Residential-type urban forest design in Buana Cicalengka Raya Estate, Cicalengka District, Bandung Regency

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Abstract. The existence of urban forests in the middle of residential areas will provide added value for beauty, comfort, and environmental health that could increase the value of land and buildings in the residential area. Residential-type urban forests need to be well designed so that they are compatible with the type of building and match the residential environment's conditions. The purpose of this design is to create an appealing, multi-benefit urban forest design, which includes aspects of the urban forest theme concept, zoning arrangement, and vegetation arrangement, including species composition, density, and planting pattern. The outcome of the design resulted in a residential type, urban forest design by the theme of RINDU BCR Urban Forest (Relaxation, Inspiration, and Education for Buana Cicalengka Raya). The RINDU BCR Urban Forest functions as (1) a place of relaxation, (2) seeking positive inspiration, and (3) environmental education for the community. The planting pattern design consists of four types, namely: (1) opposite line pattern; (2) zigzag line pattern; (3) single line pattern, and (4) mixed pattern. The front-facing area of the RINDU BCR Urban Forest is designed by planting tree species that have the criteria of being ornamental, providing shade and safety, having a height of more than 300 cm, and a diameter of more than 10 cm.

1. Introduction
Land leveling processes such as stripping, excavating, stockpiling soil in residential developments in most cases have an impact on landscape changes and causing land damage. Frequently, lands that are not developed for the purpose of public or social facilities allocation in residential complexes are categorized as marginal land. Thus, critical land is not only found in logged-over forests but also residential areas. On the other hand, the target of achieving 30% of urban forests (PP no. 63/2002) from urban areas is still rarely achieved. In this Government Regulation, urban forests are permitted to be built on private land, one of which is residential. Therefore, to increase the area of urban forests, the local government should encourage residential developers to build urban forests in residential complexes to achieve critical land restoration and create a residential ecosystem that is safe, comfortable, and pleasing.

Urban Forest is a collection of vegetation dominated by trees built in urban areas designed by experts to integrate beauty or aesthetics, safety, comfort, and health elements. The existence of forests (tree stands) in urban areas is excellent to increase the environmental quality index (EQL) such as air quality, water quality, and land cover quality [1]. There are various types of urban forests, including residential
types (built in residential areas), germplasm conservation, industrial areas, educational areas and others [2].

Residential type urban forest is one type of urban forest built in residential or residential areas [2]. The existence of an urban forest in the middle of residential areas will provide added value for beauty, comfort, and environmental health and can increase the value of land and buildings in the residential area. It is critical for residential type urban forests to be well designed so that they are compatible with the type of building and match the residential environment's conditions. In general, to design an urban forest, it is important to combine multi aspect study including spatial planning, vegetation arrangement, silvicultural technical aspects and arrangement of supporting facilities.

The development of urban forests in residential areas will provide aesthetic pleasure and comfort to its citizens. Trees in urban forests can produce oxygen and absorb carbon dioxide [3] to improve air quality in the residential environment to protect it from air pollution [2]. Trees also have an important role in storing water in the soil so that groundwater reserves can be maintained properly and water needs in residential areas are met.

This design is still in the early stages. The focus is on location compliance and tree vegetation arrangement, while the arrangement of supporting facilities will be carried out later after the tree vegetation grows. The purpose of this design is to create an appealing, multi-benefit urban forest design, which includes aspects of the urban forest theme concept, zoning arrangement, and vegetation arrangement, including species composition, density, and cropping pattern.

2. Methods

2.1. Time and Location
The urban forest development is located in Buana Cicalengka Raya (BCR) residential area, Cicalengka District, Bandung Regency, West Java Province, and designing were conducted from January until May 2021. Located at the coordinate position 7°0'27” S - 7°0'47” and 107°51'17” E - 107°51'33” E, with an altitude of 773-833 m above sea level. The area to be planted is 9,417.96 $m^2$. The position of the candidate for the urban forest is to the south of the BCR residential area presented in figure 1.

