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# Vertical Garden Identification and Plant Species Diversity of Urban Green Space in Banda Aceh City, Indonesia

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## ABSTRACT

Vertical gardens (VG) applies plant growth to various wall media and/or other vertical surfaces. In Banda Aceh City, these urban greening innovations are beginning to create trends as they boost building esthetics. The objectives of this research were to identify the various types of vertical gardens and to analyze people's preferences, including the design and variety of plants used in these types of vertical gardens, between January and September 2022 in nine sub-districts of Banda Aceh City, Aceh Province, Indonesia. The research method involved an exploratory survey of the entire city where VG was applied in various public spaces, private and public organizations, residential housing, hotels, mosques, various business culinary, and cafeterias. Data on garden preferences were collected and analyzed using descriptive methodology, and the Shannon-Wiener Formula was used to examine the species diversity index. From a total of 166 documented gardens and 150 sample locations where vertical gardens were observed, 66 plant species were discovered. Vertical gardens are most frequently used in residential housing. Ficus pumilla (dollar creeper) is the plant most frequently used by the community, and green facades are the most common style of vertical garden design applications. In the nine sub-districts, the highest diversity index was found in the Syiah Kuala Sub-district with H' 2.9, and the lowest diversity index was found in the Kuta Raja sub-district with H' 1.2. Based on plant function, there were 43 species of ornamental plants, 13 species of flowering plants, 7 species of fruitful plants, and 3 species of herbs.

## Introduction

Vertical gardens (VG) are among the most significant innovations for minimizing urban microclimates [1]. Growing gardens on walls or other non-horizontal surfaces is one of the most well-known gardening concepts worldwide [2]. Buildings are made up of sporadic, attached, or unattached plants on the exterior and interior walls [3]. Vegetation can cover buildings, perform inside walls or partitions, and be applied to balconies or building covers [4]. Applications of VG have begun to be implemented in various locations in Banda Aceh City, including public areas, workplaces, mosques, restaurants, cafeterias, houses, and hotels. Artificial VG applications have also been used to decorate various structures besides living VG. People use these locations to unwind, vacate, and sell because of the numerous modifications to indoor and outdoor green decorations. This demonstrates how the aesthetic value of VG in Banda Aceh City is becoming increasingly popular, as it can be applied to various portions of buildings with limited space (even without a yard).

The province of Aceh's capital, Banda Aceh City, has the main government offices, several private and public universities, a city of cultures, and tourist attractions for the locals of Aceh. Owing to these characteristics, this 817-year-old city has experienced numerous developments, especially in existing houses, tourism,

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educational institutions, and food-related enterprises. Urbanization in Banda Aceh City occurred over 20 years (1998–2018). The number of developments that have grown to the point where the built-up area has doubled and reached 62.87% of the total city area is a clear indicator of this tremendous expansion in urbanization. This is reinforced by the city's population of 270,321 people in 2019 [5]. Due to the 2004 Aceh earthquake and tsunami, the population of Banda Aceh City decreased from 239,146 to 177,881 people. However, throughout the three years from 2005 to 2007, this number rose significantly by 11.8% (219,857 people). If estimated using the multiple interest model, this population growth can be approximated at 11.8% annually up to 2010 and at 2.4% annually thereafter, presuming growth after that year has reverted to normal. It turns out that the presence of green open spaces in Banda Aceh City is inversely correlated with the city's population growth (which is 2.4% annually), and the number of vehicles also increases monthly, from 12,000 to 14,000 [6]. Only 14.14% of the city's total area comprises green open spaces that belong to the city [7]. This proves that this city falls short of the 30% goal for green open spaces outlined in Article 29 of the Law on Spatial Planning Number 26 of 2007 [8].

Green open spaces contribute to lowering air pollution levels and preventing urban heat islands, which are frequently observed in large cities [9], providing environmental services in the form of water resource management, biodiversity conservation, carbon sequestration, and presenting the beauty of the landscape [10]. Using a 2.4% annual population growth rate as a guide, 482,131 people will live in Banda Aceh City by 2029 [11]. In the 2030s, the city is anticipated to grow significantly. As a result, it is anticipated that building energy usage, demand for oxygen, emission of carbon dioxide, and pollution will increase dramatically in the coming years. Therefore, cities must prepare for Urban Heat Island mitigation immediately. Because implementing urban heat island mitigation measures must be in accordance with environmental conditions and specific communities, understanding community attitudes can make urban heat islands (UHI) coping strategies more appropriate [12].

