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Qualitative Identification of Tropical Climate Responsive Design Strategies in Indonesian's Traditional-Vernacular Housing

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ABSTRACT

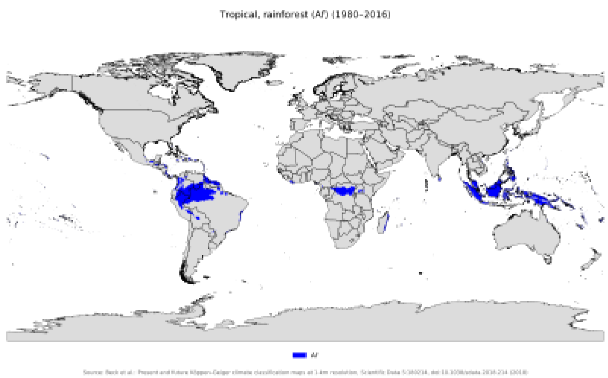
The diversity of traditional-vernacular housing type in Indonesia is mostly influenced by the micro-climate differences. As been explained in Koppen's Climate Zoning theory, the tropical climate is divided into 3 categories which are Af (Tropical Rainforest), Am (Tropical Monsoon), and Aw (Savanna). That classification can be seen from several climate-forming aspects that have different intensities and scales in each zone, such as Solar radiation, Temperature, Daylighting, Humidity, Air velocity, and Rainfall Intensity. By using qualitative identification method, this paper discusses about some Tropical Climate Responsive Design Strategies in Indonesian's Traditional-Vernacular Housing. Three steps qualitative identification analysis had been done to investigate the details of architectural aspects in 3 case studies (1) 'Mbaru Niang', from Manggarai Nusa Tenggara Timur; 2) 'Rumah Mbelin' from Karo, North Sumatera; and 3) 'Huma Betang' from Palangkaraya, Central Kalimantan). By 'learning from the past', this paper identified some Indonesia's traditional houses to initiate the further and more comprehensive studies about the tropical-climate responsive strategies that considering the occupant's well-being.
Keywords: Climate Responsive Design, Tropical Architecture, Traditional House, Vernacular, Qualitative Identification

1. Introduction

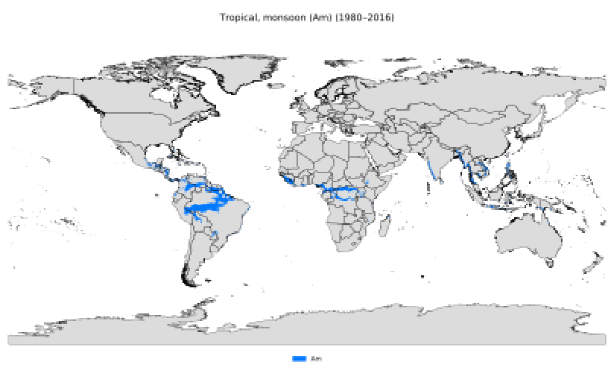
Common people know the tropical climate areaby an area with a high temperature, high rainfall, surrounded by dense forest areas, and get high sun radiation whole year. These aspects of the tropical climate have varying intensities-depending on the different geographical conditions-later has been known as the microclimate. The character of the microclimate of an area is determined by the climate classifications known internationally. There are 5 climate classification based on the international standard [1], those are: 1) Sun Climate classification; 2) Junghuhn climate classification; 3) Köppen climate classification;
4) Schmidt Fergusion climate classification;and 5) Oldeman Climate Classification.

The Köppen climate classification is one of the most widely used climate classification systems. This system was developed by Wladimir Köppen, a German climatologist, around 1884 (with some changes he added in 1918 and 1936) [2]. Based on the Koppen climate category, the tropical climate is divided into 3, namely Af, Am, and Aw.

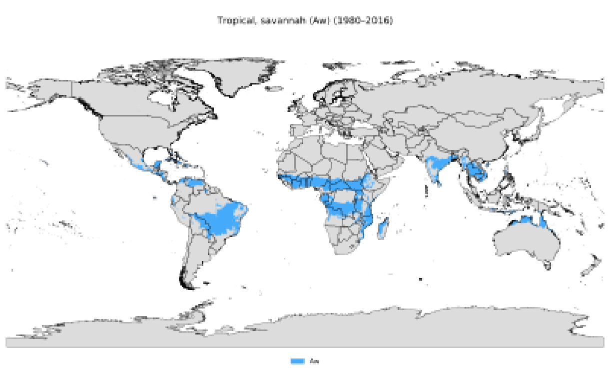
'Af' is a category of Tropical Rainforest Climate, in Indonesia an example is Pontianak City. 'Am' is a Tropical Monsoon Climate, in Indonesia an example is the city of Makassar. While 'Aw' is the Savanna Climate, in Indonesia this climate's character is shown in the city of Kupang. These three types of tropical climate classifications have different intensity of climate-forming aspects, such as in areas with a tropical climate of Aw, the rainfall rate is low yet got very high solar radiation. Meanwhile, in areas with a tropical climate type Af, the rainfall is very high, so the city tends to have a fairly high humidity as well.



