The Effect of Green Roof as Rice-Planting Media Towards Indoor Climate

Rasyid Dewangga Bagaskara Putra[1], Etik Mufida[2]
[1,2] Jurusan Arsitektur, Universitas Islam Indonesia
[2]Surel: 875120104@uii.ac.id

ABSTRACT*: The declining number of green areas especially rice fields lately encourages architects, urban planners, also researchers to maximize the existing spaces as new agricultural land. The green roof system is one of the alternative solutions to the problem of green area conversion. However, the green roof systems can affect the indoor microclimate of the building. According to Sadiq Abubakar Gulma's research there are differences in relative humidity and temperature between the green-roofed building and normal roofed building. This study discusses the thermal impact on indoor microclimate caused by the green roofs, especially the ones which are used as a rice-planting media. The method used in this study was an experimental-descriptive method that was done by creating 3D space models using green roofs as rice planting media which then would be compared with 3D space models using ordinary green roofs. Microclimate data measurement in buildings was done using Energy Plus software. Mean Radiant Temperature is used as the main indicator data in this research because it is the indicator of heat radiation transfer between environment heat into the indoor trough the building envelope. Based on the data collected, there is a difference between the model using the ordinary green roof and the green roof as rice-planting media. The difference in the use of the green roofs on both models affects its indoor microclimate.*

Keywords: *green roof, rice fields, indoor microclimate*

INTRODUCTION

The existence of rice fields is declining every year. It happens due to the change in the function of the green area into settlements and housings. According to the data from Special Region of Yogyakarta Agricultural Service (Dinas Pertanian Daerah Istimewa Yogyakarta), the decreased number in agricultural land in Special Region of Yogyakarta can reach 250 hectares per year. The conversion of agricultural land into settlements and housing was the biggest factor in the decline of green area number (Sasongko, 2019). According to Kinasih (2013), a green roof is an alternative to the green area's conversion problem.

Green roof can be defined as a flat or sloped rooftop that supports vegetation (Dvorak, 2010, p. 198). According to Kanter, R. (2005), the application of green roof in a building has several benefits, such as:

1. Creating a beautiful and comfortable city view.
2. Reducing air pollution and making cities healthier (plants can reduce air pollution by 0.5 kg per year).
3. Creating living space and places for recreation for the community.
4. Creating space for resting and relaxing.
5. Improving water and air quality.
6. Creating ecological buildings.
7. Reducing roof maintenance costs.
8. Creating green areas.
9. Preventing ultraviolet radiation and extreme temperature changes around the building.
10. Improving the city's drainage system.
11. Suppressing noises and save heat energy.
12. Decreasing radiant temperature of surrounding areas, both indoor and outdoor.