Given that there has not been any research on vertical gardens in Banda Aceh City, the application of VG is beginning to escalate. To gather complete information about the vertical garden’s design, its size, and the plants the community has chosen to use, it is necessary to conduct research on VG in this city. This research aimed to identify various types of VG and analyze people's preferences, including the design and variety of plants used in these types of VG. The presence of *pekarangan* is thought to have enormous potential as a space for mitigation and rehabilitation from problems related to urban environmental health [13]. In addition to the aesthetic function of a vertical garden, people who see it are interested and feel better [14], which positively affects health and emotions [15]. Even the role of vertical gardens in human psychology, where their presence can improve social life due to self-satisfaction, visual relief apart from the bustling urban environment, providing urban farming that has a social function for interaction, a hobby, and relaxation; sustainable lifestyle; reduce stress, fear, anger, and blood pressure; and can promote a better working and learning environment [16]. As the greenery on buildings will decrease carbon dioxide increases [5] as climate control [17], view control, physical barrier, erosion prevention, habitat for wildlife, and aesthetic function [18], and is also one of the most cost-effective strategies for addressing or preventing UHI by playing a significant role in maintaining low city surface temperatures [19].

## Method

### Study Area

The initial study was conducted between July and December 2021. This study was conducted in Banda Aceh City from January to September 2022 in nine sub-districts of Banda Aceh City, Aceh Province, Indonesia. Those are Syiah Kuala Sub-district, Meuraxa Sub-district, Ulee Kareng Sub-district, Kuta Alam Sub-district, Baiturrahman Sub-district, Lueng Bata Sub-district, Jaya Baru Sub-district, Banda Raya Sub-district, and Kutaraja Sub-district (Figure 1).

### Research Method

Step one was selected for the study ecosystem. The main variable of this study was the presence of a VG [15]. Data was collected by direct surveys all over the city using the purposive sampling method (with specific characteristics of VG chosen [20]. In step two, the sample locations that have implemented VG are documented and recorded, and interviews are conducted with the owners. The requirements for the chosen VG are gardens with a minimum area (2 × 1 m), good quality, and a full coverage vertical garden. The selected sample was grouped according to sub-district area. Step three: The type of garden is described according to its location, design, and forming structure. Furthermore, plant species have also been documented, recorded,

and identified through a literature study where the types and number of individuals were classified. Each plant was grouped based on its function and plant vertical strata [21]. Lastly, the species diversity index of VG was examined in each sub-district of the city.

**Data Analysis Method**

Step one: Garden design preferences and VG plant diversity were descriptively analyzed. The goal of the descriptive analysis was to describe the phenomenon of VG and its characteristics. The data collected were also analyzed qualitatively using frequencies, percentages, averages, and other statistics to describe the relationship [22]. The analysis was carried out after examining the biophysical conditions of the VG by determining the type of garden, location where the VG takes place, structure, and types of plants applied. VG can be classified as living walls, green facades, vegetated mat walls, landscapes, rooftops, canopies, or hanging plants [23].

In step two, the types of plants observed were identified, and each plant was classified based on the species' respective family type and grouped based on general characteristics such as plant function (vegetables, flowers, fruit plants, ornamental or herbal plant). Plants are classified into vertical and horizontal diversities. Vertical diversity describes the composition of vertical plant height, whereas horizontal variation describes the function of garden plants [24]. Plant types were identified, classified, and grouped based on eight horizontal plant functions: ornamental, medicinal, vegetable, fruit, seasoning, starch-producing, industrial, and other plants. Based on five height level classifications: strata I (< 1 m), strata II (1–1.9 m), strata III (2–4.9 m), strata IV (5–9.9 m), and strata V (> 10 m) [25].

Step three involved the determination of the Shannon-Wiener diversity index. Shannon-Wiener formula has been used extensively in environmental studies to estimate the species richness and abundance of ecosystems. The use of the diversity index works well under comparative situations [26]. This step involves calculating the diversity index, which is simulated using the Shannon-Wiener diversity index model [27], as illustrated below:

$$H' = -\{\sum pi \ln pi\} \quad (1)$$

H' : Shannon-Wiener diversity index

Pi : The relative proportion (n/N) of the individual species found. This involved dividing the (n) number of individual species by the total number of individual species (N) found in a given environment.

ln pi : The natural logarithm (LN) of Pi. Finally, the symbol implies (∑) the sum of the outputs with the final value multiplied by a negative value (–1).

The ecosystem became more stable when the species diversity index increased. The diversity index showed a high diversity of H' = > 3, medium if H' = 1 < H' < 3, and low diversity if H' = < 1. Although this index is rarely used to compare VG species diversity, this study uses the index to compare VG species diversity between sub-districts in Banda Aceh City.

