Housing Adaptations to Climate: Vernacular Settlements on the Kahayan Riverbank at Palangka Raya, Indonesia

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Abstract

Producing buildings that can adapt to climatic conditions is one of the notable abilities of people who improve the quality of their houses. Lake Tundai is a residential area in Palangka Raya, Indonesia, occupied by a fishing community, isolated and only accessible through the Kahayan River. People prefer wood materials for house construction, and with a largely impoverished population, they remain in those houses they have inherited from the past. However, it is an example of a village resistant to the effects of global climate change, because their houses are climate-friendly, although natural breeze is the only thermal comfort enjoyed by the inhabitants of Lake Tundai.

Using thermal performance simulation on the Tundai Lake houses, this research presents four types applied to four variable elements through the Ecotect analysis program to ascertain how the houses deal with the climate. Based on the climatic conditions in Lake Tundai. Type 2 with stilts, light roof, light walls, single ventilation, and ceiling is the most suitable model condition in Tundai Lake.

The research concluded in 2023 that the influence of the building floor height from the ground may affect the thermal comfort in the room. If the floor height over the water level is below 1.2 meters. This study proposes an example of housing adaptation using wood materials nearby the water.

Keywords: Housing adaptation, Riverbank, Climate change, Vernacular settlement.

Introduction

When observing a building for the first time, one of the habits of people is to look at the performance of the building in terms of its ability to adapt to climatic conditions. The climatic condition relate to global temperature. According to Goddard Institute (2022), global temperature has shown a well-documented increase since the early 20th century and mainly since the late 1970s. Worldwide since 1880, average surface temperatures have increased by about 2°F (1°C), relative to mid-20th century baselines (1951-1980). This is on top of the approximately 0.15°C additional warming between 1750 and 1880 (NASA, 2022). The latest NASA study (2023) shows that there has been an increase in the earth's temperature by two degrees Celsius or as much as 3.6 Fahrenheit above the pre-industrialization of 1880. If the earth's temperature continues to increase by two degrees, it will impact people's lives simultaneously (Abigail, 2023).

However, a building adaptation cannot avoid the influence of climate. Rapoport (1969) mentions that the availability and selection of materials and construction techniques in an architectural arrangement will influence and change the shape of a building. In the same way, a house responds to the physical pressures of the climate, such as heat, cold, humidity, and light (Rapoport, 1969). Climate data records provide evidence of indicators of climate change, such as increases in global land and ocean temperatures; rising sea levels; loss of ice at the Earth's poles and in mountain glaciers; the frequency and severity of extreme weather changes such as hurricanes, heat waves, forest fires, droughts, floods, and rainfalls; changes in cloud cover and vegetation (McCartney *et al.*, 2021). This means that one of the responses of a building to climate depends on the level of contact with the ground and water surfaces. Recently, these have undergone changes.

In Kalimantan, wooden houses are a simple choice, easily constructed, at low expenses. Therefore, they are popular among the low-income communities (Bredenoord, 2015). However, global warming has made the environment less friendly (Lai *et al.*, 2023; Bredenoord, 2015). In the face of climate change, thermal comfort within wood materials involves living without air conditioners. Climate change most easily affects thermal barriers in wooden houses or similar materials (Latha, Darshana and Venugopal, 2015). The occupants have thus directly experienced and felt the impact of global climate change, and some ideas to observe this material need consideration (Hermawan, Prianto and Setyowati, 2015; Bredenoord, 2015; Stott, 2016).

However, amidst these conditions, the inhabitants of Lake Tundai continue to live as before, pretending that nothing has happened in their environment. They don't think that climate has changed significantly (Chen, Giese and Chen, 2020). Their main livelihoods are fishing and farming (Elbaar, 1982; BPS Kalteng, 2023). People are mostly poor, and wooden dwellings survive. In other words, Lake Tundai is a resilient hamlet resistant to global climate change. Residents living in wooden houses and on the riverbanks experience various problems and obstacles, such as being periodically attacked by floods and runoff when the Kahayan River overflows (BPS Kalteng, 2023). Therefore, some residents prefer to build houses above the river to adapt to these conditions rather than on the mainland.

On the other hand, electricity energy source of Tundai Lake is a diesel engine turned on at night. It does not help the communities to use artificial air conditioning. Therefore, the natural breeze is the only thermal comfort source open to Tundai Lake residents. Thermal comfort inside a wooden house is susceptible to changing temperature and air pressure because of the permeability or density of the walls and the floors, which are open to the air and climate (or temperature) change (Hermawan, Prianto and Setyowati, 2015; Stott, 2016). Thus, as it is known, malaria and vector diseases may arise due to changes in the earth's atmosphere and living at certain temperatures (Rocklöv and Dubrow, 2020). Therefore, the effect of global warming on thermal comfort within wooden houses is an important issue.

