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Original Article

A Method for Determining Thermal Comfort of Fishermen's Houses, Case Study: South Karama Hamlet

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Abstract - *This research was located on the coast of the fishing settlement of South Karama Hamlet, covering an area of 3.14 ha at coordinates of 119o23'0"E-119o23'5"E and 5o13'35"S-5o13'40"S, the climate is tropical, humid, hot, and during the day residents feel uncomfortable when resting or doing activities. This research aims to develop innovative methods of Determining fishermen's houses' thermal comfort using survey methods, questionnaires, observations, thermal measuring instruments, Hobo data loggers, solar power meters, and photo cameras. The analysis technique uses an expert system, certainty factors with 40 factors and 160 criteria, a 10 m x 10 m grid-based map, and geographic information system-based spatial analysis. The research results show that this determining thermal comfort method is innovative, significant, and accurate after being validated by thermal measuring instruments. A total of 38 fishermen's houses (52.05%) with thermal comfort potential value of 125-225 have less comfortable thermal comfort (25.8°C-27.1°C), specifically having a temperature of 25.84°C-26.98°C, relative air humidity of 89.95%-84.75%, with THI temperature outside the house at 25.31°C-26.15°C. A total of 35 fishermen's houses (47.95%) have a potential thermal comfort value <125 with uncomfortable thermal comfort (>27.1°C), a temperature of 27.25°C-34.70°C, relative air humidity of 84.87%-67.36% and THI of 26.42°C-32.43°C occurring during the day between 11:00 am - 14:00 pm (GMT+08:00). No fishermen's houses had potential value of thermal comfort 226-325 which has comfortable thermal comfort (22.8°C-25.8°C). No fishermen's houses had a potential thermal comfort value >325 with thermal comfort more comfortable (20.5°C-22.8°C).*

Keywords - *South Karama, Expert system, GIS, Thermal comfort of fishermen's houses, Spatial analysis.*

1. Introduction

The fishermen's residential area of South Karama Hamlet in Biringkassi Village, North Galesong District, Takalar Regency, Indonesia, covers an area of 3.14 ha and is located between 119º23'0" E and 119º23'5" E and 5º13'35" S and 5º13'40" S. Residents complain that this coastal area feels hot and uncomfortable during the day, both inside and outside the house. The sensation of thermal discomfort outside the house due to the proximity of the sea, lack of vegetation, and lack of shade and trees will have a negative impact on human health [1,2]. Regional thermal comfort can be determined based on contributing factors, including air temperature, wind velocity, relative humidity, solar radiation, and land cover [3-5]. Land cover in the form of landscape, aqua space in the courtyard, use of building materials, and reducing the air temperature in the house can also contribute significantly to the thermal comfort performance of the area [6-8]. Regional thermal comfort is the sensation felt by humans. It is based on the results of measurements of air temperature, relative air humidity, wind speed and solar radiation according to the THI thermal humidity index [1, 2]. The THI classification is said to be cold if the temperature is <21°C, comfortable if the temperature is 21°C-24°C, quite comfortable, and others experience thermal stress (comfortable enough) if the temperature is 24°C-26°C, and discomfort if the temperature is already >26°C [9, 10]. The air temperature in this area can also increase if there is an increase in human activity [10]. Another source states that the thermal comfort of an area is considered uncomfortable or too cold if the temperature is <20°C, comfortable or cool if the temperature is 20°C-26°C, and feels uncomfortable or too hot if it is >26°C [11]. Outdoor thermal comfort can also be evaluated by the THI thermal humidity index, which combines the factors of air temperature, air humidity, radiation, and land surface temperature LST [1, 2]. The high air temperature outside the house due to coastal climate change causes poor regional thermal comfort and is one of the disasters in the dry season; if the air temperature exceeds 40ºC, individual members of the fishing community feel uncomfortable carrying out activities, which can affect health, productivity, and welfare [12]. Climate change refers to long-term shifts and changes in temperatures and precipitation patterns, mainly caused by human activities; the global mean surface temperature has increased by approximately 1 ◦C between 1850 and 2020, leading to significant warming over both land and ocean. Other sources state that the thermal comfort of an area is said to be uncomfortable if it is at a temperature of 33°C-39°C because it has exceeded the comfortable temperature, namely 21°C-24°C and has exceeded the quite comfortable temperature, at 24°C-26°C [12, 13]. Poor thermal comfort in areas with temperatures between 35°C-38.3°C or between 95.0°F-100.9°F [4] can be avoided by modifying or engineering the environment and architecture of the building through the use of building materials and landscaping [3]. The area around the equator has an average temperature of 35°C with high humidity, which can reach 85%, and the best temperature range for carrying out activities is 22.8°C-25.8°C with a relative air humidity of 70% [3]. Annual temperatures in the rainy season in coastal areas are ±23°C, and in the dry season are ±38°C [14].

Based on these facts, it is necessary to carry out research to determine a method for determining the thermal comfort of fishermen's houses in Dusun Karama Selatan. This method uses an Expert System (ES) and Certainty Factor (CF). The potential value results based on CF were analysed using spatial analysis based on Geographic Information System (GIS) to obtain the thermal comfort of the fishermen's homes [15]. This research is different from the previous one because it uses ES and limits the determinants of CF thermal comfort, GIS-based spatial analysis, and uses thermal comfort data recording tools for the houses and fishermen's residential areas [16, 17]. Factors determining thermal comfort include architecture and use of house materials and furniture, temperature inside and outside the house, trees, vegetation and land cover, air humidity, wind speed and solar radiation. The thermal comfort of this fisherman's house was validated by observation results using a thermal comfort data recording device [18]. This model for determining thermal comfort creates energy-saving and air condition-free fishing houses [19].

2. Literature Review

2.1. Thermal Comfort

Poor thermal comfort greatly affects the health and productivity of coastal area residents as a result of decreased concentration and thinking ability, as well as increased uncomfortable and unsafe behavior [19]. Regional and building thermal comfort have a significant relationship due to weather and climate conditions, as well as the thermal performance of buildings and areas due to the transfer of heat flow. The existence of land cover, gardens, and water elements in the architecture of buildings and areas can be a temperature modifier that creates the desired regional thermal comfort conditions. Air humidity in fishing residential areas can be influenced by several factors, including air temperature, air pressure, wind, sunlight or solar radiation, vegetation or land cover, availability of water pools, altitude, and air density. Water can reduce the air temperature of the area and buildings around it due to the absorption of heat in the process of water evaporation. However, it can increase the temperature of the area if heating occurs from solar radiation. A decrease in air temperature due to the evaporation process will increase humidity. For humid tropical climate areas such as Indonesia, which has high humidity, wind speed should be taken into consideration so that there is no increase in high humidity. The thermal comfort level of a place, based on the THI temperature, is said to be too cold or uncomfortable if the THI temperature is <20 °C, said to be comfortable or cool if the temperature is between 20°C to 26°C, and uncomfortable or hot if the temperature is >26 °C [11] and it can be calculated based on the formula.

$$THI = 0{,}8Ta + \frac{(RH \times Ta)}{500} \quad (1)$$

Information:

THI : Temperature Humidity Index.
Ta : Air temperature (ºC).
RH : Relative air humidity.

The poor thermal comfort of the area, among other things, is caused by not having many trees, not implementing eco-building and green architecture principles, not being equipped with parks or vegetation, and no shading or hydroponic plants [20]. Sea water temperature and motorboat transportation also contribute to poor regional thermal comfort during the day [21]. They can increase the thermal comfort of the area if there are mangroves, trees, rivers, lakes, ponds and/or puddles of water around the area [22].

Poor thermal comfort due to extreme weather will disrupt concentration, activities, individual health and behavior of residents of fishing residential areas [23-25]. Residential areas that have good thermal comfort will contribute to the health of fishermen's buildings and homes [26]. A healthy residential area can be realized if the relevant stakeholders, including planners, local government, and community members, have good awareness, policies, and cooperation [27].

A healthy house and area will improve good health, mentality, immunity and productivity [27, 28]. Creating regional thermal comfort is carried out by considering various environmental factors and individual factors, which make the temperature comfortable through measuring indoor temperature, outdoor temperature, wind speed, relative air humidity, heat transfer, sweat evaporation, solar radiation, and geographical location [29, 30]. Determining the precise strategy for developing thermal comfort for coastal homes is using efficient and good sheath insulation, which can be a variable to ensure indoor thermal comfort [31] and [32]. Several factors indicate the efficiency of thermal performance in house buildings, especially in coastal settlements, to be able to provide ideal comfort conditions, two of which are construction materials and architectural design. In contrast, the main variable that influences achieving better thermal comfort is construction materials [33].

