and techniques used for implementation, as well as in the shapes and layout of the building.
	8. Promotion and stimulation of creativity	3	Excellent performance as the building showcases local construction knowledge
	9. Recognition and enhancement of intangible values	3	Excellent performance because the building promotes mutual aid and community exchange.
	10. Promotion of social cohesion	2625	Good performance because the building promotes better socialization
	Notation/15	13,875 soit 92.5%	Excellent performance
Socio-economic pillar	11. Empowering local people	3	Excellent performance due to the project's affordability.
	12. Promotion of local activities	2625	Good performance due to the use of the local hand and the positive financial impact on the local level.
	13. Optimization of construction efforts	3	Excellent performance due to the simplicity of the project. This model promotes an accessible and affordable implementation in a community support ecosystem.
	14. Extending the lifespan of buildings	3	Excellent performance due to the simplicity of the maintenance and servicing process with local resources.
	15. Saving and saving resources	2625	Good performance due to resource sharing and the use of renewable energy.
	Notation/15	14.25 soit 95%	Excellent performance
	Notation Générale/45	39.75 soit 88.33%	Good performance

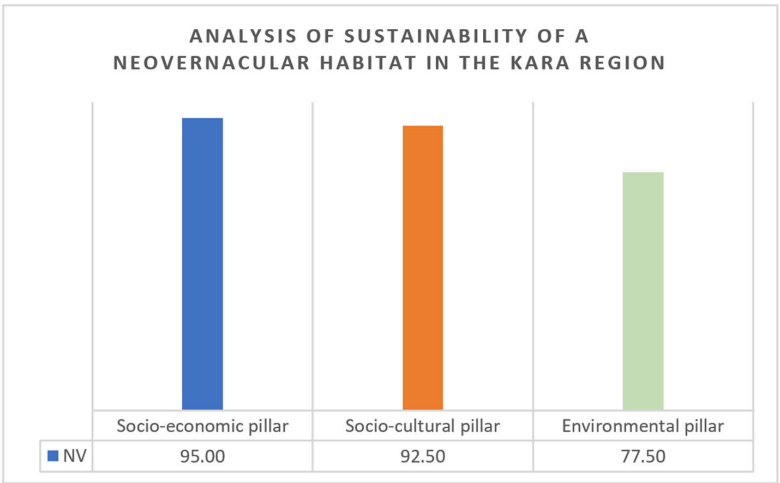


Figure 34. Analysis of sustainability of the CIDAP social hall according to the VerSus tool.

Summary of Evaluators' Judgments

Based on the criteria of the VerSus tool, the CIDAP social hall scored 95% for socio-economic criteria, 92.5% for socio-cultural criteria, and 77.5% for environmental criteria. In terms of sustainability, the CIDAP social hall has a result of 88.33% according to the VerSus tool.

2.3.2. Analysis of Vulnerability to Climatic Hazards According to the PTVA Method

The PTVA method was recently updated by Papathoma-Köhle et al. [32] to assess the vulnerability of buildings to specific climatic hazards, namely strong winds, heavy rains, and hail. The scientific method derived from this work was utilized in our research to assess the vulnerability of the CIDAP social hall to climate hazards, namely heavy rains, strong winds, and high heat. It is based on four main axes: the identification of climatic hazards, the identification of indicators that affect the vulnerability of buildings to these hazards, the scoring and weighting of indicators, and the calculation of the physical vulnerability index (PVI).

Identification of Climatic Hazards in Kara Region

Based on the information provided by the First Communication on Climate Change Adaptation (PCACC) [6], the Kara region is facing various climate risks, including strong winds, heavy rain, and high heat. Table 5 presents the characteristics of these climatic hazards.

Table 5. Characteristic of climatic hazards in Kara region.

Climatic Hazards in Kara Region	Characteristics
Strong winds	The ANAMET data indicates that the Kara Region is frequently subject to strong winds with speeds ranging between 100 and 115 km/h.
Heavy rains	In Togo, data from ANAMET indicates that precipitation classified as intense typically exceeds 50 mm and may reach as much as 100 mm within a 24-h period.
High heat	Heat periods are characterized by particularly high temperatures. Every year, in the Kara Region, such phenomena occur and can locally reach temperatures of 39.5 °C, according to data provided by ANAMET.

Identification of Indicators That Affect the Vulnerability of Buildings

The indicators that affect the vulnerability of habitats in the Kara region were identified using data provided to us by the technical services of the local branch of the National Civil Protection Agency (ANPC). Table 6 presents the indicators of vulnerability to different types of climatic hazards.

Table 6. Indicators of vulnerability to different types of climatic hazards.