Source: (Beck et al, 2018) [2]
Figure 1: Tropical climate zones Af around the world.



Source: (Beck et al, 2018) [2]
Figure 2: Tropical climate zones Am around the world.



Source: (Beck et al, 2018) [2]
Figure 3: Tropical climate zones Aw around the world.

As been said by Bodach [3], vernacular architecture is the result of hundreds of years of optimization to provide a comfortable in a local climate using available shelter materials and known construction technologies. The characteristics' differences of the tropical climate that have been described above, lead to the diversity of the house's designs in the different tropical climate classifications area.

The tangible manifestation of this is the diversity of Indonesia's traditional-vernacular house designs. They adapted to the micro-tropical climate conditions in the area where the houses are located. Indonesia's traditional community's endeavor to increase the thermal comfort, as it's the most disturbing factors directly felt during their occupancy, results to different strategies that can be shown in the architecture aspect, such as the roof shape, building orientation, material usage, ventilation openings, substructure, and other parts.

Source: (Wisma Bahasa) [5]
Figure 4: Several Indonesia's Traditional Houses Type

By looking closely to each different tropical climate-responsive strategies, this paper aim to search and discover the underlying climate responsive strategies conceived in Indonesia's traditional-vernacular houses. This purpose can be easily understood if the climate responsive strategies analysis visualized and explained in qualitative identification description. This method previously presented in researchs that have been done by Bodach [3] in 2014 and Nguyen et al in 2011 [6].

In Nguyen et al's research [6], six old houses in rural and urban areas spread over the 3 regions of Vietnam, were thoroughly investigated to understand the climatic design strategies employed by using 6 methods which are: 1) Climate Zoning (Climate analysis); 2) Collecting data (Architectural Typology); 3) Systematic Analysis (Qualitative Evaluation),4) In-Situ Survey (2-day quantitative evaluation); 5) Building Simulation Tools (Whole year quantitative evaluation); and 6) Systematic Analysis (Concluding remarks). The qualitative identification analysis method they used can be seen in figure 5 below.

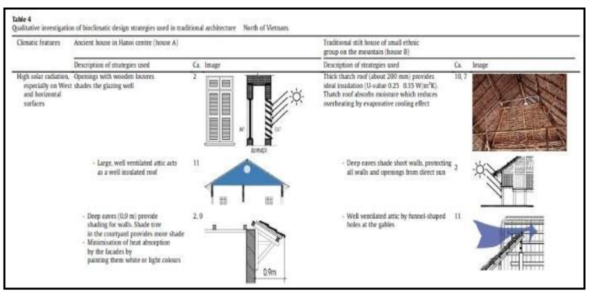


Table 4
Qualitative investigation of bioclimatic design strategies used in traditional architecture North of Vietnam.

Climatic features	Ancient house in Hanoi centre (house A)			Traditional stilt house of small ethnic group on the mountain (house B)		
	Description of strategies used	Ca.	Image	Description of strategies used	Ca.	Image
High solar radiation, especially on West and horizontal surfaces	Openings with wooden louvres shades the glazing well	2		Thick thatch roof (about 200 mm) provides ideal insulation (U-value 0.25 0.35 W/m²K). Thatch roof absorbs moisture which reduces overheating by evaporative cooling effect	10, 7	
	- Large, well ventilated attic acts as a well insulated roof	11		- Deep eaves shade short walls, protecting all walls and openings from direct sun	2	
	- Deep eaves (0.9 m) provide shading for walls. Shade tree in the courtyard provides more shade - Minimisation of heat absorption by the facades by painting them white or light colours	2, 9		- Well ventilated attic by funnel-shaped holes at the gables	11	

Source: (Nguyen et al, 2011) [6]
Figure 5: Sample of the qualitative identification analysis of Climate Responsive Design in Vietnam

Meanwhile, in Bodach et al's article [3], they compared some characteristics of vernacular houses in subtropical climate of Nepal by presenting the qualitative identification analysis in a table (figure 6).

By adapting to Bodach and Nguyen's qualitative identification analysis methods, this paper identified some Indonesia's traditional houses to initiate the further and more comprehensive studies about the tropical-climate responsive strategies that considering the occupant's well-being.

Table 5
Characteristics of vernacular houses in warm temperate climate of Nepal.