![Site plan and aerial photo of BCR](image-url)
2.2. Material and tools
In designing this urban forest, seedlings are specifically selected based on 2 – 3 m height and 10 – 15 cm diameter (DBH). The details regarding species names and the number of seedlings can be seen in Table 1. For data collection purposes, Unmanned Aerial Vehicle (UAV) utilized in this designing process is DJI Phantom Pro-4, with Dronedeploy as a mapping assisting software. Agisoft 1.4.5 is utilized to process images to form a complete aerial image of the existing area. ArcMap 10.4.1 is utilized to process the resulting image.

Table 1. Details of species specification and quantity

| No | Latin name     | Local name          | Height (m) | Diameter (cm) | Quantity |
|----|----------------|---------------------|------------|---------------|----------|
| 1  | Khaya antocteca | Mahoni Uganda       | 2-3        | 3-5           | 10       |
| 2  | Maniltoa grandiflora | Sapu Tangan | 2-3        | 3-5           | 10       |
| 3  | Cerbera manghas  | Bintaro             | 2-3        | 3-5           | 10       |
| 4  | Spathodea campanulata | Ki Acret | 2-3        | 3-5           | 10       |
| 5  | Ficus benjamina  | Kiara               | 2-3        | 3-5           | 10       |
| 6  | Acacia spp.     | Akasia Golden       | 2-3        | 3-5           | 10       |
| 7  | Terminalia catappa | Ketapang        | 2-3        | 3-5           | 10       |
| 8  | Barringtonia asiatica | Keben           | 2-3        | 3-5           | 10       |
| 9  | Samanea saman   | Ki Hujan            | 2-3        | 3-5           | 100      |
| 10 | Ziziphus mauritiana | Bidara        | 1-1.5      | 1-2           | 30       |
| 11 | Alstonia scholaris | Lame/Pulai    | 3-4        | 10-20         | 30       |
| 12 | Swietenia macrophylla | Mahoni         | 2-3        | 3-5           | 100      |
| 13 | Wodyetia bifurcata | Palem Bajing    | 2-3        | 3-5           | 30       |
| 15 | Gmelina arbore  | Gmelina           | 1.5-2      | 2-2.5         | 500      |
| 16 | Ocroma bicolor  | Balsa             | 2-3        | 3-5           | 100      |
| 17 | Filicium desipien | Kisabun        | 2-3        | 3-5           | 100      |
|    | Total           |                     |            |               | 1070     |

In designing this urban forest, seedlings are specifically selected based on 2 – 3 m height and 10 – 15 cm diameter (DBH). The details regarding species names and the number of seedlings can be seen in Table 1. For data collection purposes, Unmanned Aerial Vehicle (UAV) utilized in this designing process is DJI Phantom Pro-4, with Dronedeploy as a mapping assisting software. Agisoft 1.4.5 is utilized to process images to form a complete aerial image of the existing area. ArcMap 10.4.1 is utilized to process the resulting image.

2.3. Designing procedure
The design process is carried out in several stages. This design consists of field observations, creating location maps, structuring tree vegetation, and arranging planting designs. The description of each stage is as follows

2.3.1. Field observation. Field observation aims to collect data and information on existing conditions in the field, including dimension, coordinate points, topography, land conditions, and site plan for Buana Cicalengka Raya (BCR) estate. In this activity, interviews were also conducted with the housing developer.

2.3.2. Creating location maps. The process of making a location map consists of two stages, namely (a) taking aerial photos and (b) image processing. The purpose is to three-dimensionally map the area to
figure out elevation differences [4] and figure out the exact area to be planted, hence zoning the area could be based on the actual condition.

2.3.2.1. Obtaining aerial photos. Aerial photography is carried out by using a DJI Phantom Pro-4. Image retrieval was carried out on a manual plot at an altitude of 150 meters above the surface with assistance from Dronedeploy software. Images were taken based on the initial site plan of the BCR estate, and plots were created by using Dronedeploy features. The drone is flown from an altitude of approximately 800 meters above sea level, and after the take-off checklist is completed, the drone takes off from the starting point at the Mosque yard. Site aerial photography was taken for 15 minutes and was controlled automatically via Dronedeploy and supervised by a drone pilot. After image retrieval is complete, the drone then lands at the starting point. The resulting image resolution is 4,572 cm/pixel and then combined into a complete image along with the Digital Elevation Model using Agisoft 1.4.5 software on the "High" setting. For the resulting image, it is anticipated that there will be slight differences in planimetric accuracy affected by the image matching algorithm used in the image processing software. Collecting data through aerial photography for urban planning has been done before and is proven to provide aerial imagery data by which the planners can better inform the public by the latest way, also having mean absolute errors up to a few centimeters [5]. Having an unmanned aerial vehicle to obtain data also provides higher accuracy and speed to fill in the gap of existing technology in urban planning [6]. This method of urban planning through UAV has been done in Mexico City [7].

