Vertical forest: green open space alternative in urban area development

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Abstract. Addressing environmental problems in urban areas, the Law No. 26 of 2007 has mandated local governments to preserve Green Open Space (GOS) covering minimum 30% of its area. However, some local governments barely meet this obligation due to high price of lands and budget constraints. Meanwhile, an innovation in the form of vertical forest started to be applied in developed countries may be adopted to overcome the limited land constraint for developing GOS. This study was conducted to determine the opportunities for implementing vertical forest as an alternative solution for the constraints. In addition, it also aims to find out the possibility of its application for spatial planning policies so that it supports the national sustainable development goal. This study is an explorative research with qualitative method. The study concluded that vertical forest essentially is suitable to be implemented as an alternative solution to limited land for the GOS development. From the policy perspective, the development of vertical forest can encourage the competitiveness of the green city program. Therefore, the government need to design incentive policies for local governments and the private sectors to develop vertical forest. It is also necessary to adjust GOS developing regulation to become more accommodating so that vertical forest can be recognized as part of GOS.

1. Introduction
Development activities in urban areas have caused consequences in the form of environmental quality reduction, the emergence of various urban climatological problems and air pollution [1-3]. The various environmental problems that arise are a big question on how to create a sustainable city [4].

As an effort to overcome and reduce the negative impact of development activities on the degradation of urban environment quality, particularly the problem of urban climatology, Law No. 26 of 2007 concerning Spatial Planning mandates provincial and city/district governments to provide Green Open Space (GOS). The local government must provide land for developing GOS purposes covering 20% of city/district area for public GOS and make sure that 10% of area is developed by the private sectors. However, most regions have not been able to fulfill the minimum area required for GOS as mandated. According to the Ministry of Public Works and Public Housing, by the end of 2019, only 12 of 174 cities (6% cities) participating in the Green City Development Program had fulfilled the obligation to provide public green open space in accordance with applicable regulations. This figure indicates the low achievement of the minimum green open space target according to the law [5]. In general, the obstacle to achieving the green open space area is the limited land available for green open space development. This obstacle is usually the main reason for the failure of local governments to provide green open space that meets statutory provisions.

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In order to respond the need for GOS as an effort to overcome urban climatological problems and face the challenges of climate change amidst the constraints of limited land in urban areas, it is necessary to study the possibility of implementing vertical forests in Indonesia within the framework of achieving sustainable national development goals.

2. Method

This study is an exploratory research with qualitative method. Exploratory research is a type of research that aims to explore, deepen knowledge or find new ideas about a particular matter, in order to formulate problems in more detail. An exploratory research is conducted to have a better understanding of the existing problem and to identify detail issues that can be the focus for future research [6]. The data were collected through interviews and literature study which were analyzed descriptively and qualitatively. Data collection and analysis were carried out in January to May 2021. In order to draw conclusions from this study, the analysis used a sustainable development theory approach. Thus, it will be known whether the application of vertical forests also supports the achievement of environmentally-based sustainable development goals in Indonesia.

3. Results and discussion

3.1 Vertical forest concept

The concept of a vertical forest has actually existed since ancient times as evidenced by the Babylonian Hanging Plant relic from the reign of King Nebuchadnezzar II. The Hanging Garden of Babylon is considered to be one of the seven wonders of the world located in the Babylonian Capital (now in Southern Iraq). Some researchers suggest that the Hanging Garden is not really a hanging garden, but is a roof garden on a terraced ziggurat equipped with an irrigation system in which water source comes from the Euphrates River [7].

During the trend of vine trees in the Mediterranean about 2000 years ago, humans began to use vine trees as shade on building facades so that they provided a double benefit, fruit yield and also cooling effect of the trees shade. This trend is the beginning of vertical greening systems. Currently, vertical greening systems are seen as very promising as a measure to mitigate the impacts of climate change, so research in this field continues to be developed to promote green infrastructure that provides optimal environmental, social and economic benefits [8]. This concept prompted an Italian architect named Stefano Boeri, to build The Bosco Verticale project in 2014. The Bosco Verticale is an innovation of integrating greenery with residential buildings with the application of green balconies [9].

