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The Strategic Role of the Purwodadi Botanical Garden Flora Collection in the Conservation of Indonesia's Biodiversity (KEHATI)

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A B S T R A C T

Indonesia as a megabiodiversity country faces serious challenges in conserving biological diversity (KEHATI). Ex-situ conservation through botanical gardens is an important complementary strategy. This study aims to identify the of plant species diversity in the Purwodadi Botanical Garden (KRP) and analyze the strategic role of KRP in the conservation of typical tropical dry lowland flora. The research was conducted descriptively over two months (March–April 2025) at the KRP scientific collection processing unit through an inventory of the flora collection based on a digital database and reception records analyzed according to species and number of individual plants in the collection, supported by a literature review. The inventory results showed that KRP manages more than 11,000 plant specimens of various Species across six environment area collection. In addition to conservation, KRP plays a role in research, education, ecosystem service provision, and developing innovations such as collection digitization and community engagement. This study concludes that KRP contributes significantly to national biodiversity conservation through an integrated ex-situ conservation approach combined with research and education

INTRODUCTION

Indonesia is categorized as a megabiodiversity country due to its priceless biological diversity. The Indonesian archipelago, stretching from Sabang to Merauke, is home to a variety of extraordinary ecosystems, including beautiful dry savannas, cold and misty mountain peaks, and dense tropical rainforests that are wet all year round. Each of these ecosystems is home to thousands of plant species, most of which are endemic species that cannot be found anywhere else in the world. The uniqueness and richness of Indonesia's flora is not only part of the nation's identity, but also has enormous scientific, economic, and social potential. However, Indonesia's biodiversity faces a number of serious threats. The survival of many plant species has been challenged by the high rate of deforestation caused by land conversion for infrastructure development, plantations, and agriculture, as well as the impact of global climate change. Global deforestation causes significant habitat degradation, threatening the survival of endemic and specialist species, and has the potential to reduce biodiversity and ecosystem stability in the long term (Jainuddin, 2023).

Conservation has become an important measure in addressing this KEHATI issue. There are two main methods of KEHATI conservation strategies: ex-situ conservation, which involves the preservation of KEHATI outside its natural habitat, and in-situ conservation, which involves the preservation of KEHATI in its natural habitat. In-situ conservation is the main method of plant preservation because it maintains KEHATI in its natural genetic and geographical centers. However, if this approach is not possible or needs to be supplemented, ex-situ conservation serves as a complementary strategy to increase the effectiveness of species preservation. Ex-situ conservation plays an important role in maintaining genetic diversity, providing genetic reserves when in-situ conservation fails, and supporting species propagation for restoration and utilization. Under certain conditions, this approach becomes the only option for conserving certain plant species combine into a shorter, more concise and clearer version (Lee, 2023). These two strategies work well together and are important for maintaining the sustainability of Indonesia's KEHATI.

Ex-situ conservation is an effort to preserve KEHATI components outside their natural habitat, which plays an important role in saving endangered plant species. This approach is carried out by transferring genetic resources to controlled locations, such as seed banks, botanical gardens, or living collections. Ex-situ conservation facilitates the recovery of wild populations, preserves germplasm, provides alternatives for natural resource utilization, and supports educational and research activities without disturbing natural populations. Various techniques are used, including cryopreservation, tissue culture, and other genetic storage methods, depending on the type of material and availability of resources (Mounce et al., 2017). In this case, botanical gardens play a central role by developing and maintaining collections of native species, as well as providing plant stocks to support ex-situ conservation and sustainable plant use.

Botanical gardens are strategic locations for various fields of scientific research. In addition to serving as centers for taxonomic and systematic studies, botanical gardens are also important sources of ecological data such as phenological information as indicators of climate change, plant physiology and

growth strategies, and interactions between plants and animals. The diverse species collection in botanical gardens allows for the analysis of plant functional characteristics, including studies on the trade-off between specific traits and plant performance (Chen & Sun, 2018). In this context, botanical gardens are at the forefront of ex-situ plant conservation in Indonesia.