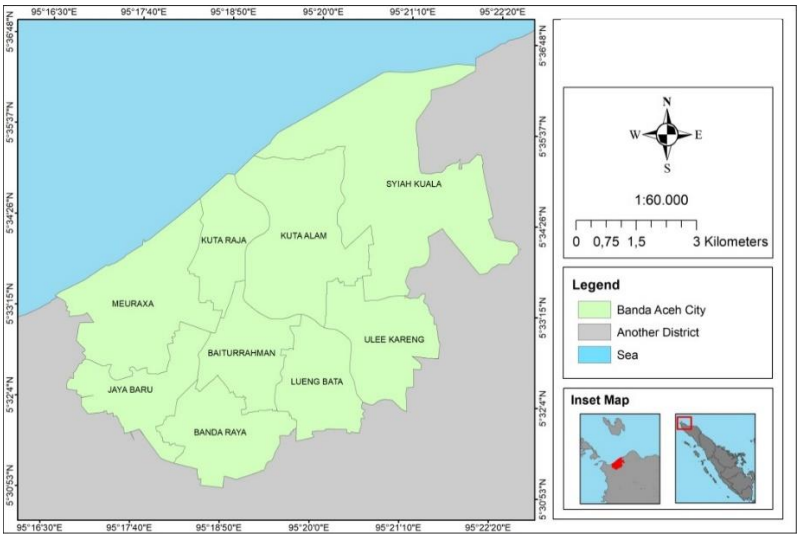


**Figure 1.** Map of Banda Aceh City.

**Result and Discussion**

In general, living walls and green facades are two types of VG. Living walls are VG applications that use polypropylene plastic containers, geotextiles, and particular pot structures with growing material, irrigation systems, and vegetation. The prepared vertical media/walls of the green façade were covered in a VG with plant roots in the ground. However, VG currently has a variety of design advancements, offering a more precise classification into several types of VG. Nevertheless, according to the VG previously existing in Banda Aceh City, the following garden types (Table 1) were categorized in this study: living walls, green facades, vegetated mat walls, green landscapes, rooftop gardens, and green canopies. One hundred fifty sample locations with VG were discovered during field observations in nine Banda Aceh City sub-districts, and 166 VG were observed there. The 68 varieties of green facades and 44 green canopies are most frequently used by citizens as vertical gardens. Furthermore, 40 living walls, 10 roof gardens, two vegetated mat walls, and two green landscape gardens were found.

**Table 1.** The distribution of Vertical Garden in 9 sub-districts of Banda Aceh City.

| Sub-district | Large total areas ($km^2$) | Variety of building functions | Number of vertical gardens (locations) | Variety of garden types | Total variety of garden types |
|---|---|---|---|---|---|
| Meuraxa | 7.26 | 7 RH, 2 CF, 1 HT | 10 | 1 rooftops garden, 6 green facades, 2 living-walls, 4 green canopies | 13 |
| Jaya Baru | 3.78 | 15 RH, 1 PA | 16 | 1 Rooftops garden<br>10 green facades<br>5 living-walls | 16 |
| Banda Raya | 4.79 | 13 RH, 2 CF, 1 SL, 1 HT, 1 OF | 18 | 12 green facades<br>5 living walls<br>1 canopy | 18 |
| Baiturrahman | 4.54 | 2 PA, 12 RH, 1 CF, 1 OF | 16 | 1 rooftops garden, 6 green facades, 1 living-walls, 1 green landscape gardens, 9 green canopies | 18 |
| Lueng Bata | 5.34 | 1 HT, 16 RH, 1 WP | 18 | 2 rooftops garden<br>6 green façade, 6 living-walls, 6 green canopies | 20 |
| Kuta Alam | 10.05 | 14 RH, 1 CF, 4 HT, 2 OF, 1 SL, 1 PA, 1 TI, 2 HO | 26 | 4 rooftops garden, 9 green facades, 8 living-walls,1 vegetated mat walls 9 green canopies | 31 |
| Kuta Raja | 5.21 | 9 RH | 9 | 2 green facades<br>2 living-walls<br>5 green canopies | 9 |
| Syiah Kuala | 14.24 | 16 RH, 2 UN, 1 SL, 2 CF, 1 OF, 1 HT | 23 | 1 rooftops garden, 10 green facades, 6 living-walls, 1 green landscape, 1 vegetated mat walls, 7 green canopies | 26 |
| Ulee Kareng | 6.15 | 12 RH, 1 PA, 1 HO | 14 | 7 green facades, 5 living-walls, 3 green canopies | 15 |
| TOTAL | 61.36 $km^2$ | | 150 | | 166 |

Information: RH (Residential house), WP (Worship Place), OF (Office), HT (Hotel), CF(Cafeteria/Restaurant), SL (School), UN (University), HO (Clinic/Hospital), PA (Public area), SC (Shopping Centre).