	Hill house in Dolakha	House in Salle	Newar house	Indo-Nepalese house	Adobe house	Gurung house	Limbu house
Settlement pattern	Scattered	Scattered	High	n.s.	High	Medium	Scattered
Building form	Rectangular floor plan	Rectangular elongated	Rectangular plan with interconnecting courtyards	Rectangular plan along terrace	Rectangular plan	Round shaped	Rectangular form
Building orientation	Longer side southwards	Longer side oriented downhill	n.s.	South, south-east or south-west	Main long façade south-west wards	n.s.	Parallel to river
Stories	2-2.5	2	3-3.5	2	2.5	1.5	1.5-2.5
Internal space arrangement	Ground floor: kitchen and living; 1st floor: sleeping, storage	Ground floor: veranda, kitchen bed and prayer room, 1st floor: bed rooms, storage, balcony	Vertically use of space: ground floor: storage; 1st floor: bedrooms; 2nd floor: living room; 3rd floor: kitchen	Dominant horizontally, 1st floor used as storage, provision of semi-open space	Vertically, ground floor: shop, storage, 1st floor living and bed room, 2nd floor: kitchen	Internally almost open space, few divisions, mezzanine as fodder	More horizontally, ground floor is main living area
Semi-open spaces	Shaded veranda and balcony	Closed veranda and balcony	Courtyard	Open courtyard	No	Veranda	Veranda and balcony
Wall material	Stone, plastered and painted	Stone and mud	Burnt brick (outside), sun dried brick with mortar (inside)	Stone-mud with mud plaster	Adobe wall (sun dried clay bricks)	Wooden lathe covered with mud	Stone and mud, white or ocher mud plaster
Wall thickness	40–50 cm	50cm	28–70 cm	35–50cm	50–60 cm	Thin	Thick
Roof material	Stone slates on timber structure	Thatch and stone slate	Burnt clay tiles on mud layer and timber structure	Thatch or slates on wooden roof structure	Burnt tiles on mud layer above timber structure	Thatch on timber structure	Thatch on timber structure
Roof type	Saddleback roof	Pitched roof	Gable roof	Pitched roof	Pitched roof	Steep	Steep pitched roof
Roof overhang	Wide	Yes	Wide	Yes	Wide	Wide	Wide
Foundation	Stone plinth covered by mud/earth	n.s.	60–80 cm deep stone plinth	30–50cm stonework platform	Foundation of stones	Low plinth	Stone plinth
Floor	Mud layer	Mud/earth covered	n.s.	n.s.	Mud layer	Mud and cow dung	n.s.
Ceiling	Very low, wooden beams and lathwork	Wooden structure with lathwork and mud covering	Wooden beam	Wooden structure with lathwork and mud layer	Structure of timber and bamboo	n.s.	n.s.
Openings	Medium sized	Medium sized openings toward valley side	Small windows, only for living room large window	Small wooden windows on southwards facades	Rather small,	Very small, grilled windows	Medium sized windows

Source: (Bodach, 2014) [3]
Figure 6: Sample of the qualitative comparation analysisof Climate Responsive Design in Nepal

2. Methods

The main idea of this research is to identify tropical-climate-responsive strategies in some case studies with qualitative descriptive method. By adapting to the previous research done by Bodach et al in 2014 [3] and Nguyen at al in 2011 [6], the qualitative identification analysis in this paper is defined in three steps, which are: 1) Climate Analysis, 2) House's Typology Analysis, and 3) Climate Responsive Design Analysis. Those steps will be qualitatively described in some tables.

The materials for the Climate analysis are the differences of Tropical Climate zonings. As stated in the background, Indonesia has 3 different tropical climate zoning according to Koppen's classification. So, in the discussion it will also be divided into Af, Am, and Aw zone.

The second step contains the houses' typology descriptions. This part provides any information regarding the architectural detail of the houses. These details later become the supporting materials for the climate responsive design analysis as can be seen from the example in figure 5.

The Climate Responsive Design Analysis is the third step in this research. By considering some tropical climate aspects and any problem that arousing the uncomfortable thermal experience according to Bodach (marked with *) and Nguyen's research (marked with **), these are the parameters that become the analysis tools considered in this step:

1. Building orientation and shape**
2. Solar shading**
3. Natural ventilation (cross ventilation (a), stack ventilation (b), single-side ventilation (c)) **
4. Natural lighting techniques**
5. High thermal mass**
6. Evaporative cooling**
7. Earth cooling**
8. Thermal insulation by material**
9. Thermal insulation by design (e.g. well ventilated attic, doubleskin**
10. façade.)
11. Passive solar energy**
12. Flood prevention**
13. Rainwater discharge**
14. Moisture and condensation prevention**
15. Semi-open spaces*
16. Ceiling*
17. Building Stories*
18. Internal Space arrangement*
19. Roof (Types, material, overhang)*

Based on the list above, it's been resumed to be 6 main parameters that later will be analyzed, those are:

1. Solar radiation
2. Temperature
3. Daylighting
4. Humidity
5. Air velocity
6. Rainfall Intensity

Then, 3 Indonesia's traditional-vernacular houses were chosen as the case studies of each parameters. The houses are: 1) 'Mbaru Niang', from Manggarai Nusa Tenggara Timur; 2) 'Rumah Mbelin' from Karo, North Sumatera; and 3) 'Huma Betang' from Palangkaraya, Central Kalimantan.