Indicators	Heavy Rain	High Heat	Strong Wind
Roof material	✓	✓	✓
Roof shape	✓		✓
Roof slope	✓		✓

Table 6. *Cont.*

Indicators	Heavy Rain	High Heat	Strong Wind
Length of overhang	✓	✓	✓
Foundation height	✓		
Foundation material	✓		
Elevation material	✓	✓	✓
Waterproofing of intersections on the building	✓		
Presence and state of gutter	✓		
Resistance of plastering materials	✓	✓	
Windows type	✓		✓
Building shape		✓	✓
Height of the building			✓
Windows material			✓
Construction typology			✓
Building maintenance status	✓	✓	✓

The Scoring and Weighting of Indicators

- The scoring of indicators

Discussion groups of about twelve individuals, consisting of local builders and trainers from the local chambers of trades, allowed for the rating of each identified indicator. At this stage, to mitigate the degree of inherent subjectivity, stakeholders were afforded the opportunity to put forward suggestions and recommendations concerning the relative importance of each indicator in the assessment of building vulnerability. Tables 7–9 present the ratings of the different indicators.

Table 7. Scoring grid for indicators of the severe rain hazard. Source: Awoussi et al., 2025 [46] (10.3390/buildings15132249).

	Indicators	Scoring									
1	Roof material		Metal roof	Reinforced concrete slab	Clay slab	Clay tile		Straw			
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
2	Roof shape		Conical	Pyramid		Gable roof	Multi-slope roof	Hangar			Flat roof
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
3	Roof slope		21–30° and >30°				11–20°				0–10°
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
4	Length of overhang		>50 cm		25–50 cm				10–25 cm		No overhang
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
5	Foundation height	Built on piles	45–80 cm	30–45 cm	10–30 cm		0–10 cm		<0 cm		No basement
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1

Table 7. *Cont.*

	Indicators	Scoring									
6	Foundation material	Lateritic stone, or schist			Cement blocks and concrete						Raw mud
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
7	Elevation material	Lateritic stone or schist			Cement Block	Earthen wall					Raw mud
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
8	Waterproofing of intersections on the building		Good				Normal		Bad		No waterproofing of intersections
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
9	Presence and state of gutter		Good				Normal		Bad		No gutter
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
10	Resistance of plastering materials	Stone surface		Nere juice and cow dung			Cement plaster and paint		Plastering in earthen		
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
11	Windows type			Sliding window	Casement windows		Louvers				
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
12	Building maintenance status		Preventive maintenance			Corrective maintenance				Curative maintenance	
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
		highest performance								lowest performance	

Table 8. Scoring grid for indicators of the high heat hazard. Source: Awoussi et al., 2025 [46] (10.3390/buildings15132249).

	Indicators	Scoring									
1	Roof material		Metal roof	Reinforced concrete slab	Clay slab	Clay tile		Straw			
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
2	Length of overhang		>50 cm		25–50 cm				10–25 cm		No overhang
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
3	Elevation material	Lateritic stone or schist			Cement Block	Earthen wall					Raw mud
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
4	Resistance of plastering materials	Stone surface		Nere juice and cow dung			Cement plaster and paint		Plastering in earthen		
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
5	Building shape		Round hut					Rectangular hut			
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
6	Building maintenance status		Preventive maintenance			Corrective maintenance				Curative maintenance	
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
		highest performance								lowest performance	

Table 9. Scoring grid for indicators of severe wind hazard. Source: Awoussi et al., 2025 [46] (10.3390/buildings15132249).

	Indicators	Scoring									
1	Roof material		Metal roof	Reinforced concrete slab	Clay slab	Clay tile		Straw			
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
2	Roof shape		Conical	Pyramid		Gable roof	Multi-slope roof	Hangar			Flat roof
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
3	Roof slope		21–30° and >30°				11–20°				0–10°
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
4	Length of overhang		>50 cm		25–50 cm				10–25 cm		No overhang
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
5	Elevation material	Lateritic stone or schist			Cement Block	Earthen wall					Raw mud
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
6	Windows type			Sliding window	Casement windows		Louvers				
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
7	Windows material			Metal	Wood		Sheet metal		Single Glazing/Naco		
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
8	Building maintenance status		Preventive maintenance			Corrective maintenance				Curative maintenance	
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
9	Building shape		Round hut					Rectangular hut			
	Score	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
10	Construction typology	Monolithic envelope (stone)		Concrete structure and cement block filling		Monolithic envelope (earthen)					
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
11	Height of the building		Single storey					Two-story			
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
					highest performance				lowest performance		

- The weighting of indicators

A second round of focus groups, comprising twelve participants drawn from architects registered with the ONAT (Ordre National des Architectes du Togo) and agents of the local civil protection services, was conducted with the aim of classifying the identified vulnerability indicators. At this stage, participants were invited to propose and substantiate the relative importance of each indicator in the assessment of building vulnerability, thereby contributing to a further reduction of the inherent subjectivity of the process. The weighting of the indicators was conducted using the Analytic Hierarchy Process (AHP) method, which was developed by R.W. Saaty [47]. The AHP method is widely recognized and valued as a participatory approach for determining the weights of various indicators. This approach utilizes a pairwise comparison process to assign a weighting to each indicator. Table 10 presents the weighting of the different indicators.