Purwodadi Botanical Garden (KRP), strategically located in East Java, plays an important role in the conservation of flora typical of unique and highly valuable dry lowland forest areas. KRP was established on January 30, 1941, in response to the need for conservation of dry lowland plants in Indonesia, which could not be optimally carried out at the Bogor and Cibodas Botanical Gardens. Located in Pasuruan, East Java, and now managed by BRIN, KRP covers an area of 85 hectares with 183 plant collection plots based on family. As a branch of the Indonesian Botanical Gardens, its main functions include ex-situ plant conservation, research, education, and the preservation of rare species from tropical dry ecosystems. Since opening to the public in 1963, KRP has continued to develop through collection strengthening, facility development, and genetic resource exchange, with a vision of becoming a center of excellence for the conservation and research of dry lowland plants in Indonesia (Putri et al., 2023). Through various conservation and research initiatives, KRP plays an important role in preserving the unique flora of Indonesia's dry lowland forest areas, while supporting the development of science, environmental conservation, and sustainable community welfare.

LITERATURE REVIEW

Information on plant diversity at KRP and its strategic role in addressing conservation challenges is still relatively limited. Therefore, this study was conducted to collect data on the diversity of plant species conserved by KRP. The results of this study are expected to serve as a basis for plant collection management, conservation strategy development, and KEHATI conservation efforts in the region.

METHODOLOGY

The research was conducted over two months (March–April 2025) at the KRP scientific collection processing unit. This research was descriptive in nature, starting with the inventory of all flora collection data based on the database, followed by data tracing through the database in the collection database Excel file and rechecking the data with reference to the plant receipt records. The results were then analyzed based on plant species, genus, and origin, as well as a literature search on the diversity of the species collection.

This study was conducted by observing the distribution of flora in each environment within the Purwodadi Botanical Garden (KRP). To provide a visual representation of the location of the flora environment area collection in KRP, the distribution map of the environmental area is presented in Figure 1.

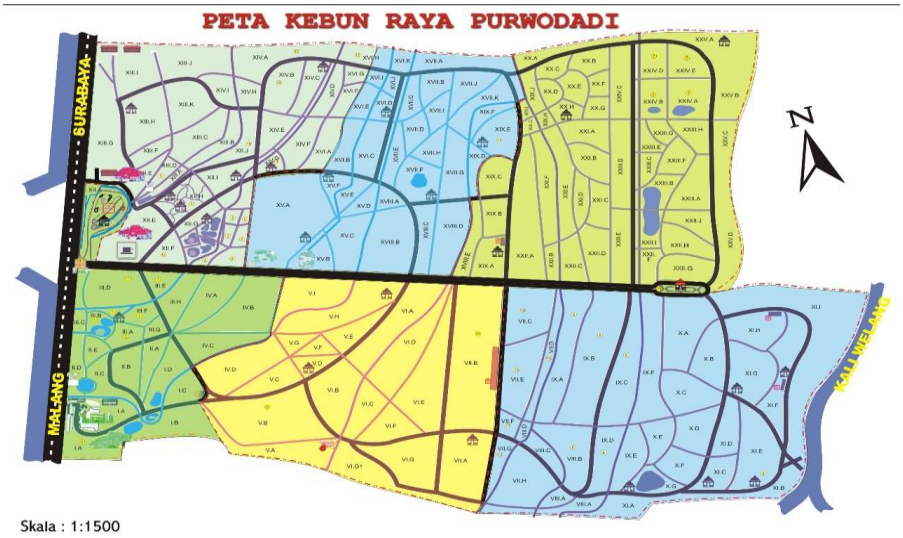

Figure 1. Distribution of Flora Environments Area Collection in Purwodadi Botanical Garden (KRP)

The data obtained was then analyzed descriptively and processed into tables and graphs, enabling the identification of plant types and individual counts.