The Bosco Verticale (Vertical Forest in English) are in two residential towers with a height of 116 meters and 85 meters respectively located in the Porta Nuova district, Milan, Italy. Initially, The Bosco Verticale project was aimed to rebuild a comfortable city in the highly polluted environment of Porta Nouva. Therefore, The Bosco Verticale Facade is decorated by a vegetation structure formed by more than 13,000 trees of 90+ species, including from large tree species with a height of up to six meters that are placed on the balcony. The construction process involves arboriculturists, horticulturists, landscapers and botanists. The Bosco Verticale brings the concept of a green skyscraper, which is a building that also functions as a provider of a new ecosystem in the city, so that it can improve environmental quality and microclimate, absorb air pollution, increase humidity, and ultimately increase thermal comfort in urban areas [10]. The Bosco Verticale in Milan is the first vertical forest in the world [11].
Urban development and urbanization trigger climatological problems. Some climatological problems that are often encountered in urban areas include: Urban Heat Island (UHI), air pollution, and an increase in air temperature [13]. Urbanization causes the construction of many new buildings and structures needed to support various human activities. As a result, green areas and undeveloped land are converted into built-up land which causes the UHI phenomenon. UHI is a phenomenon where urban areas have higher temperatures than rural or suburban areas [14]. This temperature difference related to UHI causes various other negative impacts such as an increase in air temperature (the occurrence of heat waves in urban areas) to cause health problems and even human death [15]. Several cities in Indonesia have been identified experiencing UHI. Research also shows that urban development and urbanization in Jakarta, Bogor, Depok, Tangerang and Bekasi areas have an impact on increasing temperatures by 2-3°C during the period 1980-2015 [16].

To create an optimal cooling effect, the United Nations Environment Program (UNEP) recommends the use of green spaces both vertically and horizontally. Meanwhile, to specifically address the negative effects of UHI, UNEP recommends the use of green roofs. The existence of vegetation will provide a shading and cooling effect which also plays a role in lowering the air temperature of the surrounding environment so as to minimize the use of air conditioning [17] and help prevent global warming which is a major environmental problem today [18]. The use of vegetation on green roofs also increases CO$_2$ sequestration [19], produces O$_2$ and absorbs pollutant particles so that it can improve urban air quality.

A green roof is basically a roof that is modified so it can be planted with vegetation [18]. Green roof is one of the vertical greening systems, which also includes green facades, green walls, green terraces, forest elevations and vertical forests [20]. According to the research, providing an appropriate landscape is also an important strategy in mitigating UHI and global warming [21], such as integrated vegetation in the form of vertical plant walls as one of the designs for an optimal UHI mitigation strategy [22].
In some countries, vertical forests are built with the aim of controlling air pollution. The existence of a vertical forest can reduce CO$_2$, NO$_2$ and various other harmful gases from the atmosphere, while also producing O$_3$. The ability of vertical forests to control air quality and influence the urban microclimate has made many countries begin to adopt the vertical forest model in their urban infrastructure development. These countries include Egypt, Canada, Swiss and China [23-26]. The last two countries mentioned are countries with the second and third vertical forests in the world [25]. In Egypt, the vertical forest development was also reported, besides being useful for producing clean air, natural reforestation and maintaining animal habitats, to be very important for improving the mental quality and physical health of the surrounding population [23].

In terms of ecological functions, especially those related to air quality and climatological issues, the vertical forest developed in Italy has similarities with the functions and objectives of developing green open space in Indonesia. Green open space which is dominated by vegetation cover has the function to reduce air pollutants, potentially store and sequester carbon, support microclimate regulation, thus contributing to the sustainability of urban ecosystems [27, 28]. The important aspects in the ecological function of green open space are the vegetation coverage and canopy area. Vegetation coverage will affect the air humidity, as well as provide a cooling and shade effect [29]. Likewise, the larger tree canopy area, the greater ecological benefits generated [27]. This shows that green open space will function optimally and effectively in providing cooling effects, shade effects and benefits for microclimate control because of the vegetation that composes it, beside influenced by the area of green open space itself. On the other hand, if the green open space is extensive but covered with non-vegetation or in the form of hardened ground surface (for example paving blocks and asphalt concrete), it will increase the degree occurrence of UHI and environmental temperature [30].