2.2. Expert System

An expert system is a tool or means for providing knowledge, either obtained directly or indirectly, from various scientific experts. These experts help to support decisions as solutions that can be used for various kinds of problems that occur [35]. An expert system is a computer program that resembles human thinking, even surpasses it in solving problems that occur, and is part of the science of human intelligence [36]. An expert system is a combination of knowledge with conjectures and conclusions, or it can also be interpreted as an expert system, which is the same as knowledge and inference [37-39].

An expert system is a human-made intelligence that obtains the desired decision or results as a solution to a problem based on several experts in technical fields, including medicine, to diagnose and treat diseases [18, 19]. The parts of an expert system are software that contains components or categories to build a system to determine goals or objectives [36, 40]. The important parts of an expert system are rules or conditions, factors and categories, and weighting the value of certainty factors.

They are a tool and a quick way to find out a goal to be achieved[41]. The expert system has advantages and disadvantages. The advantage is that it can store and access extensive and more detailed knowledge from various theories and experts in certain fields, such as the field of thermal comfort. In addition, the way it works is fast, accurate, and timely in problem-solving and decision-making, and it works continuously without fatigue or errors compared to human thinking. The downside is that it is not 100% correct because a person's subjective level of accuracy has limitations in its preparation. After all, the approach can vary and be biased, so it must be evaluated and tested before use [18, 35, 37].

2.3. Certainty Factor

Certainty Factors (CF) in their use also have advantages and disadvantages. The advantage of CF is that it can provide results based on the level of confidence of the symptoms experienced by users in processing data, which is often uncertain and incomplete. For this reason, the preparation of the CF must be more comprehensive and more thorough in order to produce correct decisions that are more accurate and consistent by considering various factors that influence it [40].

The weakness of CF is that the preparation is incomplete and not thorough; in other cases, the results will not be precise and relevant. Therefore, the relevant determining factors must be more complete, more comprehensive and more thorough, and the criteria for each factor must be clearer, more thorough and more precise so that the results obtained are more precise [39, 41, 42]. The CF method is a probability model included in bivariate statistical analysis. This method was originally proposed by Shortliffe and Buchanan and later refined by Heckerman [15].

2.4. Vegetation

Vegetation is one of the most important components that contributes to thermal comfort, influences temperature and climate changes, and can maintain biodiversity and ecology [43]. Vegetation can play an important role in exchanging oxygen, carbon, water and energy [43]. Vegetation can contribute to lowering temperatures according to the type of vegetation. Trees that have a canopy and cover the surrounding area can reduce direct solar radiation and direct the wind to create thermal comfort. Apart from trees, shading, vegetation, gardens, air temperature outside the house, and relative humidity, the use of materials and architecture of fishermen's houses on the coast during the day also contribute to the creation of thermal comfort for the house and the surrounding area [43]. Creating thermal comfort in fishermen's houses requires treatment of vegetation, gardens and the surrounding environment.

3. Materials and Methods

Research on methods for determining thermal comfort in fishermen's residential areas in the case study of South Karama Hamlet used algorithms, expert systems, certainty factors, 10 m x 10 m grids, and GIS-based spatial analysis. The expert system consists of software, hardware, data and personnel that can enter, engineer, analyse and present information related to everything related to locations and events on the earth's surface [44]. An expert system is a computer program that resembles human thinking and can even exceed it in solving problems. It is part of the science of human intelligence [35]. An expert system is a combination of knowledge with conjectures and conclusions or the same as knowledge + inference [37].

An expert system is an artificial intelligence to obtain a desired decision as a solution to a problem based on expertise in the technical field, including the medical field, to diagnose and treat disease [36], and [45]. Thermal comfort focuses on health and safety issues, then on reducing energy consumption and climate change, and finally on human health and thermal comfort, thermal comfort of homes, and thermal comfort of residential areas.

This research uses surveys, distributing questionnaires, observing administrative data collection, identifying the names and numbers of heads of fishermen's households, and identifying the activities of residents of fishermen's houses. Spatial data, land cover, architectural data, especially the use of house materials, furniture materials, number of fishermen's houses, thermal comfort data for houses, thermal comfort data for fishermen's residential areas, as well as environmental data for fishermen's residential areas were also used. Spatial data is obtained through Google Earth 2023, a survey and observations of 40 variables consisting of 160 criteria/categories related to architectural data on fishermen's houses, environmental data on residential areas, and thermal comfort data.

Expert System

Impossible Fisherman's House Area	*Thermal Comfort of Fisherman's Houses Restraint Area*	*Other*
Rule 1	Activities Sitting around (CF=9), Eating (CF=7), Nap (CF=5), Sports (CF=3)	Other
Rule 2	Ceiling Height > 3 m (CF=9), 2,75–3 m (CF=7), 2,50–2,75 m (CF=5), <2,5 m (CF=3)	Other
Rule 3	Village Office Walking distance <50 m (CF=9), Walking distance 50-100 m (CF=7), Walking distance 101-150 m	Other
Rule 4	House Of Workship Walking distance <50 m (CF=9), Walking distance 50-100 m (CF=7), Walking distance 101-150 m	Other
Rule 5	Cultural heritage Cemetery Distace 10 m (CF=9), Distace 20 m (CF=7), Distace 30 m (CF=5), Distace 40 m (CF=3).	Other
Rule 6	Mangrove Forest Distace 10 m (CF=9), Distace 20 m (CF=7), Distace 30 m (CF=5), Distace 40 m (CF=3).	Other
Rule 7	Sea Altitude of place > 30 m from sea level (CF=9), Altitude of place 20 m from sea level Altitude of place 30 m from	Other
Rule 8	River Distace 10 m (CF=9), Distace 20 m (CF=7), Distace 30 m (CF=5), Distace 40 m (CF=3).	Other
Rule 9	Catchment Area 0-1 m (CF=9), 1-3 m (CF=7), 2-3 m (CF=5), > 3 m (CF=3)	Other
Rule 10	High accessibility area for motor vehicle Hallway (CF=9), Local road (CF=7), Collector road (CF=5), Arterial road (CF=3)	Other
Rule 11	High accessibility area for fish landing Fish landing distance 0-50 m (CF=9), Fish landing distance 51-100 m (CF=7), Fish landing distance 101-150 m (CF=5), Fish landing distance 151-200 m (CF=3)	Other
Rule 12	Building density <25% (very low) (CF=9), 25-50% (low) (CF=7), 51-75% (high) (CF=5), >75% (very high) (CF=3)	Other
Rule 13	Thermal comfort fisherman's houses, based: Optimum comfort 22,8-25,8 °C (CF=9), Comfortably warm 25,8-27,1°C (CF=7), Comfortably cool 20,5-22,8 °C (CF=5), Uncomfortable <20,5 °C (CF=3).	Other
Rule 14	Humidity (%) > 70% (CF=9), 60-70% (CF=7), 50-60% (CF=5), <50% (CF=3)	Other
Rule 15	Temperature Humidity Index-THI (°C) Comfortable or slightly cool (20-26°C) (CF=9), Slightly warm (26-28 °C) (CF=7), Uncomfortable or cold (<20 °C). (CF=5), Uncomfortable or hot (>28 °C)	Other
Rule 16	Wind velocity 0.15-0.25 m/s (CF=9), 0.25-0.35 m/s (CF=7), 0.35 - 0.45 m/s (CF=5), > 0.45 m/s (CF=3)	Other
Rule 17	Radiation Temprature 08:00-10:00 am (CF=9), 10:00-12:00 am (CF=7), 14:00-16:00 pm (CF=5), 12:00-14:00 pm (CF=3)	Other
Rule 18	Trees (tree) 6 - 7 m (CF=9), 4 – 5 m (CF=7), 2-3 m (CF=5), < 1 m (CF=3), No tree (CF=1)	Other
Rule 19	Outcard yard Luas >9 m^2 (CF=9) Luas >6-9 m^2 (CF=7) Luas >2-5m^2 (CF=5) Luas <2m^2 (CF=3)	Other
Rule 20	Pool > 3 m (CF=9), 2-3 m (CF=7), 1-2 m (CF=5), < 2 m (CF=3) 0 m (CF=1)	Other
Rule 21	Innercourt < 9 m2 (CF=9), 6-9 m2 (CF=7), 2-5 m2 (CF=5), < 2 m2 (CF=3), < 3 m2 (CF=1)	Other
Rule 22	Chimney > 6 m (CF=9), 6 m (CF=7), 5 m (CF=5), <5 m (CF=3), < 3 m (CF=1)	Other
Rule 23	Insulation > 9 m^3 (CF=9), 7-9 m^3 (CF=7), 5-7 m^3 (CF=5), 3-5 m^3 (CF=3), No insulation (CF=1)	Other

