Evaluation of ecosystem quality, comfort, and services of eco-friendly residences in Lowokwaru District, Malang

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Abstract. This research aimed to evaluate the quality of residential ecosystem at Lowokwaru District, Malang. The research was conducted in five different densities residences namely BCT (Bukit Cemara Tujuh), BHPH (Bukit Hijau & Permata Hijau), BP (Bumi Palapa), GJM (Graha Jati Mulya) and PJ (Permata Jingga) and a traditional residence TW (Tunggul Wulung) as a reference, using a purposive sampling method. In each sampling sites, we observed the quality of vegetation of Green Open Space (GOS), microclimate, geography, comfortable index, and ecosystem services. Data were analysed by PCA and clustered by using PAST 3.0 software. The results showed GOS coverage in all locations met the government standard of Malang City and showed similar performance in comfort, although each residence having varied GOS distribution. House density affected the GOS coverage dominating by non-native trees with C and D stratification. Furthermore, GOS vegetation in BP effectively reduced dust deposition, noise and attracted wild bird visitors such as Pycononotus aurigaster. Besides BP, PJ and GJM became potential eco-friendly residences by planting more native trees species.

1. Introduction
Malang City is located 90 km south of Surabaya City and is the second-largest city in East Java, Indonesia. Malang is known as a city of education and tourism that provides comfort for resting. Malang is supported by a variety of eco-friendly residences. This is the reason for visitors to stay or to settle in the region [1]. In 2017, the most population was residing in Lowokwaru District [2], so the needs to activity and residential area is increased [3]. This is indicated by the growing development of residential areas and reduced Green Open Space (GOS). This activity can meet the needs of the economy, but on the other hand also provides losses, especially declining ecological functions and city structures that are unbalanced.

To create a balance between residential areas and eco-friendly residences, it needs an adequate area of GOS. The residential area can be residential complex and traditional residence. Furthermore, the residential complex development is more intensive than the traditional residence and designed to be eco-friendly, so that residents feel the comfort, safety, beauty, and environment health. The quality residential ecosystem depends on the quality GOS which includes the structure, functions and ecosystem services. Therefore, the existence of GOS is very important and needs to be designed properly in the residential development or urban plan [4]. Beside that, government policy is needed to validate the regional spatial planning (RTRW), detailed spatial planning (RDTR) and provide permits to establish residences and area with GOS vegetation. [5].
GOS vegetation will be functions optimally if the structure, extent, distribution, and composition meet the requirements of ecological, socio-economic and architectural functions [6], [7]. The other functions of GOS are includes oxygen production, soil and water protection, microclimate control, carbon storage, biodiversity conservation, recreational facilities, visitor attraction and beautiful landscape [8]–[10]. When GOS vegetation is ignored, this will have an impact on the quality residential ecosystems, for example biodiversity and habitat quality will be poor [11], air conditions that tend to be hot and uncomfortable [12], [13], flood [14], air pollution like dust and noise [15]–[17] this had been happened in several large cities. Therefore, in order to optimize the quality residential ecosystem, it is necessary to evaluate quality of GOS vegetation, microclimate, geography, comfort index, and ecosystem services.

2. Methods
This research was conducted in January - August 2019 at residential area in Lowokwaru District, Malang. The study was conducted at sunny weather. Research location was determined using a purposive sampling method based on residence densities or residence extents according to RTRW Regulation number 4 of 2011 on Malang City, high density or small residence (a house has an area > 54-120 m$^2$), moderate density or moderate residence (> 120-600 m$^2$) and low density or large residence (> 600 - 2000 m$^2$). The location was determined using Google Earth Pro software and verified by direct observation. The research locations were in several residential complexes (BCT, BHPH, BP, GJM, and PJ), and a traditional residence (TW) as a comparison.

At the research locations, measurements were taken at three different points and evaluations was done to assess the quality of GOS vegetation, microclimate, geography, comfort index, and ecosystem services. Semi-structural interviews were also conducted with the people living in the residential complex.

2.1. GOS vegetation quality
GOS is a place where plants grow naturally or intentionally with the elongated or clustered area. Evaluation GOS vegetation quality was measured on its plant coverage, tree richness, tree stratification, and tree biomass. GOS plant coverage was measured in each residential complex using Google Earth Pro software and validated by exploring directly the whole residential area.

