Contents available at: www.repository.unwira.ac.id

ARTEKS
JURNAL TEKNIK ARSITEKTUR

https://journal.unwira.ac.id/index.php/ARTEKS

Research paper doi: 10.30822/arteks.v7i3.1662

Green roof on tropical house as architectural innovation responding Covid-19 pandemic

Sri Yuliani*, Ana Hardiana, Amin Sumadyo, Tri Yuni Iswati

Department of Architecture, Faculty of Engineering, Universitas Sebelas Maret
Jl. Ir. Sutami, no. 36A, Surakarta, Indonesia

ARTICLE INFO

Article history:
Received June 07, 2022
Received in revised form Nov. 06, 2022
Accepted November 23, 2022
Available online December 31, 2022

Keywords:
Covid-19 pandemic
Green roof
Roof innovation
Space exploration
Tropical house

***Corresponding author**: Sri Yuliani
Department of Architecture, Faculty of Engineering, Universitas Sebelas Maret, Indonesia
Email: sriyuliani71@staff.uns.ac.id
ORCID: https://orcid.org/0000-0002-4288-2959

ABSTRACT

Green roof researches have many benefits in supporting a sustainable environment. During the covid-19 pandemic, there was a change in lifestyle due to demands for the prevention of transmission, so many activities were carried out at home. These two phenomena will be integrated into this study, to provide solutions for space expansion in residential areas during the covid-19 pandemic. The research method uses an online questionnaire in several regions in Indonesia and a small number outside Indonesia; conducting a content analysis on previous green roof research; then linking the results of community responses and the potential for green roofs. The results of the study found that there were still few people who knew about the opportunity for a roof to expand its space which was more useful, even though there have been many findings of green roof innovations. In addition, there is still little research on green roofs that relates to the pandemic situation, particularly in Indonesia.

Introduction

Efforts to deal with Covid-19 are widely viewed from several sectors. One that was studied by Goel et al. (2020) states that environmental conditions need to be considered, because when a coronavirus outbreak forces the use of disinfectants with other antimicrobial substances that endanger humans and the environment and the ecosystems in them. The handling cycle and the impact of the corona pandemic are illustrated in figure 1 can cause other diseases due to climate change due to environmental damage. As a result, improper handling can provide the risk of environmental damage including animals and lead to other crises that affect humans.

Figure 1. Schemes that show various factors cause increased zoonotic appearance
Source: (Goel et al. 2020)

In a more specific discussion in the scope of the built environment, research conducted by Megahed and Ghoneim (Megahed and Ghoneim

2020) provides an illustration of Covid-19 pandemic linkages to the built environment as in figure 2.

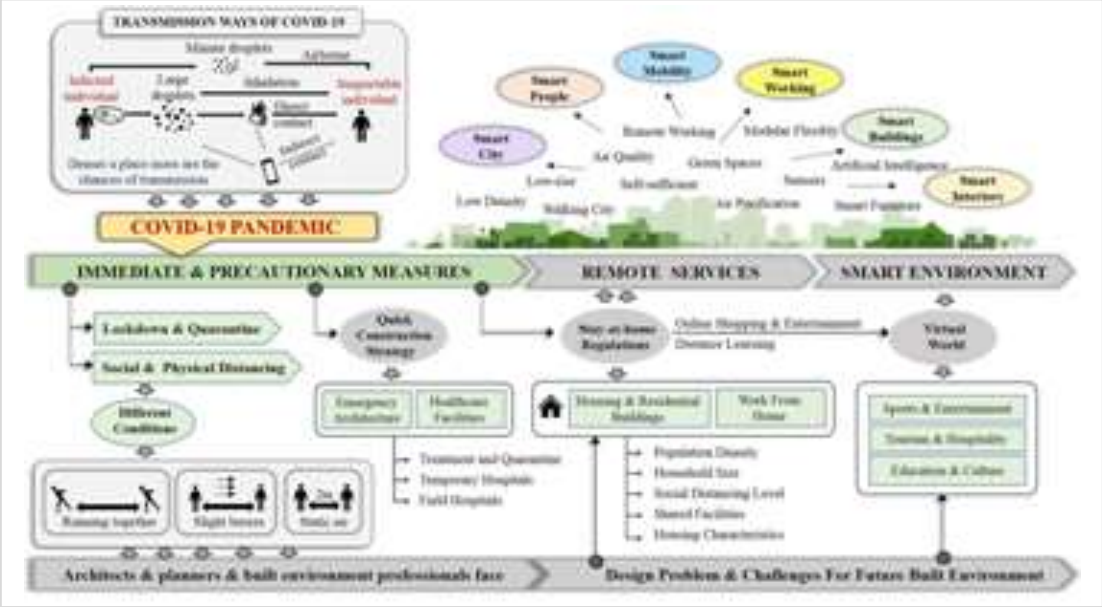

Figure 2. Social distancing, lockdown and variable relationship schemes
Source: (Megahed and Ghoneim 2020)