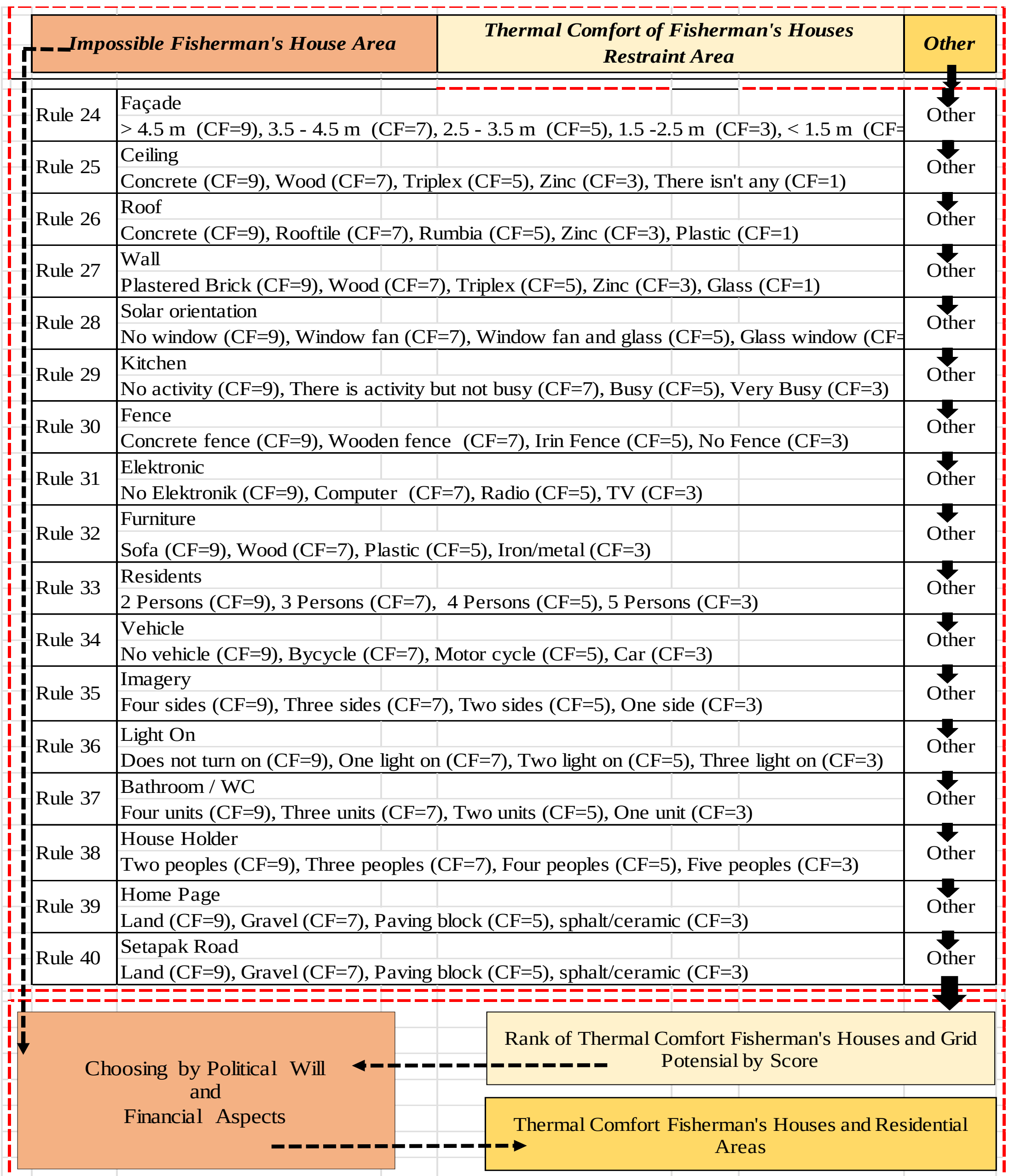

Fig. 1 Expert System 40 Rules

Source: [37]

Architectural data for fishermen's houses include floor, wall, ceiling, roof materials, availability of facades, wind catchers, chimneys, and insulation. Environmental data includes research location boundaries, land use, land cover, footpath access, fish landing, motor vehicle road access and pedestrian paths, availability of house of work, swamp or puddle or catchment area, sea, tree, building density, out card yard, pool and inner court. Thermal comfort data includes air temperature, air humidity, solar radiation and wind speed. The tools used to measure thermal comfort are Hobo data logger UX100-003 and Hobo data logger U12-012. Recording architectural data on fishermen's houses used questionnaires, measuring meters and photo cameras. All of this important data contributes to the thermal comfort of the house and area.

The tools used in this research are algorithms, expert systems, Certainty Factors (CF), and geographic information systems [46] based on spatial analysis. An expert system is a form (entity) of expertise, and the relationship, nature or characteristics (attribute), the nature of the relationship (relationship attribute) and the arrangement or structure [47]. To determine the potential value of the thermal comfort of fishermen's homes and their area, expert systems, certainty factors and GIS-based spatial analysis are used [41].

Expert systems are software consisting of parts containing components or categories to build a system for determining a goal or objective [40] and [39]. The important parts of an expert system are rules or provisions, factors and categories, and the weighting of certainty factor values. It is a tool and a fast way to find out a goal that you want to achieve [40]. The expert system consists of several rules that are prepared based on theory and knowledge or inference, which consist of 40 factors and 160 criteria/categories related to architectural data on the fishermen's houses, environmental data on residential areas, and thermal comfort data. Certainty factors are a given weight value according to the weight of influence and importance of the factor and category [37], [41], and [35], as shown in Figure 1. Spatial data is obtained through Google Earth 2023, a survey and observation of 40 variables consisting of 160 criteria/categories related to environmental data, including research location boundaries, land use, land cover, footpath access, fish landing sites, motor vehicle road access and pedestrian paths, the presence of workhouses, swamps or puddles of water or water catchment areas, the sea, trees, building density, outside yards, ponds and inside yards. The fishermen's house's architectural data include the floor, wall, ceiling, roof materials, availability of facades, wind catchers, chimneys and insulation. Thermal comfort data includes air temperature, air humidity, solar radiation, and wind speed. The tools used to measure thermal comfort were a U12-012 Hobo data logger, solar power meter, and photo camera, while to record architectural data on fishermen's houses, questionnaires, interviews, measuring meters, and photo cameras were used. All this data contributes to the thermal comfort of the house and the area. The tools that will be used in this research are algorithms, expert systems, Certainty Factors (CF), and geographic information systems based on spatial analysis. Expert means expertise, and system means entities and relationships, properties or characteristics, relationship attributes and arrangement or structure [33,34]. To determine the potential value of the thermal comfort of fishermen's houses and the thermal comfort of the area, an expert system, certainty factors and GIS-based spatial analysis were used [21, 23, 34-36]. After the expert system was compiled with restrictions on 40 thermal comfort rules for houses and fishing residential areas, a certainty factor was created by giving weight to 160 categories/criteria, as in Table 1.

Table 1. Certainty factors

Factor	Category/Criteria	CF	Code
Activities	Sitting around Eating Nap Sports	9 7 5 3	AS
Ceiling Height	> 3 m 2.75 – 3 m 2.50 – 2.75 m < 2.5 m	9 7 5 3	CH
Village Ofice	Walking distance <50 m Walking distance 50-100 m Walking distance 101-150 m Walking distance >150 m	9 7 5 3	VO
House Of Workshop	Walking distance <50 m Walking distance 50-100 m Walking distance 101-150 m Walking distance >150 m	9 7 5 3	HW
Cultural heritage, Cemetery	Distance 10 m Distance 20 m Distance 30 m Distance 40 m	9 7 5 3	CH
Mangrove forest, mangrove	> 3 m 2-3 m 1-3 m < 1 m	9 7 5 3	MF
Sea	Altitude of the place is > 30 m from sea level Altitude of the place is 20 m from sea level Altitude of the place is 30 m from sea level Altitude of the place is < 10 m from sea level	9 7 5 3	SE
River	Distance 10 m Distance 20 m	9 7	RI