In this context, this study examined wooodedn houses in Tundai Lake at two locations: one on land and one in water. It aims to find out how climate affects the building design of these houses. The objectives are

1) To identify the effect of the earth's temperature and floor height of the wooden houses above the ground, on the interior of the house.
2) To identify the effect of the earth's temperature and floor height of the wooden houses above water, on the interior of the house.

Theoretical Framework

Building Density, Air Circulation and Ventilation

Building densities are one of the principal factors influencing the micro climatic condition that determine ventilation and air temperature (Huang, 2021). The symptoms of significant warming have affected a city's density rather than its size. Densely packed buildings worsen the ventilation conditions (Liu *et al.*, 2022). On the other hand, high density also reduces sunlight on the buildings during summer. The effect of city density on ventilation depends on wind conditions, space arrangement and building height (Nugroho, Triyadi and Wonorahardjo, 2022).

Density is a term having many meanings. Webster's dictionary defines it is the average number of individuals per unit of space such as when one talks bout population density of 500 per square mile, and a housing density of 10 houses per acre. However, high-density characteristics involve tight spaces, large and tall buildings, and a significant population (Churchman, 1999). The Asian Development Bank (ADB) refers to the high-density buildings in Indonesia, as a Kampong condition (2022).

Physical form dominates high-density buildings, narrow road circulation patterns, and scattered open spaces (Pattacini, 2021). Building density has a different definition. The two views depict the density characterized by a high population, tight space, and domination of residential areas. Quantitatively, the density parameter refers to the total number of people per hectare (Pafka, 2022). Density is the allowable building floor space permitted on a property, measured by dwelling units per hectare (single-family) or floor area ratio (FAR) (Bolton, 2021). Density defines if the building number reaches 80-100 buildings per hectare or more than 100 buildings per hectare in high-density areas. In other words, the floor area ratio reaches 50-70% for medium-density and more than 70% for very-density housing (Ardiansyah *et al.*, 2018).

Wooden House

Meanwhile, regarding climatic change conditions in the hot, humid tropics, wooden house development will affect the building's heating process. Heating of a building is undoubtedly so influenced by the use of roof elements as the most prominent heat receiver, wall elements, ventilation and ceiling materials. All the building elements affect the achievement of building thermal comfort. Therefore, selecting suitable building materials and ventilation systems in areas with specific climatic conditions is very important (Ahmed, Kumar and Mottet, 2021).

The global warming effect on thermal comfort inside the wood house influences the volume of the house against global temperature (Hermawan, Prianto and Setyowati, 2015). It means a differential temperature gap outside a house compared to the inside of a house (Nguyen, Schwartz and Dockery, 2014). If the extreme temperature outside the house becomes the same as the temperature inside the house, the permeability level of the house is vulnerable to global temperature changes (Iordache *et al.*, 2016). Hence, the gap still happens if the house temperature is against the outdoor temperature (Asumadu-Sakyi *et al.*, 2021). It means that the place is unexposed to changes in the global temperature (Lai *et al.*, 2023). In other words, climate change effects do not influence temperature of the house or the residents.

The changing temperature inside a house or room depends upon some critical factors in design, such as the opening of doors and windows, including non-tight wooden walls and floors. In addition, the influence of building materials can bring many problems for the occupants (Lai *et al.*, 2023). Wood materials do not have the same density, durability, and strength grades (Bredenoord, 2015). Thermal comfort arises from a building's construction and materials to various degrees (Medved, 2022). The height of a building also affects the temperature inside a room (Karimimoshaver and Shahrak, 2022). If the stilt is so near the soil, a wooden house floor will experience a higher vulnerability to temperature change than a floor away from the surface (Lenssen *et al.*, 2019). In short, building design determines thermal comfort within a wooden house. It means the level of contact with the ground dan water is critical.

Research Methodology

This research employs a quantitative research methods. It examines case studies in the Danau Tundai sub-district (Kelurahan), Palangka Raya, Central Kalimantan Province, Indonesia. Information was collected through photos, identification of buildings in Lake Tundai, and simulation through ECOTECT.

There are two types of wooden buildings based on their construction, with stilts on the ground and buildings without stilts floating on the water (Lanting). Lanting comes from the *Banjarnese* language and means a house floating on water (Aufa *et al.*, 2021). In addition, there are buildings with different house stilt height variations, an average of above one meter and below one meter from the ground. In the Lanting building, there is a difference in floor height above 0.3 meters and below 0.2 meters from the river water level.