Tree richness and stratification on the GOS vegetation measured by creating a square plot with a size of 10 x 10m and calculated the number of trees with a trunk diameter > 5cm. The results trees data collection were then classified according to native or non-native tree types. Tree biomass was measured by non-destructive method [18]. Measurement of tree biomass in the tropical area uses the allometric formula as below;

\[
\text{Humid (1500-4000 = (ABG) est = 0.0509 x } D^2 \pi H)\]

Notes:
(ABG) est : Above ground tree biomass, (kg per tree)
D : DBH (cm)
H : tree height (m)
\(\pi\) : Specific wood density (g.cm$^{-3}$) (secondary data)

2.2. Microclimate
Microclimate of every point of the research locations were measured. Measurements are made during sunny weather conditions. The measurements are carried out for air temperature, humidity, wind speed, and light intensity.

2.3. Comfortable index
The comfortable index measurement is carried out at each point of research location in the morning (07.00 - 09.00), noon (10.00 - 14.00) and afternoon (15.00 - 17.00). The comfortable index used is
modified THI (Temperature Humidity Index), with the category (Table 1) so that the THI formula is obtained as follows [19], [20]:

\[
THI = 0.8Ta + \frac{RH \times Ta}{500}
\]

Notes:
THI : Temperature humidity index (°C)
Ta : Air temperature (°C)
RH : Relative humidity (%)

Table 1. Category of Temperature Humidity Index

| THI (°C) | Category       |
|---------|----------------|
| 21 – 24 | Comfortable    |
| 25 – 27 | Quite comfortable |
| >27     | Uncomfortable  |

2.4. Ecosystem services
Ecosystem services are used to assess and determine policies to enhance conservation and sustainable ecosystems that can contribute to human well-being. The assessment of environmental services is measured from four aspects: provisioning, regulating, cultural and supporting [21].

2.4.1. Provisioning. Ecosystems can produce a product that can be beneficial for the life of living things. Residential ecosystems such as GOS areas, gardens, rice fields, and open land provide habitat and food for wildlife, such as diurnal wild birds. Birds fly to search for food and perch around the ecosystem [22]. Observation of wild birds conducted by interviewing people who live in the residential areas.

2.4.2. Regulating. Regulations on ecosystem provides benefits for conservation activities and ecosystem sustainability. One of the observed regulation is the process of maintaining air quality [7], [23]. Air quality was evaluated by measuring noise intensity, PM 2.5 and deposited dust on a leaf. Noise intensity was measured using a sound level meter. Noise intensity measurements were made at each point of the study site per 20 seconds in two minutes. Based on Malang City Regulation number 1 of 2012 concerning buildings, there are four zonation based on the management of environmental impacts of noise, i.e;

Table 2. Noise quality standard

| Zone | Location | Noise level(dB) |
|------|----------|----------------|
|      |          | Recommended maximum | Recommended allowed |
| A    | Hospitals, research sites, health care, social, etc. | 35 | 45 |
| B    | The place for education, residences, and recreation | 45 | 55 |
| C    | Market, trade, and office | 50 | 60 |
| D    | The train station, bus station, and industry | 60 | 70 |

PM 2.5 dust was measured using an air quality multimeter that were performed at each point. Deposited dust on the leaf was measured using the gravimetric method. Leaf samples taken from 10 strands facing the highway, then stored in sealed plastic. Each leaf is weighed before and after
cleaning. Total leaf surface area was measured using graph paper [24], [25]. The following is a formula of the gravimetric method [26].

\[
\text{Deposited dust on leaf (mg/cm}^2\) = \frac{\text{before cleaning} - \text{after cleaning (mg)}}{\text{total leaf surface area (cm}^2\)}
\]

2.4.3. Cultural. Sustainable ecosystem utilities can support human welfare. To be able to support human welfare, ecosystems that have aesthetic value and a sense of place [23]. Aesthetic assessment was conducted by interviewing the people who live around residential areas. Exploration and recording the elements of ecosystem diversity was performed to assess the sense of place value. Aesthetic services, sense of place and important values of the cultural landscape can have implications for community preferences, perceptions and land use policies in residential areas [27], [28].