2.3.2.2. Map processing. Map processing is done by stacking the drone images, then calibrating to produce a two-dimensional map image. The map is then compared with the BCR residential plan/layout, then delineated the boundaries of the area, and the topography is displayed. The process of processing the map of the location of the urban forest development is carried out using ArcMap 10.4.1 software. The steps in processing the map are as follows: first, the results of the drone aerial images/photos that have been combined previously using the Agisoft Photoscan software are imported into the ArcMap. Set the coordinate reference to UTM Zone 48S projection coordinate (the zone covers the West Java area in the projected coordinate system). Second, input Buana Cicalengka Raya site plan to ArcMap for the process of Overlay or overlapping maps of aerial photographs using drones. Third, georeferencing map site plan BCR residential with drone aerial photo map for the two images overlap with the exact position. As technologies are key elements supporting the management planning in every service activity, using GIS application in urban forestry management planning could help urban forest managers to provide astounding environmental services to the citizens by optimizing green areas usage [8].

2.3.2.3. Arrangement of tree vegetation. Vegetation arrangement includes determining the appropriate species, determining the spacing (density) and pattern (design) of plants. The arrangement of vegetation is adjusted to the concept/theme of the urban forest to be built. The arrangement of vegetation is also adjusted to the conditions of the land to be planted and the availability of seeds.

2.3.2.4. Plant pattern design. The process of making a 2-dimensional plant pattern design is carried out using ArcMap 10.4.1 software using an aerial photo layout from drones as a base map. The next step is to convert the real distance based on the map scale. After getting the exact number, the pointing is done by adding the shapefile point into the base map according to the distance determined. The design of the planting pattern is only a visualization/description of the spacing that will be applied in the field later.

3. Results and discussion

3.1. Land characteristics
In general, the land conditions for the prospective urban forest development sites in the BCR estate are marginal. Slope conditions range from flat to very steep but are dominated by steep slopes. The land used to be peeled off so that the topsoil layer was gone, stripping the topsoil down to the subsoil layer.
The physical condition of the soil is very dense after being constantly passed by tractors and operational transportations, and the porosity is very poor [9]. The mineral content of clay is very high so that in the rainy season, it becomes slippery, and in the dry season, it will be dense, and cracks or gaps arise. The average daily temperature ranges from 29℃-38℃. The average annual rainfall is low, and the humidity ranges from 75% -85%.

3.2. Urban forest theme
The urban forest development in the Buana Cicalengka Raya residential estate carries the theme "RINDU BCR Urban Forest" which is an urban forest that has a function for Relaxation, Inspiration, and Education (RINDU) in Buana Cicalengka Raya (BCR). It is hoped that the RINDU BCR Urban Forest can be a place for residents of the BCR estate to relax with relatives on spare days or holidays by enjoying the urban forest facilities built close to the Kassiti Mosque. Besides that, the community or mosque congregation can relax while looking for positive inspiration by enjoying the urban forest vegetation's shade, comfort, and beauty. The function of an educative urban forest is to provide knowledge for its citizens to recognize the biodiversity of forest trees in West Java. Another urban forest that emphasizes residence understanding of environmental preservation to drive sustainability could also be found in Malang [10]. Because its position is close to the mosque, the selection of vegetation types and plant designs must be combined with Islamic religious elements, including planting the type of Bidara (Ziziphus mauritiana), which is one type that is often used in the Sunnah of the Prophet (ruqyah) medicine. This concept of urban forest as urban green spaces in the proximities of the mosque has been done in another mosque, including Istiqlal Mosque [11].