Data was collected as follows:

1) On average, buildings in Tundai Lake use stilts with a height of between 0.9-meters and 1.1-meters above ground level, so the selection of buildings is distinguished from stilts that are 1-meter above ground level and stilts whose stilts do not reach 1-meter.
2) For buildings that float on water (Lanting), the research chooses the type of building with a building floor above 0.3meters and a building below 0.2-meters above the water level.
3) In a building with a stilt type with a height above 1.1 meters, cross ventilation is selected, then the temperature in the room is measured
4) In a building with a stilt type with a height of 0.9-meters, a building that does not have cross ventilation is chosen.
5) In buildings that float above the water surface (Lanting) or the type without stilts with a floor 0.3-meters above the water surface, the choice is only in a building with one ventilation. This is done because the average building above the river has only one ventilation (window)
6) A building that floats above the water surface (Lanting) with a floor 0.2-meters above the water is chosen to build with cross-ventilation
7) After identifying the construction, room temperature of each type of building is measured.
8) After taking measurements in the field, an Ecotect version 2011 simulation is carried out, at the Environment and Housing Laboratory (PPIIG) of the University of Palangka Raya.

The Tundai Lake: Existing Houses and Conditions

The village of Danau Tundai is located in the cultural heritage area of Palangka Raya and is the source of fish in the city of Palangka Raya. All the residents of this hamlet have built their houses with wooden constructions on the riverbank. Sooner or later, in the end, there will be a process of weathering wooden houses either due to climate change, flooding, or moths/termites (insects) attack. However, the poor people living in Lake Tundai have no choice but to build their houses. Timber construction is the cheapest and most accessible alternative for manipulating villages far from land transportation systems and dependent on river transportation. It has obstacles in developing concrete or brick residential buildings. Therefore, housing with wooden construction is the best solution available.

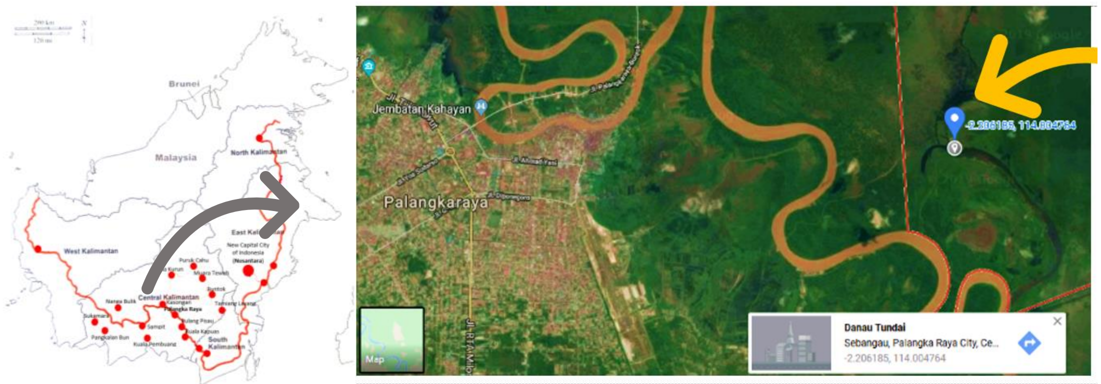

Fig. 1: The Lake Tundai in Palangka Raya
Source: Google Maps, 2022

This research was conducted in Lake Tundai, administratively under the Municipality of Palangka Raya as a sub-district (Kelurahan). However, the location is separated by the Kahayan River and is still surrounded by wilderness as a cluster. The Lake Tundai (Kelurahan) distance is only 9.82 km from the city center of Palangka Raya (BPS Kalteng, 2023).

Fig. 2: Street on the Kampungs of Tundai Lake
Source: Author, 2022

Fig. 3: Housing on the River Bank of Tundai Lake
Source: Author, 2022

The Tundai lake-wide area is 33.445 m^2, settled in 84 buildings. It includes ten elementary school buildings, four office buildings, and residential buildings, all facilities customary below 50-70%. It means that Tundai Lake is not very dense.

Fig. 4: Four types of Buildings situated in Tundai Lake were selected, and their density.
(Source: Modify from Google Maps, 2022)

After identifying Lake Tundai, we have specified four distinct types of residential type 1, type 2, type 3, and type 4. This comprehensive study encompasses all existing homes in the area. The following are the defining characteristics of each type:

Table 1. The Type of Houses Data in Tundai Lake was selected
Source: Author, 2022

Types	**Floor stage**	**Roof**		**Wall**		**Ventilation**		**Ceiling height**		**Temp ^{0}C** indoor
		Low	**High**	**Low**	**High**	**V1**	**V2**	**0**	**1**	
Type 1	Under 1 m	4m		3m		v			2.75m	30.8
Type 2	Upper 1 m		6m		3.5m	v	v		3.5m	28
Type 3	Under 0.2 m	2.5m		2m		v		na		37
Type 4	Under 0.3 m		4m		3m	v		na		32

Notes: v: available; na: not available.