RESULTS AND DISCUSSION

Flora Collection as a Representation of Biodiversity

Purwodadi Botanical Garden (KRP) manages more than 11,000 live plant specimens from 2,000 species, including Fabaceae, Orchidaceae, Zingiberaceae, and Lamiaceae, which have high ecological and economic value (Sulistiani et al., 2020). The featured collection includes medicinal plants, tropical fruits, and species endemic to East Java and Nusa Tenggara. These plants are stored and cared for in thematic collections such as orchid gardens, palm gardens, and greenhouses specifically for rare plants (Purnomo et al., 2015). KRP conservation efforts also include research and mapping of rare plants to preserve biodiversity (Hidayah et al., 2020).

KRP is one of the ex-situ conservation centers that plays an important role in preserving Indonesia's KEHATI, especially flora from dry lowland forest areas such as East Java, Nusa Tenggara, Sulawesi, and Maluku. As part of these conservation efforts, KRP manages plant collections in various thematic environments or zones, each of which houses different types of plants and varying numbers of individuals. In its management, KRP divides its collection area into six environment area collection, as shown in Table 1. This garden organizes its collection according to plant relationships and has a total of 2,472 plant species in its collection, making it one of the centers for dry lowland tropical plant conservation in Indonesia.

Table 1. Division of the Six Environment Area of the Purwodadi Botanical Garden

Environment	Location (Plot)	Number of Plant Species
1	I.A,B,C,D II.A,B,C,D,E III.A,B,C,D,E,F,G,H IV.A,B,C XII.A	468
2	IV.D V.A,B,C,D,E,F,G,H,I VI.A,B,C,D,E,F,G VII.A,B	332
3	VII.C,D,E,F,G,H VIII.A,B,C,D IX.A,B,C,D,E,F X.A,B,C,D,E,F,G XI.A,B,C,D,E,F,G,H	114
4	XII.A,B,C,D,E,F,G,H,I,J XIII.A,B,C,D,E,F,G,H,I,J,K XIV.A,F,G,H	687
5	XV.A,B,D,E,F XVI.B,C,D,E,I,J,K XVII.A,B,C,D,F,G,H,I,J,K	360

Environment	Location (Plot)	Number of Plant Species
	XVIII.A,B,C,D XIX.D,E,F	
6	XVIII.E XIX,A,B,C,G,H,I,J XX.A,B,C,D,E,F,G,H XXI.A,B,C,D,E,F XXII.A,B,C,D,E,F,G,H,I,J XXIII.A,B,C,D,E,F,G,H XXIV.A,B,C,D,E XXV.A,B,C,D	511

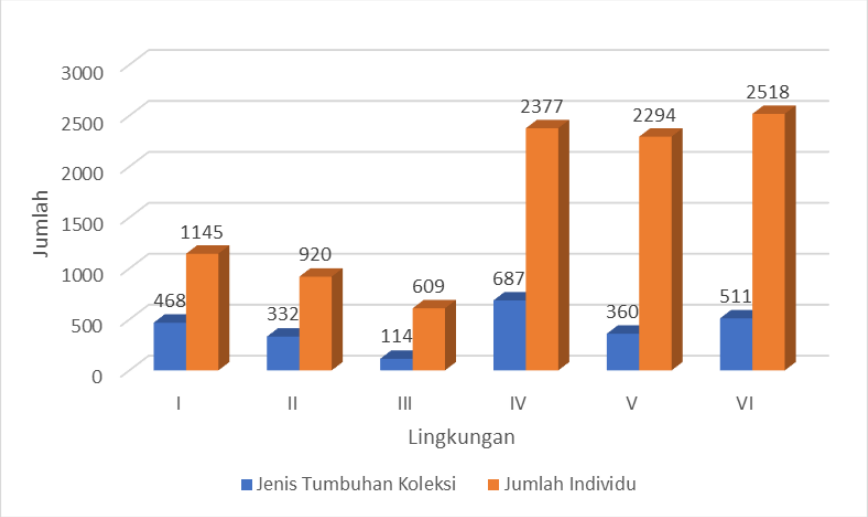

Figure 2. Graph of Speceis and Individuals Number in the KRP Flora Collection

Based on the data shown in the graph of the types and number of individuals in the KRP flora collection, there are six main environments that make up the structure of the collection in KRP, namely Environment I to Environment VI. Each of these environments shows the characteristics of the number of plant species in the collection and the total number of plant individuals collected, which directly reflects the intensity of conservation and taxonomic focus in each area.