3. Results and Discussions

a) Climate Zoning

In this part, several climate condition being explained and compiled as the basic data to understand the micro-climate character. The micro-climate parameter that had to bewritten are such as [7]: 1) Latitude and Longitude; 2) meters above sea level (MASL); 3) Mean temperature; 4) AnnualRelative Humidity; 5) Annual Rainfall Intensity; and 6) Sun radiation. The following table 1 explain the comparation of the 3 traditional-vernacular houses

Table 1. The Comparation Data of 3 Case Studies' Micro-Climate Parameter

No	Micro-climate parameter	Mbaru Niang	Rumah Mbelin	Huma Betang
		Manggarai, NTT	Karo, North Sumatra	Palangkaraya, Central Kalimantan
1	Latitude and Longitude	$119^0$30'-$120^0$30' East Longitude and 8^0 North Latitude-$8^0$30'-South Latitude $3^0$19' (Aw)	$97^0$55'-$98^0$38' East Longitude and $2^0$50'-$3^0$19' North Latitude (Af)	$113^0$30'-$114^0$07' East Longitude and $1^0$35'-$2^0$24' South Latitude (Af)
2	Meters Above Sea Level (MASL)	45-1.171 m ASL	280-1420 m ASL	< 100 m ASL

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3	Mean temperature	32,29^0 C	16^0-17^0 C	30,83^0 C
4	Annual Relative Humidity	77,8%	82%	83%
5	Annual Rainfall Intensity	1.154 mm/year	1.000–4.000 mm/year	2.300–2.700 mm/year
6	Solar radiation	6.530	2.261	2.365

Source: various sources, compiled by Satwikasari, 2021

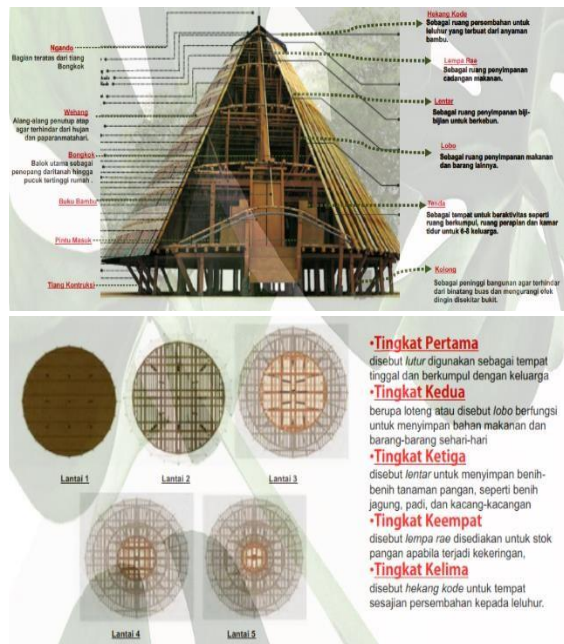
In Indonesia, the distribution of tropical savanna climates or wet and dry tropical climates (Aw) is mostly in the southern and southeastern regions of Indonesia, it can be seen in the table 1, 'Mbaru Niang' house located in Manggarai NTT is classified as Aw Climate Zone area. Meanwhile, both of 'Rumah Mbelin' and 'Huma Betang' are classified in Af Climate Zone. According to the MASL data, Rumah Mbelin has the highest geographical position, it leads to the city also has the lowest mean temperature whole year. Both of Karo and Palangkaraya have fair period of monsoon and drought season, but in Manggarai where the 'Mbaru Niang' house placed, the city 'haunted' by longer drought season because it has low annual rainfall intensity. In the other side, we have to continue to the second part of analysis to know whether 'Mbaru Niang' has special strategy to avoid the high solar radiation.

b) *Typology Analysis*

This part explain the proper analysis for the three houses' Typology. Before analysing the climate-responsive strategies, we had to see closely on to the layout, the elevation, the facade, and also other architectural details of the house. Some photos are also very useful to be added as the supporting materials.

1) 'Mbaru Niang'

The traditional-vernacular 'Mbaru Niang' House has unique layout and typology. It usually has five floors with different usage. Yori Antar even discussed the detail of each floor and the design elements in a book published in 2011. This house is identical to the cone shape and has a very large and wide roof dimension that almost touches the ground. Usually the roof use palm fiber as the cover and for the superstructure, the people choose wood or bamboo. The most unique construction detail is in its frame joint that doesn't need nails but rattan ties instead [9][10].