Megahed and Ghoneim (2020) stated that the pandemic increased the requirements for policy makers, planners and architects to think further, try to reshape our physical space, and reorganize the existing building environment or develop further from existing land uses in the future. Shelters need to be designed to be built in a sufficient, independent and healthy environment and make intelligent use of available technology. At a macro level, it is very important to make urban areas more resilient to emergency response, to deal with epidemics and other possible emergencies in the future. In the end, Megahed and Ghoneim (2020) explained that there are two paradigms that need to be considered in planning development, i.e., looking back by conducting environmentally friendly activities and looking forward to increasing innovative technology to meet needs. The first paradigm, which is to look back naturally, can be done with efforts to approach the natural environment naturally through an urban approach, one of which is urban farming; architectural approach, including focusing on green space and providing good air quality. Meanwhile, the second paradigm considers advanced technology through modular construction, adaptive reuse and lightweight architecture.

The results showed that anxiety about going out affected perceptions of openness and publicity, while fear of COVID-19 infection affected the impression of space, brightness, and naturalness. This psychological effect is reflected in the total floor area, window area, and color planning. This effect reveals how the designer's psychological state affects the spatial elements in architectural design (Yu and Fujii 2022).

The needed of physical distance adapt many architectural design, such as garden. A study in Indonesia concluded that garden designers agreed to use border elements to implement physical distancing in public parks. In general, green elements are likely to be used even though garden designers prefer hardscapes over softscapes as border elements (Santoso and Setyabudi 2021).

Related to density, the research of residential density affects the spread of the virus during the covid pandemic (Irandoost et al. 2022).

Equally important, previous studies in the realm of architecture are related to the discussion of plural settlements to single occupancy, in particular green roofs. Green roof research among them conducted by de Munck et al. (2018)

concluded that green roofs are useful for maintaining environmental quality and are the most effective way to reduce energy consumption, not only in summer but also every year. Agree with the research (Ziogou et al. 2017; Peng et al. 2019; Ran and Tang 2017; Bevilacqua, Bruno, and Arcuri 2020) The effects of various greening actions that might occur during different seasons are finally overcome by compiling a comprehensive inventory of climate impacts of the strategy. In addition, (Dimond and Webb 2017) added that the performance of a green roof is beneficial for the improvement of ecology, energy and water conservation and architecturally can add to the aesthetic value of a building and area. In a general context, the application of green elements can provide many positive benefits for the environment, cities, residential areas and buildings in terms of various disciplines (Masson et al. 2014; Perini and Roccotiello 2018). The positive effect of green areas can reduce pollution, reduce greenhouse gas emissions and reduce environmental heating, which in turn gives energy efficiency benefits to buildings. Further, delivered by Qin, Hong, and Jiang (2018) that green roofs and green walls not only reduce pollutants, but also provide heat reduction and healthier air. This research was supported by some researchers (Rowe 2018; Gourdji 2018; Teotónio, Silva, and Cruz 2018; Sangkakool et al. 2018; Pushkar 2019).

Although many studies of green roofs have concluded how strategic green roofs are for buildings, it is also important to know the prospects and sustainability of green roof implementation. Research conducted by Yuliani and Setyaningsih (2018) on the sustainability of green spaces that focus on the role of the community, concluded that the sustainability of green spaces is strongly influenced by the carrying capacity of the community's role. When the green element is applied to housing, it is necessary to have the involvement of the residents of the house to hold it continuously throughout the year. If the community's role is neglected, the green element will become nonexistent so that sustainability cannot be achieved. However, if the community's role is very active and takes place continuously, the spatial design that brings plants to the shelter will be sustainable. In addition, the involvement of building occupants is necessary given that care is needed for green roofs (Yuliani, Hardiman, and Setyowati 2020a). The implementation of a green roof on occupancy is very beneficial (Teotónio et al. 2020).

The relationship between research on green roofs in residential areas with efforts to deal with the Covid-19 pandemic and its effects apparently has a causal relationship that is solvable because green roof innovations can provide positive solutions that do not add to the burden on the environment. Covid-19 pandemic requires integrative handling by involving various viewpoints of scientific fields. The spread of the coronavirus is very fast, eventually leading to the necessary policies i.e., large-scale restrictions in several regions in Indonesia, to prevent the spread of the coronavirus, then the house as a place of residence is demanded to be a place that supports activities during the pandemic. Activities at home during the pandemic period include office work for those who work, school work for students and students to do refreshing also remain at home. The house as a place to stay that was originally just to unwind and do light or casual activities, is now a place that houses all day activities for all family members. Changing the atmosphere of the house is very important to support the productivity of the residents of the house. The roof as an expansion in tropical dwelling will be important to create residential-friendly and environmentally-friendly roofs.