Most VG are used in Banda Aceh residents' houses. Of the 150 VG locations (Table 2), 111 were community residents. Green facades and canopies are the most frequently used designs. The majority of plants used for green façades are grown directly on the ground, using wooden or concrete walls and fences as media for plant propagation. Similarly, the community's green canopy is typically planted directly on the ground, and the stems and leaves will spread out to fill the canopy. Banda Aceh's green canopy commonly made of iron or wood structures. On the one hand, among all other species, *Vernonina elliptica* (Lee Kuan Yao) and *Ficus pumilla* (dollar creeper) are the most widely used plants in the installation of green facades. The most popular plants used in green canopy designs, on the other hand, are *Thunbergia grandiflora*, *Combretum indicum*, and *Vitis* sp. (grapes).

**Table 2.** The types of vertical garden in Banda Aceh and its location distribution.

| Types of location | Amount of location | Location | Amount of VG | Types of VG |
|---|---|---|---|---|
| Residences/ houses | 111 | 111 houses | 115 | Green facade, green canopy, roof garden, living-wall, vegetated mat walls, green landscape garden |
| University | 2 | Agriculture Faculty of Syiah Kuala University | 1 | Green canopy |
| | | Teacher Training and Education Faculty of Syiah Kuala University | 4 | Green facade |
| Offices | 4 | Aceh Forestry and Environmental Service | 1 | Green facade |
| | | Mayor Office of Banda Aceh City | 1 | Green facade |
| | | *Dinas Lingkungan Hidup Kebersihan, Keindahan Kota Banda Aceh* (DLHK3) | 3 | Living-wall, Green canopy |
| | | Banda Aceh's Regional Library | 1 | Roof garden |
| Worship places | 2 | Oman Mosque, Lampriet | 1 | Green canopy |
| | | Al 'Ala Mosque, Cot Mesjid | 1 | Living-wall |
| Hotels | 9 | Kryad Muraya Hotel | 2 | Living-wall, Green facade |
| | | Aldila Hotel | 1 | Green facade |
| | | Mekkah Hotel | 1 | Green facade |
| | | Oasis Hotel | 2 | Green facade, Green canopy |
| | | Sei Hotel | 1 | Green facade |
| | | The Pade Hotel | 1 | Green facade |
| | | Permata Hati Hotel, Meuraxa | 3 | Green facade, Living-wall, Green canopy |
| | | Al Faris Guest House | 1 | Green facade |
| | | Bougenvil residence, Lampriet | 1 | Roof garden |
| Restaurant/ Cafeteria | 10 | Quantum & Roastery, | 2 | Green facade |
| | | Chops.id, | 1 | Green facade |
| | | Burger Blepot, | 1 | Roof garden |
| | | Banda Seafood, | 1 | Green facade |
| | | Ivory Coffe & Culinary, | 1 | Green facade |
| | | Dumpatna Kupi, | 1 | Vegetated mat walls |
| | | Paopia Garden, | 1 | Living-wall |
| | | Banda cafe | 1 | Green facade |
| | | Coffe Bay | 1 | Green facade |
| | | Twohapeut | 1 | Green facade |
| Public Area | 4 | Jaya Baru Parks | 1 | Green facade |
| | | Putroe Phang Parks | 1 | Green canopy |
| | | Museum Tsunami of Aceh | 1 | Green landscape garden |
| | | Pango Bridge of Ulee Kareng | 1 | Green facade |
| Hospitals & Clinics | 4 | Jeulia Clinic Peunayong | 1 | Green facade |
| | | Zainoel Abidin Hospital | 2 | Living-wall, Green canopy |
| | | dr. Munadia, Sp.KFR clinic | 2 | Green facade |
| | | Vivi Spa Beauty Clinic, Kuta Alam | 1 | Green canopy |
| Shopping Center | 1 | Plaza Aceh | 1 | Green facade |
| Schools | 3 | Sekolah Bunga Matahari | 1 | Green facade |
| | | MIN 6 Banda Aceh | 1 | Roof garden |
| | | SD IT Al Azhar Cairo | 2 | Living-wall |
| Total | 150 | | 166 | |