	Distance 30 m Distance 40 m	5 3	
Catchment area	0-1 m 1-3 m 2-3 m > 3 m	9 7 5 3	CA
High accessibility area for motor vehicle	Hallway Local road Collector road Arterial road	9 7 5 3	HA
High accessibility area for fish landing	Fish landing distance 0-50 m Fish landing distance 51-100 m Fish landing distance 101-150 m Fish landing distance 151-200m	9 7 5 3	FL
Building density	<25% (very low) 25-50% (low) 51-75% (high) >75% (very high)	9 7 5 3	BD
Thermal comfort fisherman's houses, based	Optimum comfort 22,8-25,8 °C Comfortably warm 25,8-27,1°C Comfortably cool 20,5-22,8 °C Uncomfortable <20,5 °C	9 7 5 3	TC
Humidity (%)	> 70% 60-70% 50-60% <50%	9 7 5 3	HU
Temperature Humidity Index-THI (°C)	Comfortable or slightly cool (20-26°C) Slightly warm (26-28 °C) Uncomfortable or cold (< 20 °C). Uncomfortable or hot (> 28 °C)	9 7 5 3	TH
Wind velocity	0.15-0.25 m/s 0.25-0.35 m/s 0.35 - 0.45 m/s > 0.45 m/s	9 7 5 3	WV
Radiation Temprature	08:00 - 10:00 am 10:00 - 12:00 am 14:00 - 16:00 pm 12:00 - 14:00 pm	9 7 5 3	RT
Trees (tree)	Height > 5 m Height 4 - 5 m Height 2 - 3 m Height < 1 m	9 7 5 3	TR
Outcard yard	Area > 9 m^2 Area 6-9 m^2 Area 2-5 m^2 Area < 2 m^2	9 7 5 3	OY
Pool	> 3 m^2 2-3 m^2 1-2 m^2 < 2 m^2	9 7 5 3	PO
Innercourt	Area > 9 m^2 Area 6-9 m^2 Area 2-5 m^2 Area < 2 m^2	9 7 5 3	IC

Chimney	Height > 6 m Height 6 m Height 5 m Height <5 m	9 7 5 3	CH
Insulation	> 9 m^2 7-9 m^2 5-7 m^2 3-5 m^2	9 7 5 3	IN
Façade	Length > 4.5 m Length 3.5 - 4.5 m Length 2.5 - 3.0 m Length 1.5 -2.0 m	9 7 5 3	FC
Ceiling	Concrete Wood Triplex Zinc	9 7 5 3	CL
Roof	Concrete Roof tile Spandex roof/scorching Zinc	9 7 5 3	RO
Wall	Plastered brick Wood Triplex Spandex roof/scorching	9 7 5 3	WA
Solar Orientation	No window Window fan Window fan and glass Glass window	9 7 5 3	SO
Kitchen	No activity There is activity, but not busy Busy Very busy	9 7 5 3	KC
Fence	Concrete fence Wooden fence Irin fence No fence	9 7 5 3	FN
Electronic	No electronic Computer Radio TV	9 7 5 3	EC
Furniture	Sofa Wood Plastic Iron/metal	9 7 5 3	FR
Residents	2 Persons 3 Persons 4 Persons 5 Persons	9 7 5 3	RS
Vehicle	No vehicle Bicycle Motor cycle Car	9 7 5 3	VH
Imagery	Four sides Three sides	9 7	IG

	Two sides One side	5 3	
Light On	Doesn't turn on One light on Two lights on Three lights on	9 7 5 3	LO
Bathroom / WC	Four units Three units Two units One unit	9 7 5 3	BR
House Holder	Two peoples Three peoples Four peoples Five peoples	9 7 5 3	HH
Home Page	Land Gravel Paving blocks Asphalt/ceramic	9 7 5 3	HP
Footpaths	Land Gravel Paving blocks Asphalt/ceramic	9 7 5 3	SR

The analytical technique used in the research method for determining the thermal comfort of fishermen's residential areas is based on algorithms, expert systems, and certainty factors consisting of 40 factors and 160 criteria, first carried out by determining the potential value of thermal comfort for the fishermen's houses followed by determining the potential value of thermal comfort for a 10 m x 10 m grid based on land cover and using interpolation to obtain a regional thermal comfort map.

4. Results and Discussion

The thermal comfort of fishermen's houses depends on air temperature, air humidity, wind speed, air temperature entering from outside the house, use of house materials, and also land cover, including non-fisherman houses, ground surface, grass, paving blocks, asphalt roads, trees, sea, and catchment area or swamp. Land cover, as in Figure 2, plays an important role in reflecting and/or absorbing radiant heat from the sun and radiation from other sources, which causes the area air to become hot and flow into the house, thus contributing to thermal comfort in fishermen's homes.

The land cover map of South Karama Hamlet is shown in Figure 2. Thermal comfort of fishermen's houses in South Karama Hamlet, according to the potential value of thermal comfort of each fishermen's house, based on 40 factors and 160 categories, with GIS-based spatial analysis is shown in Figure 3, The potential thermal comfort value of fishermen's houses is respectively more comfortable with a temperature of 20.5°C-22.8°C with a potential thermal comfort value of >325 for 0 houses or 0%, and comfortable 22.8°C-25.8 °C with a potential value of 226-325 for 0 houses or 0%. 38 houses have less comfortable thermal comfort of 25.8°C-27.1°C with a potential thermal comfort value of 125-225 or 52.05%, and 35 houses or 47.95% are uncomfortable with a temperature of >27.1°C with a value of <125.

The thermal comfort of these houses is determined by the incoming air temperature, air humidity, wind speed, radiation, insulation and land cover. The sea and swamps have hot temperatures during the day.

This sample of houses with thermal comfort was validated using thermal measuring equipment, both for fishermen's houses and for the thermal comfort of non-fishermen's houses. Thermal comfort measurement shows uncomfortable for the fisherman's house number 33 as in Figure 4, fisherman's house number 41 as in Figure 5, fisherman's house number 42 as in Figure 6, and fisherman's house number 60 as in Figure 7.

Thermal comfort measurement results are not in fisherman's house number 101, as in Figure 8, and not in fisherman's house number 103, as in Figure 9. The results of measuring thermal comfort are shown inside and outside the fisherman's house numbers 33, 41, 42, 60, 101, 1st 103 are in Table 2. The results of the research show that the fisherman's house number 33 has less comfortable thermal comfort with a minimum temperature of 26.89°C, no wind speed or 0.000 m/s, relative humidity of 87.21% and THI at 26.20°C at 06.00:45 am (GMT +08:00). At 02:15 pm (GMT +08:00) the maximum temperature was 31.07°C with humidity of 79.77%, the wind speed remained zero or 0.000 m/s. The THI rose showing 29.80°C as in Figure 4, because some architectural elements do not contribute optimally.

The fisherman's house number 41, as in Figure 5, shows the sensation of poor or uncomfortable thermal comfort at 06:15 am (GMT+08:00) with a minimum temperature of 27.25°C, wind speed at 0.003 m/s, relative humidity 84.87 % and the Thermal Humidity Index at 26.42°C. Meanwhile, at 01:30 pm (GMT+08:00), the maximum temperature of that fisherman's house rose to 32.84°C, with relative humidity at 73.64% and THI 31.10°C.

This is due to various factors, including architectural elements of the house that do not contribute to the formation of good thermal comfort, such as house materials and paths made of paving blocks in the yard of the house. The fisherman's house number 42, as in Figure 6, shows that the thermal comfort in the house is very bad or uncomfortable at 06:15 am (GMT+08:00) with a minimum temperature of 29.38°C.

The relative humidity inside reached 79.86%, the wind speed was 0.223 m/s, and the minimum THI value was 28.26°C. At 01:15 pm (GMT+08:00), the maximum temperature reached 34.70°C, and the relative humidity reached 67.36%. The wind speed at maximum temperature at fisherman's house number 42 was none or 0.000 m/s, and the THI temperature reached 32.43°C.

This is because the level of solar radiation during the day increases, and architectural elements do not contribute optimally to the thermal comfort of the fisherman's house. Fisherman's house number 60 has comfortable thermal comfort at 06:00 am (GMT+08:00) with a minimum temperature of 26.98°C, relative humidity in the house reaches 84.75% and wind speed at 0.177 m/s.

The THI temperature reached 26.15°C while the maximum temperature at 10:00 am (GMT+08:00) reached 34.44°C, the relative humidity reached 82.24%, the wind speed was 0.015 m/s, and the THI temperature was 33.21°C as shown in Figure 7.

Meanwhile, in the research conducted on houses that are not fishermen's houses, especially at house number 101, comfortable thermal comfort result was obtained with a minimum temperature at 05:45 am (GMT +08:00) of 25.72°C, which is below a temperature of less than 26°C.

The relative humidity in this non-fisherman's house was 88.12%, the wind speed was none or 0.000 m/s, the THI temperature reached 25.10°C, but the maximum temperature was uncomfortable at 12:30 pm (GMT +08:00) at 30.26°C with a wind speed of 0.510 m/s, relative humidity of 80.02%, and THI temperature reaching 29.04°C, shown in Figure 8.