During Covid-19 pandemic, people did not have many choices, as for people the best choice was to stay at home. As people adjust to the new living arrangement, adaptation to space and space flexibility require an innovation to rearrange and organize rooms to create a mutually supportive relationship between the people and their activities at home. Therefore, this study aims to identify, map and formulate a space innovation strategy on residential roofs as an effort to expand space during activities at home. So far, green roof research that is relevant to the conditions of Covid-19 pandemic from an architectural point of view is still very rare. For this reason, the results of this study aim to contribute to the innovation of roof space expansion as a space that can complement the needs of activities at home for people to feel comfortable and stay productive. Thus, roofing innovation will be able to help achieve the acceleration of the handling of the 19th pandemic from the science of architecture. This research focuses on the innovation of tropical residential roofs to provide innovative roof function development so that all parts of the residential space have optimal, effective and

efficient function values in that the space requirements for occupancy during work at home during the Covid-19 pandemic can be met. The formulated innovations accommodate the expectations and needs of the community and further discuss previous studies that deal with green roofs.

Method

Online questionnaires were analyzed from 171 respondents internationally and specifically from 62 cities across Indonesia, including major ten islands, i.e., Batam, Sumatra, Kalimantan, Sulawesi, Java, Bali, Madura, Lombok, Ternate and West Papua. The research method identifies the needs of the Indonesian people in sensing the space occupied by tropical dwellings, while facing the Covid-19 pandemic. The respondents answered multiple choice and open-ended questions. The data were analyzed with comparison of answers from respondents, and conclusions were drawn as a basis for consideration to develop a roof innovation strategy that is the focus of research.

The questions addressed in this questionnaire are: city of resident, responding to residential situations, interesting to the room at home, efforting to the needs of room, supporting to make over the room, understanding of the quality of space in residential, knowing on the potential of residential roofs, and desiring for the function of space on the roof, see table 1.

Table 1. The list of questions

No	Question
1	During the COVID-19 pandemic, do you feel comfortable staying at home?
2	Which part of the house makes you feel happy doing activities?
3	Do you have the desire to make changes to the room in the house?
4	While at home, write down your ideas for making changes to the room?
5	Do you know which part of your home has the opportunity to be developed into a comfortable and productive space?
6	In your opinion, does the roof have the opportunity to become a strategic space to be a comfortable and productive room?
7	What kind of space atmosphere do you want, when the roof of your residence turns out to be a space for activities?

Covid-19 pandemic distribution map in Indonesia, as published by the Covid-19 Task Force for Accelerating Handling through the official website https://covid19.go.id/peta-sebaran presents data that areas that have patients with Covid-19 are on the island of Java, which is indeed the most populous island, as in figure 3.

Figure 3. Map of Covid-19 distribution in Indonesia in October 2021
Source: (Pemerintah Republik Indonesia 2021)

Covid-19 distribution maps in Indonesia could be a priority reference for handling a pandemic. Therefore, this study collects 86% of the sample of respondents in Java (figure 4).

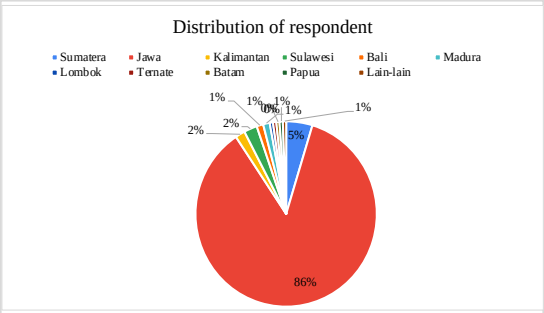

Figure 4. Respondent distribution

The data obtained is the basis for consideration in determining the prospects for green roof innovation. In the next stage, the research was carried out by considering a theoretical study of the findings of several recent green roof studies in depth through content analysis methods to be adapted to the needs of the community formulated through survey results from respondents.

Result and discussion

The study set out with questions to find out how the community responded while staying and working at home. Results show that 74% of the

people felt happy living at home, while 7% were not happy (figure 5). Meanwhile, 19% felt forced to continue their activities at home, because they were constrained by regulations during the pandemic. A very high percentage of happy people show that people gained the desired atmosphere while staying at home. This condition is an encouraging result because with many who were content at home, the WHO recommendation to stay at home and work from home could be implemented properly (World Health Organization 2020). The positive response at home could be interpreted that the community is aware of the need to stay at home during a pandemic and feel the comfort of the space available at home.