The VG design applied in Banda Aceh City is still quite simple. Generally, only 1 to 3 types of plants are applied to one garden. However, there are two places where high-complexity VG is applied with more plants. Both are DLHK3 and Banda Aceh's Regional Library applied two green canopies and one living-walls. In this office, a green canopy with *Vitis* sp. (grapes) provides shade for the motorbike parking area, and other green canopies applied to *Combretum indicum* (rangoon creeper) provide shade for the car park area. Meanwhile, the living walls use bag planter soil as the planting medium arranged on the main wall of the second floor of the office buildings. The living walls include *Philodendron brulee* (philodendron), *Nephrolepis exaltata* (Boston fern), *Nephrolepis cordifolia* (fishbone fern), and *Platycerium bifurcatum* (Elkhorn fern) (Figure 2).


**Figure 2.** (a) Living-wall at DLHK3, (b) Green facade at one of citizen's home, (c) Green canopies at one of beauty clinic in Banda Aceh, (d) Roof garden at Banda Aceh Regional Library, (e) Green landscape garden at Museum Tsunami Aceh, (f) Vegetated mat walls at Zainoel Abidin Hospital of Banda Aceh.

In addition, a green roof was applied on top of the parking area of Pustaka Wilayah Kota Banda Aceh. Green roof gardens can directly benefit city centers, where environmental degradation has the most severe impact [28]. Eleven types of plants were applied, presenting a very beautiful landscape in a limited area. Plant species applied to library green roofs are *Vernonina elliptica* (lee kuan yao), *Dypsis lutescens* (butterfly palm), *Casuarina equisetifolia* (Australian pine), *Syzygium myrtifolium* (red lip), *Zoysia japonica* (Japanese lawngrass), *Trachelospermum jasminoides* (star jasmine), *Alocasia* sp. (alocasia), *Anthurium andraeanum* (red anthurium), *Aglaonema commutatum* (aglonema), *Bougenviellia spectabilis* (bougainvillea) dan *Furcraea foetida* (mauritius).

In addition, according to surveys and observations, there were 66 different plant species spread among the 150 VG locations (Table 3). The most common plant species used in Banda Aceh City's VG are *Ficus pumilla* (dollar creeper), *Vernonina elliptica* (lee kuan yao), and *Vitis* sp. (grapes). Popular applications of these three plants involve propagation techniques in different growing media. While *Vitis* sp. is frequently used as a green canopy that offers natural shade and bears edible fruit, *Ficus pumilla* propagates on building walls and fences as a green facade design, and *Vernonina elliptica* is frequently propagated on fence media or installations on balconies or terraces of buildings.

The species diversity index (H') was calculated using Shannon–Wiener equations (Table 4). The species diversity index is considered high if the H' value is more than 3, medium if the H' value is between 1 to 3, and low if H' is less than 1. The species diversity index was calculated for each sub-district of Banda Aceh City. The results show that all Sub-districts in Banda Aceh City have a medium VG species diversity index (H' value is among 1 to 3). Syiah Kuala Sub-district has the highest diversity index with an H' value of 2.9, and the Kuta Raja Sub-district has the lowest species diversity index value with an H' value of 1.2.