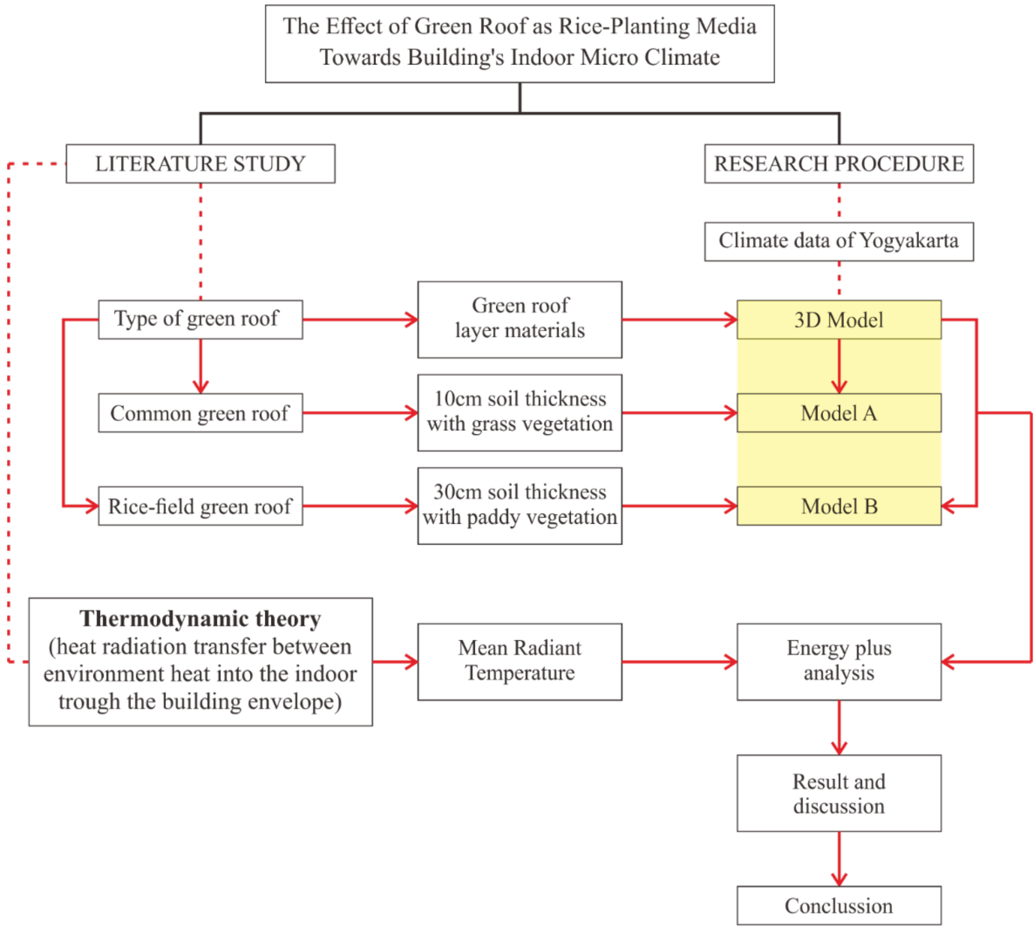
From those benefits, the green roof system is suitable to be applied especially in Indonesia that has a wet tropical climate with mostly high temperature, high air humidity level, and lower air velocity. This research analyzes the comparison between common green roof and green roof as rice-planting media towards its microclimate. It because Indonesia has a lot of green areas used for rice field and green roof that used as rice planting media is one of the solution of the declined of agricultural land that change into settlements and commercials. Green roof as rice planting media can be applied in several function such as in the commercial building like shopping mall, campus, mixed used buildings, apartments, etc. This type of green roof also can be applied in settlements such as apartment and vertical housing.

According to Sadiq Abubakar Gulma (2014), Green roofed building has different indoor microclimate rather than bare roofed building (common roof materials only). The microclimate is composed of solar radiation, wind, temperature, and humidity of the air, and precipitation in the scope of small spaces (Frickdan suskiyatno, 2007). Mean Radiant Temperature is used as the main indicator data in this research because it is the indicator of heat radiation transfer between environment heat into the indoor trough the building envelope (thermodynamic theory).

This research inspired from Sadiq Abubakar Gulma's research (2014) about the difference of indoor microclimate depended on its roof material. In that reference paper, Sadiq Abubakar Gulma and team compared the bare roof material (common roof material) with green roof material. This paper will compare both of green roof system but in different vegetation types and the thickness of the soil. That comparison of vegetation layer is depended on C. Y. Jim's research (2011) that compared the effect of different vegetation layers in the green roof system towards the indoor air temperature. In that reference, the vegetation that used as comparison are shrub, ground cover herbs and turfgrass. While in this research will compare the common grass vegetation and upland rice vegetation (padi gogo).

RESEARCH METHOD

The method used in this study was an experimental-descriptive method, namely by creating 3D space models using green roofs as rice planting media which then would be compared with 3D space models using ordinary green roofs. The measurement of microclimate data in buildings was done using Energy Plus software, a part of the Open Studio Legacy software that is commonly used to examine microclimate, thermal elements, and lighting from the 3D models. Mean Radiant Temperature is used as the main indicator data in this research because it is the indicator of heat radiation transfer between environment heat into the indoor trough the building envelope. The statistical data obtained were then compared with each other using descriptive methods to explain the comparison and differences between the models. The models were a room unit model with 3m x 3m size and 3,5m height that used 2 kinds of green roof materials, model A was the model using the common green roof for its roof material, while the model B was using the green roof for rice-planting media.



Picture 1. Procedure diagram of the research
source: writer's document 2020

In this study entitled "The Effect of Green Roof as Rice-Planting Media Towards Building's Indoor Micro Climate", the variables are as follow:

a. Independent variable:

The independent variable of this research is the construction layers of green roof models.

