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The Development of Real-time Monitoring and Managing Information System for Digitalization of Plant Collection Data In Indonesian Botanical Garden

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ABSTRACT
In the last 2021, Indonesia has had 43 botanical gardens with more than 104.000 specimens that are collected in the Indonesian Botanical Garden. 152 species of them are in threatened condition based on The International Union for Conservation of Nature's Red List of Threatened Species (IUCN) data. To conserve the floras and exploring them for other purposes such as science development, economic development, and medicine development, the stakeholders including the Indonesian government find it difficult to access the real-time data and information. Indonesia does not have a connected system at the national level that can provide real-time data from all botanical gardens in Indonesia for monitoring and managing the specimens. Some botanical gardens have tried to develop their system to maintain and monitor plant collections. However, without a national connected system that is implemented in all Indonesian gardens, it raises new issues such as long-time collecting data process, inaccurate data, different mechanisms to treat data and different business processes to maintain the plant collections. The purpose of this study is to develop a system, named Makoyana, that can address the issues and provide real-time monitoring and managing information for plant collection at the national level. Software Development Life Cycle (SDLC) and Software Testing Life Cycle (STLC) methodologies are combined to manage the project. The outcomes of this study are the system that provides one gateway platform for stakeholders to find all information about plant collections data, IUCN status, updated statistics, and a national standard for maintaining and collecting data for plant collections in the Indonesian Botanical Garden.

Keywords: Indonesian Botanical Garden, Makoyana, Plant collections, real-time monitoring system, plants conservation.

Introduction

Indonesia is a tropical archipelago country that is also known as a mega biodiversity country. According to Kusmana and Hikmat [1], Indonesia is the 7th biggest country in the diversity of flora. 25% of flowering plants in the world can be found in Indonesia. 40% of them are endemic to Indonesia. At least, there are more than 35.000 species that have grown in Indonesia [2]. However, IUCN states that in 2013, 404 species of flora in Indonesia, are in the threatened category field [3]. It consists of 115 species of critically endangered, 77 species of endangered, and 212 species of vulnerable. It is believed that in wild nature, the number of threatened species is more than the IUCN's data. According to Purnomo, et al. [3], as a part of the international community, Indonesia has a responsibility to conserve the flora.

The botanical garden is a solution to solve flora conservation issues. The Indonesian Government already issued a policy regarding the development of botanical gardens. It can be discovered in presidential decree no.93 the year 2011. It states that the Indonesian botanical garden has some responsibilities to develop plant collections, maintains plant collections, conserves plant collections, and develop a database about the plant collections [3]. The government has developed 43 botanical gardens that consist of 5 botanical gardens under the National Research and

Innovation Agency (BRIN), 36 botanical gardens under regional government management, and 2 botanical gardens under the universities management [4]. However, the Indonesian Botanical Garden still struggles with digitalisation and data management at the national level. The plant collection data from Indonesian botanical garden is an essential aspect to support conservation, generating policies, and improving economic sector.

In some countries, there are some researches about digitization data in the botanical garden. In the New York Botanical Garden, a study about digitization data has been initiated in 1995 [5]. They already digitalised more than 1.4 million specimens and the data has been shared on the website and data sharing portal. In 2017, the herbarium collection in Central Siberian Botanical Garden (CSBG), Russia, also was generated in digitization data. According to Kovtonyuk, et al. [6], CSBG has digitized more than 12500 specimens that are stored in the CSBG database. In the Czech Republic, Botanical Information System BotanGIS was implemented to provide information about plants in botanical gardens and flora conservation. Dobesova, et al. [7] state that the system was generated to empower the botanic educational process at the University.

In Indonesia, Indonesian Botanical gardens face some issues in the digitalisation process and data management. First of all, plant collection data from all Indonesian botanical gardens are not accessible to stakeholders. For instance, when stakeholders from the government or parliament need data about flora biodiversity in the Indonesia botanical garden, it needs more time and effort to gather the data from each botanical garden. This situation can disturb the process of policy development regarding Indonesian flora biodiversity or other issues related. It is caused by the system that is not available at the national level that can be implemented to help all Indonesian botanical gardens for maintaining plant collections and developing plant collections data. Secondly, there is no integration of data at the national level generating a lack of accuracy, consistency, and efficiency in processing and accessing data. It is caused by the monitoring and controlling of data management that is not effective and efficient. The source of the issue is that there is no standard business process for plant collections management and the differentiation of interpretation of the main procedure for the management of specimens provides a gap among Indonesian botanical gardens. Consequently, every botanical garden develops its own information system with no standardisation in business processes and data structure. For instance, In Cibodas Botanical Garden, the system named SINDATA was developed to manage plant collections data management with climate data and spatial data [8]. In 2016, Purwodadi Botanical Garden also developed Sikatan to manage data in the registration division [9]. Bogor botanical gardens also developed Lakasi to cover data management. As the result, the systems are not integrated, inconsistent with each other, having different business process models, having different data structures, and being hard to be monitored. To solve the issues, Indonesian botanical gardens need to develop an integrated information system at the national level that can be implemented in all Indonesian botanical gardens. So, stakeholders can be easy to access the data and monitor the update of information about plant collections in all Indonesian Botanical Gardens. In addition, an information system can help organisations to develop a standard business process. It is caused by an information system that is developed from a business process model that has been implemented in the organisation [10]. Secondly, this system needs to be implemented in the cloud platform. According to Hallmans, et al. [11], the Cloud platform has some advantages such as resource sharing, user interaction, data sharing, software updates, life cycle, and provider independence. It means that the data from all botanical gardens will be stored in a national database. All data movement can be directly monitored by the system. Thus, real-time information about plant collection data and IUCN red list status can be monitored by the system. In addition, the information system will be easy to be maintained and be implemented because of the integrated system that will be maintained on a server at the national level. An integrated system will provide holistic information for stakeholders in the organisation that will be useful to generate a business strategy [10].