2.4.4. Supporting. An effort to support the sustainability of the ecosystem services is to evaluate the water use and disaster mitigation by the community. This evaluation will indicate the capacity of the soil to absorb the water [23]. To assess this, we conduct interviews with the community and measuring the soil bulk density. Bulk density can be used to determine the effectiveness of plantations based on soil types. Besides, it can confirm good absorption of water into the soil. The soil bulk density is calculated using the gravimetric method using ring soil. Soil sampling conducted at each point and then air-dried until it reaches a constant weight. The following is the formula for soil bulk density [29]:

\[
\text{Bulk density} = \frac{\text{dry soil mass}}{\text{soil volume}} \text{ g/cm}^3
\]

\[
\text{Soil volume} = \pi r^2 t
\]

2.5. Data analysis

The data obtained was analyzed to determine the relationship between variables using PCA and Cluster analysis to determine the similarity between research sites, using PAST 3.0 software.

3. Results and Discussion

3.1. GOS vegetation quality in residential areas

The residential areas are located in lowlands and there were variations in the distribution patterns of GOS in Lowokwaru district, Malang. The composition GOS includes barrier trees, parks, yards, gardens, fields, and open lands. The community utilizes the GOS for production, breeding, planting animal feed and as a platform for communication in the neighborhood.

| Location | Elevation (m asl) | Land slope (°) | GOS distribution patterns |
|----------|------------------|----------------|--------------------------|
| TW*      | 541              | 0              | √                        |
| GJM      | 531              | 2.4            | √                        |
| BHPH     | 540              | 3.2            | √                        |
| BCT      | 589              | 0              | √                        |
| BP       | 532              | 0              | √                        |
| PJ**     | 519              | 0              | √                        |

Table 3. Geographical conditions and distribution patterns of residential GOS

Notes: * Negative reference site
      ** Positive reference site
Based on Table 3, there were variations on the GOS distribution patterns provided by both of residential developers and community. GOS was distributed evenly on the location of BP and PJ, moreover residential developers also provided complete public facility such as garden and sport facilities. The communities in BP and PJ residences had the initiative to create small gardens in front of the house, consequently it might increase aesthetic, socio-economic and ecological value. The existence of park area had an important function in maintaining environmental balance, biodiversity, and as a space to relax [4], [30]. The community and residential developers had collaborated adding more GOS area that could be used as production activities such as tomato, chayote, papaya, bananas, and palm garden.

**Figure 1.** GOS quality vegetation in residential areas of Lowokwaru district, Malang: a. plant coverage vegetation of GOS; b. variation in residence densities; c. slope variation.

Based on Figure 1, the availability GOS area at a research location has met the standards set by Malang City government Regulation number 4 of 2011. Variations in residence densities and slope can affect GOS vegetation distribution pattern in residential areas (Fig. 1b & 1c). Variations of residences / building density might contribute pattern on GOS vegetation distribution pattern by 92% (Fig. 1a). The slope level factor was quite influential (51%) on the distributed pattern of GOS vegetation (Fig. 1b), while the remaining 49% was influenced by other factors. Characteristic GOS in low building density like BP and PJ area were many trees and dominated wide canopy. However, this is different from TW and GJM, where the GOS was dominated by production areas and open land which had narrow canopy trees character due to its high building density. Slope can be an important factor in structuring the tree community [31]. This corresponds to the general pattern in which low-density residential and slope tent to have good, diverse and abundant GOS vegetation conditions [12].

Trees in the residential GOS area were dominated by C and D stratification. The variation in residence density also corresponded by variations in the tree stratification of the GOS in residential area. Stratification of native tree species is strongly influenced by variations in residential density.
Based on Figure 2, variations in tree stratifications occurred due to variations in residence density. C stratification trees both of native and non-native trees were found abundantly in GJM and PJ area. D stratification native trees were found abundantly at BHPH, BP, and PJ area, while the non-native species were mostly found in GJM and BPHH. Low residence density showed a correlations with the high presence of C stratification native and non-native trees species (Fig. 2a). However, at low-density residences were found many D stratification native trees (Fig. 2b). Low-density residential have abundant vegetation especially native tree species. There was a common sense that both of the residential developers and the community had not paid attention on type of trees being planted. They tend to prefer trees that had high aesthetic value and easy on maintenance.

Tree richness at the study site was dominated by non-native species that had high tree biomass except in TW and GJM where even if the number of native tree found was low, but its biomass were high.