Table 10. The weight of the indicators for each climatic hazard. Source: Awoussi et al., 2025 [46] (10.3390/buildings15132249).

Indicators	Heavy Rain	High Heat	Strong Wind
Roof material	0.17	0.25	0.11
Roof shape	0.17		0.22
Roof slope	0.24		0.15
Length of overhang	0.04	0.16	0.22
Foundation height	0.06		
Foundation material	0.08		
Elevation material	0.03	0.04	0.03
Waterproofing of intersections on the building	0.01		
Presence and state of gutter	0.04		
Resistance of plastering materials	0.01	0.06	
Windows type	0.02		0.02
Building shape		0.38	0.04
Height of the building			0.04
Windows material			0.02
Construction typology			0.07
Building maintenance status	0.12	0.1	0.07

The exact number of participants, the method of selecting participants, the formation of discussion groups, the schedule of discussions, and the consensus method are presented in Table 11.

Table 11. Details of the organization of focus groups for vulnerability assessment.

Method of Selecting Participants	Stage	Participant	Number	Consensus Method	Period
Selection by reasoned choice to question individuals capable of providing relevant answers.	The scoring of indicators	local builders and trainers from the local chambers of trades	12	To reduce the level of subjectivity, stakeholders had the opportunity to make suggestions and recommendations on the importance of each indicator in the vulnerability of buildings	July 10,11,12,15,16 2024
	The weighting of Indicator	architects regularly registered at the ONAT (Ordre National des Architectes du Togo) and agents of the local civil protection services	12	Stakeholders could suggest and recommend the importance of each indicator in building vulnerability in order to reduce part of subjectivity.	August 7,8,9,10,12,14, 2024

Physical Venerability Index (PVI)

The analysis of the vulnerability elements of the CIDAP social hall to climatic hazards (heavy rains, strong winds, and high heat) is presented in the tables (Tables 12–14) and the figures (Figures 35–37).

- Vulnerability index to the severe rain hazard

Table 12. Vulnerability index in relation to heavy rain hazard.

		Roof Material	Roof Shape	Roof Slope	Length of Overhang	Foundation Height	Foundation Material	Elevation Material	Waterproofing of Intersec-tions	Presence and State of Gutter	Plastering Material	Windows Type	Building Maintenance Status
NV	Weight	0.17	0.17	0.24	0.04	0.06	0.08	0.03	0.01	0.04	0.01	0.02	0.12
	Score	0.7	0.2	0.2	0.2	0.2	0.4	0.5	1	1	0.6	0.4	0.5
	Weight × Score	0.119	0.034	0.048	0.008	0.012	0.032	0.015	0.01	0.04	0.006	0.008	0.06
	PVI	0.392											

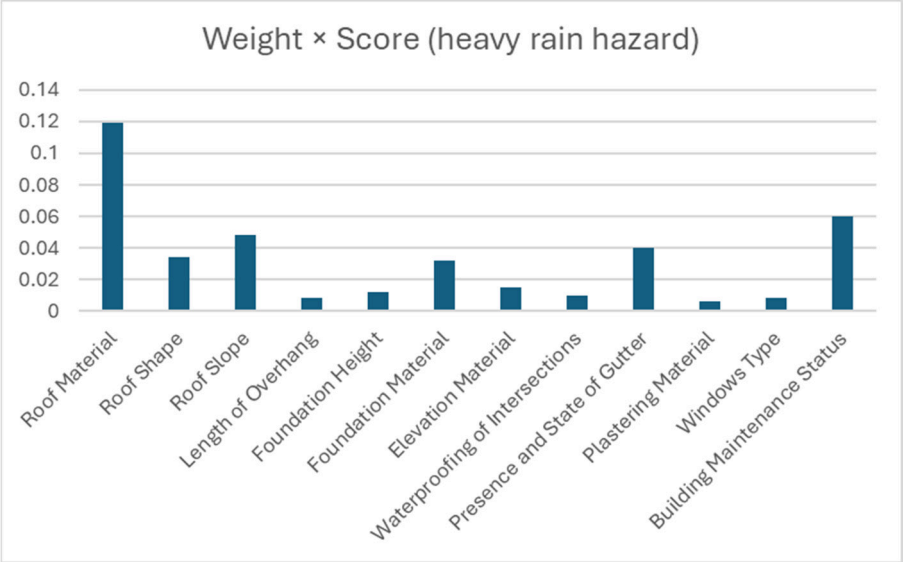


Figure 35. Weight × Score in relation to heavy rainfall hazard.

- Vulnerability index in relation to the high heat hazard

Table 13. Vulnerability index in relation to high heat hazard.