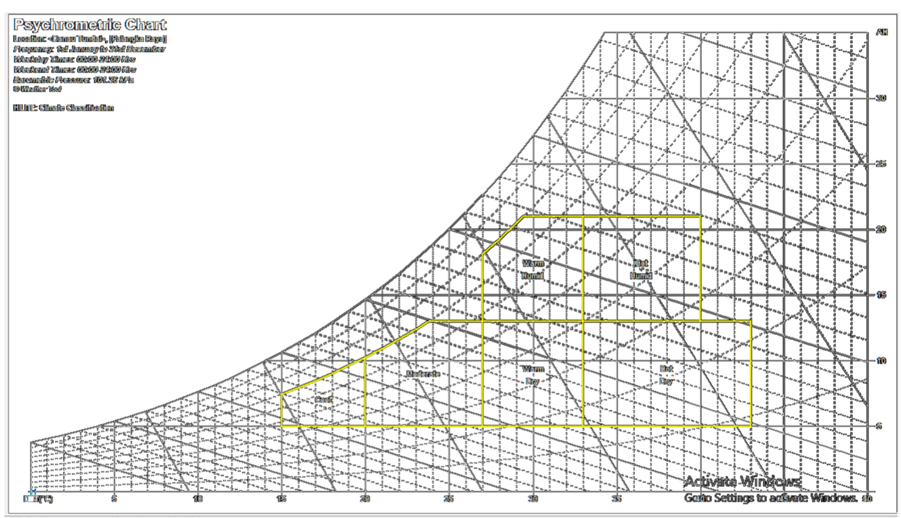

Fig. 5: Comfort zones in Tundai lake, Palangka Raya
Source: Ecotect, 2022

Based on Psychometric data in Lake Tundai, the dry bulb temperature is between 59 ^{0}F (15 ^{0}C) and 109.4 ^{0}F (43 ^{0}C), and the wet bulb temperature is between 59 ^{0}F (15 ^{0}C) and 69.8 ^{0}F (21 ^{0}C).

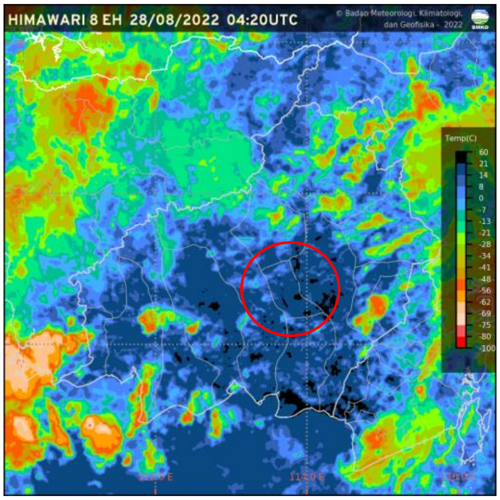

Fig 6: The Temperature and Air Circulation That Passed Palangka Raya is High (Red Zone) Source: BMKG Central Kalimantan, Indonesia, 2022

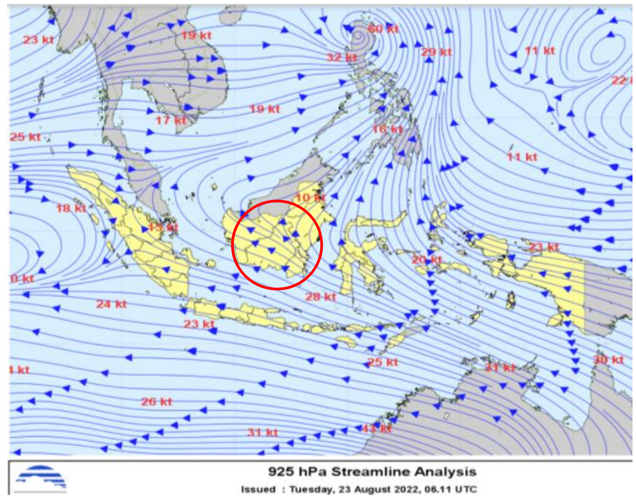

Fig 7: Air Circulation
Source: BMKG Central Kalimantan, Indonesia, 2022

Based on BMKG data for 2022, the highest average temperature is 31 ^{0}C, and the lowest is 24 ^{0}C. Meanwhile, the average wind speed passing through Palangka Raya is 22 km/hour.