GOS in a residential area showed variations in vegetation composition. Tree composition in all locations was dominated by non-native tree species (Fig. 3a). The domination of non-native species was the result of random selections of tree species planted by the residential developer and the community or naturally grown on the GOS. Based on the interviews, the communities tent to plant a flower providing an additional aesthetic value surrounding their houses. Besides flower, they preferred to plant trees producing fruits, so that it might be beneficial for the homeowners and could be shared.
to neighbors. The availability of trees were needed by the community to increase comfort and coolness around the environment. Community awareness was also needed in the efforts to plant and to care for trees to create eco-friendly residences, following the mission of the Malang City Government, to increase the role of the community in implementing eco-friendly development.

The dominance of non-native trees could produce a high amount of biomass shown in BCT and PJ areas. However, in TW and GJM area planted abundant non-native trees, but its biomass was lower than the biomass of the native trees (Fig. 3b). This revealed that the trees species, age and stem densities may affect the amount of tree biomass [32, 33].

3.2. Microclimate quality in residential areas

All factors of the microclimate in the residential area: the air temperature, humidity, and wind speed has the same quality in all research locations. However, for light intensity, there is difference found only at the BCT area.

| Location | Light intensity (lux) | Air temperature (°C) | Wind speed (m.s⁻¹) | Air humidity (%) |
|----------|-----------------------|----------------------|--------------------|-----------------|
| TW       | 112233 ± 4743.8a      | 30.7 ± 0.8a          | 1.14 ± 0.97a       | 69 ± 8a         |
| GJM      | 111500 ± 1322.9a      | 30.7 ± 0.3a          | 1.45 ± 0.95a       | 69 ± 4a         |
| BHPH     | 118500 ± 8584.3a      | 30.9 ± 1.5a          | 1.07 ± 0.23a       | 68 ± 11a        |
| BCT      | 82666.7 ± 611ab       | 30.6 ± 1a            | 0.68 ± 0.63a       | 67 ± 11a        |
| BP       | 112400 ± 1705.9a      | 31.0 ± 0.5a          | 1.11 ± 0.16a       | 63 ± 4a         |
| PJ       | 95733.3 ± 13785a      | 30.6 ± 0.8a          | 0.73 ± 0.49a       | 66 ± 6a         |

The light intensity can affect air temperature as in BCT area that shows different light intensities compared to other areas, where the BCT area has a lower light intensity and this affects the air temperature so that the place has lower or cool temperature (Tab. 4). However, cool temperature also occur in all research areas. Based on the interviews with the community about airflow in the region, people's perceptions are very diverse, some people feels it is already adequate, sufficient enough and inadequate. Such community perceptions are the impact of the tree presence on the area, that in which fewer trees are presents in the environment, it will be resulted on the decreasing capability of trees to control microclimate conditions [9].

3.3. Comfortable Index

All study locations showed a similar comfort in the morning and afternoon, but during the noon, all sites showed uncomfortable conditions.

![Figure 4. Comfortable index in the morning, noon and afternoon in a residential area](image_url)
Based on Figure 4, in the morning and afternoon, the weather conditions have similar comfort conditions. However, the comfort felt in the morning and afternoon is different. The community feels that the conditions in the morning tend to be cool and fresh, while in the afternoon the conditions tend to be cool and cold. When approaching the afternoon, the air becomes uncomfortable, due to high light intensity and increasing the air temperatures and decreasing air humidity around the residential area.

3.4. Ecosystem services

3.4.1. Provisioning. The composition of the GOS vegetation becomes a natural habitat for wild birds. *Pycnonotus aurigaster* and *Lanius schach* are beautiful chirping birds seen in a residential area (Tab. 3).

**Table 5.** Bird diversity in residential area

| Location | Local name | Scientific name       |
|----------|------------|-----------------------|
| TW       | Emprit     | Lonchura punctulata   |
|          | Gereja     | Passer montanus       |
|          | Walet      | Collocacia linchi     |
| GJM      | Emprit     | Lonchura punctulata   |
|          | Gereja     | Passer montanus       |
| BHPH     | Merpati    | Columba Olivia        |
|          | Gereja     | Passer montanus       |
| BCT      | Emprit     | Lonchura punctulata   |
|          | Merpati    | Columba Olivia        |
|          | Gereja     | Passer montanus       |
| BP       | Kutilang   | Pycnonotus aurigaster |
|          | Emprit     | Lonchura punctulata   |
|          | Derkuku    | Streptopelia chniensis|
|          | Gereja     | Passer montanus       |
| PJ       | Emprit     | Lonchura punctulata   |
|          | Cendet     | Lanius schach         |

Wild birds that are almost seen in all residential areas are *Passer montanus* and *Lonchura punctulata*. GOS diverse vegetation are able to attract the existence of chirping birds such as *Pycnonotus aurigaster*, and *Lanius schach*. The diverse composition of GOS can attract wild birds to came for food, perch or become their natural habitat.