		Roof Material	Length of Overhang	Elevation Material	Plastering Materials	Building Shape	Building Maintenance Status
NV	Weight	0.25	0.16	0.04	0.06	0.38	0.1
	Score	0.7	0.2	0.5	0.6	0.2	0.5
	Weight × Score	0.175	0.032	0.02	0.036	0.076	0.05
	PVI	0.389					

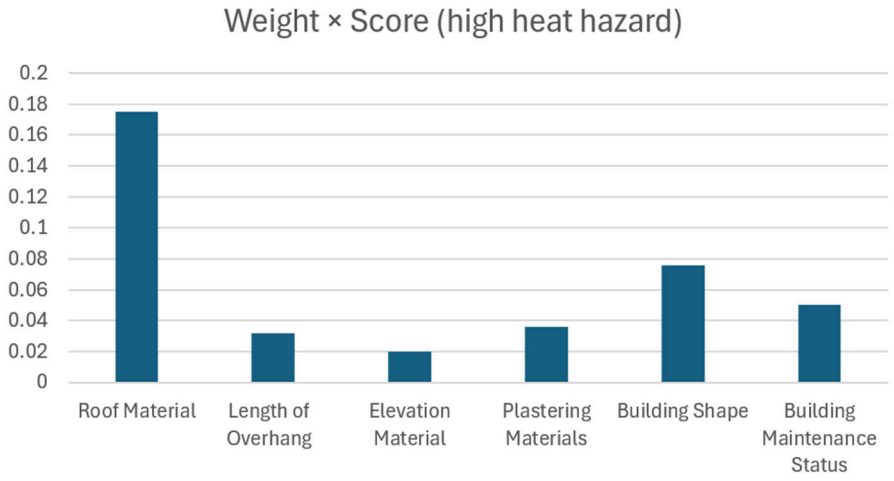


Figure 36. Weight × Score in relation to high heat hazard.

- Vulnerability index to strong wind hazard

Table 14. Vulnerability index in relation to violent wind hazard.

		Roof Material	Roof Shape	Roof Slope	Length of Overhang	Elevation Material	Windows Type	Building Shape	Height of the Building	Windows Material	Construction Typology	Building Maintenance Status
NV	Weight	0.11	0.22	0.15	0.22	0.03	0.02	0.04	0.04	0.02	0.07	0.07
	Score	0.7	0.2	0.2	0.2	0.5	0.4	0.8	0.5	0.2	0.3	0.2
	Weight × Score	0.077	0.044	0.03	0.044	0.015	0.008	0.032	0.02	0.004	0.021	0.014
	PVI	0.309										

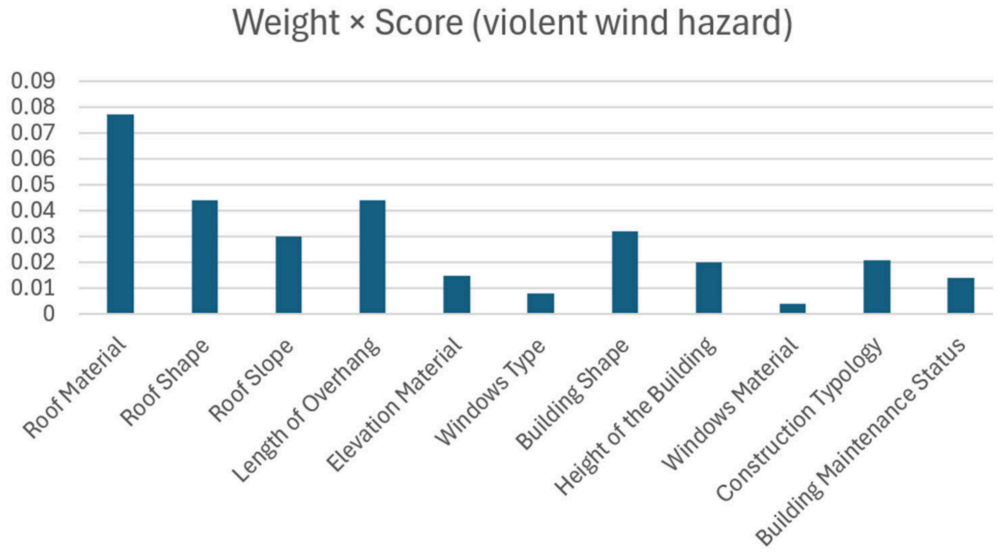


Figure 37. Weight × Score in relation to violent wind hazard.

Interpretation of the Final Result

The PVI calculated for each type of climatic hazard is often expressed as a percentage ranging from 0% to 100% [32]. A higher index value, closer to 100%, indicates the building's higher vulnerability to the hazard. Maria Papathoma-Köhle et al. [32] proposed a three-level classification scale to enhance understanding of the results. This scale is as follows:

- A PVI value from 0% to 40% corresponds to low vulnerability.
- A PVI value from 40% to 60% corresponds to medium vulnerability.
- A PVI value from 60% to 100% corresponds to high vulnerability.

A high vulnerability rating indicates that the building is highly susceptible to damage from the hazard under consideration, with the indicators carrying the highest vulnerability index being identified as the most critical. A low vulnerability rating represents the most favorable outcome, signifying that the building is well integrated within its environment and exhibits a high degree of resilience. A medium vulnerability rating denotes an intermediate condition, in which targeted interventions are warranted to reduce the overall vulnerability index by addressing the indicators presenting the highest levels of vulnerability.

