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Assessing Ecosystem Health in Botanical Gardens

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ABSTRACT

Botanical gardens have an important role as ex-situ plant conservation areas, so the health condition of the botanical garden ecosystem must be considered so that it remains sustainable. However, currently not many studies have been carried out regarding the health of botanical garden ecosystems, especially in Lampung Province. Therefore, this research was conducted to assess and compare the health of ecosystems in all botanical gardens in Lampung Province. Measurement and analysis of research data was carried out using the Forest Health Monitoring (FHM) method based on ecological indicators in which the categories were bad, medium, and good. The research results obtained show that CL1 has a bad category with a value of 6.18; CL2 has a bad category with a value of 5.64; CL3 has a good category with a score of 7.89; and CL4 has a good category with a value of 7.61. Thus, the health condition of the ITERA Botanical Gardens and Liwa Botanical Gardens ecosystem has a final average score of 6.83 which is included in the medium category. It is important to always maintain and improve the health status of forests, considering that the existence of botanical gardens provides many benefits for the surrounding environment and society.

1. INTRODUCTION

A botanical garden is defined as an ex-situ plant conservation area in which there are various plant collections that have been documented and recorded based on taxonomic, bioregional, thematic classification patterns, or a combination of several patterns for conservation, research, education, tourism and environmental service purposes [1]. Apart from being a place to protect germplasm sources, botanical gardens also have ecological and social functions for the community [2]. Currently, Lampung Province has two botanical gardens, namely the Liwa Botanical Gardens and the ITERA Botanical Gardens. In line with this statement, it was also explained that Lampung Province was the first province in Sumatra to have two botanical gardens [3]. Liwa Botanical Gardens has an area of 86.7 hectares. The Liwa Botanical Gardens are managed directly by the West Lampung Research and Development Agency (Balitbang) [4]. The construction of the Liwa Botanical Gardens aims to preserve the flora of southern Sumatra and other plant collections. Meanwhile, the ITERA Botanical Gardens has an area of 75.52 hectares which is divided into three zones, namely the tourism zone, conservation zone and management zone. The ITERA Botanical Gardens are managed directly by the Sumatra Institute of Technology (ITERA). The ITERA Botanical Gardens were built as a campus forest that can represent and preserve Sumatra's mega biodiversity [5]. Liwa Botanical Gardens and ITERA Botanical Gardens have the same functions, including conservation, education, research, tourism and environmental services. These two botanical gardens are important assets in Lampung Province so the health of their ecosystem needs to be studied further [6]. As a green open space which socio-culturally functions as a space for social interaction, recreation facilities, and as a cultural city landmark in Lampung Province, it is important that the health of botanical gardens in this area needs to be studied further.

The current problem is that there has not been much research regarding the health of botanical garden ecosystems, especially in Lampung Province. In fact, knowing the health value of botanical garden ecosystems is one effort to control the level of damage that occurs [7]. This is also very useful for managers; The data obtained can be used to make decisions and take action quickly and accurately to preserve the ecosystem. A healthy ecosystem is a criterion for sustainable management [8]. An ecosystem is said to be healthy if it is still able to carry out its functions according to the main functions that have been determined previously. A healthy botanical garden ecosystem is described as having a good balance between its constituent components and being able to carry out its main functions [9]. Therefore, a healthy botanical garden ecosystem can be an indicator of successful management and implementation of a silvicultural system, so it is very important to assess the health condition of the botanical garden.

Ecosystem health studies in botanical gardens can be carried out using a forest health approach [10]. This forest health approach is carried out by assessing forest health indicators and parameters in the botanical garden ecosystem. Forest health indicators and parameters are assessed based on the Forest Health Monitoring (FHM) method [11]. This method of assessment uses ecological indicators consisting of indicators

of vitality, biodiversity, productivity and site quality. Vitality indicators are used to see the condition of trees in botanical gardens in terms of tree damage and canopy cover. Biodiversity indicators are used to assess the diversity of flora that makes up a botanical garden. Productivity indicators are used to measure tree growth rates; If the tree's growth rate is high, it indicates good health. Meanwhile, location quality indicators are used to determine the quality of the growing place or soil quality in a botanical garden. If these four indicators show good results, then this indicates a healthy ecosystem [12]. However, until now it is not known whether these four indicators can be applied to botanical garden locations. Therefore, this research is very important to examine indicators and parameters that can be used to assess the health status of botanical garden ecosystems, namely the ITERA Botanical Gardens and the Liwa Botanical Gardens. Thus, the aim of this research is to assess and compare ecosystem health in all botanical gardens in Lampung province.