3.4.2. Regulating. The number and diversity of the trees, will affecting the air quality in the surrounding environment. GOS vegetation could be effective in reducing dusts and noises.
Based on Figure 5a and 5b, GOS vegetation in BP area could reduce dust accumulation on leafs and PM 2.5 dust effectively [17]. Based on Figure 5c, the accumulation dust generated by motor vehicle intensity is 68% and influenced by other factors, for example, buildings development intensity and GOS vegetation composition. Meanwhile, the motor vehicle intensity has a weak effect on the presence of PM 2.5 dust (Fig. 5d).

Based on Figure 6a, GOS vegetation in the BP area is also effective in reducing noise. This noise is strongly influenced (98%) by motor vehicle intensity (Fig. 6b). Effects resulting from vehicle can be reduced in the presence of GOS [7]. GOS vegetation composition in BP has wide canopy character. The tree species in BP area are *Terminalia catappa* L., *Averrhoa carambola* L., *Polyalthia longifolia* (Sonn.), *Mangifera indica* L., *Syzigium aqueum* (Burm.f.) Alston., *Roystonea regia* (Kunth) O.F.Cook., *ArthSocarpus heterophyllus* Lam., *Muntingia calabura* L., dan *Gliridia sepium* (Jacq.) Walp. Narrow canopy trees are less effective in reducing deposited dust, PM 2.5 dust and noise, as shown in the TW and BCT areas (Fig. 5a, 5b & 6a).

3.4.3. Cultural. Ecosystem in residential area are quite diverse and ecologically useful, so that the community also uses it for socio-economic activities such as production, breeding, fodder plantation, media to establish communication, and add residential aesthetic value.
Table 6. Ecosystem diversity in residential areas

| Location | Ecosystem diversity | Score Sense of Place* |
|----------|---------------------|-----------------------|
| TW       | Chili and tomato fields, open land, yards, road protective tree, field, shrubs, park | 2 |
| GJM      | Road protective tree, field, shrubs | 2 |
| BHPH     | Cassava and banana plantations, road protective tree, park | 3 |
| BCT      | Yards, road protective tree, park | 2 |
| BP       | Tomato, papaya and banana plantations, yards, road protective tree, shrubs, park | 3 |
| PJ       | Palm necessary, road protective tree, park | 3 |

* score: 1 = poor; 2 = moderate; 3 = good

Based on observations and interviews with the community, ecosystem diversity is often used by the community for production activities, which is usually for the production of fruit, rice, and tubers (Tab 6). This production activity is beneficial to increase the economy. Besides, it also used as nursery and as a source of animal feed. The development and community developers provide park areas for platform of communication between neighbors so that they can establish good hospitality and neighborhood. In some residences, in addition to good residential management, it is supported by attractive photo spots such as the BHPH, BP, and PJ areas that can add the aesthetic value of the residential areas.

3.4.4. Supporting. Soil types in residential areas especially in GOS are sands and loam [29].

Based on observations and interviews with the community, ecosystem diversity is often used by the community for production activities, which is usually for the production of fruit, rice, and tubers (Tab 6). This production activity is beneficial to increase the economy. Besides, it also used as nursery and as a source of animal feed. The development and community developers provide park areas for platform of communication between neighbors so that they can establish good hospitality and neighborhood. In some residences, in addition to good residential management, it is supported by attractive photo spots such as the BHPH, BP, and PJ areas that can add the aesthetic value of the residential areas.