**Table 3.** Plants used in Banda Aceh City's.

| Scientific name | Other name | Family | Function | Frequency | Height level |
|---|---|---|---|---|---|
| *Adenium obesum* (Roem. & Schult.) | Dessert rose | *Apocynaceae* | Flower | 1 | III |
| *Aglaonema* sp. (Schott) | Aglonema | *Araceae* | Ornament | 1 | I |
| *Aglaonema commutatum* (Schott) | Aglonema | *Araceae* | Ornament | 1 | I |
| *Aglaonema modestum* (Schott) | Aglonema | *Araceae* | Ornament | 1 | I |
| *Aglaonema crispum* | Aglonema | *Araceaa* | Ornament | 1 | I |
| *Alamanda blanchetti* (A.DC) | Purple allamanda | *Apocynaceae* | Flower | 1 | III |
| *Alamanda cathartica* (L.) | Golden trumpet | *Apocynaceae* | Flower | 4 | III |
| *Alocasia* sp. | Alokasia | *Araceae* | Ornament | 3 | I |
| *Agryeia nervosa* (Burm.f) | Baby woodrose | *Convulvulaceae* | Flower | 3 | I |
| *Antigonon leptopus* (Hook. & Arn.) | Coral vine | *Polygonaceae* | Flower | 1 | I |
| *Anthurium andraeanum* (Linden.) | Red anthurium | *Araceae* | Ornament | 1 | I |
| *Anthurium hookeri* (Kunth.) | Bird's nest anthurium | *Araceae* | Ornament | 2 | I |
| *Aucuba japonica* (Thunb.) | Japanese laurel | *Garryaceae* | Ornament | 1 | I |
| *Bougainvillea spectabilis* (Willd.) | Bougainvillea | *Nyctaginaceae* | Flower | 9 | III |
| *Callisia repens* (Jacq.) | Creeping basketplant | *Commelinaceae* | Ornament | 1 | I |
| *Canna flaccida* (L.) | Golden canna | *Cannaceae* | Flower | 1 | II |
| *Casuarina equisetifolia* (L.) | Australian pine | *Casuarinaceae* | Ornament | 1 | IV |
| *Chlorophytum comosun* (Thunb.) | Spider plant | *Asparagaceae* | Ornament | 1 | I |
| *Cissus verticillata* (L.) | Princess vine | *Vitaceae* | Ornament | 1 | I |
| *Clitoria ternatea* (L.) | Butterfly pea | *Fabaceae* | Herbs | 1 | I |
| *Cocos nucifera* (L.) | Coconut | *Palmae* | Fruit | 1 | V |
| *Coleus scutellarioides* redhead (L.) | Painted nettle | *Lamiaceae* | Ornament | 1 | I |
| *Coleus scutellarioides* (L.) | Red painted nettle | *Lamiaceae* | Ornament | 1 | I |
| *Combretum indicum* (L.) | Rangoon creeper | *Combretaceae* | Flower | 9 | I |
| *Ctenanthe opphenheimiana* (Schum) | Giant bamburanta | *Marantaceae* | Ornament | 1 | I |
| *Dieffenbachia amoena* (Schott) | Dumb cane | *Araceae* | Ornament | 1 | II |
| *Dimocarpus longan* (Lour.) | Dragon's eye | *Sapindaceae* | Fruit | 1 | IV |
| *Dracaena reflexia* (Lam.) | Song of india | *Asparagaceae* | Ornament | 1 | I |
| *Dracaena angustifolia* (Roxb.) | Narrow leave dracaena | *Asparagaceae* | Ornament | 1 | I |
| *Dypsis lutescents* (H.Wendl.) | Yellow palm | *Aracaceae* | Ornament | 1 | IV |
| *Eoudia ridleyi* (Hochr.) | Golden green | *Rutaceae* | Ornament | 1 | I |
| *Epipremnum aureum* (Linden & Andre) | Betel ivory | *Araceae* | Ornament | 9 | I |
| *Episcia cupreata* (Hook.) | Cleopatra flame violet | *Gesneriaceae* | Ornament | 1 | I |
| *Eguenia aquea* (L.) | Water rose apple | *Myrtaceae* | Fruit | 3 | IV |
| *Excoecaria cochinchinensis* (Lour.) | Chinese croton | *Euphorbiaceae* | Ornament | 1 | I |
| *Ficus microcarpa* (L.) | Banyan | *Moraceae* | Ornament | 1 | III |
| *Ficus pumilla* (L.) | Dollar creeper | *Moraceae* | Ornament | 59 | I |
| *Furcraea foetida* (L.) | Mauritius | *Furcraea* | Ornament | 1 | I |
| *Hibiscus rosa-sinensis* (L.) | Rose of Sharon | *Malvaceae* | Flower | 1 | II |
| *Hylocereus undatus* (Harworth.) | Dragon fruit | *Cactaceae* | Fruit | 2 | II |
| *Jasminum sambac* (L.) | Jasmine | *Oleaceae* | Flower | 1 | II |
| *Mangifera indica* (L.) | Mango | *Anacardiaceae* | Fruit | 2 | V |
| *Monstera pinnapipartita* (Schott.) | Philodendron silver queen | *Araceae* | Ornament | 2 | II |
| *Nephrolepis exaltata* (L.) | Boston fern | *Nephrolepidaceae* | Ornament | 3 | I |
| *Nephrolepis cordofolia* (L.) | Fishbone fern | *Nephrolepidaceae* | Ornament | 3 | I |
| *Passiflora quandrangularis* (L.) | The giant granadilla | *Passifloraceae* | Fruit | 2 | I |
| *Pellaea rotundifolia* (Hook.) | Lemon button fern | *Pteridaceae* | Ornament | 1 | I |
| *Philodendron brulee* (Marx) | Burle Marx | *Araceae* | Ornament | 2 | I |
| *Piper ornatum* (N.E.Br) | Red betel | *Piperaceae* | Herbs | 4 | I |
| *Piper bettle* (L.) | Betel vine | *Piperaceae* | Herbs | 4 | I |
| *Platycerium bifurcatum* (Cav.) | Elkhorn fern | *Polypodiaceae* | Ornament | 1 | I |
| *Portulaca oleracea* (L.) | Little hogweed | *Portulaceae* | Flower | 1 | I |
| *Psidium guajava* (L.) | Guava | *Myrtaceae* | Fruit | 1 | IV |
| *Rhaphidophora hayi* (Boyce -Bogner) | Shingle plant | *Araceae* | Ornament | 1 | I |
| *Sansevieria trifasciata* (Prain) | Snake plant | *Dracaena* | Ornament | 1 | I |
| *Scindapsus pictus* (Hassk) | Satin photos | *Araceae* | Ornament | 1 | I |