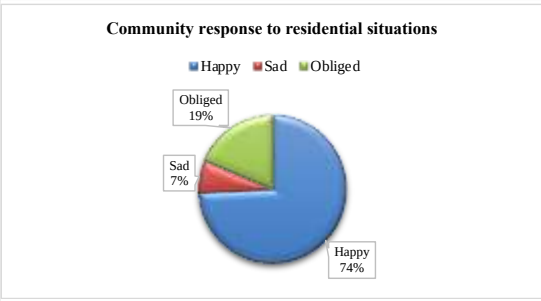

Figure 5. Community response to residential situations

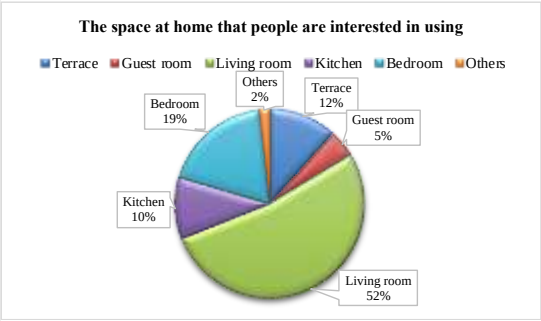

Figure 6. The space at home that people are interested in using

Next, the questionnaire asked further about the part of the room that is of interest to the respondent while staying at home pertinent to the respondents' choice of space, figure 6. The results show that the majority of the community prefers carrying out activities in the family room (52%). Meanwhile, 19% respondents prefer the bedroom, 12% on the terrace, and 10% in the kitchen. 5% respondents prefer the guest room, and 2% other places. The family room as the most desirable space is due to many considerations, such as being a larger area and having more facilities. In addition, the family room is also the most open space, yet still provides privacy, in that the residents feel comfortable in the room to work and interact with family members.

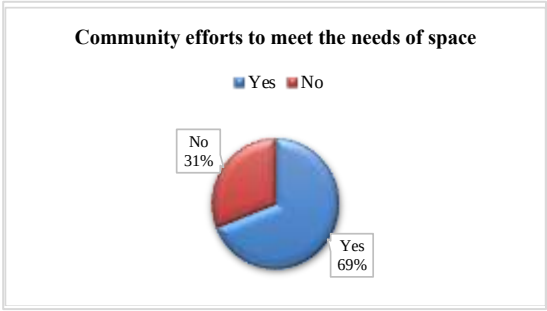

Figure 7. Community efforts to meet the needs of space

As far as room improvement is concerned, 69% respondents wished to make changes as opposed to 31% who chose not to (figure 7). Such a choice was based on how people attempted to meet the needs of space as comfortably as possible during the time spent at home for a relatively long time due to Covid-19 pandemic. To obtain information related to community efforts to make changes in the room, the study identified the extent of the respondents' desire to make improvements.

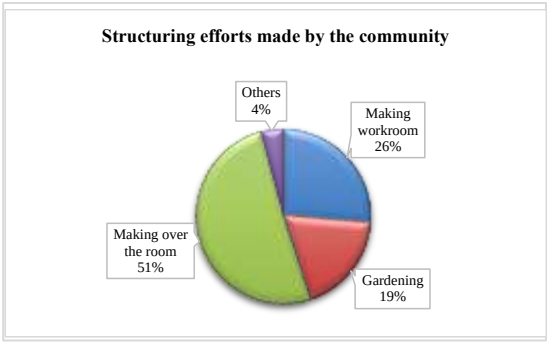

Figure 8. Structuring efforts made by the community

Based on the opinion of respondents, during Covid-19 pandemic the community restructured activities on their respective dwellings in several ways, i.e., decorating room 51%, adding workspace 26%, gardening 19%, and other activities 4% (figure 8).

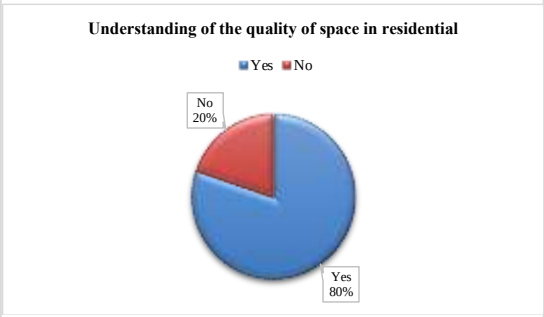

Figure 9. Understanding of the quality of space in residential

Understanding the quality of space is crucial to inspire spatial planning in buildings. Figure 9 indicates the response of the community to the space in occupancy. The majority of people (80%) appeared to understand which space had the potential to be developed in their homes.