Environment I has 468 species of plant collections with a total of 1,145 individuals. This figure shows that this environment has a fairly high level of species diversity compared to other environments such as Environments II and III. The number of individuals is also quite large, indicating that many species in this environment are collected in relatively more than one, allowing for redundant conservation as well as morphological and ecological adaptation observations (Smith, 2019).

Environment II collected 332 plant species with 920 individuals. This number is slightly lower than Environment I in terms of both diversity and population. This may indicate that this environment focuses on collecting plants

that require more growing space or may contain taxa that are rarer and more difficult to propagate vegetatively.

Environment III recorded the lowest numbers among all environments, with only 114 plant species and 609 individuals. The low number of species and individuals in this environment may indicate that the area has limited land area or that conservation efforts in this area are focused on very specific species that may be difficult to grow in ex-situ conditions. However, each individual collected is still important for conservation, especially if the species is endemic or endangered.

Environment IV shows very high numbers in the collection, with 687 plant species and 2,377 individuals. This is the environment with the highest number of species collected from all existing environments. This data shows that Environment IV is the center of the highest diversity in KRP. The high number of individuals reflects an intensive conservation strategy and the possibility of breeding efforts to maintain the survival of the species. This diversity may include plants from various regions with diverse ecological characteristics, indicating successful adaptation and good planting environment management.

Environment V contains 360 plant species with 2,294 individuals. Interestingly, although the number of plant species is not as high as in Environment IV, the number of individuals is almost equivalent. This suggests that some species in Environment V may be collected in very large numbers, either because of their high conservation value, good reproduction rates, or as an effort to provide sufficient material for research and education.

Environment VI has 511 plant species and 2,518 individuals, making it the environment with the highest number of individuals of all environments. Although it does not have the highest number of species, the abundance of individuals reflects a focus on developing strong populations for each species collected. This is important in conservation because it increases the likelihood of species survival in the long term and provides sufficient genetic resources for reintroduction or further research.

Overall, the distribution patterns of species and individual numbers in each environment indicate different conservation strategies in KRP. Enviroment area with high diversity (such as IV and VI) show a comprehensive conservation approach to many taxa, while environment area with high numbers of individuals but fewer species (such as V and VI) show a conservation approach that emphasizes strengthening the populations of certain species (Apriliani et al., 2024). Conversely, environments with low numbers of species and individuals (such as III) may be focused on exclusive collection or growth experiments of very rare species (Marista et al., 2022). These differences not only reflect the ecological diversity within the KRP collection, but also show that conservation management there is carried out adaptively and based on a scientific approach in accordance with the characteristics of each species and conservation needs (Smith, 2019). KRP preserves a variety of plants that are unique to Indonesia. Among the notable collections are lotus flower (Nelumbo nucifera), kapok tree (Ceiba pentandra), and slipper orchid (Paphiopedilum glaucophyllum), as

shown in Figure 3, which represent endemic plant groups and have significant conservation value (KRP Collection Catalog, 2012).

Figure 3. *(a) Paphiopedilum glaucophyllum* (b) *Nelumbo nucifera* (c) *Ceiba petandra*

The results of the study show that each species has high appeal in terms of both aesthetics and ecology. Nelumbo nucifera has large flowers with a blooming period of several days and displays a unique pollination mechanism, namely protogyny and the involvement of different pollinators, such as nocturnal beetles and bees, making it visually and biologically attractive (Hirthe & Porembski, 2003). Ceiba pentandra displays large flowers that bloom at night with abundant nectar production, playing an important role in supporting pollination activities by bats. This characteristic not only adds aesthetic value to the landscape, but also provides a vital ecological function as a food source for nocturnal animals (Nathan et al., 2005). Meanwhile, Paphiopedilum glaucophyllum is known for its unique slipper-shaped flower morphology and striking colors. Flowers in this genus have a relatively long flowering period due to anatomical adaptations that reduce water loss. This uniqueness gives Paphiopedilum high horticultural value, but also makes it vulnerable to overexploitation, prompting various studies focused on conserving its population and natural habitat (Zhang et al., 2021; Romadlon et al., 2021).