2. RESEARCH METHODS

2.1 Time and location of research

This research was carried out at the ITERA Botanical Gardens, South Lampung Regency (Figure 1) and the Liwa Botanical Gardens, West Lampung Regency (Figure 2) during June–August 2023. The research location can be seen in Figure 1 and Figure 2. The Liwa Botanical Gardens has an area of 86.7 hectares. The Liwa botanical garden is included in 47 botanical gardens representing 17 ecoregion types. Liwa Botanical Gardens has 98 types of nursery plants, 96 types of orchids, 25 types of Araceae, 17 types of Begoniaceae, 11 types of Piperaceae, 8 types of Nepenthaceae, two types of Aeschinantus, and one type of hiya. The green vegetation in this place is full of Jamuju or dew wood, cypress, pine and monkey tail fern. Meanwhile, the ITERA Botanical Gardens has an area of 75.52 hectares which is divided into three zones, namely the tourism zone, conservation zone and management zone. ITERA Botanical Gardens already has 11,315 greening plants consisting of 109 types of plants, as well as 232 plant collections consisting of 49 families.

2.2 Tools and materials

The aim of this research is to assess and compare the health of ecosystems in all botanical gardens in Lampung province, so the appropriate method to use to achieve this goal is as follows.

2.3 Methods

The aim of this research is to assess and compare the health of ecosystems in all botanical gardens in Lampung province, so the appropriate method to use to achieve this goal is as follows:

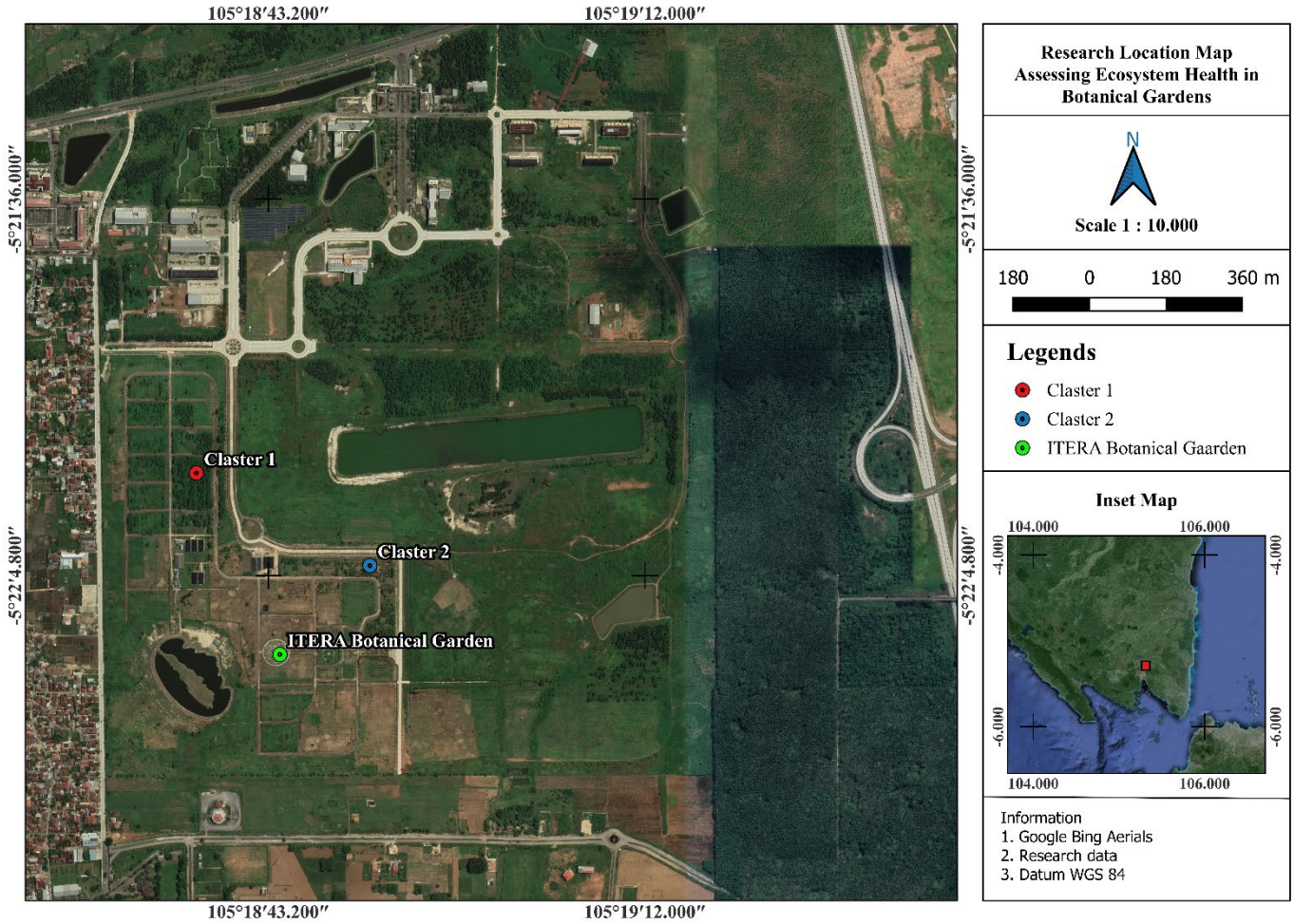

Figure 1. Location of clusters in the ITERA Botanical Gardens

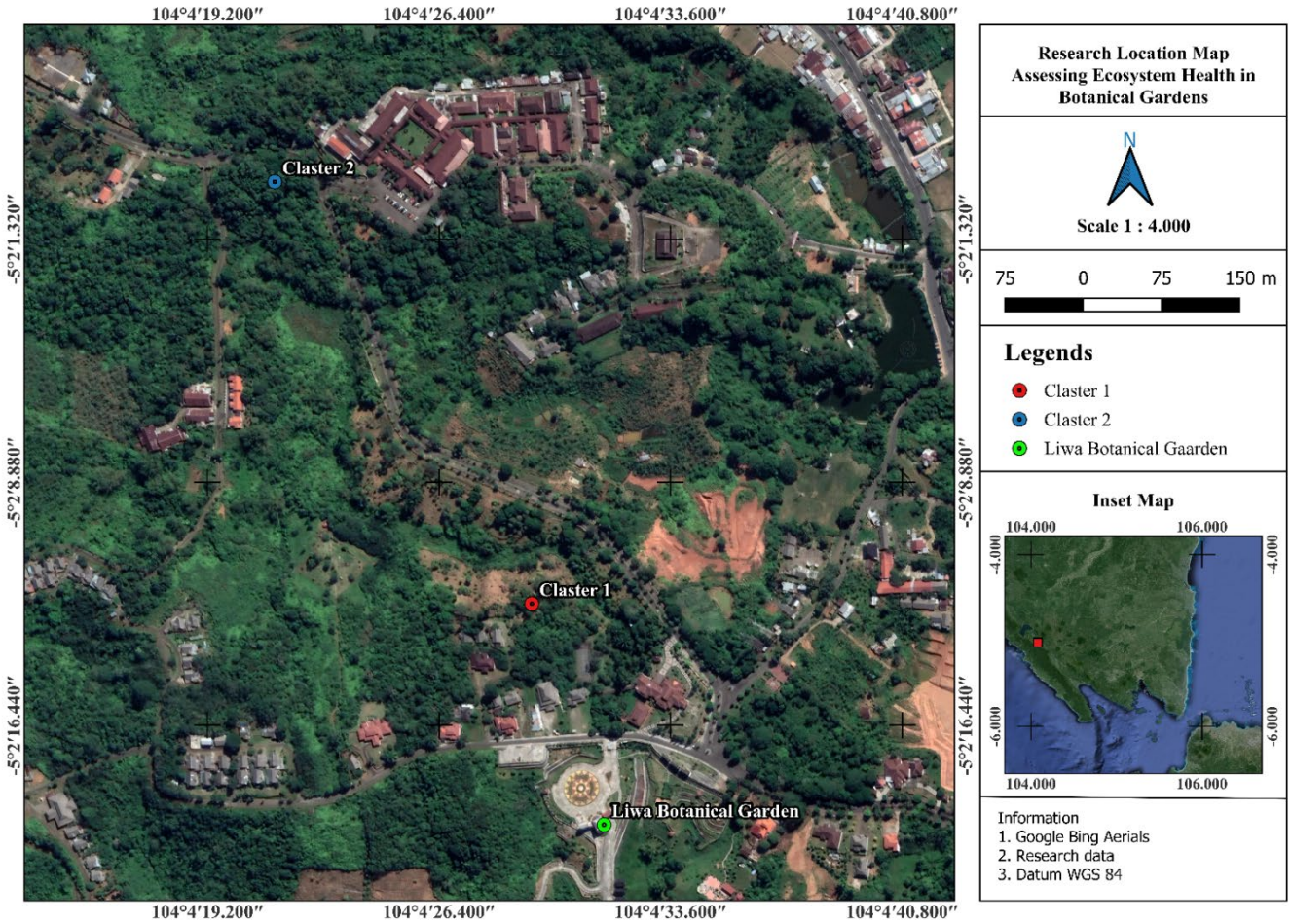

Figure 2. Location of clusters in Liwa Botanical Gardens

2.3.1 Observation

Observations were carried out at the Liwa Botanical Gardens and ITERA Botanical Gardens to determine the current conditions in the field. The observation results are used to determine existing problems and determine the location of cluster plots [13].

2.3.2 Determination of FHM cluster plot points

Determining cluster plot points using GPS. The number of cluster plots created was 4 clusters, of which 2 cluster plots were in the Liwa Botanical Gardens and 2 cluster plots were in the ITERA Botanical Gardens [14]. Determining the number of plot clusters was carried out using the purposive sampling method. The considerations used are planting year and planting distance.

2.3.3 Creation of cluster plots

The cluster plot points that have been obtained are used to create FHM clusters. Cluster plots are sample plots used to measure forest health indicators and represent populations [15].

2.3.4 Measurement of forest health indicators

The indicators measured are tree vitality, biodiversity (plant diversity), productivity (tree growth), and site quality [16].

1) Vitality: There are two parameters measured in the vitality indicator, namely canopy condition and damage condition. There were five canopy parameters observed, namely live crown ratio, canopy transparency, canopy density, crown diameter and dieback (CDB). Meanwhile, damage parameters were observed in all parts of the tree, from roots to leaves. Then note the type or types of damage and its severity.
2) Productivity: the parameters observed are tree growth by measuring the trunk diameter and tree height then calculating the tree base area (LBDs). Where LBDs are analyzed with the formula LBDs = ¼ x π x d^2.
3) Biodiversity is used to determine the diversity of plant types in the research cluster location. The parameters observed were the species and the number of individuals of each species.
4) Site quality: the parameter measured is pH to determine the level of soil fertility.