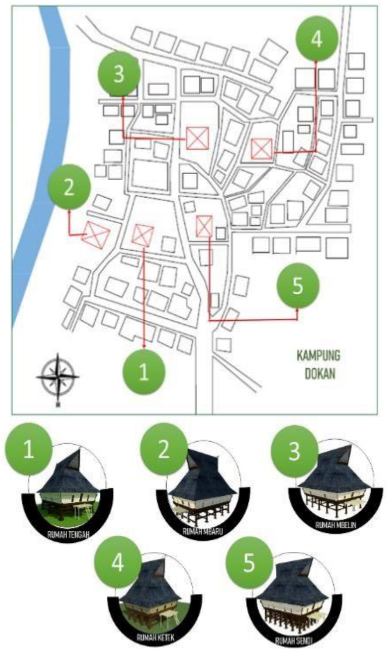


Source: (Antar, 2011, re-compiled by Ismawan, 2020) [8]

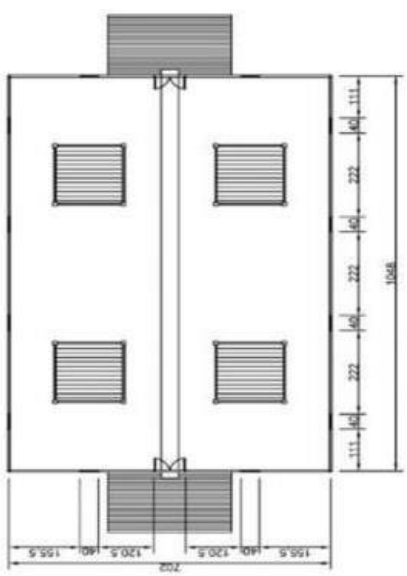
Figure 7: 'Mbaru Niang' House typology

2) 'Rumah Mbelin'

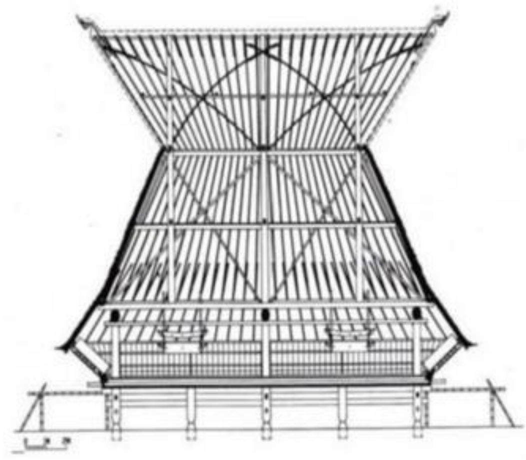
The following discussion is the typology analysis from 'Rumah Mbelin' house. From a research had been done by Aditya et al in 2017, there were some visualizations of a settlement pattern, layout, and elevation of 'Rumah Mbelin' in Kampong Dokan, Karo District North Sumatra.



Source: (Aditya, 2017, re-compiled by Suwandi, 2020) [11]
Figure 8: Settlement pattern and 5 house typology types of 'Rumah Mbelin' in Kampung Dokan, Karo, North Sumatra



Source: (Aditya, 2017, re-compiled by Suwandi, 2020) [11]
Figure 7: Layout of 'Rumah Mbelin' in Kampung Dokan, Karo, North Sumatra



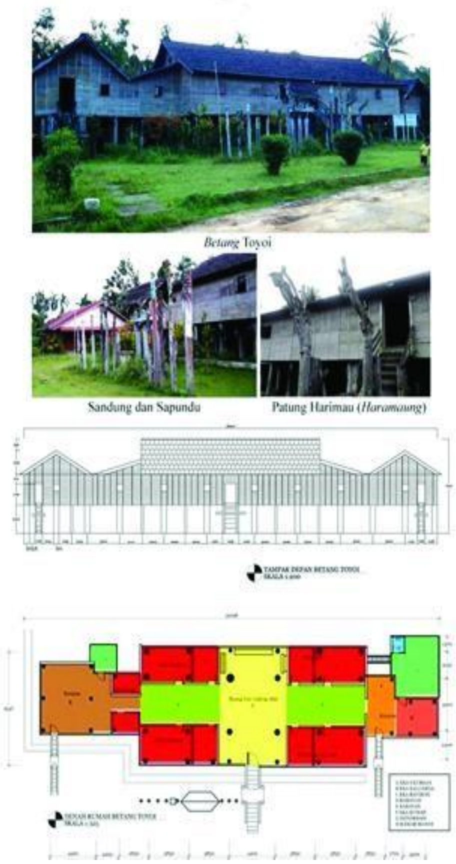
Source: (Aditya, 2017, re-compiled by Suwandi,2020) [11]
Figure 7: Elevation of 'Rumah Mbelin' in Kampung Dokan, Karo, North Sumatra

According to the same article, some of the architectural aspects that can be useful for the third analysis step can be resumed, those are:

- 'Rumah Mbelin' is a Stilted House
- The total height could be 12 m above theground.
- It doesn't have interior partition
- Commonly occupied by 8 member family.
- It has four fireplaces named 'Para-para'
- It has high-roof with steep angle of inclination 800
- It has strong foundation from cement,rubble stone, and sand.