Based on this classification, the CIDAP social room generally exhibits low vulnerability to the hazards of heavy rain, intense heat, and strong winds (Table 15).

Table 15. Interpretation of the PVI index value.

	Interpretation of the PVI Index Value		
	Heavy Rain	**High Heat**	**Strong Wind**
Indicators Increasing Vulnerability Type of Building	**Roof Material Building Maintenance Status**	**Roof Materials**	**Roof Material**
PVI of CIDAP social hall	0.392 or 39.2%	0.389 or 38.9%	0.309 or 30.9%
Interpretation of the PVI index value	low vulnerability	low vulnerability	low vulnerability

2.3.3. Result of the Thermal Comfort Element Analysis

The Kara Region is characterized by a dry season extending from November to March, followed by a rainy season for the remainder of the year. Although multiple data collection campaigns were conducted over the course of this study, the data presented herein are drawn from the December to January period, selected on account of the significant temperature variations recorded during this interval. Indeed, the months of December and January correspond to the driest period of the year in the region [67]. Precipitation levels decline significantly during this period as a result of the harmattan, a dry Saharan wind that blows in a southwesterly direction. This wind, frequently charged with dust particles, is characterized by markedly arid and hot conditions during the day and notably cold conditions at night. The analysis of the region's climatic data, obtained from the National Meteorological Agency of Togo (ANAMET) over a period from 1990 to 2024, indicates that the lowest temperatures are recorded during the month of December amid the dry season rather than during the rainy season. During this same period, the relative humidity value decreases. This significant variation in temperature and relative humidity makes this period suitable for data collection. The analysis of the thermal behavior of the CIDAP social hall is presented in Table 16 and the figures (Figures 38 and 39).

Table 16. Summary of data collection results.

House	Temperature Range	(Temp Max Out—Temp Max Ins) °C	(Temp Min Out—Temp Min Ins) °C	Thermal Offset (Hours)	Difference Between Upper and Lower Indoor Area Temp °C	TDR Temperature Difference Ratio
NV	Around 19 °C	Between 8 and 10 °C	4 to 6 °C	5 a.m. to 6 p.m.	0 to 2 °C	**0.634**

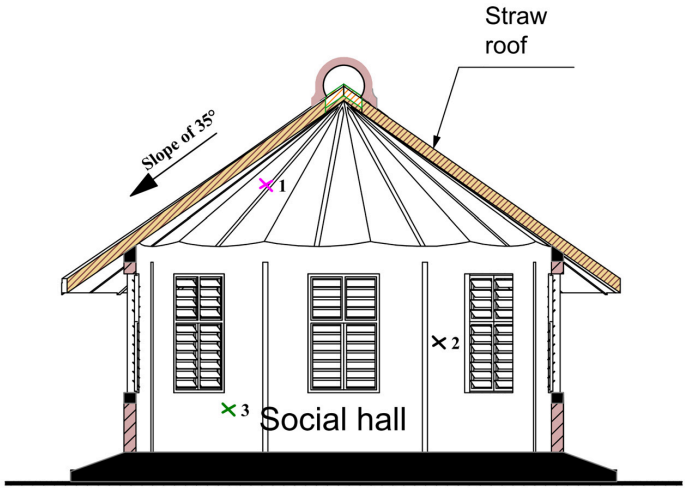


Figure 38. Sensor placement inside the social hall.

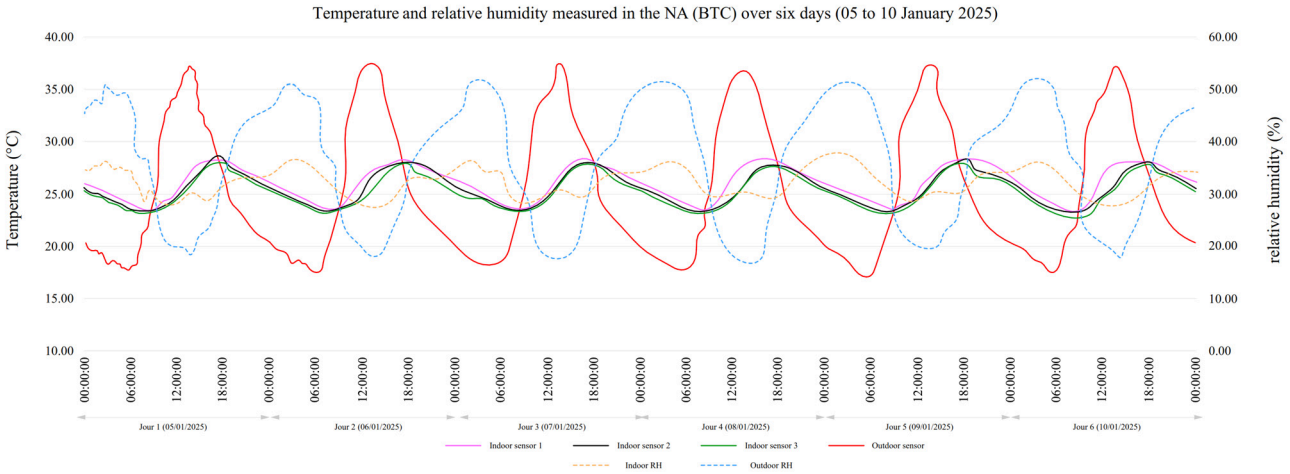


Figure 39. Temperature and relative humidity measured in the social hall over 6 days from 5–10 January 2025.