Findings and Discussion

Climate Data and Housing Characteristics in Tundai Lake

In Tundai Lake, the coldest month is January. The average monthly air temperature is 28.2 ° C with a maximum of 33.9 ° C and a minimum of 20.4 ° C. The average monthly air humidity is 73.4%; the highest is 93.2%, and the minimum is 43.8%. The horizontal radiation level reaches 5550 wh / m2 with a 17.06 mm/month precipitation rate. The hottest month is April. The air temperature average goes to 30.4 ° C, with a maximum of 36.9 ° C and a minimum of 22.9 ° C. The average air humidity in the hottest month at Tundai Lake is 71.04%; the peak is 96.2%, and the lowest is 41.4%. Detailed the climatic conditions are shown in Tables 2 and 3.

Table 2: Climate data in the study area in the coldest month in January 2022
Source: BMKG Measurement, Tundai Lake, 2022

Location	Air Temperature			Air Humidity			Precipitation (mm/month)	Radiation (Wh/m^2)	Air Velocity (m/s)
	Av	Max	Min	Av	Max	Min			
Tundai Lake	28,2	33,9	20,4	73,4	93,2	43,8	17,06	5550	4

Table 3: Climate data in the study area in the hottest month April 2022
Source: BMKG Measurement, Tundai Lake, 2022

Location	Air Temperature			Air Humidity			Precipitation (mm/month)	Radiation (Wh/m^2)	Air Velocity (m/s)
	Av	Max	Min	Av	Max	Min			
Tundai Lake	30,4	36,9	22,9	71,04	96,2	41,4	81,7	5967	3

Building Characteristics

Most of the wooden buildings in Lake Tundai use lightweight materials for floors, roofs, walls, and ceilings. Each building has various openings and cross ventilation, such as windows and doors open throughout the day. In Lake Tundai, buildings do not have a uniform building orientation. Based on the investigation shows that in the density of buildings, the BC coefficient ranges from 50-70%. Under certain conditions, the BC coefficient can reach more than 70%. On the other hand, in Lake Tundai, the characteristics of the buildings are slightly different from those in urban areas. Albeit using simple materials, it has resilient to climate change. However, in detail, the characteristics of the buildings in the study area can be categorized as permanent buildings on the land and non-permanent above the river. It can be shown in Figure 8-11. Based on a simulation study, this study evaluates building characteristics in terms of wall, roof, ventilation, and ceiling materials.

Fig. 8: Type 1
Source: Author, 2022

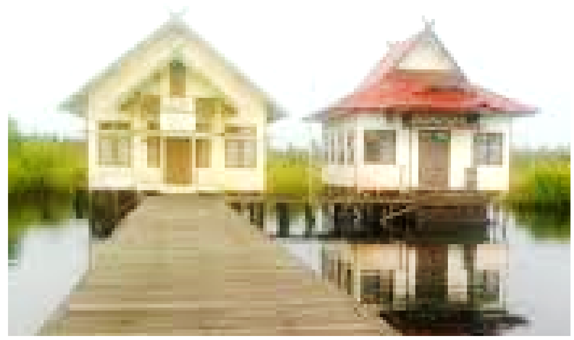

Fig. 9: Type 2
Source: Author, 2022

The research examined the role of variables of the roof, wall, ventilation use, and ceiling usage. The field of observation has identified some types and architectural variants.

Fig. 10: Type 3
Source: Author, 2022

Fig. 11: Type 4
Source: Author, 2022

The study identified four types and building variants. The research identified a 4 x 6 m² having an opening and roof covering with a height of 3 m as Type 1. The type represents the most straightforward building or space. The analysis is to understand through the simulation of all types and variants. Based on the ECOTECT analysis simulation program, the appropriate and inappropriate varient for each type's thermal comfort is established.

Table 4
Zones analysis in the hottest month (April. 10)
Source: Author, 2023

Zones	**Type 1**	**Type 2**	**Type 3**	**Type 4**
Zone 1	Below the stage 1m	Upper the post 1m	Water	Water
Zone 2	Kitchen	Kitchen+restroom	Family room	Kitchen
Zone 3	Family room	Office	Kitchen+Veranda	Family room
Zone 4	Living Room	Hallway	Roof (no celling)	Roof (no celling)
Zone 5	Roof (with ceiling)	Top (with the ceiling)	-	-

Generally, the initial approach to managing climate change focused on thermal comfort design in its interior, particularly within a wooden house.