The result of the research is that non-fisherman houses in house number 103 also have comfortable house thermal comfort, minimum temperature and uncomfortable maximum temperature. The minimum temperature of the house was at 25.79°C at 06:00 am (GMT +08:00), the relative humidity of the house was 88.75%, the wind speed at the minimum temperature was none or 0.000 m/s, and the THI temperature was 25.20°C.

The maximum house temperature at 12:30 pm (GMT +08:00) showed 30.41°C, which is in the uncomfortable category. The relative humidity reached 78.55%, the wind speed was zero or 0.000 m/s, and the THI temperature was 29.09°C as shown in Figure 9. This uncomfortable temperature continued to decrease until the evening and the morning of the following day, including the afternoon at 12:00 pm (GMT +08:00), which remained low at around 26.5°C.

This is due to the lack of solar radiation; even though there is no wind or the speed is 0.000 m/s, the relative humidity is higher, reaching 91% at 13:00 (GMT +08:00). Houses number 101 and number 103, each of which are not fishermen's houses, have a comfortable thermal comfort sensation with a minimum temperature of <26 °C in the morning compared to fishermen's houses, which remain uncomfortable with temperatures of >26 °C even in the morning.

The thermal comfort sensation of the non-fishermen's houses has a maximum uncomfortable temperature of 29.4°C and 29.9°C, while the houses have a maximum uncomfortable temperature of 29.80°C and >30°C.

The reasons why non-fisherman's houses have better thermal comfort compared to the thermal comfort of fishermen's houses in the morning are: evaporation of the seawater at night, high air humidity, being around puddles of water, being close to fish landings, low air temperature, lack of radiation sun, plastered red stone walls, lack of activity in turning on the stove in the kitchen, electronic TV and radio equipment not operating, furniture made of wood which absorbs heat, daily vehicles are bicycles, and lights are not turned on.

The fishermen's houses have an uncomfortable sensation of thermal comfort with temperatures >26°C due to, among other things, using a tin roof, breathable plank walls, no ceiling, some use lights during the day, close to asphalt roads and paving blocks, close to the sea and puddles of water with high evaporation, no land cover in the form of parks and trees, the air temperature is hot during the day with high solar radiation and low air humidity.