2.4. Potential for Research Application

2.4.1. Discussion on the Sustainability Elements of the Social Hall

- Socio-economic level

The notion of affordability in the context of state-funded projects is inherently relative, insofar as such projects are most commonly subject to competitive tendering processes that incorporate specific fiscal parameters and constraints. As part of this project, the cost per square meter of the social hall is 200,000 FCFA/m^2, or about 305 €/m^2. This ratio is lower than that of the other buildings in the project. The infirmary, which is a cement brick building with a metal roof, is valued at 300,000 FCFA/m^2, or 457 €/m^2. The cheese factory, which is a double-walled cement brick building with a ventilated double roof, costs 600,000 FCFA/m^2, or €915/m^2. The social hall building is the most affordable for this project. This finding is in agreement with the results of the research conducted by Basile Cloquet and Mathilde Chamodot in Mali, which also highlighted the economic intelligence in the ecological principles of traditional Dogon housing [68]. Through a pilot project developed in Bandiagara, Basile Cloquet and Mathilde Chamodot demonstrated that a house made of locally produced earth bricks costs half as much as an equivalent construction made of cement blocks. In addition to offering better thermal comfort than a modern construction, traditional housing is also financially affordable. Y. Adjibadé has also demonstrated in his work that constructions using earth materials in a mutual aid and community work ecosystem are cheaper than constructions using concrete blocks [24]. This reality is different in the context of a project financed by a private individual because the solutions used to reinforce the building (concrete, cement, reinforcement, and roof structure) have an impact on the budget compared to traditional housing. In the case of a private project, this factor decreases affordability at the time of implementation. However, in the long term, it becomes a profitable investment because the quality of the structure considerably reduces the cost of maintenance. This observation is also shared by Y.Adjibadé [24], who states that the use of concrete to reinforce the building decreases the affordability of the project during its execution phase but improves its profitability in the long term.

The concrete structural framework, comprising footings, columns, and beams, additionally confers enhanced structural resistance to the building. In traditional dwellings, walls are conventionally constructed from raw earth using the cob technique. When left without adequate maintenance, such walls exhibit considerable vulnerability to water infiltration and fail to provide a sufficient level of structural safety for the occupants. The adoption of cement-stabilized earth bricks, a contemporary evolution of the adobe con-

struction method, offers markedly improved resistance to moisture while preserving the inherent thermal properties of the earth material [63]. With the exception of the structural elements and openings, which are fabricated from industrial materials, namely reinforced concrete and aluminum, the remaining materials employed in the construction are of natural origin, comprising raw earth, wood, and straw, and are sourced locally. These natural materials fulfill a significant role in reducing the environmental impact of the building while simultaneously contributing to the stimulation of the local economy. Furthermore, the overall management of the project by a local enterprise ensures that local artisans derive tangible economic benefits from its realization. The project has enabled various local actors to acquire skills and knowledge that they can apply in their homes or utilize in other projects for financial compensation, thereby fostering a sustainable community development model that enhances their livelihoods.

With regard to empowerment, it is worth noting that the social hall does not incorporate dedicated spaces for the storage or processing of products, nor for commercial activities. Nevertheless, the users of this building benefit from access to the communal facilities of the CIDAP center, including drying, production, and other ancillary installations made available to them. This pooling and sharing of resources, a principle that extends to all other buildings within the center, constitutes a meaningful expression of solidarity that reinforces the overall autonomy and self-sufficiency of the project.

- Socio-cultural level

According to the CIDAP center, students who use the social hall said they were very satisfied with the comfort and well-being provided by this building because it meets their need for modernity. In the local African context, cement is gaining more ground. This situation is caused by the public authorities supporting the installation of cement industries [69,70]. According to Y. Adjibadé [24], it is the consequence of the vulnerability of raw earth habitats and the miserabilist image that this conveys. CIDAP's social hall project proves that by adopting new construction techniques inspired by the local and global, earth can provide benefits comparable to cement in terms of strength. In addition, it is much better than the latter in terms of thermal regulation. Ingenuity, through the mixing of construction materials (earth and cement) and the promotion of local know-how, especially with the straw roof, has allowed the social hall building to prove its effectiveness by going through the rainy and heat seasons of the years 2023, 2024, and 2025 without major difficulty, thus convincing reluctant local communities. In addition, the scalable nature of the building with the addition of other similarly shaped modules allows builders to have the necessary tools to initiate similar projects. The simplicity of the construction techniques, which are straightforward to reproduce, also contributes to this goal. This goal reflects the desire for knowledge transfer and sharing of traditional know-how that this project carries. The CIDAP center primarily pedestrianizes its paths, fostering human interaction and bolstering the project's social cohesion. Traditional huts are inherently characterized by limited natural lighting, attributable to the absence or reduced dimensions of window openings [26]. This limitation has been addressed in the social hall through the incorporation of an adequate number of Naco-type louvred windows, which ensure a satisfactory level of natural light within the interior space. Whether in the open or closed position, Naco windows fitted with glass slats provide sufficient daylighting conditions throughout the day. In their closed configuration, they additionally serve as an effective barrier against water ingress, insects, and dust penetration.