3) 'Huma Betang'
This traditional house was built since 1870 and uniquely most of the original houses remain strong until now, even after being inherited for some generations. The environment is identic with densed forest area with a lot of wild animals. This house usually face the river or to the east. The building is commonly oriented north-south.

This house usually have high-stilted construction, mostly using wood as the main material, gable style roof, wood- board floor, and have several wide openings.



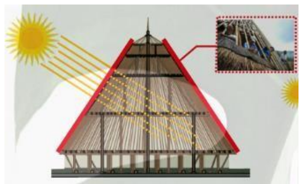
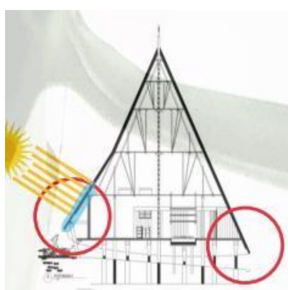
Source: (wardani et al, 2020) [12]
Figure 8: Layout of 'Huma Betang' in Central Kalimantan

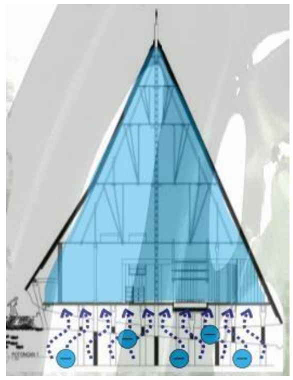
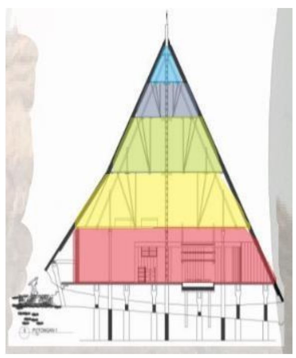
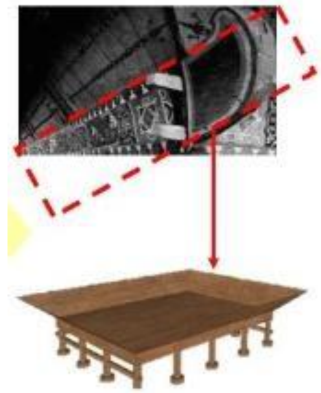
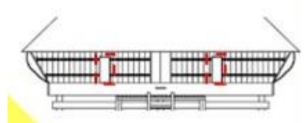
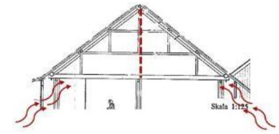
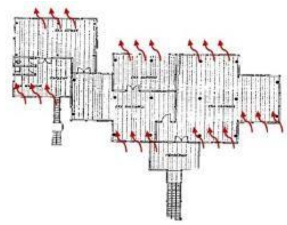
Wardani et al [12] stated in their article that a Betang house is a long and wide house that is square in shape. Huma Hai, which means a big house, is a term for a longhouse in Ngaju Dayak language. The size of Betang varies, depending on the number of household heads who inhabit the house. There are only 10-20 families and some betang houses can accommodate more than 100 households.

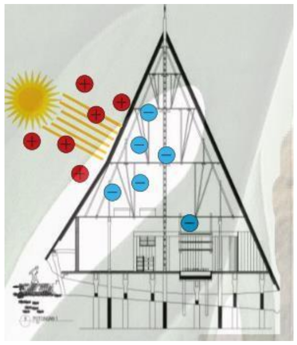
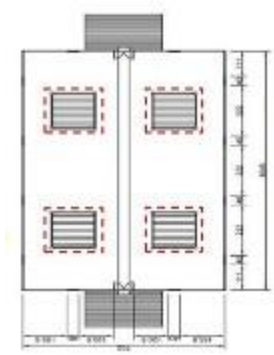
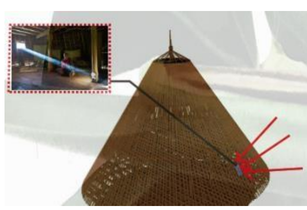
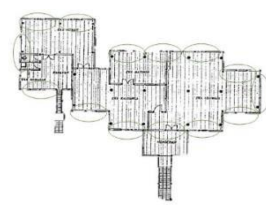
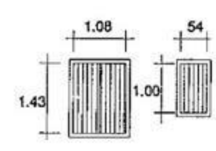
c) Climate Responsive Design Analysis