3.3. Planting pattern design
In general, the composition of plant species is divided into two groups (clusters), namely monoculture and heteroculture clusters (mixed jungle). The cropping pattern in the mixed jungle cluster used a mixture of plant species in a zigzag pattern with a spacing of 2 meters x 2 meters. Monoculture cropping patterns in the cluster consist of three patterns of the line of sight (opposite line trees), a zigzag line pattern, and a single line pattern.

3.3.1. Opposite line cropping pattern. The opposite row cropping pattern is placed in the front-facing area, with the distance between plants in one row is 6 m, while the distance between rows is 9 m. The species planted in this cluster consisted of Lame (Alstonia scholaris) on the east side of the mosque and Mahogany (Swietenia macrophylla) on the south side of the mosque. In this pattern, there are Lame clusters presented in figure 2 and Mahogany clusters in figure 3.

3.3.2. Zigzag line pattern. This pattern is planted with Bidara (Ziziphus mauritiana), so it is called a Bidara cluster. The Bidara cluster is located next to the Mahogany cluster, precisely on a sloping plot to the west of the mosque. Bidara cluster is projected to have an area of approximately 722.63 m². In

**Figure 2.** Site condition for Lame cluster (left) and Lame arrangement for the cluster (right)
this cluster, one tree that is also planted at the end of the cluster is the *Trembesi* tree (*Samanea saman*). The number of rows of plants in the *Bidara* cluster is 3 rows in a zigzag pattern. The distance between lines is 2.5 meters wide, while the distance between trees in the same row is 6 meters wide. The total amount of *Bidara* to be planted in this cluster is 25 trees and one *Trembesi* tree. The cropping pattern design (two-dimensional) of the *Bidara* cluster is presented in figure 4.

3.3. *Single line pattern*. The single row pattern is located on the outer boundary of the south side of the complex, next to the water channel, which is the boundary with the village residents' settlements. In this cluster, Foxtail Palm (*Wodyetia bifurcata*) is planted with a spacing of 6 meters between each as seen in figure 5.
3.3.4. Mixed patterns. Mixed patterns are planted with mixed tree species, thus forming jungle clusters. The jungle cluster is located in two locations, namely below the Bidara cluster, bordering the village residents' settlements and at the southern end of the lowest location (figure 6). The types of plants consist of various types of trees, including Ugandan mahogany, sapu tangan, bintaro, ki Acret, kiara, golden acacia, ketapang, balsa, acacia, kisabun, keben, and others. The spacing between trees is 2m x 2m in a zigzag pattern. It is estimated that the number of plants reached 890 stems.

3.4. Arrangement of tree vegetation

The selection of tree species to be planted in the RINDU BCR Urban Forest is based on consideration of several aspects, namely aspects of aesthetics, comfort, and safety, as well as considerations of silvicultural engineering aspects.

In the relaxation cluster, species that are selected based on beautiful flowering criteria, not favored by the caterpillar or harmful insects, do not bear large fruit, which is feared to be dangerous if they fall from the tree, deeply rooted so that they are strong and not easy to collapse if blown by strong winds, and accommodating proper shades with leaves that rarely fall. Several types of trees that meet these criteria include ki acret [12], dadap [13], tabebuia, sapu tangan, lane, mahogany, golden acacia, bintaro, ketapang, and kisabun. Meanwhile, for planting in mixed forest clusters, species with a shady canopy and the ability to grow on marginal lands are selected, such as Gmelina sp., kiara, kihujan, and balsa. The spacing in mixed forest clusters is intentionally tighter to give the impression of a jungle after the trees have grown big.
The technical aspects of silviculture are important to note. The types of trees planted in urban forests generally require larger dimensions of height and trunk diameter than seedlings to be planted in production forests or others [14]. For the front-facing area of the urban forest or the area around the mosque, large trees are chosen with a minimum diameter of 10 cm and a height of 300 cm. The selected seeds result from techniques, such as root ball, that are not provided by generative nurseries. Because the planted tree seeds are larger, a stronger support structure is needed so that the plants can stand upright and strong. Maintenance of large seeds is of course more difficult than small seedlings. A proper robust protective fencing should be enough to protect the newly transplanted trees from any disturbance [15].