- Environmental level

The approach in a local context as advocated by K. Frampton [18] is illustrated through the use of earth material for the walls and straw for the roof. This ensures better thermal

and hygrometric comfort [71]. The color of the plaster applied to the structural elements is clay red to imitate the texture of the earth material. All these choices allow users to identify and orient themselves in a building that adapts harmoniously to its natural environment. Beyond physical perception, K. Frampton's notion of tactile [18] is also taken into account, illustrated by the smell, humidity, and heat/cold management of the materials. This characteristic gives the space a special or significant character, allowing local users to reconnect with their environment. The PAFPE program has financed toilets with septic tanks to improve sanitation conditions. Although this system is now appreciated, the CIDAP center also has ecosan-type dry toilets, which are less expensive to install, save water, and provide manure that is beneficial to the soil. The CIDAP center has several vegetated areas that prevent soil erosion, filter dust, and provide additional shade. In terms of energy for lighting, as well as for water supply, solar panels are used to ensure energy independence for the building. In addition, the choice of materials such as earth and straw makes considerable energy savings possible thanks to the passive cooling of the building [24]. The use of materials such as reinforced concrete, steel, aluminum, and quicklime may raise concerns because they are heavily processed industries and often imported from neighboring countries, increasing the project's carbon footprint. In a local context where the protection of flora is a priority, choosing metal for doors and windows instead of wood seems more judicious.

The building of the CIDAP social hall shows, in terms of sustainability, a result of 88.33% according to the VerSus criteria. The work of Awoussi et al. [26] demonstrated that contemporary architecture in the Kara region presents a sustainability level of 35.83%. The CIDAP social hall therefore offers better performance compared to contemporary constructions in the region. Table 17 compares the sustainability scores of different forms of vernacular architecture in the Kara region.

Table 17. Sustainability scores of different forms of vernacular architecture in the Kara region.

	Sustainability of the Neo-Vernacular Architecture of CIDAP's Social Hall in the Kara Region	**Sustainability of Vernacular Architecture in the Kara Region Regarding the VerSus Criteria [26]**		
VerSus Criteria	**Neo-Vernacular Architecture of the CIDAP Social Hall**	**Contemporary Architecture (CA)**	**Kabiye Vernacular Architecture (KVA)**	**Nawdeba Vernacular Architecture (NVA)**
Environmental level	77.50%	15%	77.50%	77.50%
Socio-economic level	95%	60%	85.00%	90%
Socio-cultural level	92.5%	32.50%	87.50%	87.50%
Durability Performance regarding the VerSus criteria	88.33%	35.83%	83.33%	85%

2.4.2. Discussion of the Vulnerabilities of the Social Hall

The circular shape of the building, its state of strength, the shape of the roof, and its slope have greatly improved the resilience of the building. The vulnerability index of the CIDAP social hall is approximately 0.392 for the heavy rain hazard, 0.389 for the high heat hazard, and 0.309 for the violent wind hazard. By way of comparison, these results are considerably more favorable than those obtained for contemporary architectural buildings in the Kara region, as documented in the work of Awoussi et al. [46]. According to Awoussi et al., the vulnerability index for a contemporary architectural model in the Kara region, as assessed using the PTVA tool, stands at 0.499 for heavy rain, 0.522 for high heat, and 0.456 for strong winds. The CIDAP social hall demonstrates an overall low vulnerability with respect to climatic hazards. Nevertheless, the characteristics pertaining to roofing materials present notable weaknesses, particularly with respect to the hazards of heavy rain

and high heat. While thatching material can achieve a service life of 20 years or more [72] when subject to regular maintenance, it remains inherently vulnerable to deterioration induced by both water infiltration and solar radiation. Water infiltration in particular constitutes a critical factor in the degradation process, as it creates conditions conducive to biological attacks by microorganisms. Beyond biological deterioration, the prevalence of termites in tropical regions represents an additional and significant aggravating factor in the degradation of thatched roofing material. Straw, when exposed to solar radiation, may be damaged. Due to exposure to solar radiation, intercellular lignin undergoes oxidation, resulting in micro-cracking. This micro-crack promotes water infiltration, which increases vulnerability to biological attack. Preventive maintenance is therefore necessary to limit the influences of water and sun exposure.