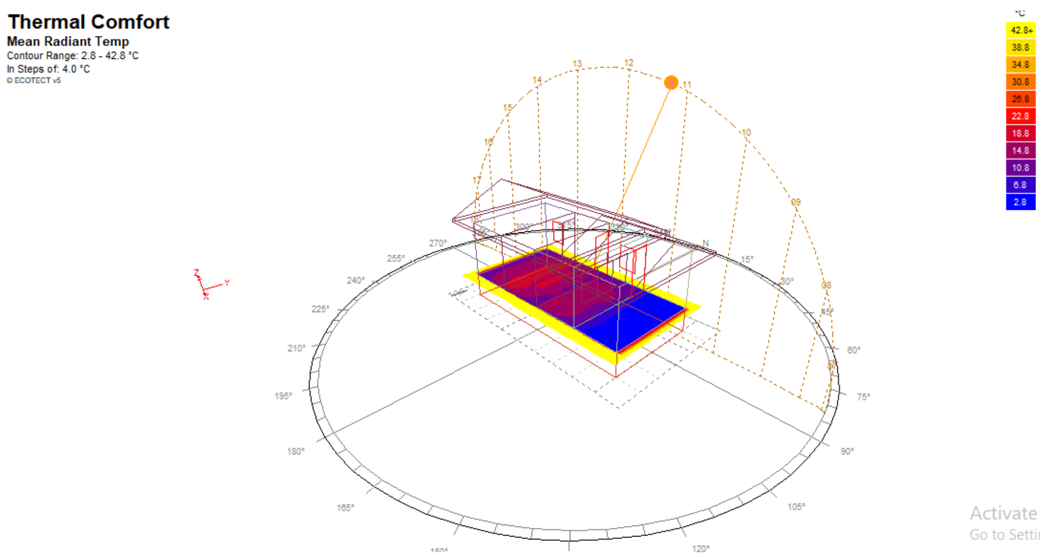

Fig. 12: Type 1 Thermal Comfort in the Hottest Peak (April)
Source: Author, 2022

Type 1 found zones 2, 3, and 4 with 30.80 ^{0}C as the hottest areas. In this type, the floor was situated 1 meter above the ground. According to the psychometric chart, temperature is in the warm-dry zone during 5-10 AH (average hour). Then it increases to become warm-humid in 15-20 AH. The veranda (zone 5) is the most comfortable zone in April.

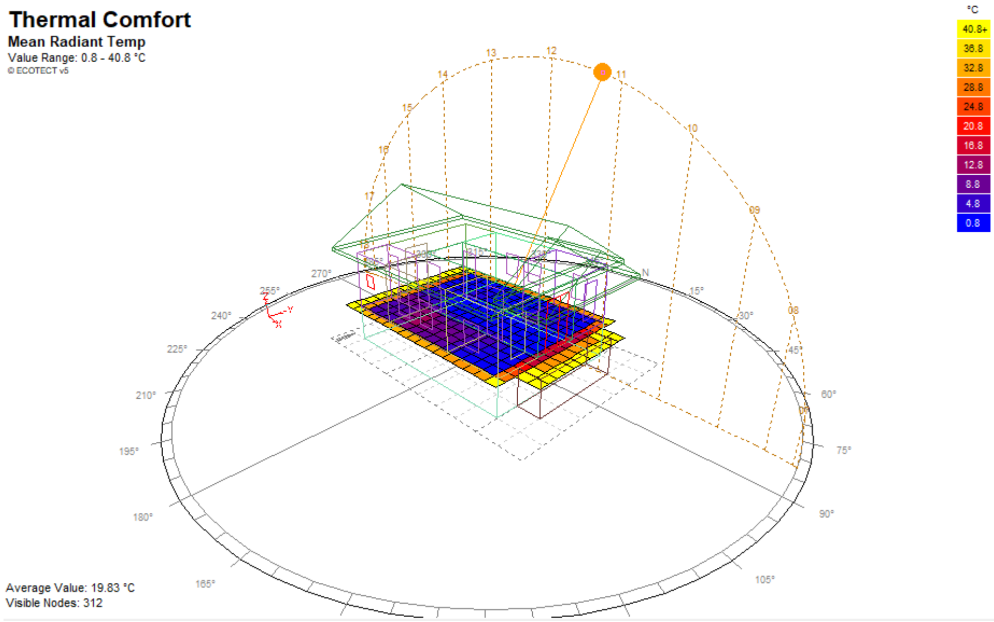

Fig. 13: Type 2
Source: Author, 2022

In Type 2, the floor is at the same level as Type 1. It has windows crossing each other, and thermal comfort dominates the hallway and the Northside of the building. In this type, the average temperature value reached 28,8 ^{0}C in the hottest zone. Temperature is moderate, according to Tundai Lake's psychometric chart.