The Strategic Role of in KEHATI Conservation

The role of botanical gardens in Indonesia is increasingly significant, not only as a means of education and tourism for the community, but also as a starting point for various research and innovation activities. This role supports the sustainable use of natural resources and contributes to increasing the national economic value. In addition to their main functions in conservation and education, botanical gardens also provide important ecosystem services such as green open spaces, urban lungs, oxygen producers, and water catchment areas that can collect rainwater and replenish groundwater reserves in the surrounding area. These ecological values need to be widely communicated to policymakers and the general public. In its development, botanical gardens also function as centers for the development of regional botanical garden networks, making them a key element in national conservation strategies (Irawanto, 2024).

Botanical gardens that serve as centers for ex-situ conservation play an important role in protecting endangered plant species through the management of living collections and seed banks. This conservation is crucial in the face of threats such as deforestation, climate change, and overexploitation that threaten the survival of many plant species. Botanical gardens also function as centers for

scientific research, facilitating studies in the fields of taxonomy, ecology, plant physiology, and biotechnology (Borsch & Lohne, 2014). Botanical gardens play an important role as locations for scientific research, including studies on plant ecology, climate change, physiology, and plant-animal interactions. Botanical gardens provide a variety of species for studying the functional trade-offs between species traits and plant performance. In addition, botanical gardens are ideal for research on pollination, seed dispersal, and other ecological interactions (Girmay, 2023).

Based on a review by Krishnan and Novy (2017), 21st-century botanical gardens have several main functions, including as a location for the acclimatization of exotic plants, a resource for taxonomic research, and a source of germplasm for the hybridization of superior plants. Botanical gardens also support the conservation of endangered plants, provide propagation facilities, and play a role in the commercialization of globally important plants. In addition, botanical gardens serve as training centers for conservation and horticulture, as well as recreational centers with aesthetic value. In this context, KRP is an important research institution, particularly in the conservation of flora typical of dry lowland forest areas. The flora collection is an important resource for studies on physiological adaptation to drought, biochemical potential, and pharmacological applications. The results of this research contribute significantly to the development of tropical botany and global biodiversity conservation.

Another important role of botanical gardens, apart from their scientific function, is as a means of public education. Through direct visits, the public can enjoy the beauty of the garden landscape while gaining knowledge about the importance of plant conservation. The educational programs offered by botanical gardens cover various age groups, from students to the general public, and are an important means of building environmental awareness. By educating and involving the public, botanical gardens encourage a sense of responsibility for environmental protection (Mounce et al., 2018; Edwards & Jackson, 2019). The plant collection at KRP also has great potential to directly support environmental research and education. One of its outstanding collections is aquatic plants arranged in thematic gardens, which not only have aesthetic value but also function in phytoremediation or water quality restoration through pollutant absorption. The ponds in KRP, which are scattered in various areas, serve to collect water from irrigation and drainage. This makes the aquatic plant collection relevant as an educational model for aquatic ecosystem restoration (Irawanto, 2024).

Botanical gardens serve as strategic information centers on the importance of plant conservation. Direct interaction between the community and botanical gardens can foster environmental awareness, which is key to the success of conservation programs (Irawanto, 2023). Overall, the role of the flora collection at KRP cannot be separated from KEHATI's national conservation strategy. As part of the ex-situ conservation system, KRP complements in-situ efforts carried out in protected areas. The data and knowledge generated through research at KRP also strengthen evidence-based conservation policy-making. Collaboration between in-situ and ex-situ conservation with KRP as one of the main actors in

the preservation of tropical dry flora is key to preserving Indonesia's biodiversity for future generations.