2.4.3. Discussion on the Thermal Comfort of the Social Hall

The collected data reveal a recorded temperature range of approximately 19 °C. The differential between maximum outdoor and indoor temperatures is in the order of 8 to 10 °C, while the thermal lag is estimated at approximately 5 to 6 h. Upon entering the interior space, occupants experience an immediate perception of thermal freshness. The social hall maintains notably cool interior conditions throughout the day, even as outdoor temperatures reach their peak values. The differential between minimum indoor and outdoor temperatures ranges from 4 to 6 °C. The nocturnal use of the space by students for academic revision contributes to a moderate increase in indoor temperature. Consequently, even as exterior temperatures reach their minimum values, the indoor nighttime temperature remains relatively mild. This thermal regulation pattern is consistently observed across both the upper and lower internal sensor readings. This observation confirms that earth material is not a thermal insulator but rather has an excellent thermal inertia [73]. The straw roof also contributes to this thermal regulation. The thatched roof attenuates heat transfer towards the interior by virtue of the air pockets trapped between its constituent fibers, thereby acting as a natural thermal insulator. This property effectively preserves cooler interior conditions within the building during periods of elevated outdoor temperatures [74]. The circular configuration of the buildings also plays a significant role in enhancing thermal comfort, as it serves to minimize solar radiation heat gain within interior spaces. According to Mr. Butera [75], the circular shape minimizes the surface area of the walls exposed to solar radiation. The TDR value is 0.634, which is close to the performance of traditional habitats, according to research by Awoussi et al. [46]. The selection of materials employed in this project confers notable advantages with respect to thermal performance.

3. Study Limitations

Our article examines the overall performance of neo-vernacular architecture through a unique case study. It provides a useful evaluation of the durability, vulnerability, and thermal comfort of the CIDAP social hall. While the findings emphasize the advantages of applying vernacular principles in new constructions, analyzing a single case does not provide a sufficient sample size to generalize the results at a regional level. To effectively generalize these findings, it is essential to consider a variety of cases involving numerous examples of both neo-vernacular and traditional vernacular architectures to conduct a comparative analysis and enhance the conclusions. Additionally, it is crucial to acknowledge the limitations of the analytical tools utilized in this research. The performance evaluation conducted in this research is not an exact measure but rather an assessment based on criteria and indicators. Firstly, despite its optimization for the analysis of vernacular constructions, the VerSus tool exhibits a significant degree of subjectivity. To remedy this, during our field survey, we asked respondents to justify their answer unanimously to reduce the risk of

error due to subjectivity. The PTVA method used does not allow for the analysis of the simultaneous effect of climatic phenomena (such as the high heat hazard followed by violent rain accompanied by strong winds), which can cause a cumulative vulnerability that differs from the simple sum of the vulnerability index of these three climatic phenomena. We limited ourselves to the relative vulnerability index, which is nothing more than an absolute score that expresses the vulnerability of the element at risk to the climatic phenomenon. In addition, the characteristics of climatic phenomena, such as intensity, variation over time, or the occurrence of climatic hazards, could not be defined in our study. The choice and weighting of indicators can be complemented by laboratory experiments to better assess different parts of buildings and refine the selection of indicators. The evaluation of indicators can also involve a larger number of local participants and experts from different countries and fields to ensure the accuracy of the methodology over a wide area. The evaluation of thermal performance, utilizing sufficient resources, can be applied to various vernacular structures to enhance the TDR calculation formula based on minimum and maximum temperatures and to facilitate precise predictions. This study provides statistics on the evaluation of performance over a short period. A prolonged data-gathering initiative might be beneficial for generalizing the findings. Moreover, another improvement to this analysis could be the consideration of adaptive comfort from the perspective of the user.

4. Conclusions

This study evaluated a neo-vernacular architecture in the Kara region based on the idea that the lessons learned from ancestral building practices coupled with green technologies can formulate, in the region, a contemporary architectural response in line with the imperatives of galloping demography, modernity, affirmation of cultural identity, resilience, and climate adaptation. This work explores a series of both qualitative and quantitative tools to analyze the CIDAP social hall building regarding the criteria of durability, vulnerability, and thermal comfort. This work reveals that the neo-vernacular architecture of the CIDAP social hall achieves a sustainability score of 88.33% according to the criteria of the VerSus tool. The vulnerability index of the CIDAP social hall, according to the PTVA tool, is around 0.392 for heavy rain, 0.389 for high heat, and 0.309 for violent wind. As far as thermal behavior is concerned, the TDR (Temperature Difference Ratio) of this building is around 0.634. In view of the criteria considered, all of these results reflect a satisfactory performance of the CIDAP social hall in terms of durability, vulnerability, and thermal comfort. This work is important for local decision-makers as they select constructive solutions that draw inspiration from vernacular housing and new technologies. The goal is to create a new vernacular architecture that aligns with the everyday realities of their population.

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