3.3 Vertical forest as a solution to the constraints of limited land for green open space

As previously mentioned, the obstacles to developing green open spaces in urban areas in Indonesia are generally caused by limited land available. This land limitation is due the existing condition of the city which is already crowded with buildings. This condition causes the unavailability of land in sufficient area for green open space development, so the minimum target of 20% public and 10% private green open space cannot be met. Meanwhile, the high price of land in urban areas has also made local governments unable to purchase additional land for the development of green open spaces. The budget allocated for purchasing land to be used as green open space is also very limited. On the other hand, the high price of land also makes the private sector not interested in developing private green open space because it is considered less economical.

The land unavailability for green open space development is usually caused by the progress of previous development. Many provinces or districts still do not have a master plan, especially the green open space development master plan in their Urban Land Use Plan (Rencana Tata Ruang Wilayah/RTRW), so the lands that should be left for green open space eventually are built up for other facilities. This condition illustrates the importance of urban spatial planning with the provision of optimal green open space, especially during the initial phase of urban development [31]. The level of compliance to the RTRW is also one of the factors that need to be considered. To overcome the constraints of limited land and budget, local governments usually buy land on the outskirts of the city to develop their green open space. Land in suburban areas is considered cheaper so that it is expected to meet the minimum target of green open space. However, the development of green open space on the outskirts of the city (sub urban area) is less effective in tackling urban climatological problems that tend to be in center of the city [32]. For this reason, strategies and other alternatives are needed in the development of green open space in the center of the city which is a solution to limited land, as well as effective in dealing with climatological problems in urban areas.

As a solution to limited land for the development of green open space, vertical forest has some advantages so it can be used as an alternative form of green open space. Vertical forest is the small forest that can be established on a building using less space and creating significant clean air. Plants can make a building more attractive and eco-friendly. This type of building can be used commercially or for
residential purpose. It could also reduce the temperature of the building [33]. Thus, in addition to having a role in influencing the surrounding microclimate, the type of integrated building-vertical forest can also reduce the temperature of the building itself, so that it is effective in tackling the occurrence of UHI. With vertical forest, green open space can also be planned to be developed in scattered locations so that the shading and cooling effect of the vegetation will be evenly and effectively provide a comfort to the environment.

3.4 Opportunities for implementing vertical forests in Indonesia

Development, on the other hand could have a negative impact on the environment. However, environmental quality must be maintained for human comfort, health and productivity. Therefore, Indonesia seeks to achieve a balance development that still takes into account the quality of the environment and its sustainability in the future within a framework of sustainable development.

Sustainable development is simply defined as a form of development whose activities seek to meet the needs of the present without sacrificing future generations in meeting their needs. This concept emerged in line with the worsening environmental conditions and the awareness of the current generation that economic development is not the only goal, and environmental protection efforts are also important. Sustainable development is also mandated in Law No. 32 of 2009 concerning Environmental Protection and Management. Article 2 of Law No. 32 of 2009 states that environmental protection and management must be carried out on the principles of sustainability and fairness.

Development of green open space is based on the Spatial Planning Law. Green Open Space (Ruang Terbuka Hijau/RTH) according to Law No. 26 of 2007 concerning Spatial Planning is an elongated/lane and/or clustered area utilized more openly, where plants grow either naturally or planted. The law regulates the obligation to provide green open space. The mandate of developing green open space is to create a balance between the quality of the ecosystem and development in the modern era.

In terms of its essence, the green open space development policy is based on the need for the ecological functions produced by green open space, where the function is similar to the vertical forest ecological function developed by Stefano Boeri. Both of them play a role in maintaining ecosystem functions, environmental quality and ecosystem sustainability in the midst of development and increasingly dense urban population activities. In this case, vertical forest can be implemented as a substitute for green open space to overcome limitations in the development of green open space. Therefore, it can be concluded that vertical forest can be applied to be categorized as green open space, especially if an urban area is facing limited land which causes obstacles in meeting the green open space targets regulated by law.