3.4.4. Supporting. Soil types in residential areas especially in GOS are sands and loam [29].

Based on Figure 7, in planting trees, shrubs, and herbs, the soil conditions in the GOS is ideal. This condition is very supportive for plant growth. Heterogeneous vegetation is more effective because it has diverse root system ranging from plants with short, medium and deep roots. This condition supports the absorbing process of the water into the soil. GOS vegetation can be utilized to manage water resources [34]. Based on the results of interviews with the community, during the rainy seasons, the water is directly absorbed into the ground. Puddles can occurred but did not because flooding. The puddle can have the potential to become dengue mosquito nest. The fact is, in this past year there are dengue fever case happened in BP and GJM area, this is because the drainage system was poor and does not maintain cleanliness. The solution implemented by PJ residences to overcome this dengue was held fogging activities during the rainy season every month.
3.5. PCA and cluster analysis of residential ecosystem

According to the results of the PCA and cluster analysis, potentially ideal residential areas as an eco-friendly place to live are at BP, PJ and GJM area.

![Figure 8. PCA and cluster analysis of eco-friendly residential ecosystems quality](image)

Based on Figure 8, the housing ecosystem can be divided into four groups. The first group is PJ which has abundant native tree species. Native tree species can reduce dust and noise, but could not block sunlight, so the temperature in the PJ area tends to be hot. The comfort index in the morning is at a comfort category but the level is still more comfortable in other areas such as TW and BCT.

The conditions are different from the second group, BCT. BCT areas are characterized by high level of dust and noise. It doesn’t guarantee protection against pollution factors such as dust and noise, despite numerous native trees and wide canopy. However, it can block sunlight that makes condition of BCT area tends to be comfortable in the morning.

The third group, BHPH, characterized by high light intensity and noise but low dust level. This correlates with less number of wide canopy trees in BHPH area but is still capable of reducing dust. The noise occurs is caused by vehicle traffic on the surrounding areas.

The GJM, BP and TW areas are belongs to the fourth group. In the fourth and third groups have something similar: the tendency of hot temperatures and low tree biomass. In the GJM and BP area, there are quite a lot of native trees so that they can reduce dust and noise effectively. However, at TW area the level of noise and dust is higher, because there are only few trees both of native and non-native tree species. On the contrary, TW area is the most comfortable place in the morning due to the diversity of other ecosystems such as fields and plantations.

Based on PCA analysis, the BP, PJ and GJM areas are potential places to become eco-friendly residences. Because at the locations, we found many native tree species such as *Pterocarpus indicus* Willd, *Mangifera indica* L., *Artocarpus altilis* (Parkinson), *Pometia pinnata* J. R. Forst., *Averrhoa blimpii* L., *Terminalia catappa* L., *Morinda citrifolia* L., *Borassus flabillifer* L., dan *Calophyllum inophyllum* L. To improve the quality eco-friendly residential ecosystems, it is necessary to add more native trees species in order to increase architectural, socio-economic and ecological value. The
addition of native species trees on the GOS vegetation can add ecological value like the effectivity to reduced air pollution factors such as dust and noise, microclimate regulators to provide comfortable conditions, and as a means for biodiversity conservation. GOS vegetation dominated by native trees can also support socio-economic and architectural values. GOS is useful for production activities, sports, socio-communication and adding aesthetical value to the landscape.

4. Conclusion
Evaluation residential ecosystem quality can be measured through GOS vegetation quality, microclimate, geography, comfort index, and ecosystem services. GOS vegetation in the residential area on this research have met the standards of Malang city government with a pattern of GOS vegetation that dominated by C and D stratifications of non-native tree species. Although the number of native tree species is low, it can provide high biomass as in TW and GJM. GOS vegetation quality is also affected by variations of residence densities and land slope. Low residence densities, such as in BP and PJ, have good and high-quality GOS vegetation. It can regulate the conditions microclimate and make people feel comfortable on such environment. It is also effective in reducing dust and noise. GOS vegetation in the residential area is not only beneficial for the community but also able to become a habitat, a source of food for wild birds, and as an added beauty for the residential landscape. In conclusions, BP, PJ, and GJM area are potential places as an eco-friendly residences.

5. Acknowledgment
The author thanks my family, Mrs. Endang Arisoesilaningsih and Mr. Dian Siswanto for providing motivation and encouragement. Then family Laboratory Ecology UB (Mrs. Catur, Mr. Purnomo, and Mr. Yusuf), postgraduate biology UB, and Lab assistant Biology UMM as sampling team which has helped and facilitated.

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