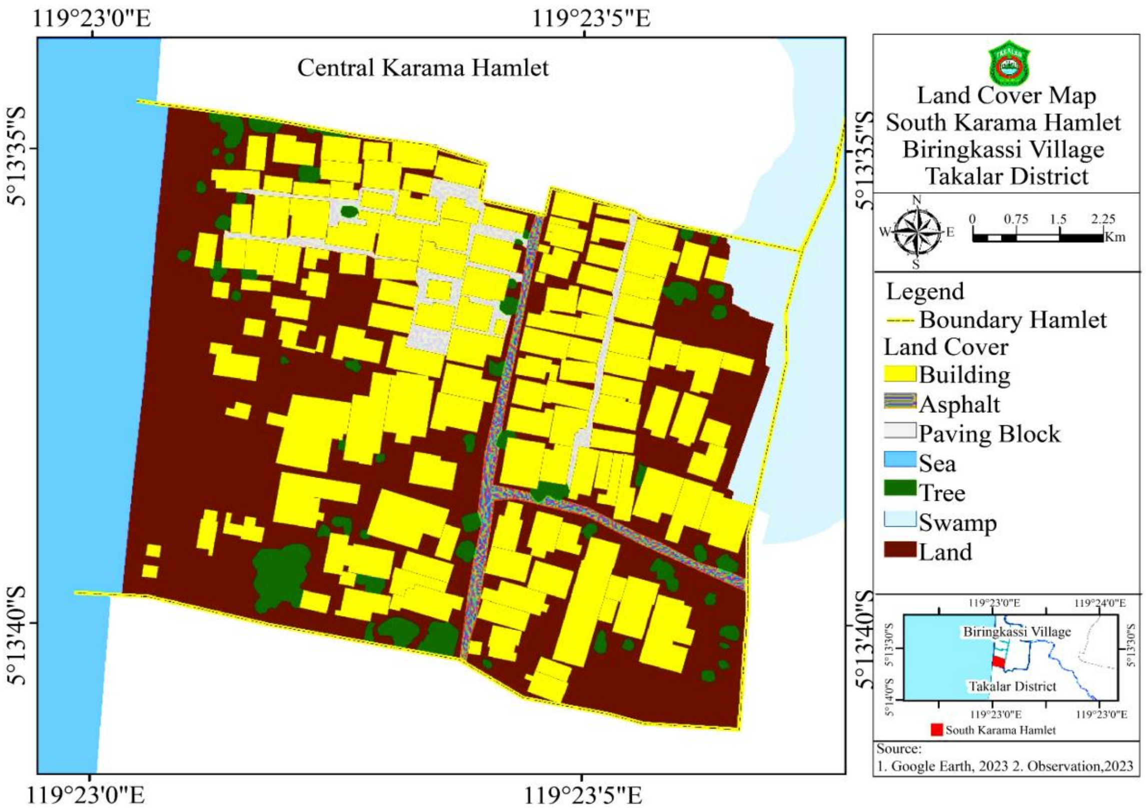

Fig. 2 Land cover map of south karama hamlet

Source: Google Earth 2023 and Observation Results, 2024

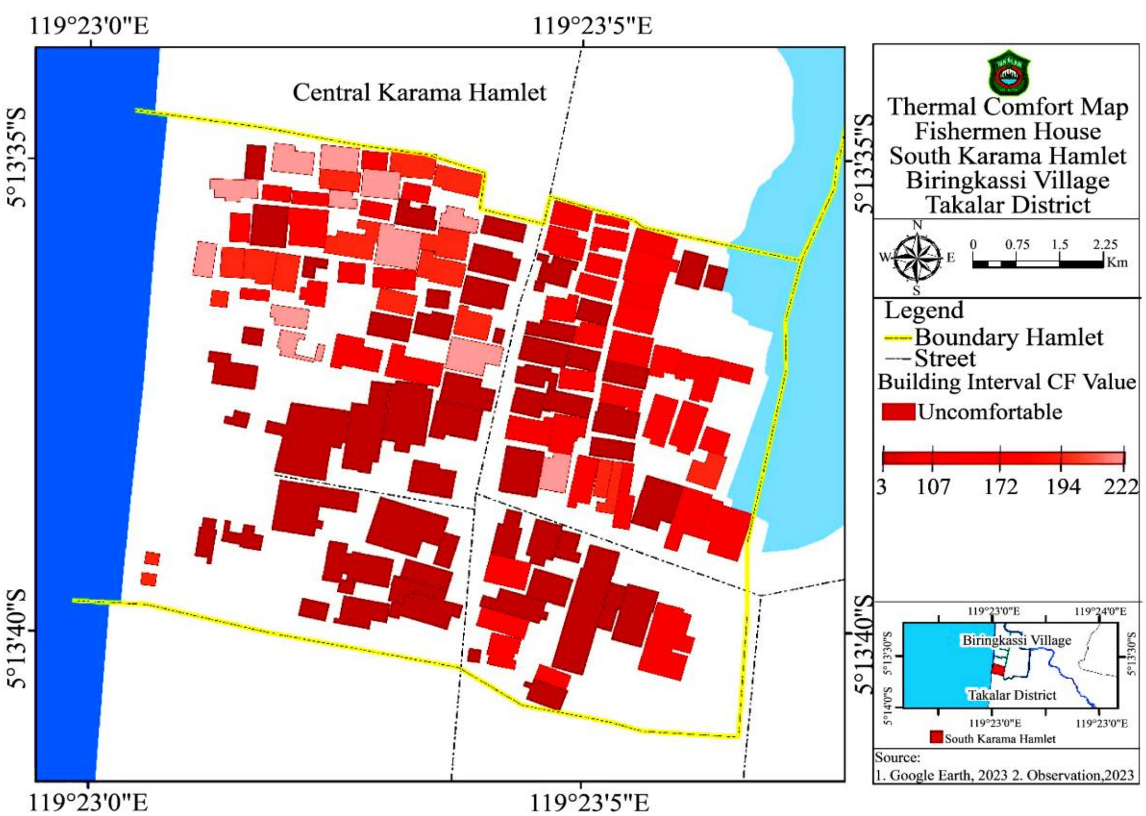

Fig. 3 Map of thermal comfort of fishermen's houses in south karama hamlet

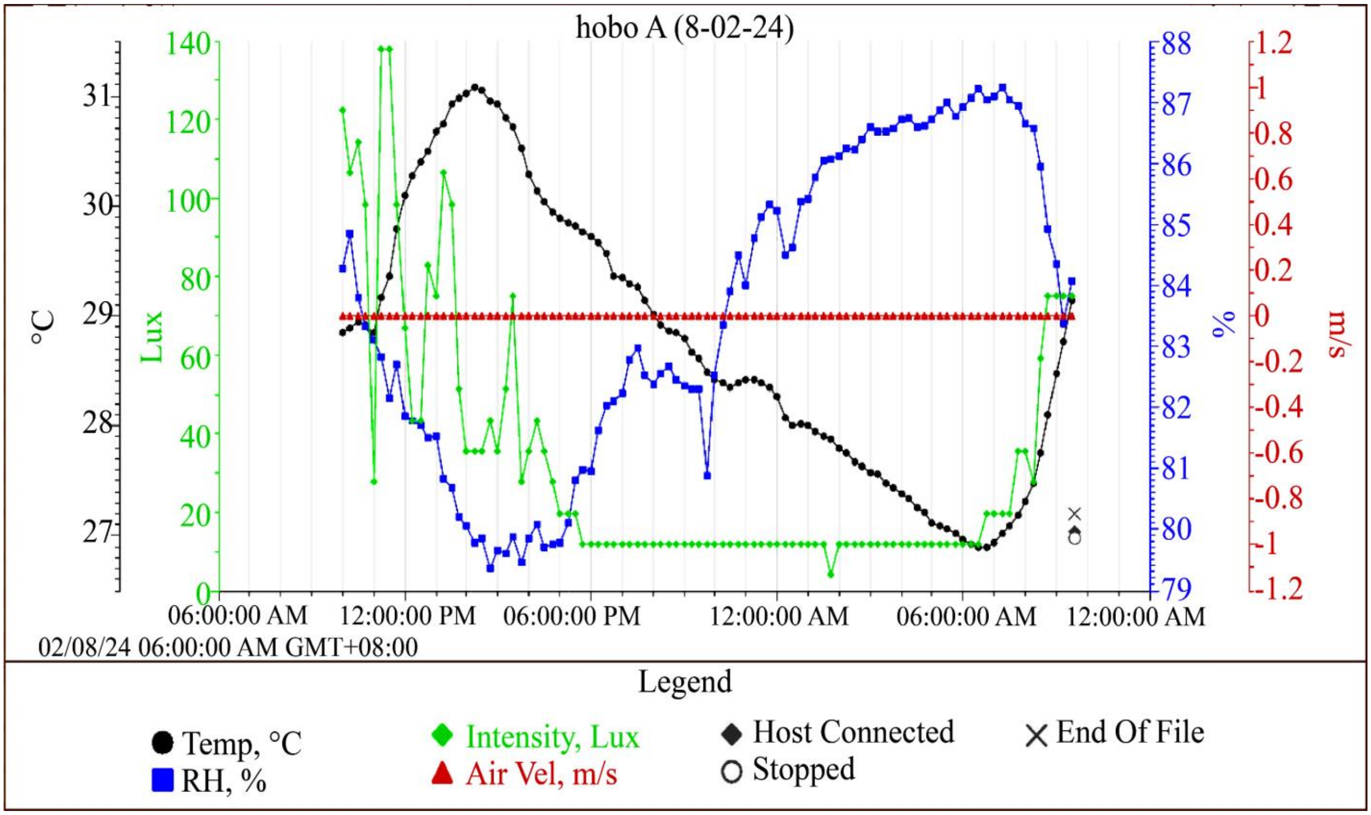

Fig. 4 Thermal comfort graph for fisherman's house number 33

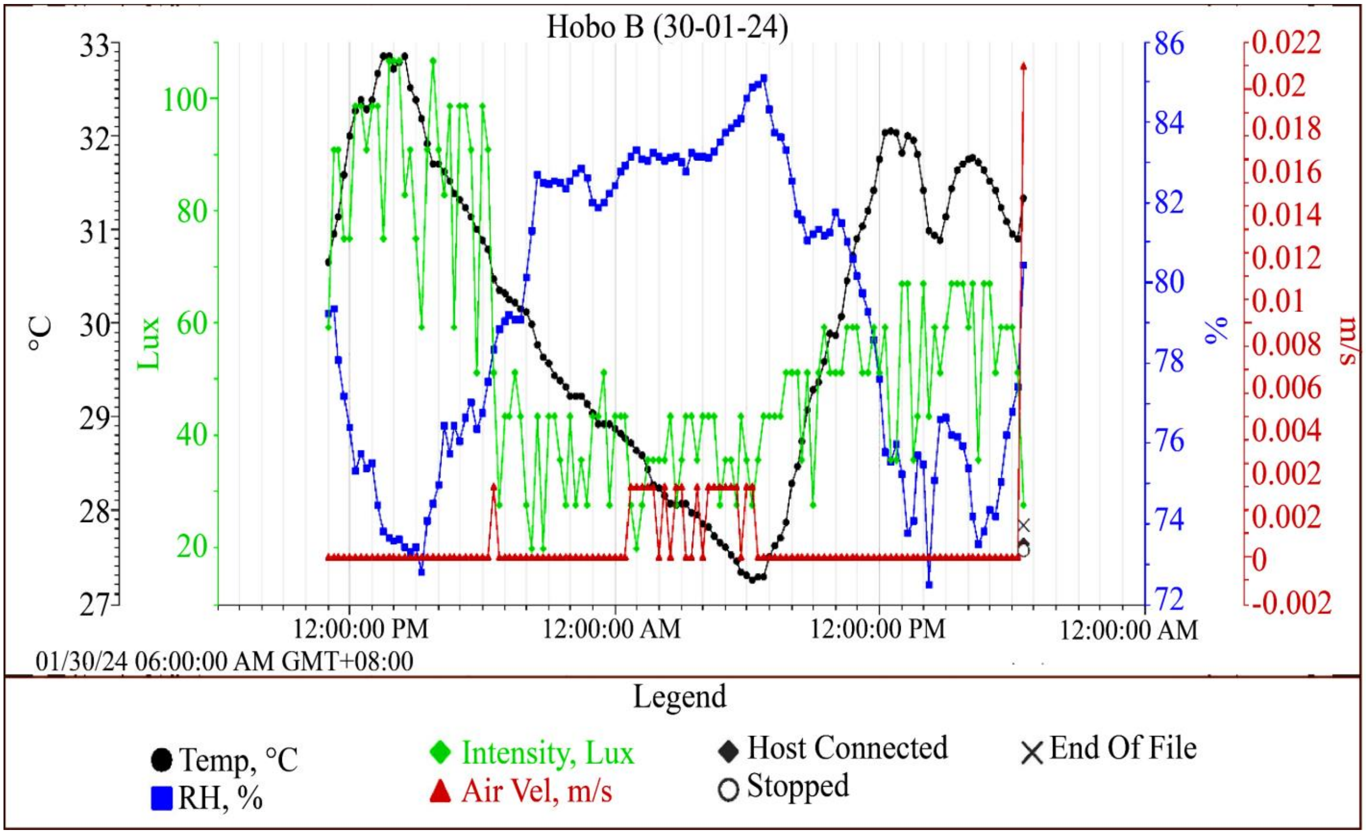

Fig. 5 Thermal comfort graph for fisherman's house number 41

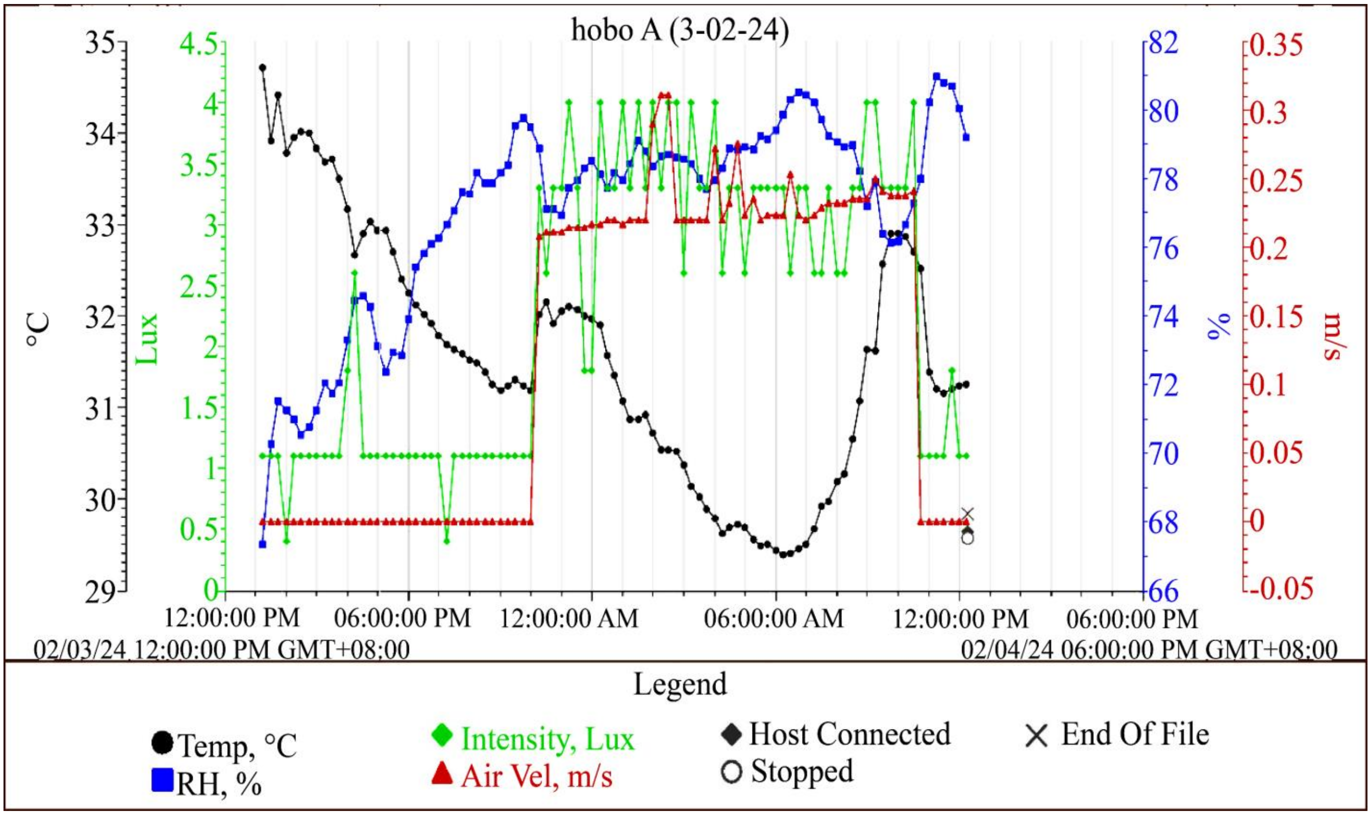

Fig. 6 Thermal comfort graph for fisherman's house number 42

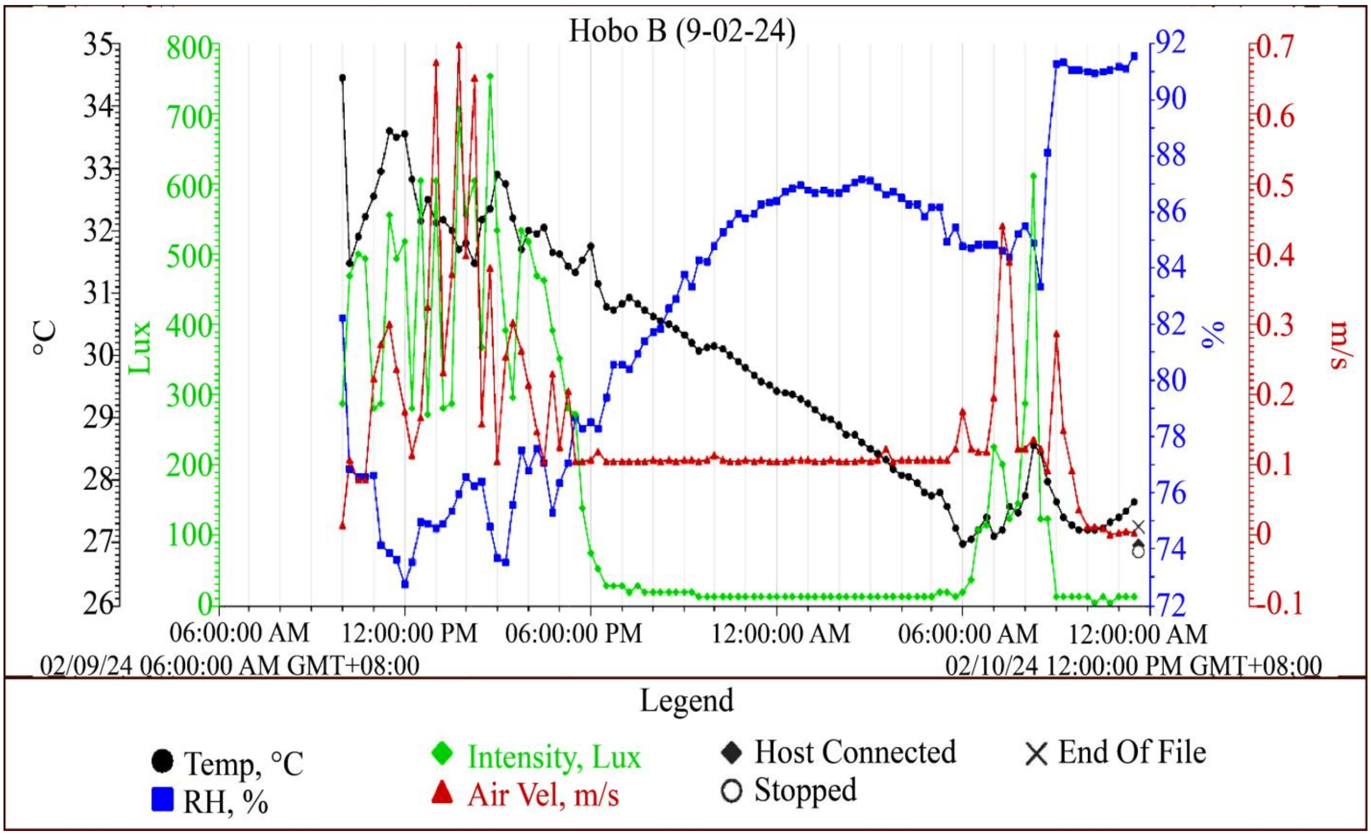

Fig. 7 Thermal comfort graph for fisherman's house number 60

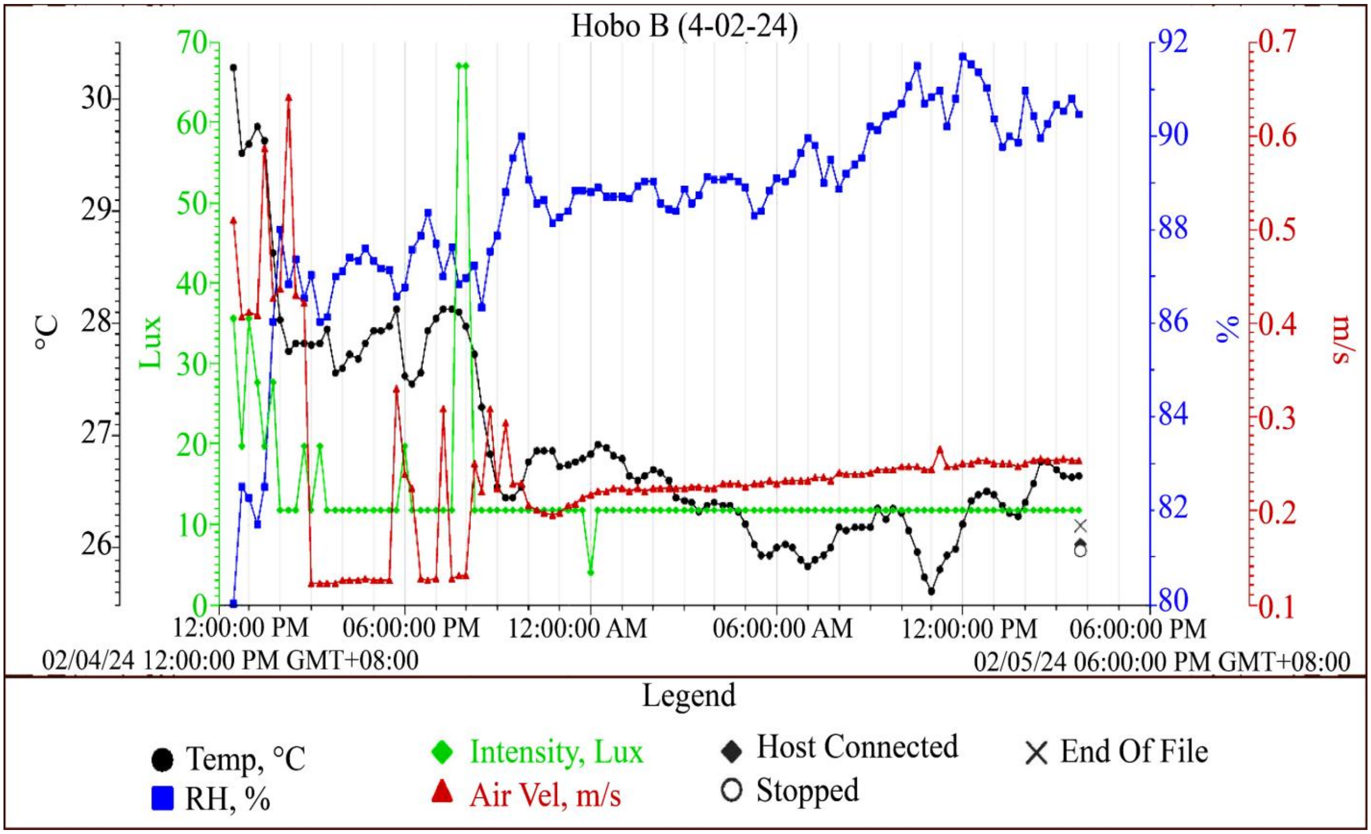

Fig. 8 Thermal comfort graph for non-fisherman's house number 101

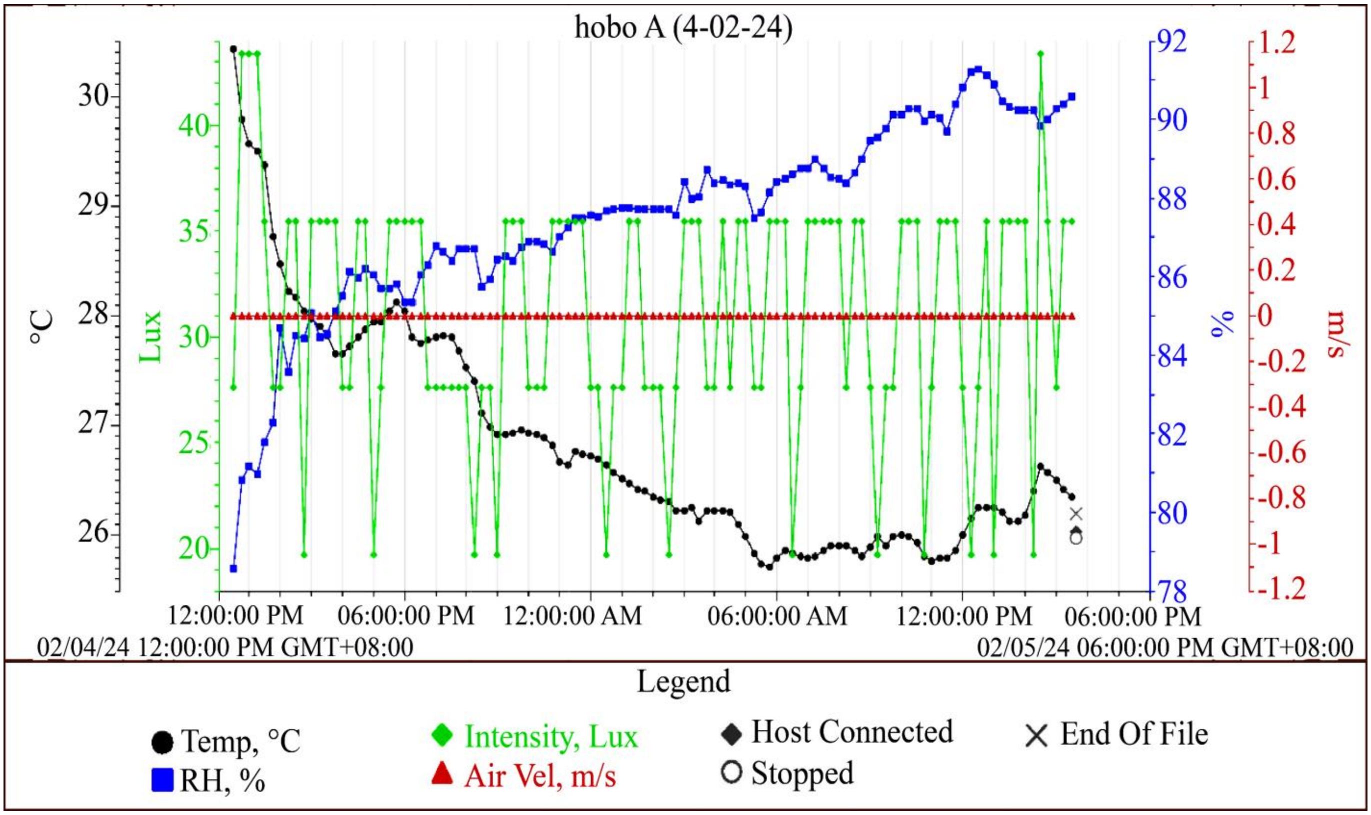

Fig. 9 Thermal comfort graph for non-fisherman's house number 103

Table 2. Thermal comfort fisherman's house number 33, 41, 42, 60, 101, and 103

House Number	Solar radiation (W/m^2)	Temperature (°C) inside the house		Sensation of thermal comfort	RH Humidity (%)	Wind velocity (m/s)	THI (°C)	Sensation of thermal comfort
33	057,3	Min	26,89	Less comfortable	87,21	0,000	26,20	Uncomfortable
		Max	31,07	Uncomfortable	79,77	0,000	29,80	Uncomfortable
41	019,7	Min	27,25	Uncomfortable	84,87	0,003	26,42	Uncomfortable
		Max	32,84	Uncomfortable	73,64	0,000	31,10	Uncomfortable
42	124,7	Min	29,38	Uncomfortable	79,86	0,223	28,26	Uncomfortable
		Max	34,70	Uncomfortable	67,36	0,000	32,43	Uncomfortable
60	117,3	Min	26,98	Less comfortable	84,75	0,177	26,15	Uncomfortable