| | | | | | |
|---|---|---|---|---|---|
| *Syzygium myrtifolium* (Walp) | Red lip | *Myrtaceae* | Ornament | 1 | IV |
| *Terminalia mantaly* (H.Perrier) | Satellite tree | *Combretaceae* | Ornament | 1 | V |
| *Trachelospermum jasminoides* (Lind) | Star jasmine | *Apocynaceae* | Flower | 1 | II |
| *Tradescantia pallida* (Rose.) | Purple queen | *Commelinaceae* | Ornament | 1 | I |
| *Tradescantia spataceae* (Sw.) | Boat lili | *Commelinaceae* | Ornament | 1 | I |
| *Trasdecentia zebrina* (Hunt.) | Inch plant | *Asteraceae* | Ornament | 1 | I |
| *Thunbergia grandiflora* (Roxb.) | Thunbergia | *Acantachea* | Flower | 10 | I |
| *Vernonina elliptica* (DC.) | Lee kuan yao | *Asteraceae* | Ornament | 25 | I |
| *Vitis vinifera* (L.) | Grapes | *Vitaceae* | Fruit | 24 | I |
| *Zoysia japonica* (Steud.) | Japanese lawn grass | *Poaceae* | Ornament | 1 | I |

**Table 4.** Vertical garden species diversity index value in each sub-district.

| Sub-district | H' index value |
|---|---|
| Syiah Kuala | 2.9 |
| Luengbata | 2.7 |
| Kuta Alam | 2.6 |
| Meuraxa | 2.1 |
| Jaya Baru | 2.1 |
| Baiturrahman | 1.6 |
| Banda Raya | 1.5 |
| Ulee Kareng | 1.3 |
| Kuta Raja | 1.2 |

The two largest sub-districts in Banda Aceh City are Syiah Kuala and Kuta Alam. The sub-district in Banda Aceh City with the smallest area is Jaya Baru. The frequency and density of species in each VG had a greater impact on the species diversity index than the area of the sub-district and the number of VG in each sub-district. VG are more frequently used in built-up regions with modern architectural designs. VG planting is less common in older architecturally styled buildings, because the yards of this typical building design tend to be larger. Fruit trees are the most common option in sub-districts with larger yards, where tree planting is still an option for green open space *pekarangan*. Baiturrahman, some areas of Syiah Kuala, and some areas of Kuta Alam are where housing with an older architectural style is usually found. In addition, there aren't many VG in the areas most impacted by the tsunami and earthquake of 2004, including Jaya Baru, Kuta Raja, and Meuraxa, as well as three villages in Syiah Kuala. This is apparently due to the area's slower pace of development than that of the other five sub-districts.

Based on vertical diversity (height level/strata), we found that strata I plants (45 species), strata II (7 species), strata III (5 species), strata IV (6 species), and strata V (3 species). Seven strata II plant species are hibiscus (*Hibiscus rosa-sinensis*), dragon fruit (*Hylocereus undatus*), dumb cane (*Dieffenbachia amoena*), golden canna (*Canna* sp.), star jasmine (*Trachelospermum jasminoides*), jasmine (*Jasminum sambac*) dan monstera (*Monstera pinnapipartita*); 5 strata III plant species are Japanese cambodia (*Adenium obesum*), bougenvillia (*Bougenvillia spectabilis*), banyan vines (*Ficus microcarpa*), purple alamanda (*Alamanda blanchetti*) and golden trumpet (*Alamanda cathartica*); 6 strata IV plant species are longan (*Dimocarpus longan*), yellow palm (*Dypsis lutescents*), rose apple (*Eguenia aquea*), guava (*Psidium guajava*), australian pine (*Casuarina equisetifolia*) and red lip (*Syzygium myrtifolium*); also 3 strata V plant species are coconut (*Cocos nucifera* L), mango (*Mangifera indica*), and satellite tree (*Terminalia mantaly*).