Digitalization and Data Access

Purwodadi Botanical Garden (KRP) has implemented strategic steps as an adaptation effort to the increasingly complex challenges of KEHATI due to global dynamics and technological developments. One of the key strategies implemented is the digitization of its flora collection. Digitization is the process of converting media from print to electronic format (Asaniyah, 2017). This is done to strengthen its role as a plant conservation center. This digitization is not merely a transfer of data from physical to digital format but is part of an institutional transformation towards more open, structured, and integrated scientific data management. KRP has developed and uses the Makoyana website as a medium to document and distribute information about its flora collection. This platform functions as a botanical garden collection data management information system that presents various information related to biodiversity (Apriyanto, 2022). Through this site, data from thousands of plant specimens that have been collected and conserved ex situ are presented in a systematic and informative manner.

Figure 4. Map of Botanical Garden Distribution in Indonesia on the Makoyana BRIN Platform

The map of botanical garden distribution in Indonesia displayed through the Makoyana BRIN platform (https://makoyana.brin.go.id) shows a wide and even distribution across various regions, from Sumatra to Papua. The highest concentration is seen on the island of Java, reflecting the high level of research and educational activity in the region. This distribution reflects the strategic role of botanical gardens as an ex-situ conservation network that supports the preservation of local flora, environmental education, and scientific research (Edwards & Jackson, 2019). Integration through the Makoyana system also strengthens collaboration and data-driven policy-making to support national biodiversity conservation.

The Makoyana website provides a range of important information about each specimen, such as its scientific name, family, geographical origin,

morphological description, natural habitat, conservation status (e.g., whether it is classified as endangered or not), and photographic documentation of specimens in the field and in botanical gardens. The data documented through this technology-based approach is very useful in supporting policy formulation at the national level, particularly for the Ministry of Environment and Forestry regarding flora conservation, economic development, and global political dynamics. The data also plays an important role in research activities at the national and international community levels. KRP provides open and easily accessible data to the public so that it can be used by researchers, students, environmentalists, and policy makers to conduct various scientific studies and strategic analyses (Apriyanto, 2022). Thus, digitization and data access through the Makoyana website marks a new chapter in the management of botanical gardens as centers for conservation, research, and education. This step is in line with the spirit of scientific, participatory, and future- oriented biodiversity conservation

Conservation Challenges at KRP

Purwodadi Botanical Garden (KRP) is one of three botanical gardens in Indonesia specializing in the conservation of dry lowland plants and plays an important role in the preservation of biodiversity outside its natural habitat or ex-situ (Riska et al., 2020). Established in 1939 and housing a collection of more than 5,000 plant species on 85 hectares of land, this botanical garden performs a dual function that includes research and conservation activities, as well as providing educational, nature, and recreational tourism facilities (Farada et al., 2020; Riska et al., 2020). Despite its diverse and important role, conservation efforts at KRP are not without challenges that require solutions to ensure its sustainability (Apriliani et al., 2024).

One of the main challenges faced is how to maintain the right balance between essential conservation functions and increasing demand for tourism and recreation (Asmoro & Yusrizal, 2021; Yuanjaya, 2021). The increase in the number of visitors to botanical gardens has the potential to have a negative impact on the preservation of valuable plant collections if management is not carried out optimally and sustainably (Yuanjaya, 2021). Therefore, enforcing existing regulations, such as maintaining the cleanliness of the botanical garden area and prohibiting destructive actions or the removal of flora and fauna, is crucial to minimize the potential negative impacts of tourism activities (Asmoro & Yusrizal, 2021). In addition, success in maintaining a diverse plant collection, conducting sustainable research, and developing supporting facilities for educational tourism is highly dependent on the availability of adequate resources (Kehutanan et al., 2014; Apriliani et al., 2024).