		Max	34,44	Uncomfortable	82,24	0,015	33,21	Uncomfortable
101	007,8	Min	25,72	Comfortable	88,12	0,000	25,10	Comfortable
		Max	30,26	Uncomfortable	80,02	0,510	29,04	Uncomfortable
103	026,9	Min	25,79	Comfortable	88,75	0,000	25,20	Comfortable
		Max	30,41	Uncomfortable	78,55	0,000	29,09	Uncomfortable

5. Conclusion

The poor thermal comfort of fishermen's houses was discovered based on the innovative development of models for determining thermal comfort using expert systems, certainty factors and GIS-based spatial analysis. The results of this model development have been validated by measuring thermal hobo data logger instruments and solar power meters related to temperature, air humidity, wind speed and solar radiation at several points. The results of the research on the thermal comfort of fishermen's houses were that all 73 houses had poor thermal comfort, particularly less comfort and discomfort. There are 38 fishermen's houses that have less comfortable thermal comfort, or 52.05%, and 35 fishermen's houses that have uncomfortable thermal comfort or 47.95%. The poor thermal comfort in the fishermen's houses is caused by the hot sun not applying the principles of eco-architecture, eco-building, eco-cooling, and the principles of sustainable development. The fishermen's houses use materials that have low heat reduction and easily transmit radiant heat. The materials in question are zinc and spandex, do not use insulation and facades, do not have ceilings or only use materials with a small specific gravity such as plywood, high