In addition, based on the functional classification (horizontal diversity), three types of plant functions were found following the application of VG (ornamental plants, fruit plants, and medicinal plants). From total of 66 plant species we found six most common plants applied in Banda Aceh VG application are: *Ficus pumilla*, *Thunbergia grandiflora*, *Vitis* sp., *Combretum indicum*, *Vernonina elliptica*, *Epipremnum aureum* (Figure 3). From total 66 species: 55 ornamental plant species (13 of them were flowering ornamental plants, while the other 42 were non-flowering ornamental plants); 8 fruit plants; and 3 medicinal plants (Figure 4). No vegetable, spice, starch-producing plants, industrial plants and others were found in the application of VG community.

As the effects of climate change in humid tropical regions, such as Indonesia, may encourage the spread of disease and insect infestations and have a negative impact on plant commodities, such as rice [29], the same problem might occur in VG plants. Therefore, plant selection suitable for the weather in Banda Aceh is highly recommended. Even if this particular research has not yet been conducted, it may be useful as a starting point for future research, as VG types with green facade designs, green landscapes, and green canopies tend

to be simpler and easier to apply than living walls, vegetated mat walls, or rooftop gardens. This is because green facade gardens, green landscape and green canopy generally only use one or two types of plants that are planted directly on the ground, and the stems and leaves fill the growing media provided to form perfect coverage.

This requires minimal costs. However, it will take longer to completely cover all the expected VG media. Another drawback is that if one plant in this design dies, the entire VG is usually damaged and must be replaced and replanted. Of course, this is different from living walls, vegetated mat walls, or rooftop gardens, where a variety of plants are applied. It incurs higher costs at the design stage because it requires various supporting media such as soil, irrigation systems, planter bags or pots, various plant seeds, and sturdy steel or wood frame materials. The consumer simply needed to replace one dead plant in those designs because if only one plant perishes, the VG as a whole will not be harmed. All types of VG have their own advantages and disadvantages, and can be conditioned according to the desires and budgets of consumers.

Vertical gardening appears to have gained popularity in Banda Aceh. Additionally, the size of the VG varies significantly, from 1 × 2 meter to tens of meters. The presence of greenery, especially VG, in urban environments, has also been shown to contribute positively to general health and emotional states [15]. More details regarding species that may be applied in cities with calm and dry weather are needed so that more species can be applied to the VG of the city. With better knowledge, VG structures and designs can be implemented to improve biodiversity. It may be possible to create a city structure and design that is more resource-efficient by integrating the participation of users and city planners in this assessment process [30], and improving biodiversity and ecosystem services in gardens may escalate exposure to green space and help restore nature-relatedness [31]. With the various benefits offered, it would be very good if this trend continuously developed in urban areas that experienced significant progress for more advanced and environmentally sustainable development.


**Figure 3.** Six most common plants applied in Banda Aceh VG application (a) *Ficus pumilla*, (b) *Thunbergia grandiflora*, (c) *Vitis* sp., (d) *Combretum indicum*, (e) *Vernonina elliptica*, (f) *Epipremnum aureum*.

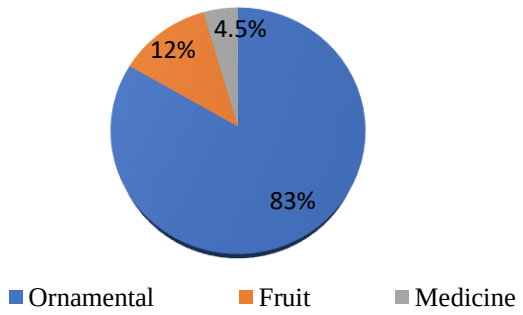


**Figure 4.** Plants chart based on plant clasififcation.

## Conclusion

This research discovered several types of VG that are used, along with the most popular plant types and designs. Urban populations now use a surprising amount of VG, making it possible to say that this type of gardening is a fairly common trend among Banda Aceh City residents. Despite the fact that the design is still quite simple or basic, every VG design has its own positive and negative values. However, every design and size of VG is important as it contributes to urban green areas in the city. Furthermore, future research is required to determine the relationship between VG and its positive impact on climate change. More research is also needed to identify how people view VG and the types of plants that can be used, depending on the weather conditions in Banda Aceh City. Based on people's interests, the author believes that the number of VG may increase in the future.


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