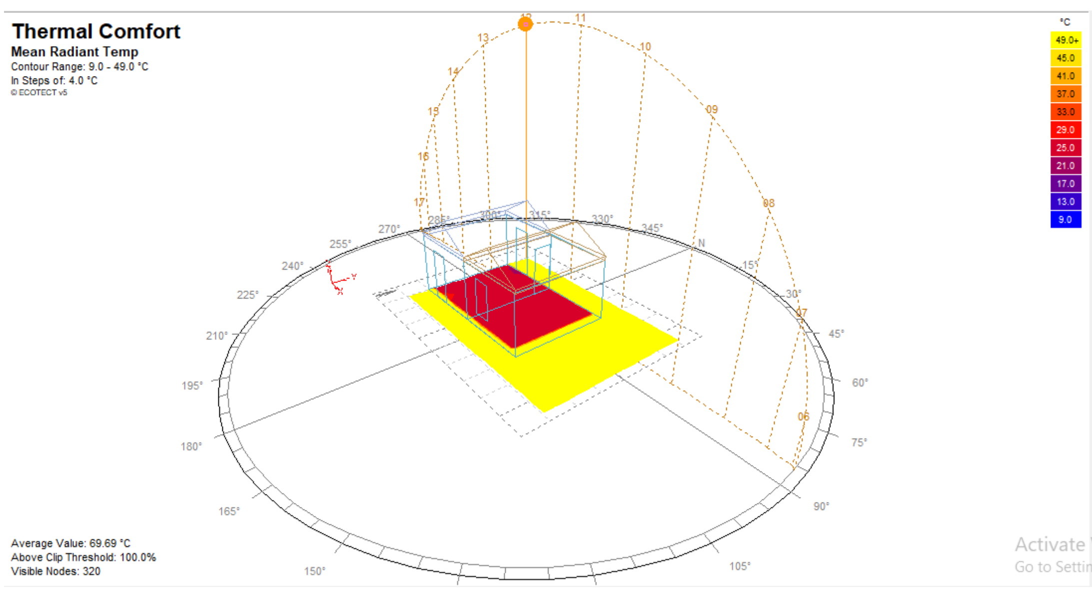

Fig 14. Type 3
Source: Author, 2022

In Type 3, with more cavities depicted, the building floor is nearly 0.2 meters above the river level. It experiences warm, dry conditions and affects the outside temperature zones. The room has a moderate comfort zone near the doors and windows. Temperature is 37 ^{0}C in the hottest zone.

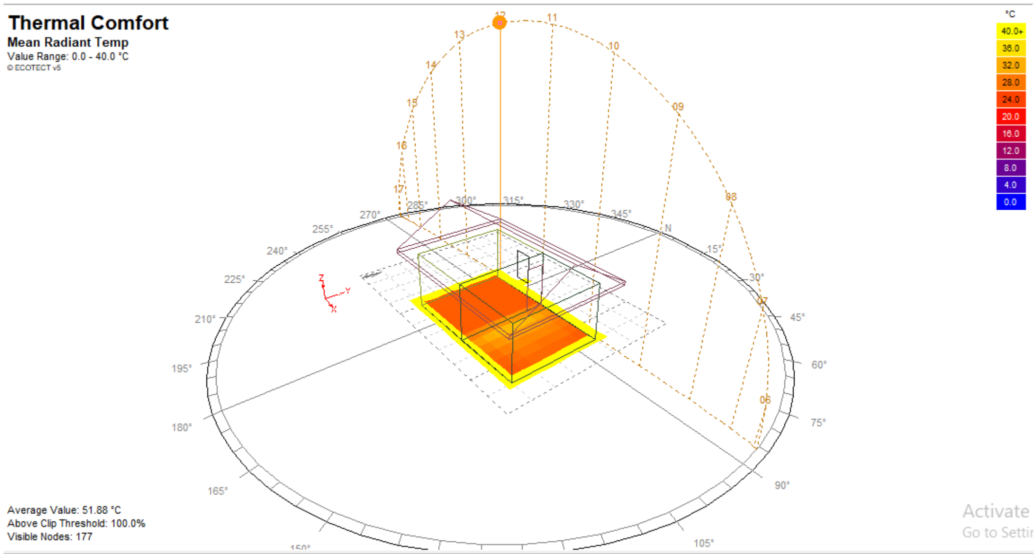

Fig. 15: Type 4
Source: Author, 2022

In Type 4, with the narrow cavities shown, the building floor attached is raised 0.3 meters above the river level. Its experiences are highly affected by outside temperature. However, in the same type, the floor passes between 0.2 meters and 0.3 meters above the river level, and thermal level reaches the hot, dry zone. Nevertheless, when the floor lifts between 0.3 meters and 1.2 meters, the thermal level reaches a higher level of about 32 ^{0}C. However, the best thermal comfort zones are 1.2 – 2.2 meters above river level, and the temperature in the hottest zone reaches 28 ^{0}C.