The study assessed public knowledge on whether they know that the roof can be modified into a room that is no less comfortable with other rooms. Figure 10 shows that the number is not yet quite encouraging. 41% respondents agreed to such a notion, while 33% were still doubtful and 26% did not know. Accordingly, research on green roofs needs to be further continued so that people know and can take a more active role.

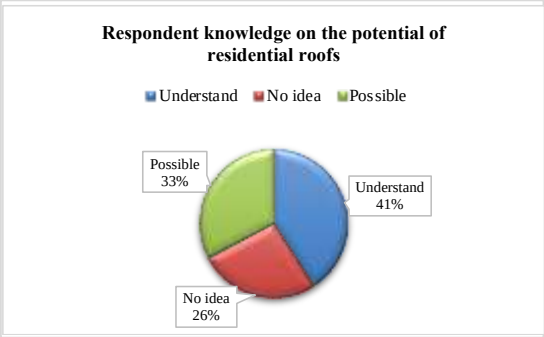

Figure 10. Respondent knowledge on the potential of residential roofs

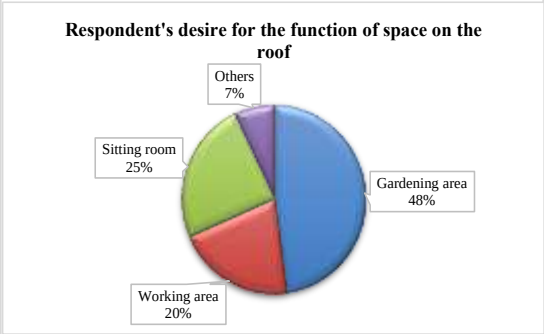

Figure 11. Respondent's desire for the function of space on the roof

The study explores the aspirations of respondents to the assessment of community needs and expectations of the criteria for roof space as an expansion of space in residential. 48% respondents in figure 11 revealed that the roof space could be used for gardening areas in that it is beautiful, comfortable, and shady. These results reinforce the findings of previous research by Yuliani, Hardiman, and Setyowati (2020b) in that it turns out that the role of the community is directly proportional to the expectations of the community's need to bring green space to occupancy, providing great support for green roof innovation.

The description of the results and previous studies show a condition that the residential space requires innovation during Covid-19 pandemic to adjust to the demands of work and study at home. Opportunities that can be made to add to the atmosphere of the rooms, including the roof. The roof of a dwelling can be an expansion of a room in the dwelling with several criteria, i.e., environmental considerations, building energy, air quality supply and aesthetic aspects. Therefore, the roof could be a potential capacity in the environment. The roof of the building has the highest heat load and is the largest field of heat reflection of a building. Roofs with green elements will be able to reduce the heat load of buildings and reflections on the environment (Dimond and Webb 2017; de Munck et al. 2018; Yuliani et al. 2021).

The roof as the top part of the building provides not only a shade, but also an avenue for quality air. Previous studies maintain that roofs with plants have the ability to provide better air quality in rooms inside the buildings and outside spaces in the surrounding environment (Abdel-Aty 2018; Malys, Musy, and Inard 2014; Masson et al. 2014).

The study of building energy can be considered from the aspect of the building envelope i.e., the roof and walls. The roof of the building with a layer of plants on it can reduce energy use in buildings. Furthermore, the parameters of building energy efficiency determine that the roof covering of energy-efficient buildings according to SNI 6389-2011 does not exceed 35 Watts (Yuliani et al. 2021; de Munck et al. 2018; Dimond and Webb 2017; Yuliani, Hardiman, and Setyowati 2020b).

From the aesthetic aspect of the building, the roof can also play a strategic role even though it is in a position above which is sometimes not covered by views. The building has an increasingly attractive appearance when combined with natural elements, one of which is combined with plants. The roof is no exception, as it will be able to look more attractive with an addition of plants on it. Harmonious plant management and routine plant maintenance will add to the building's aesthetics.

Residential roofs can be a space expansion in tropical housing during Covid-19 pandemic by meeting several aspects requirements. There are three basic aspects that are needed for a roof to meet the criteria for space in tropical dwellings, i.e., roof design that is environmentally friendly, aesthetic, and productive. The design of a roof that is environmentally friendly, aesthetic, and productive. The roof that is used as a space for activities for daily needs taking into account the efficiency, productivity, and effectiveness of space functions. In detail, the roof space as follows: environmentally-friendly roofs, have an understanding of the roof as a space that is able to adapt to balance the conditions of the natural environment and local climate. Environmentally-friendly roofs are designed with the application of green elements, plants that are placed can be in the form of shrubs or upright plants that are suitable for roof construction, taking into account the load and strength of the roofing material. Aesthetic roof is a roof that is designed architecturally considering aesthetic rules that are harmonious and have a rhythm in harmony with the environment. Whereas, productive roofing can be achieved by providing space for gardening and space for work. The room has easy access, allowing the residents to carry out activities. Productive roof has a role to provide space for gardening on the roof by selecting short-lived vegetable plants so that they can be harvested immediately for consumption of daily needs, such as eggplants, peanuts, green beans, tomatoes, chilies, spinach or medicinal plants, and ornamental plants.