The final health indicator score for botanical gardens in each cluster plot is weighted and then classified according to good, moderate, and bad categories. According to Ajijah et al. [17], the final health score for the Botanical Gardens is calculated using the following equation:

$$NKKR = \sum (NT \text{x} NS) \quad (1)$$

3. RESULTS AND DISCUSSION

ITERA Botanical Gardens and Liwa Botanical Gardens as ex-situ conservation sites, have various collections of plants. Plants or trees, as biological components, have a major role in the botanical garden ecosystem [18]. The results of the study of ecosystem health at the Liwa Botanical Gardens and ITERA Botanical Gardens for each indicator can be seen in Table 1.

Table 1. Ecosystem health indicator values in botanical gardens in Lampung Province

Location	Plot Clusters	Vitality		Productivity (LBDs)	Biodiversity (H')	Site Quality (pH)
		Tree Damage (CLI)	Header Condition (VCR)			
ITERA Botanical Gardens	CL1	3.69	2.37	0.043	0.0	5.9
	CL2	4.09	2.36	0.043	0.0	5.9
Liwa Botanical Garden	CL3	2.93	2.12	4.3	2.02	5.3
	CL4	3.30	2.27	2.15	1.93	5.1

Based on Table 1, it can be seen that CL 1 and CL 2 are at the ITERA Botanical Garden location, while CL 3 and CL 4 are at the Liwa Botanical Garden location. The vitality indicator shows that the value of tree damage (CLI) at CL1 and CL2 is high, namely 3.96 and 4.09, while CL3 and CL4 have low values of 2.93 and 3.30. Measuring the condition of tree damage is carried out based on the location where the damage is found and is influenced by the severity of the damage and the type of damage experienced by the tree. The value of low or high tree damage is influenced by the number of types of damage found and their severity. Three types of damage were found at the ITERA Botanical Gardens: cancer (Code 01), broken or dead branches (Code 22), and excessive branching or bruising (Code 23). Of the three types of damage, it has the highest level of severity, causing a high CLI value. Meanwhile, at the Liwa Botanical Garden location, the type of tree damage found was the loss of dominant shoots (code 21). The type of tree damage that has a fairly high level of severity causes the CLI value to be high. Tree damage can disrupt the physiological processes in trees [19]. If enough damage is found with a high level of severity, it can cause the tree to die [20].