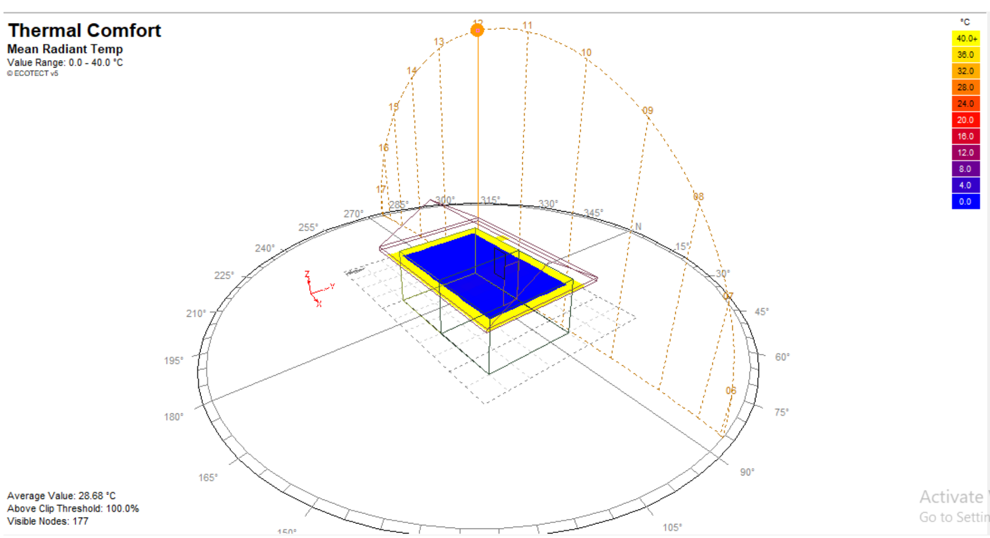

Fig. 16: Type 4 is the thermal comfort zones at 2.2-meters above the water levels
Source: Author, 2022

The results of the thermal performance simulation on Tundai Lake types were subjected to the ECOTECT Analysis program with four variable elements. Simulations were executed in the hottest month, April, and the coldest peak in January. Based on the results, the highest thermal comfort is in type 2 (Lightweight Roof-Stage-Single Light-Ventilation Wall-Plafond). At the same time, the lowest comfort is the result of the present in type 4 (Light Roofs - Variance of home buildings based on field observations).

Table 5: Types of houses on Tundai Lake
Source: Author, 2023

Types	Floor stage	Roof		Wall		Ventilation		Ceiling	
		Low	High	Low	High	V1	V2	0	1
Type 1	■	■		■		■			■
Type 2	■		■		■	■	■		■
Type 3		■		■		■		■	
Type 4			■		■	■		■	

Conclusion

Based on the findings above, not all building elements, such as cavities, materials and roofs, floors, and walls, can provide adequate thermal comfort. Based on the climatic conditions of the Tundai Lake and simulation results, type 2 with Stage, Light Roof, Light Wall, Single Ventilation, and Ceiling (S-LR-LW-V1-V2-C1) is the most suitable type for the Tundai Lake conditions. In contrast, Type 4, with Non-stage floors, Light Roofs, Heavy Walls, Single Ventilation, and Non-Ceiling (NSF-LR-HW-V1-C0), is the least suitable for Tundai Lake conditions.

Thus, the influence of thermal temperatures outside the room or house dramatically affects the thermal comfort inside the room. Climate change effects outside the room are dynamic. It will also affect the thermal comfort inside the room.

Regarding climatic conditions in hot, humid tropics, building heat is significantly affected by the roof element. The most significant heat receiver are wall elements, ventilation, and ceiling material. All the building elements impact the achievement of building thermal comfortability.

Not all building elements can provide adequate thermal comfort, particularly in low-density areas like Tundai Lake. Based on climate conditions in Tundai Lake. Type 2 (two) with a stage, lightweight roof, lightweight walls, single ventilation, and ceiling is the most suitable type of building to be constructed in Tundai Lake. It happened because Type 2 put the floor at a certain height, 1.2 meters above the water level. Meanwhile, Type 4 (four) with no stage, light roof, heavy wall, single ventilation, and no ceiling is unsuitable for Tundai Lake. In type 4, the floor is directly attached to the river level, 0.2 meters above the water level.

The best thermal comfort of a wooden house is achieved when the floor is lifted between 1.2 meters and 2.2 meters over the ground. It should avoid the outside temperature affecting the building, mainly in its interior.

The floating house should be designed with more ventilation to transform air velocity passed through the house. Global warming has increased sea level temperature at specific points. The daylight temperature is hotter than before due to sunlight directly reflecting on the floating house and affecting the floor. As suggested in the design, it should set its base at a certain level between 1.2 meters and 2.2 meters above sea level (water level-based).

Tundai Lake is a sample of building performance in terms of people who live in a wooden house. Mostly, they choose both living on the stage and floating homes. Based on this research, living in a floating wooden house is more vulnerable to the outside temperature than living in a stage house. Nowadays, urban citizens prefer to build using concrete and attach the building to the ground even though the historical side and the results of this study show that buildings will get good air at a certain height, both above the river and on land.

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