In construction, the green roof has two types of materials, which can be made from concrete, and materials other than concrete, such as steel or iron frame with corrugated zinc, see figure 12 and 13.

Figure 12. An example of a flat green roof model made of concrete for low-rise housing in urban areas
Source: (Yuliani et al. 2021)

Figure 13. An example of a sloping green roof model made of concrete for low-rise housing in urban areas
Source: (Yuliani et al. 2021)

Concrete roofs can be designed for flat, sloping, and curved roofs, while the green roof is made from non-concrete, with corrugated iron and zinc frame. The slope of a roof on corrugated zinc is made with a maximum slope of 4° or can be modified with a thin curve with the same curved angle (Yuliani et al. 2021). This slope aims to facilitate the flow of water, preventing it from settling and increasing the burden on the roof. In the implementation of green roofs, another coating is needed to adjust to the needs and conditions in the field. Access to the roof space can use iron or other lighter materials by considering the ease and safety. Access by stairs to this roof space is important because it is used as a circulation path that facilitates the activities of the offender. Around the roof should be given

a safety fence for safety for users who move on the roof of the building.

Some previous research recommends the importance of implementing green roofs, including support for a more relaxed environment and housing and cleaner air. This is relevant to the demands of the covid-19 pandemic so that the room can always circulate with clean air. On the other hand, the results of the questionnaire concluded that there are still few people who understand the potential of roofs for useful expansion space. For this reason, green roof innovation can be presented as a solution for using space that responds to the demands of the covid-19 pandemic. Innovations can be developed starting from installation techniques and green roof models, as shown in figures 12 and 13. In addition, innovations in the types of plants applied must be considered according to the needs of residents. Plants planted on green roofs can consist of shrubs, namely vegetables, medicinal plants, or ornamental plants according to their respective regions.

The strategies in green roof innovation in this study could be applied to tropical housing with climatic criteria exposed to sunlight throughout the year. As such, it will enable vegetable plants to grow productively as they could be a great prospect for household food security. During Covid-19 pandemic, the green roof prepared for housing was at least able to provide daily vegetable needs, if implemented in an integrated manner with the participation of the community as residents of the housing. Activities that are accommodated on this roof space will also be more dynamic, in addition to gardening, as the roof can also be for a relaxing space and even for sunbathing as an effort to increase immunity during covid-19 pandemic.

In the end, the research found that several studies that discussed the benefits of green roofs previously turned out to have not been adapted to the needs of the covid-19 pandemic that occurred for several years, where people were doing a lot of activities at home. The roof of the house can be modified according to the needs and size of the house. Modifications can be applied to two components, namely construction techniques and types of planting. The benefits of building roof expansion can collaborate with the function of space when working at home, as planting and working space. The covid-19 pandemic, which demands environmental support and clean air, is very relevant to the benefits of green roofs. It is still rare previous research has discussed the carrying capacity of green roofs during the covid-19 pandemic, this study links the benefits of green roofs with community response and lifestyle demands during the covid-19 pandemic.

Conclusion

Space exploration in dwelling is paramount, especially when the dwelling is the only place that can accommodate the needs of its inhabitants. The expansion of space on the residential roof is strategic but has not become an option that dominates Indonesian society. Therefore, it is necessary to educate the community to increase awareness in designing and determining choices to explore residential roofs. Community participation in managing the expansion of roof space into a soothing roof with green elements is an opportunity in that green roofs can be applied sustainably in tropical dwellings. Community knowledge and skills are key to the sustainability of tropical dwellings with green roofs, ultimately beneficial to the building itself and surrounding environment.

The roof innovation strategy that meets the environmentally friendly, aesthetic, and productive criteria can be applied to tropical dwellings. A green roof is useful as an area that provides space for efforts to meet the daily needs of growing vegetables, as well as creating workspace and lounge during Covid-19 pandemic. A green roof space requires a safe and comfortable installation in the construction process to sustain activities thereafter.

Acknowledgments

This research was conducted with the support of LPPM Universitas Sebelas Maret by Contract Number 254/UN27.22/PT.01.03/2022. Thank you for all respondents and questioner collectors who support this research.