Table 1. Independent variable of the research

Layers	Common green roof (A)	Rice-planting media green roof	Thickness	Thermal character	
				Conductivity (W/m-K)	Specific Heat (J/kg-K)
Outside Layer	grass	paddy	5cm (A) 28cm(B)	2,00	2200
Layer 2	Soil	Soil	10cm (A) 30cm (B)	0,35	1200
Layer 3	Plastic sheet	Plastic sheet	8mm	0,166	1050
Layer 4	Fiber concrete	Fiber concrete	51mm	0,24	880
Layer 5	Polyurethane	Polyurethane	10mm	0,0245	1590
Layer 6	Polyethylene	Polyethylene	8mm	0,029	1210
Layer 7	Reinforced concrete	Reinforced concrete	15cm	2,15	900

source: PT Agyaroof 2015 and Writer's document 2020

* because there a limitation data of vegetation thermal character, the thermal character between the grass vegetation and paddy vegetation use the same data of long grass vegetation (source: https://www.semanticscholar.org/)

b. Dependent variable: Indoor Micro Climate (Mean Radiant Temperature)
In this study, there are 2 research variables, with indoor micro climate parameters of the sample room that depend on the roof material.

Table 2. Indicator, variable, and parameter table

Indicator	Variable	Parameter	Data
3m x 3m empty room layout model with 12cm wall thickness and green roof material	**Common green roof** (green roof with 10cm soil thickness and grass for vegetation)	**Indoor Micro Climate** (the heat transfer of building envelope to the indoor.)	Mean radiant temperature
	Green roof as rice field (green roof with 30cm soil thickness and upland rice (*padi gogo*) for the vegetation		

source: writer's document 2020

RESULT AND DISCUSSION

1. Model A

The results of model A with these specifications are as follows:

a. Daily mean radiant temperature average of model A:

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	34.19	28.16	28.63	33.03	27.88	33.41	33.36	33.91	33.7	30.72	34.15	33.34
2	33.4	27.04	27.03	34.15	29.08	33.62	34.19	33.08	34.42	30.35	33.87	33.54
3	32.18	25.96	28.73	32.84	27.7	33.32	34.2	32.83	34.49	31.41	34.17	31.7
4	34.25	26.59	29.53	30.98	30.45	33.59	34.42	33.37	33.91	32.82	34.18	30.76
5	34.18	28.5	27.13	31.26	31.85	33.16	31.38	33.48	34.24	34.01	34.36	31.25
6	33.71	28.16	28.93	30.4	31.51	33.97	28.81	33.99	34.61	34.51	34.31	32.03
7	33.05	30.42	28.5	28.96	31.69	32.38	29.09	33.93	32.67	34.65	34.1	31.98
8	29.46	32.46	29.62	27.95	31.77	31.87	30.24	33.06	29.63	34.31	34.16	34.02
9	27.82	29.87	28.81	29.99	33.51	34.03	31.51	31.47	31.23	33.25	34.18	31.39
10	29.18	27.42	28.23	30	33.83	32.57	34.08	33.23	32.61	31.98	33.85	31.6
11	30.1	26.04	30.85	31.33	33.48	31.82	34.28	33.55	33.32	33.52	30.49	32.02
12	27.7	27.99	29.8	31.13	33.74	34.2	32.04	32.95	33.27	31.26	33.28	30.7
13	29.54	29.56	28.12	31.45	35.33	35.06	28.88	32.75	33.49	31.26	34.15	29.56
14	31.13	28.61	28.11	33.1	34.47	34.96	30.04	33.49	33.87	33.56	34	29.18
15	30.32	27.13	30.4	34.18	34.93	34.15	30.93	33.86	34.06	33.01	33.21	30.27
16	28.12	26.84	31.33	34.26	35.44	33.71	29.94	34.07	34	31.91	31.09	29.15
17	26.07	29.28	30.33	30.95	35.34	33.67	29.18	33.65	34.02	31.01	31.72	27.62
18	28.16	29.69	32.55	32.4	35.44	32.18	30.31	32.08	33.36	33.05	33.01	28.04
19	27.93	28.01	31.73	33.39	35.61	27.36	33	31.04	33.82	31.42	32.1	29.71
20	28.72	26.72	28.2	33.62	35.73	29.83	30.92	32.57	33.65	31.87	32.91	30.4
21	29.12	25.86	29.66	33.38	32.15	32.73	30.76	34.58	33.47	33.94	33.29	30.8
22	28.66	28.66	31.88	33.6	32.32	33.96	31.11	33.95	33.5	34.88	31.16	28.61
23	28.23	30.41	32.29	29.49	34.88	34.05	31.53	33.77	33.77	30.42	30.13	29.53
24	30.85	31.95	32.7	30.73	35.18	32.02	33.08	34.28	32.09	30.74	31.68	31.78
25	29.71	32.38	33.18	33.71	35.2	32.5	30.71	34.54	30.68	33.38	33.65	32.08
26	28.56	30.79	32.88	33.88	35.15	31.98	29.62	34.15	33.05	34.42	33.81	31.12
27	31.5	32.13	32.07	31.85	35.41	32.46	30.78	33.95	33.96	34.36	31.23	31.42
28	33.01	30.37	32.28	32.07	34.56	31.24	33.21	33.62	34.39	33.89	30.89	33.28
29	33.18		33.26	32.02	29.53	33.17	32.3	33.65	34.08	29.72	33.4	33.57
30	31.63		31.83	28.55	30.37	33.59	34.09	33.61	33.31	31.39	34.39	31.45
31	28.4		31.17		33.51		34.13	33.2		34.01		27.18
Average	30.39	28.82	30.31	31.82	33.13	32.89	31.68	33.41	33.36	32.61	33.03	30.94