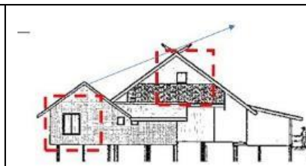
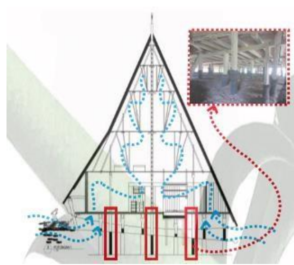
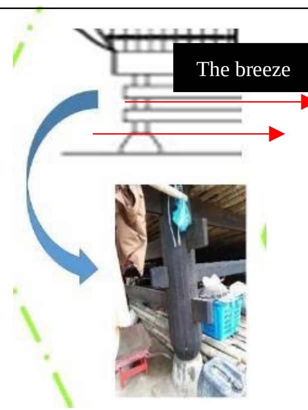
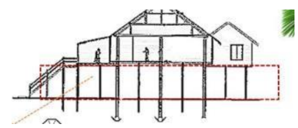
The following table is the comparation of some strategies applied in the three sample houses:

Table 2. Climate Responsive Design Analysis of 3 case studies

No	Micro Climate Parameter	Mbaru Niang	Rumah Mbelin	Huma Betang
		Manggarai, NTT (Compiled by Ismawan, 2020)	Karo, North Sumatra (Compiled by Suwandi, 2020)	Palangkaraya, Central Kalimantan (Compiled by Faliha, 2020)
1	Solar radiation	 The main usage of palm leaf and palm fiber is for the roof's heat insulation. The material has a capability as the heat absorber so it can maintain the lower temperature inside the house during the day.  The roof's overhang being used as the shading device to prevent from the solar radiation.	 The roof's overhang being used as theshading device to prevent from the solar radiation. • The choosen natural materials such as palm fiber, wood, and bamboo placed in the roof as the heat-insulation during the day and cold-insulation during the night.	 1 meter length roof's overhang is the strategy to prevent the high solar radiation and protect the indoor thermal environment.  The shingle roof cover has a capability to become the heat-insulation

2	Temperature	 The temperature and air pressure from the below part of the house could go through the cleft in between the floor board and increase the thermal comfort during the hot weather.  The roof height can be used as the big air circulation inside the house, so the hot-air wouldn't be trapped.	 There is a thick boards mounted upright similar with a wall with decorative ornaments named 'melen-melen'. 'melen-melen' serves as a protector from cold breeze and keeps the warmth inside. 	 The high ceiling in this house purposively became the 'hot-air trapper', so the temperature inside the house will remain low.  As the breeze could blow in and out from the ventilations that are located in every part of the house and in the body-level height, the indoor temperature remains in the comfort level.

		 The palm leaf and palm fiber roof cover is functioned as the thermal insulation so it can help to reduce the high temperature from the outdoor.	Since the annual temperature is mostly low, Karo people tend to provide a little of side-ventilation/opening to maintain the warmth and prevent from the cold breeze&temperature from the outside.  There are even four fireplaces placed inside the house to maintain the warmth.	
3	Daylighting	 At some parts of the roof, there are small openings that can be used to be additional daylight source.	 Most of the daylighting inlet in the 'Rumah Mbelin' house are from every building's envelope such as the windows, doors, board walls, and even the board floors.	 The openings were located at each side of the house to provide the best daylighting for the house.  

				 The windows located in the west and east side of the house sized 1x1,5 m and can effectively provide the proper lighting for the rooms inside.
4	Humidity	 The 150 cm stilted structure purposely to ease the wind flows through the below part to the upper part of the house. This action could help to maintain the ideal humidity in the below and inside the house.	 The stilted construction is a strategy to prevent from the high humidity caused by wet-ground. The breeze that crossed thoroughly houses' foundation columns helped to maintain the ideal temperature and humidity at the substructure part of the house.	 The stilted construction is a strategy to prevent from the high humidity caused by wet-ground. The breeze that crossed thoroughly houses' foundation columns helped to maintain the ideal temperature and humidity at the substructure part of the house.

Website : jurnal.umj.ac.id/index.php/icecream

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<td>5</td>
<td>Air Velocity</td>
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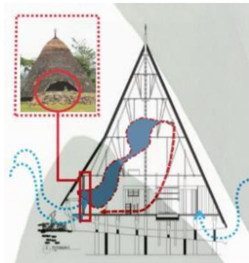
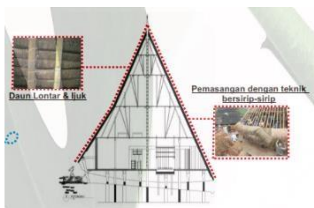


The air flows through the cleft in the main door as the inlet and blows around inside the house to each floor level.