4. Conclusion
The design of this urban forest with the theme RINDU BCR Urban Forest stands for relaxation, inspiration and education for Buana Cicalengka Raya, which is used for (1) a place of relaxation, (2) seeking positive inspiration and (3) environmental education for the community. The planting pattern design consists of four types, namely: (1) opposite line pattern; (2) zigzag line pattern; (3) single line pattern and (4) mixed pattern. Pattern one was applied to the lame and mahogany clusters, pattern two to the bidara cluster, pattern three to the foxtail palm cluster and pattern four to the mixed jungle cluster. The front-facing area of the RINDU BCR Urban Forest is designed by planting tree species that have the criteria of being ornamental, shady and safe, having a height of more than 300 cm and a trunk diameter of more than 10 cm.

5. References
[1] Crosby M K, McConnell T E, Holderieath J J, Kjartansson B, Traustason B, Jónsson Þ H, Snorrason A and Oddsodtti E S 2021 Urban street tree characteristics and benefits in the city centre Reykjavik Iceland Trees For People 4 100066
[2] Dahlan E N 2008 Total CO2 Emissions and Selection of Very Decay Plant Types High A Case Study in Bogor City Journal of Conservation Media 13 85-89
[3] Kusumaningrum N 2008 Potential of Plants in Absorbing CO2 and CO to Reduce Global Warming Impacts Journal Settlement 3 96-105
[4] Rogers K, Jarratt T and Hansford D 2011 Torbay’s Urban Forest Assessing urban forest effects and values A report on the findings from the UK i-Tree Eco pilot project Treeconomics Exeter.
[5] Ahmad A, Tahar K N, Udin W, Hashim K, Darwin N, Hafis M, Room M, Abdul H, Nurul F, Azhar N and Azmi S M 2013 Digital aerial imagery of unmanned aerial vehicle for various applications IEEE International Conference on Control System, Computing and Engineering 2013 ICCSCE 2013 Malaysia
[6] Erenoglu R C, Erenoglu O and Arslan N 2018 Accuracy Assessment of Low-Cost UAV Based City Modelling for Urban Planning Technical Gazette 25 1708-1714
[7] Wang T 2003 Interdisciplinary urban GIS for smart cities: advancements and opportunities, Geo-Spatial Information Sciences 16 25-34
[8] Jenkins N A L 2015 An Application of Aerial Drones in Zoning and Urban Land Use Planning in Canada Preliminary Review Canada Ryerson University
[9] Tasoulas E, Varras G, Tsiriosiannis I and Myriounis C 2013 Development of a GIS Application for Urban Forestry Management Planning Procedia Technology 8 70-80
[10] Gürsoy S 2021 Soil Compaction Due to Increased Machinery Intensity in Agricultural Production: Its Main Causes, Effects and Management [Online], IntechOpen Available at https://www.intechopen.com/online-first/77140 (Accessed 13 August 2021)
[11] Subadyo T, Tutuko P and Jati R M B 2019 Implementation Analysis of Green City Concept in Malang – Indonesia International review for spatial planning and sustainable development 7(2) 36 – 52
[12] Permata N D, Syartinilia and Munandar A 2018 The actual use of urban forest for Jakarta’s dwellers IOP Conf. Ser: Earth Environ. Sci. 179 012036
[13] Trigo J R and Santos W F dos 2000 Insect Mortality in Spathodea campanulata Beav. (Bignoniaceae) Flowers Rev. Brasil Biol. 60(3) 537-538

[14] Kuroda K, Chuma I, Kihara T, Murakami T, Takashina K, Hiraoka D, Kameyama N 2017 First report Fusarium soalni species complex as a causal agent of Erythrina variegate decline and death after gall formation by Quadrastichus erythrinaeon (Okinawa Island, Japan)

[15] Saebo A, Borzan Z, Ducatillion C, Hatzistathis A, Kagerstrom T, Supuka J, Garcia-Valdecantos JL, Rego F and Slycken JV 2005 The selection of plant material for street trees, park trees and urban woodland (Verlag Berling Heidelberg: Springer)

[16] The Government of Hong Kong Greening, Landscape and Tree Management Section Development Bureau 2014 Guidelines on Tree Transplanting The Government of the Hong Kong Special Administrative Region https://www.greening.gov.hk/ filemanager/content/pdf/tree_care/ Guidelines_on_Tree_Transplanting_e.pdf Accessed on June 2021

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