Global climate change and the threat of invasive species are also significant challenges faced by botanical gardens (Gunawan et al., 2011; Rahayu & Badiah, 2021). Climate change can affect the growth, reproduction, and even survival of various plant species in botanical garden collections, while invasive species can disrupt the balance of ecosystems and threaten native biodiversity around conservation areas (Gunawan et al., 2011; Rahayu & Badiah, 2021). Thus, research focusing on adaptation to climate change and efforts to control invasive

species is very important to ensure the long-term conservation function of botanical gardens (Gunawan et al., 2011). To effectively address these complex conservation challenges, strong collaboration with various parties is needed, including other research institutions, local governments, and active participation from the wider community (Falah, 2013; Purnomo et al., 2013; Ekoputro et al., 2024).

In addition to challenges related to ecology and conservation, KRP also faces bureaucratic challenges arising from its integration into the National Research and Innovation Agency (BRIN) (Marista et al., 2022). One of the issues that has arisen is the structuring of human resources, where the placement of employees is not always in line with their scientific fields or competencies (Marista et al., 2022). Furthermore, there has been a shift in the focus of KRP management, which includes the separation of research and collection functions from education and tourism functions, which are now managed by the private sector (Marista et al., 2022). Overall, KRP faces diverse and interrelated challenges, including KEHATI conservation efforts, sustainable tourism management, and adaptation to organizational changes and broader environmental dynamics.

Innovation and The Future of KRP Conservation

Purwodadi Botanical Garden (KRP) has thousands of plant species in its collection that need to be maintained and protected from various threats originating from biotic and abiotic factors, thus requiring targeted and responsive sustainable efforts to various environmental changes (Ningrum, 2020). KRP has several strategic steps that can be taken to address the challenges of KEHATI conservation in an era of climate change, habitat degradation, and development pressures.

One strategy that can be implemented is to strengthen collaboration between divisions within the garden to carry out educational programs for visitors. The purpose of this education is to raise public awareness about the importance of plant conservation and encourage them to make wiser choices in using natural resources (Edwards & Jackson, 2019). Through an integrated approach, visitors not only gain a recreational experience but also gain a better understanding of their role in protecting KEHATI.

The involvement of local communities is also a step in conservation efforts. Communities around botanical gardens can be involved in plant management, environmental preservation, and biodiversity protection through various empowerment programs (Edwards & Jackson, 2019). This involvement not only strengthens the effectiveness of conservation but also builds a sense of responsibility and ownership of the local ecosystem. By combining public education and community participation, botanical gardens can achieve sustainable and inclusive conservation.

These steps can be supported by increasing the capacity of human resources (HR), from KRP employees and volunteers, which will be fundamental. Human resources are a combination of the intellectual and physical abilities possessed by each individual. Their character and behavior are influenced by genetic factors and the surrounding environment, while their performance is driven by the desire to achieve personal satisfaction. The selection and

maintenance of superior and high- quality HR requires the direct involvement of HR, which greatly influences the achievement of success and the implementation of the vision, mission, and objectives of plant conservation at KRP. HR development in KRP is carried out through various types of training, including skills training, general training, and training focused on character or personality development (Adawiyah & Dayat, 2019).

CONCLUSION AND RECOMMENDATION

Purwodadi Botanical Garden (KRP) plays a strategic role in the conservation of Indonesia's biodiversity through an ex- situ approach, especially for flora typical of tropical dry regions. With a collection of more than 11,000 specimens of various species and families. KRP is an important center for preservation, education, and scientific research. The varied distribution of the collection across six environment areas demonstrates an adaptive and science-based conservation strategy. Conservation challenges such as tourism pressure, climate change, and institutional integration are addressed with innovative measures such as digitizing the collection through the Makoyana platform and involving local communities. Increased human resource capacity and collaboration among stakeholders are key to supporting sustainable conservation functions at KRP. These efforts strengthen KRP's contribution as a national conservation center oriented towards sustainability and ecosystem empowerment. This study concludes that KRP contributes significantly to national biodiversity conservation through an ex- situ approach integrated with research and education.

FUTHER STUDY

This research still has delays, so it is necessary to conduct further research related to the topic The Strategic Role of the Purwodadi Botanical Garden Flora Collection in the Conservation of Indonesia’s Biodiversity (KEHATI) in order to improve this research and add insight for readers.

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