References

Abdel-Aty, Yaser Yehya Amin. 2018. ‘Proposals for Seismic Retrofitting of Timber Roofs to Enhance Their In-Plane Stiffness and Diaphragm Action at Historical Masonry

Buildings in Cairo'. *Journal of Cultural Heritage* 32 (July): 73–83. https://doi.org/10.1016/j.culher.2018.02.005.

Bevilacqua, Piero, Roberto Bruno, and Natale Arcuri. 2020. 'Green Roofs in a Mediterranean Climate: Energy Performances Based on in-Situ Experimental Data'. *Renewable Energy* 152 (June): 1414–30. https://doi.org/10.1016/j.renene.2020.01.085.

Dimond, Kirk, and Amy Webb. 2017. 'Sustainable Roof Selection: Environmental and Contextual Factors to Be Considered in Choosing a Vegetated Roof or Rooftop Solar Photovoltaic System'. *Sustainable Cities and Society* 35 (November): 241–49. https://doi.org/10.1016/j.scs.2017.08.015.

Goel, Saurav, Sara Hawi, Gaurav Goel, Vijay Kumar Thakur, Anupam Agrawal, Clare Hoskins, Oliver Pearce, et al. 2020. 'Resilient and Agile Engineering Solutions to Address Societal Challenges Such as Coronavirus Pandemic'. *Materials Today Chemistry* 17 (September): 100300. https://doi.org/10.1016/j.mtchem.2020.100300.

Gourdji, Shannon. 2018. 'Review of Plants to Mitigate Particulate Matter, Ozone as Well as Nitrogen Dioxide Air Pollutants and Applicable Recommendations for Green Roofs in Montreal, Quebec'. *Environmental Pollution* 241 (October): 378–87. https://doi.org/10.1016/j.envpol.2018.05.053.

Irandoost, Kayoumars, Hooshmand Alizadeh, Zahed Yousefi, and Behzad Shahmoradi. 2022. 'Spatial Analysis of Population Density and Its Effects during the Covid-19 Pandemic in Sanandaj, Iran'. *Journal of Asian Architecture and Building Engineering*, March, 1–8. https://doi.org/10.1080/13467581.2022.2047983.

Malys, Laurent, Marjorie Musy, and Christian Inard. 2014. 'A Hydrothermal Model to Assess the Impact of Green Walls on Urban Microclimate and Building Energy Consumption'. *Building and Environment* 73 (March): 187–97. https://doi.org/10.1016/j.buildenv.2013.12.012.

Masson, V., C. Marchadier, L. Adolphe, R. Aguejdad, P. Avner, M. Bonhomme, G. Bretagne, et al. 2014. 'Adapting Cities to Climate Change: A Systemic Modelling Approach'. *Urban Climate* 10 (December): 407–29. https://doi.org/10.1016/j.uclim.2014.03.004.

Megahed, Naglaa A., and Ehab M. Ghoneim. 2020. 'Antivirus-Built Environment: Lessons Learned from Covid-19 Pandemic'. *Sustainable Cities and Society* 61 (October): 102350. https://doi.org/10.1016/j.scs.2020.102350.

Munck, C. de, A. Lemonsu, V. Masson, J. Le Bras, and M. Bonhomme. 2018. 'Evaluating the Impacts of Greening Scenarios on Thermal Comfort and Energy and Water Consumptions for Adapting Paris City to Climate Change'. *Urban Climate* 23 (March): 260–86. https://doi.org/10.1016/j.uclim.2017.01.003.

Pemerintah Republik Indonesia. 2021. 'Peta Sebaran'. Covid19.Go.Id. 2021. https://covid19.go.id/peta-sebaran#.

Peng, Lilliana L.H., Xiaoshan Yang, Yunfei He, Zhenyu Hu, Tianjing Xu, Zhidian Jiang, and Lingye Yao. 2019. 'Thermal and Energy Performance of Two Distinct Green Roofs: Temporal Pattern and Underlying Factors in a Subtropical Climate'. *Energy and Buildings* 185 (February): 247–58. https://doi.org/10.1016/j.enbuild.2018.12.040.

Perini, Katia, and Enrica Roccotiello. 2018. 'Vertical Greening Systems for Pollutants Reduction'. In *Nature Based Strategies for Urban and Building Sustainability*, 131–40. Elsevier. https://doi.org/10.1016/B978-0-12-812150-4.00012-4.

Pushkar, Svetlana. 2019. 'Modeling the Substitution of Natural Materials with Industrial Byproducts in Green Roofs Using Life Cycle Assessments'. *Journal of Cleaner Production* 227 (August): 652–61. https://doi.org/10.1016/j.jclepro.2019.04.237.