building density >75%, near the sea and paved highways, and lack of trees and parks, both indoors and outdoors. All fishermen's houses in South Karama Hamlet have poor thermal comfort with temperatures >27.1 °C, exactly at 31.07 °C, 32.84 °C, 34.70 °C, and 34.44 °C, especially during the day around 11:00 am to 14:00 pm. In the morning, it was found that several fishermen's houses and non- fishermen's houses had good or comfortable thermal comfort with temperatures below 27.1 °C, specifically 25.79 °C, 25.84 °C, 26.89 °C, and 27.25 °C including having comfortable thermal comfort outside the home or THI <26 °C at 25.20 °C, 25.31 °C, 26.40 °C and 26.42 °C. This model for determining the thermal comfort of fishermen can be used in planning and evaluation to demonstrate the construction of houses, housing, settlements, or other buildings that are air condition-free, energy efficient, low operational costs, and development that is environmentally sound and sustainable.

Conflicts of Interest

Regarding the publication of this research article entitled A Method for Determining Thermal Comfort of Fishermen's Houses, Case Study: South Karama Hamlet, there is absolutely no conflict of interest in it. This research was carried out voluntarily, at my own expense, without using the costs of other parties. It was specifically carried out in connection with the completion of my studies in the Doctoral Program (S3) in Architectural Science at the Faculty of Engineering Hasanuddin University, Makassar, Indonesia.

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