Picture 2. Model A daily MRT results
source: writer's document 2020

2. Model B

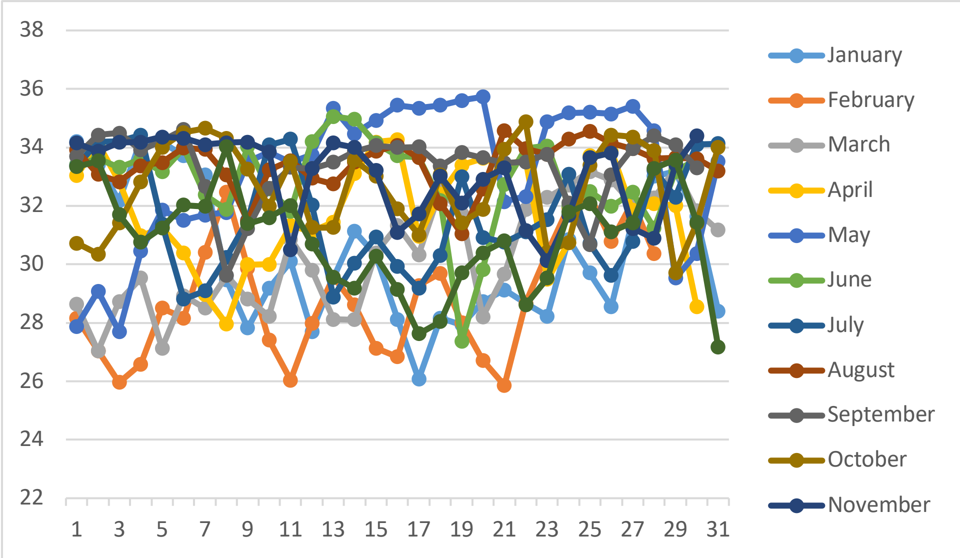
The results of model A with these specifications are as follows:

a. Daily mean radiant temperature average of model B:

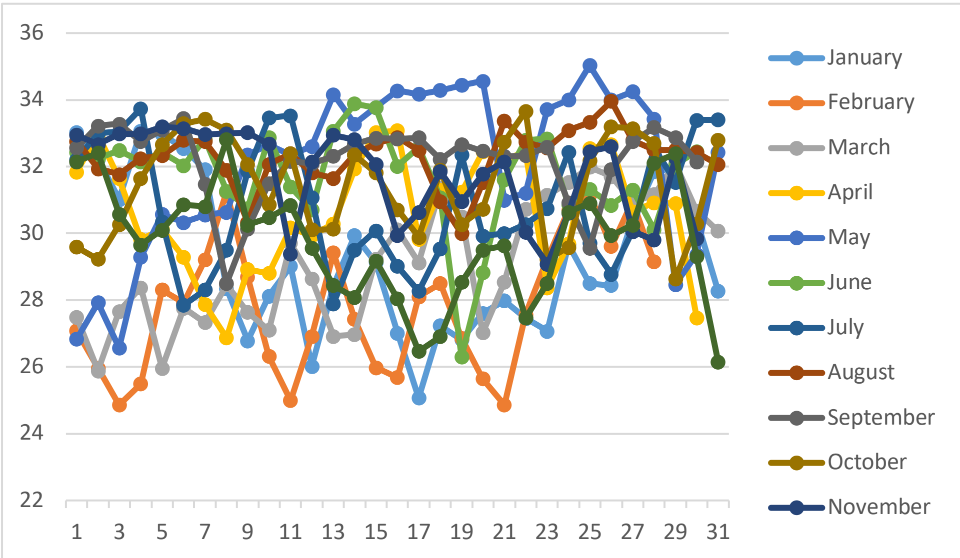
	January	February	March	April	May	June	July	August	September	October	November	December
1	33.02	27.08	27.49	31.84	26.83	32.43	32.21	32.76	32.56	29.59	32.94	32.15
2	32.23	25.96	25.89	32.96	27.93	32.25	33	31.94	33.22	29.23	32.67	32.41
3	31.02	24.86	27.67	31.64	26.57	32.48	33.05	31.77	33.28	30.26	32.98	30.58
4	33.07	25.49	28.38	29.82	29.29	32.15	33.74	32.25	32.75	31.64	32.98	29.66
5	32.96	28.31	25.96	30.13	30.57	32.42	30.35	32.33	33.1	32.67	33.19	30.1
6	32.55	27.93	27.76	29.29	30.33	32.03	27.85	32.79	33.44	33.29	33.15	30.86
7	31.91	29.21	27.33	27.87	30.55	32.82	28.31	32.75	31.48	33.42	32.96	30.81
8	28.35	31.25	28.46	26.87	30.64	31.27	29.51	31.89	28.51	33.1	32.99	32.82
9	26.79	28.69	27.64	28.92	32.36	30.75	31.87	30.33	30.14	32.07	33.02	30.25
10	28.13	26.32	27.1	28.81	32.66	32.88	33.46	32.07	31.5	30.86	32.68	30.47
11	29.02	24.99	29.71	30.17	32.35	31.39	33.53	32.39	32.16	32.4	29.38	30.84
12	26.02	26.92	28.63	29.94	32.61	30.7	31.08	31.81	32.09	30.11	32.14	29.56
13	28.43	29.42	26.92	30.29	34.16	33.07	27.9	31.65	32.31	30.13	32.94	28.44
14	29.94	27.43	26.97	31.93	33.28	33.88	29.51	32.36	32.68	32.35	32.81	28.08
15	29.13	25.98	29.23	33.02	33.78	33.77	30.08	32.69	32.86	31.81	32.07	29.18
16	27.02	25.68	30.11	33.08	34.28	32.02	29.02	32.88	32.83	30.71	29.95	28.04
17	25.07	28.11	29.12	29.83	34.17	32.57	28.27	32.48	32.87	29.89	30.64	26.47
18	27.24	28.5	31.35	31.3	34.29	31.07	29.54	30.96	32.22	31.89	31.85	26.91
19	26.81	26.86	30.5	31.24	34.44	26.3	32.35	29.99	32.67	30.27	30.95	28.54
20	27.61	25.65	27.03	32.45	34.56	28.83	29.93	31.53	32.47	30.73	31.78	29.51
21	27.98	24.86	28.55	32.22	31	31.61	29.99	33.38	32.31	32.74	32.15	29.63
22	27.46	27.57	30.73	32.45	31.21	32.79	30.27	32.73	32.33	33.66	30.03	27.47
23	27.07	29.25	31.14	28.38	33.72	32.84	30.74	32.56	32.59	29.22	29.08	28.51
24	29.66	40.69	31.53	29.69	34	30.86	32.44	33.09	30.91	29.58	30.62	30.64
25	28.5	31.17	31.99	32.55	35.03	31.33	29.72	33.33	29.55	32.18	32.46	30.9
26	28.44	29.61	31.71	32.66	34	30.85	28.78	33.96	31.91	33.19	32.6	29.94
27	30.41	30.96	30.92	30.65	34.25	31.31	30.06	32.79	32.75	33.15	30.06	30.25
28	31.85	29.15	31.16	30.92	33.43	30.11	32.56	32.5	33.17	32.7	29.8	32.11
29	31.97		32.09	30.89	28.47	32.05	31.54	32.5	32.88	28.63	32.26	32.39
30	30.43		30.67	27.47	29.37	32.46	33.39	32.43	32.15	30.28	29.84	29.31
31	28.27		30.07		32.43		33.4	32.06		32.8		26.15
Average	29.30	28.14	29.16	30.64	32.02	31.71	30.89	32.29	32.19	31.44	31.77	29.77