However, in the implementation of vertical forest as part of green open space in Indonesia, adjustments to the applicable laws and regulations need to be made. Currently, the achievement and success target of local governments in developing green open space only refers to the provision of a minimum area of 30% of the total area as mandated by Law No. 26 of 2007. By adopting the concept of vertical forest as a substitute for green open space in areas with ongoing land limitations, it is necessary to adjust the achievement target of green open space, apart from the width of its area. The target for green open space development has to be determined based on the characteristics and conditions of the city, for example population, required O₂ and CO₂ emissions produced. If the regulations related to the green open space target have not been adjusted, then it cannot be a motivation for local governments to develop and an encouragement for the private sector to adopt vertical forests.

In the Regulation of the Minister of Public Works No. 5/PRT/M/2008 concerning Guidelines for Provision and Utilization of Green Open Space in Urban Areas, there is actually a method for calculating the need of green open space based on population and oxygen demand. The regulation has also listed the types of plants and trees that are suitable for various types of GOS, for example roof garden. However, until now, the target of developing green open space is still focused on meeting a minimum area of 30% of the total area, according to the mandate of Law No. 26 of 2007.

Opportunities for vertical forest implementation in Indonesia have also begun to be initiated through the Green City Development Program (Program Pengembangan Kota Hijau/P2KH) in 2016. The Green
City Development Program is a program of the Ministry of Public Works and Housing which aims to create a higher quality urban space through good planning and the realization of 8 (eight) attributes of a green city. The eight attributes of a green city include the Green Building attribute in which the main activity is to make buildings greener by introducing the construction of green roofs, roof gardens, green walls and vertical gardens. However, the green city development program is now in a "suspended animation" condition due to the difficulty to provide the large area of land for green open space and the limited budget. At the same time, the high price of land makes the private sector less interested in developing green open space on their land. Therefore, in addition to adjusting the rules governing the need for green space based on city-specific characteristics and conditions, an incentive scheme is also needed for future vertical forest development so as to increase motivation and create synergy between multi sectors.

One of the most effective and more popular strategies to encourage green building is to incentivize the market through financial or structural incentives. Rewarding developers or homeowners who practice green building techniques spurs innovation and demand for green building technologies. Several incentive schemes have been implemented in various countries to motivate the implementation of infrastructure that integrating physical buildings with greening system such as vertical forests, green buildings and green roofs. This incentive system has been implemented in Berlin, China and Toronto. According to [34], Berlin was likely the first city to adopt policies stimulating building-integrated vegetation. In 1984 the German government started a landscape program with the aim of rebuilding cities that are integrated with nature. The main design is the green roof and green facade. The cost of installing the green roof is half subsidized by the government. The German government has at least a similar greening incentive program in 24 cities. This greening incentive was later adopted by other countries. In Toronto, the government provides incentives in the form of grants to the private sector who wants build green roof installations through Toronto's Eco-Roof Incentive Program [35]. Likewise in China, the government has established rules and regulations, also incentive policies to promote enthusiasm for green buildings in society. Even today, green building has become a key factor in China’s construction industry [36].

Through learning from other countries, it is hoped that the government can formulate the policies needed to support the implementation of vertical forests in Indonesia. The policy includes the adjustment of legislation and the formulation of an incentive system. Thus, limited land for green open space can be resolved, environmental quality can be maintained, the need for green open space based on city characteristics and conditions is met, and supports the private sector to contribute actively.

4. Conclusion
Greening innovation with the vertical forest concept can be an alternative to be developed as a solution to the limited land for green open space development and to overcome climatological problems in urban areas. Implementation of vertical forest as part of green open space requires regulatory adjustments related to the target area of green open space based on the characteristics and conditions of the city. In addition, it is also necessary to formulate an incentive system that can motivate local governments and the private sector to participate synergistically to achieve green open space targets.

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