There are several factors that influence the level of damage to trees, including environmental factors and unsupportive growing places, which can cause tree growth to be hampered. Apart from that, other factors such as biotic factors, namely pest attacks, diseases and the activities of living creatures are factors that can cause damage [16]. The pictures of the types of damage that predominate in the two locations of the botanical garden are shown in Figure 3.

Figure 3. Damage type of broken/dead branches in ITERA Botanical Gardens

Figure 3 shows the type of damage to broken or dead branches (code 22) as the dominant type of damage that occurred in the ITERA Botanical Gardens, with a total of 77 cases. Meanwhile, the dominant types of damage in Liwa Botanical Gardens were broken or dead branches (code 22) and loss of dominant shoots (code 21), with 55 cases and 49 cases, respectively. The symptoms that arise are that the tree branches become rotten, and over time they will die. This condition can be caused by pest and disease activity.

The canopy condition values at both locations were also low, namely at CL1 of 2.37, CL2 of 2.36, CL3 of 2.12, and CL4 of 2.27. A low VCR value indicates that the tree canopy cover is sparse or not dense and the crown size is small. Canopy cover will affect the intensity of sunlight that can enter the forest floor. The intensity of light received by trees can help the process of growing trees in the botanical garden ecosystem. In addition, the size of the tree canopy can affect the space between trees in obtaining sunlight [9].

Figure 4. Damage type of shoot loss in Liwa Botanical Garden

Apart from the many tree diseases with broken branches, dominant damage was also found in botanical gardens, namely to the crown, leaves and shoots as in Figure 4. Damage to the crown and leaves, namely damage and loss of leaves in the crown and discolored leaves. Then damage to the top of the shoot is the discovery of dead shoots. These conditions will affect the function of the canopy and leaves as part of the photosynthesis process [16, 17]. Good canopy conditions can be influenced by the availability of nutrients, sunlight, water, and sufficient growing space for tree growth and productivity.

The productivity indicators for CL1 and CL2 have the same value of 0.043. Whereas CL3 has a value of 4.3 and CL4 of 0.26. There are 2 cluster-plots showing low LBDs values caused by the trees in that location having a small diameter. Age factor will have an impact on the growth of tree diameter. This is in line with research [21] which states that increasing age can cause an increase in diameter as well. So, a tree that has an old age will have a large tree diameter.

The Botanical Gardens have a role in contributing to ex-situ conservation of Sumatran grassland plants. Thus, observing biodiversity is very important [2]. The biodiversity indicator shows that CLI and CL2 have the same value of 0.0; while CL3 has a value of 2.02 and CL4 of 1.93. This indicates that

the Liwa Botanical Garden has a larger collection of plants compared to the ITERA Botanical Garden. Diversity of species describes how interactions that occur with each other influence and are influenced by environmental conditions. Through the level of species diversity, the resilience and stability of a forest ecosystem can be known so that it can be concluded that if a forest ecosystem has a low level of biodiversity then the forest has low growth stability and has a low ability to help the forest maintain the balance of its ecosystem. In a botanical garden there are components that influence each other, both biological and physical components. In an ecosystem, the components will have a positive influence on each other so that this process will create a diversity of living things [21]. One of the factors for the difference in value can be influenced by the age of the botanical garden and the management carried out by the manager. The Liwa Botanical Garden is a botanical garden that has been around for a long time, namely from 2007, and is an area bordering the Bukit Barisan Selatan National Park. So that the Liwa Botanical Garden has a tendency with more diverse plant and tree species than the ITERA Botanical Garden. Apart from that, ITERA Botanical Garden managers tend to still plant homogeneous tree species, namely the sengon species. So the level of diversity of species is low.