Picture 3. Model B daily MRT results
source: writer's document 2020

1. Data comparison



Picture 4. Model A daily MRT line chart
source: writer's document 2020



Picture 5. Model B daily MRT line chart
source: writer's document 2020

From the two comparisons chart above, it can be seen that the increase and decrease of mean radiant temperature on a daily basis is relatively the same, this is evidenced by the shape of a similar line between chart model A and model B. The difference between the two is the position of the temperature point, where model A is higher than model B.

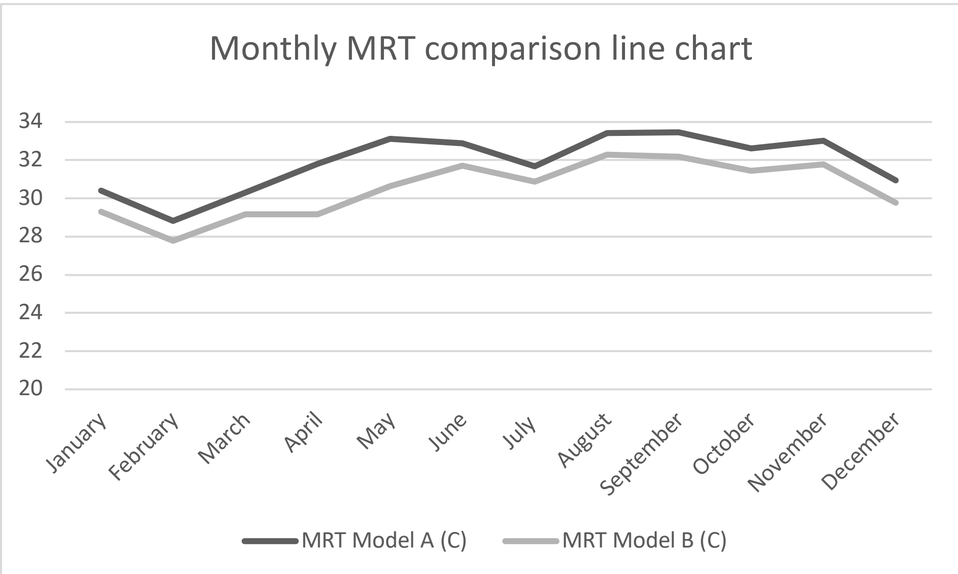
If the average of mean radiant temperature data in each month is compared directly, a comparison can be obtained as follows (table3):

Table 3. Monthly MRT Comparison results

Month	MRT of Model A	MRT of Model B
January	30,39	29,30
February	28,82	27,78
March	30,31	29,16
April	31,82	29,16
May	33,13	30,64
June	32,89	31,71
July	31,68	30,89
August	33,41	32,29
September	33,46	32,19
October	32,61	31,44
November	33,03	31,77
December	30,94	29,77