Natural materials such as palm leaf and palm fiber were chosen as the roof cover. The finned pattern has cleft that can be used as the wind inlet.
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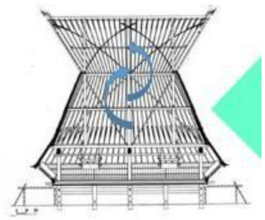
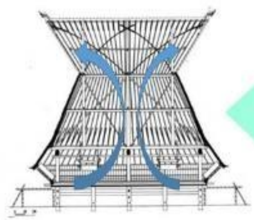
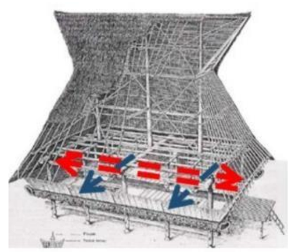
<td>




The air flow is very unstricted due to the big roof area ratio with the superstructure are that can be 7:1. The cross ventilation could be happened from the cleft plank floor to the higher part of the house.



Since there are also no interior partition, cross ventilation can be happened effectively through various ventilation inlet-outlet in the house.
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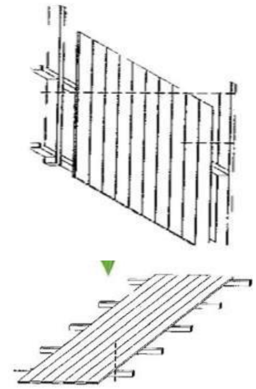
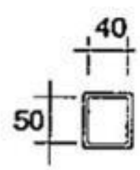


The house always use the wood-board floor and wall that identically helped the air flows through the cleft and give a better circulation inside the house.

The shingle roof cover has a strength to protect the house from storm and also become a ‘hidden’ wind inlet&outlet.

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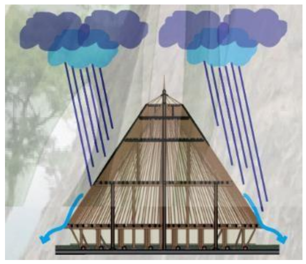
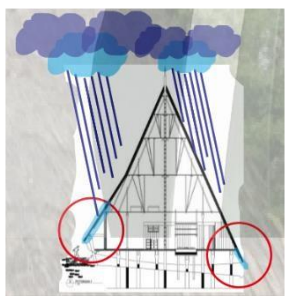
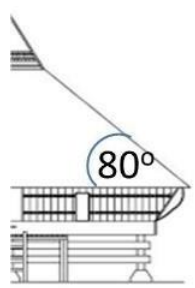
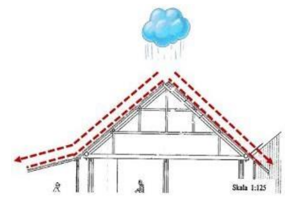
				There are also some ventilation inlet placed at the above that could help to circulated the wind inside.
6	Rainfall Intensity	 The 70 degree sloped roof can help to ease the rainwater drainage tothe ground.  The longer roof's overhang can protect the envelope and the window from the rain splash.	 at the lowest part of the roof, there are vegetation that helped to absorbed the downpour during the monsoon  The thick materials such as 20 cm palm fiber, could prevent the leak due to heavy downpour.  The steep angle of the roof can help to ease the rainwater drainage to the ground..	 The gable roof with proper angle can help to ease the rainwater drainage to the ground.  1 meter length roof's overhang can protect the envelope and the window from the rain splash.

4. Conclusion

According to the result and discussion of the three steps analysis, it can be resumed that Indonesia's traditional community actuallyhave learnt to adapted to the climate-comfort needs, especially in architectural aspects. It canbe seen from various design details in their traditional-vernacular houses that later been identified as the climate responsive designs idea. There are also some similarities and can be concluded as the most common tropical climate-responsive design strategies applied in the 3 case studies are:

1) **Natural material selection** that can be the heat insulation for the upper and also superstructure part of the house.
2) **Large roof area** could be used as the 'heat trapper' to maintain the low temperature and better air circulation.
3) **Wideous and a lot of openings** to provide a better air flows inside the house, maximise the cross-ventilation, and also as the daylighting inlet.
4) **Stilted construction** is considered to prevent from high humidity caused by the wet-ground
5) **Long roof's overhang** to protect the envelope and the window from the rain splash. This method also can be used as the shading devices from the high solar radiation
6) **Use sloped roof** to help ease the rainwater drainage to the ground.

The traditional community acknowledged the strengths and weaknesses of the surrounding micro-climate aspects by the living experience and they invented some solutions to created a better built environment. This idea later be inherited by generations yet irronically the modern community started to have misconceptions of the original design considerations.

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