Site quality describes the fertility of a location. Soil fertility is measured based on the pH value. CLI and CL2 have the same pH value of 5.9, while CL3 is 5.3 and CL4 is 5.1. This shows that the two locations of the botanical garden have an acidic pH. Soil pH will affect tree growth; tolerant trees will be able to survive in varying pH conditions, whereas intolerant trees will not be able to survive [22, 23]. The high and low pH of the soil can be influenced by the treatment given to trees such as applying fertilizer. In organic fertilizer, the organic material contained in it can increase the exchange capacity of soil pH, soil cations, and plant yields. Apart from having a direct influence on plants, pH also influences other factors, such as the availability of nutrients [12].

Based on the data and description above, it is used to formulate the value of the health status of the botanical garden ecosystem. So that the value of the health status of the botanical garden ecosystem is obtained as in Table 2.

Table 2. Value of ecosystem health status of botanical gardens in the Province of Lampung

Plot Cluster	Botanical Garden Health Value	Category
1	6.18	Bad
2	5.64	Bad
3	7.89	Good
4	7.61	Good
Average	**6.83**	**Medium**

As a basis for developing Botanical Gardens in Indonesia, academic studies need to be carried out in depth to determine the number of Botanical Gardens that are able to conserve all plants in various ecosystem conditions in Indonesia. Botanical Garden development planning must be supported by comprehensive data and an appropriate territorial division concept approach.

Based on Table 2, it shows that the health status value of the botanical gardens in CL1 is poor with a value of 6.18; CL2 is poor with a value of 5.64; CL3 is good with a score of 7.89; and CL4 is good with a value of 7.61. The average value for the health status of botanical gardens is 6.83 in the medium category. This shows that most of the ecosystem conditions in both botanical garden locations are in good condition so that the management carried out is quite good. This means that there are no significant differences between the two botanical gardens studied. Both Liwa Botanical Gardens and ITERA Botanical Gardens are in the moderate forest health category based on existing forest health indicators.

Based on the research results, it shows that these four indicators can be used to assess the health condition of botanical garden ecosystems. This illustrates that through the indicators that have been researched it is hoped that it can become a further reference for assessing the health condition of botanical gardens. As explained in previous findings, the development of forest health indicators, in this case botanical gardens, is intended to measure and assess the level of forest health so that managers can know the health condition of the forest and what decisions should be made regarding this condition quickly and accurately [24]. Good botanical garden ecosystem conditions indicate a balance between the components that make up the ecosystem, both biological and physical [25]. Good ecosystem conditions must be maintained, considering that botanical gardens also have an important role as conservation areas. The existence of botanical gardens provides many benefits for the surrounding environment and society, where botanical gardens can also preserve springs [26]. The findings of this research can have implications for the management and conservation of botanical gardens. It is hoped that the botanical garden category is in the medium category. It is hoped that this can be an illustration that the management carried out is good enough, so that further management can be improved and managed more optimally to improve the health status of the forest to good or healthy as a form of botanical garden conservation effort.

It is important to know data and information from forest health monitoring results for consideration by the government or anyone authorized to manage botanical gardens in making appropriate management decisions. No exception, the role and contribution of botanical gardens in controlling climate change. The good health condition of a botanical garden can help create a good environment for its surroundings. Good canopy conditions can help speed up the CO_2 absorption process. In addition, the higher forest conditions produced can reduce the greenhouse effect and carbon [27]. The decisions in question include appropriate planning, management and silvicultural techniques as well as actions that need to be taken in botanical gardens with low ecological indicators. It is hoped that the existing data and information can help in achieving a sustainable and sustainable management system.

4. CONCLUSIONS

The ITERA Botanical Garden and the Liwa Botanical Garden Ecosystem have an average final score of 6.83 in the medium category. The value of each cluster plot is poor CL1 with a value of 6.18; poor CL2 with a value of 5.64; CL3 is good with a score of 7.89; and CL4 is good with a value of 7.61. This shows that the health condition of the ecosystem in botanical gardens in Lampung Province is quite good. It is important to always maintain and improve the health status of forests, considering that the existence of botanical gardens provides many benefits for the surrounding environment and society.

This research makes an important contribution to the management of botanical gardens, so that improving the health

status of botanical gardens is important for botanical garden conservation which can be done by caring for existing vegetation so that it will have an impact on its productivity, as well as increasing types and improving soil conditions. Therefore, there is a need for further observational studies and research related to forest health in more diverse zones in the Botanical Garden, so that the resulting data can be a definite and precise reference in cultivation and management activities of the botanical garden.

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