source: writer's document 2020

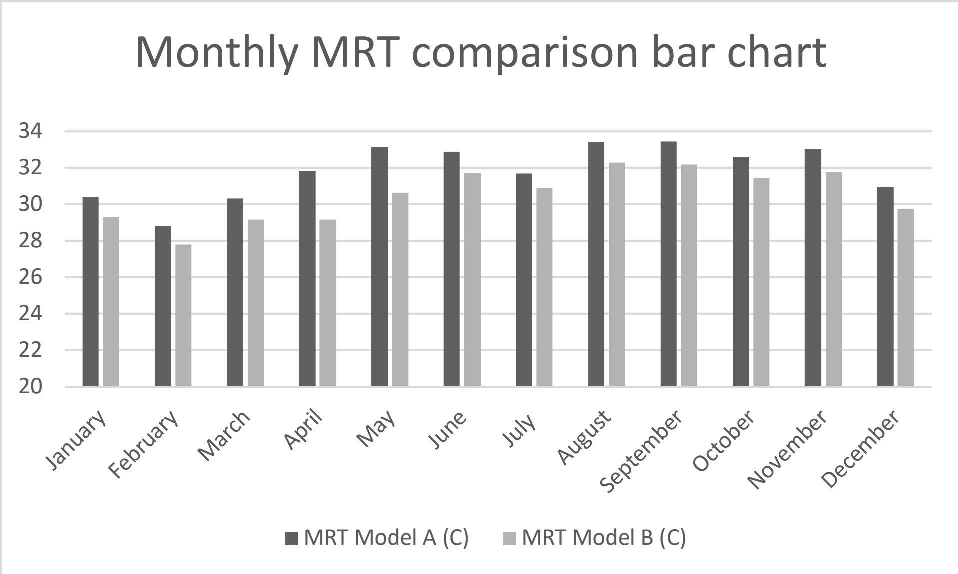
From the table above, Model A which uses a common green roof composition material has higher MRT temperature measurement results compared to Model B which uses a roofing material in the form of a green roof which is used as a rice-planting media. To find out the differences between the two models from another perspective, the data obtained is converted into 2 different chart forms (line chart & bar chart).



Picture 6. Line chart of monthly MRT Comparison results
source: writer's document 2020

From the chart above, it can be seen that the increase and decrease of the temperature in model A and model B are relatively similar. When the radiant temperature of model A has increased, model B has also increased. The difference is only in March-April, which in Model A, the temperature of the air continues to increase while in Model B the temperature of the air tends to decrease.

From the chart above, we can also find out that the temperature in model A is higher than model B. This can be seen from the chart line of model B which is always below the chart line of model A. To know the difference of the MRT from the two models more clearly, the data above is converted into a bar chart as below:



Picture 7. Bar chart of monthly MRT Comparison results
source: writer's document 2020

From the chart above, it can be seen that the average of mean radiant temperature difference of the two models is no more than 5^0 Celsius. It is seen from the difference height of the two bars do not exceed the temperature interval listed on the chart, which is equal to 5^0 Celsius.

From the data that has been obtained and analyzed, all the results show that model B which uses a green roof structure as a rice planting media (30cm soil thickness and paddy vegetation) has a lower temperature compared to model A which uses an ordinary green roof (10cm soil thickness and grass vegetation). From these statements it is evident that differences in material on the roof can cause differences in its indoor temperature. As found in the research of Sadiq Abubakar Gulma (2014) which examines the temperature difference between ordinary roofs and green roofs, the measurement results of the green roof building temperature are lower than the temperature of buildings with conventional roofs. From the data that has been obtained previously, plant type and soil thickness also affect the temperature in the building. According to the results of CY Jim's research (2011) that have examined the different types of vegetation used as an indicator of the mean radiant temperature different in buildings and produce some temperature differences in buildings that use different types of plants. In this study, building models that use as rice plant media and have thicker soil thickness have been shown to have lower temperatures compared to building models that use grass plants and thinner soil thicknesses.

CONCLUSION

From this study we can conclude that model B which uses green roof as a rice planting medium has a lower mean radiant temperature compared to model A which uses ordinary green roof. This is due to differences in thickness of the soil layer used. Model B uses soil with a thickness of 30cm while Model A only uses soil with a thickness of 10cm. The type of plant used also affects the mean radiant temperature in the building, it is proven that Model B using upland rice plants has a mean radiant temperature lower than model A which uses grass plants. This is influenced by differences in leaf surface area and plant thickness that cover the green roof area.

The results of this study also prove that Model B has a mean radiant temperature average difference of $1^0 - 2^0$ Celsius lower than Model A in each month. Increase and decrease of mean radiant temperature in both models every month in ranges from $1^0 - 2^0$ Celsius. This increase and decrease also has almost the same rhythm between the two models in each month. This is evident from the shape of the curve which have similar line shape. If we compare the results with the average of monthly outdoor temperature in Yogyakarta, we will get a difference around $1^0 - 2^0$ Celsius lower in Model A and $2^0 - 4^0$ Celsius lower in Model B.

For the next research study, it is recommended to use a larger model since the difference of the temperature can be more specific to obtain better data result. Also the specific thermal properties of the vegetation layer can be increase the novelty and value of the research.

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