Qin, Hongqiao, Bo Hong, and Runsheng Jiang. 2018. 'Are Green Walls Better Options than Green Roofs for Mitigating PM10 Pollution? CFD Simulations in Urban Street Canyons'. *Sustainability* 10 (8): 2833. https://doi.org/10.3390/su10082833.

Ran, Jiandong, and Mingfang Tang. 2017. 'Effect of Green Roofs Combined with Ventilation on Indoor Cooling and Energy Consumption'. *Energy Procedia* 141 (December): 260–66. https://doi.org/10.1016/j.egypro.2017.11.103.

Rowe, Bradley. 2018. 'Green Roofs for Pollutants' Reduction'. In *Nature Based Strategies for Urban and Building Sustainability*, 141–48. Elsevier.

https://doi.org/10.1016/B978-0-12-812150-4.00013-6.

Sangkakool, Tachaya, Kuaanan Techato, Rafia Zaman, and Thomas Brudermann. 2018. 'Prospects of Green Roofs in Urban Thailand – A Multi-Criteria Decision Analysis'. *Journal of Cleaner Production* 196 (September): 400–410. https://doi.org/10.1016/j.jclepro.2018.06.060.

Santoso, Dian Kartika, and Irawan Setyabudi. 2021. 'A Landscape Architect Preferences on Border Elements at Green Open Spaces during Covid-19 Pandemic'. *ARTEKS : Jurnal Teknik Arsitektur* 6 (2): 215–22. https://doi.org/10.30822/arteks.v6i2.691.

Teotónio, Inês, Marta Cabral, Carlos Oliveira Cruz, and Cristina Matos Silva. 2020. 'Decision Support System for Green Roofs Investments in Residential Buildings'. *Journal of Cleaner Production* 249 (March): 119365. https://doi.org/10.1016/j.jclepro.2019.119365.

Teotónio, Inês, Cristina Matos Silva, and Carlos Oliveira Cruz. 2018. 'Eco-Solutions for Urban Environments Regeneration: The Economic Value of Green Roofs'. *Journal of Cleaner Production* 199 (October): 121–35. https://doi.org/10.1016/j.jclepro.2018.07.084.

World Health Organization. 2020. 'Considerations for Public Health and Social Measures in the Workplace in the Context of COVID-19'. Www.Who.Int. 2020. https://www.who.int/publications/i/item/risk-.

Yu, Hanui, and Risa Fujii. 2022. 'Housing Design during COVID-19: Effects of Psychological States on Japanese Architecture Students'. *Journal of Asian Architecture and Building Engineering*, May, 1–17. https://doi.org/10.1080/13467581.2022.2074022.

Yuliani, Sri, Gagoek Hardiman, and Erni Setyowati. 2020a. 'Green-Roof: The Role of Community in the Substitution of Green-Space toward Sustainable Development'. *Sustainability* 12 (4): 1429. https://doi.org/10.3390/su12041429.

———. 2020b. 'Pemetaan Hasil Penelitian Atap Hijau Dalam Disiplin Ilmu Arsitektur Di Indonesia'. *ARTEKS : Jurnal Teknik Arsitektur* 5 (2): 245–54. https://doi.org/10.30822/arteks.v5i2.395.

Yuliani, Sri, Gagoek Hardiman, Erni Setyowati, Wiwik Setyaningsih, and Yosafat Winarto. 2021. 'Thermal Behaviour of Concrete and Corrugated Zinc Green Roofs on Low-Rise Housing in the Humid Tropics'. *Architectural Science Review* 64 (3): 247–61. https://doi.org/10.1080/00038628.2020.1751054.

Yuliani, Sri, and Wiwik Setyaningsih. 2018. 'The Community Role in Green Area Sustainability as a Model of Energy-Efficient Buildings in the Humid Tropical Region'. *IOP Conference Series: Earth and Environmental Science* 213 (December): 012010. https://doi.org/10.1088/1755-1315/213/1/012010.

Ziogou, Isidoros, Apostolos Michopoulos, Vasiliki Voulgari, and Theodoros Zachariadis. 2017. 'Energy, Environmental and Economic Assessment of Electricity Savings from the Operation of Green Roofs in Urban Office Buildings of a Warm Mediterranean Region'. *Journal of Cleaner Production* 168 (December): 346–56. https://doi.org/10.1016/j.jclepro.2017.08.217.

Author(s) contribution

Sri Yuliani contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

Ana Hardiana contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

Amin Sumadyo contribute to methodology, supervision, and validation.

Tri Yuni Iswati contribute to methodology, supervision, and validation.