Related to the above, this study developed Makoyana (Manajemen Koleksi Kebun Raya Indonesia) as a new integrated system to address the issues. Firstly, Makoyana has been developed to digitalise plant collection data and the system is able to be accessed by all Indonesian botanical gardens that are already registered in the system. The system is installed in the cloud platform and provides real-time monitoring and managing of plant collection data. Furthermore, business process and data management for plant collection in Indonesian botanical gardens are standardised by the system that is generated from accommodating all existing business processes in Indonesian botanical gardens. Moreover, the integrated data in the system is matched with the IUCN red list data and World Flora Online (WFO) data to provide a standardised name for plant collections data.

Theoretical framework

Information is useful knowledge that is produced from the data [12]. In the Indonesian Botanical Garden, information about plant collections is generated from daily data management and plant collections data. This information is needed by some stakeholders such as the president, ministries, researchers, private sectors, and universities for developing policies, products, and other purposes. According to Ameen, et al. [13], the quality of information depends on the organisation of data, accuracy, accessibility, updatable information, and usefulness. To provide good quality information from botanical gardens' data, an information system should be developed at the national level. An information system is developed based on the same business process and objectives[14]. Hence, the national system should be implemented to provide a national standard procedure, business process, and integrated data. A new system that can be accessed and operated by all Indonesian botanical gardens should be developed to replace the existing system in each botanical garden.

The complexity of the development process in this project is high. The variety of stakeholders and the complexity of the business process needs appropriate method to develop the system. Software Development Life Cycle (SDLC) and Software Testing Life Cycle (STLC) methodology are appropriate to be implemented. The SDLC methodology is implemented to manage the system development process and STLC is used for quality assurance to maintain the quality of project outcomes. According to Singh and Kaur [15], SDLC provides a systematic manner in the development of software and assures the products will meet the requirements. It can guarantee that all requirements from stakeholders can be accommodated in the new system and the integration process in the new system can address the issues related to the lack of data accuracy, no standard business process, and data management. SDLC contains a set of activities from the design of the system until the maintenance process. In addition, According to Dicky, et al. [16], STLC is effective to minimise the risk that is caused by a misstep in the development process. STLC can maintain the quality of the outcome products. It is useful to keep the process of development following the development plan.

Method

In this research, SDLC will be implemented to manage the project in the development proces. According to Shylesh [17], there are 6 general steps in the SDLC methodology which are:

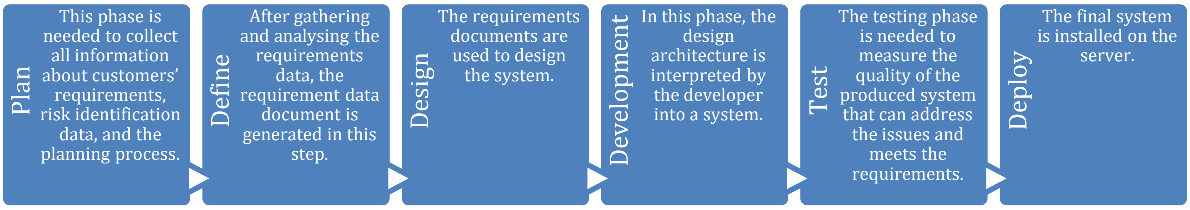


Figure 1. Six Phases in SDLC Methodology

SDLC methodology can be divided into some models such as the waterfall model, iterative model, and spiral model. In the spiral model, the mechanism is quite different. This model allows the development of prototypes and it is suitable for complex projects that demand regularly communication for updating requirements [17]. For developing a big system that has complex business processes, the spiral model can accommodate the project's needs. Hence, the spiral model was implemented in this research project.

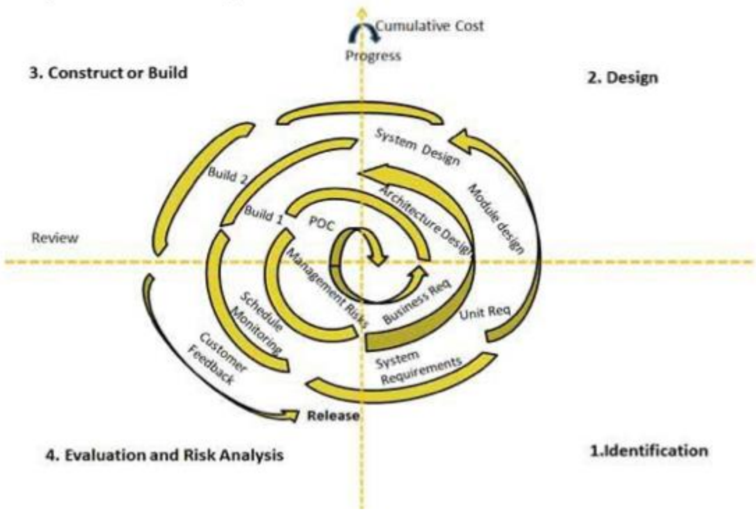


Figure 2. SDLC Spiral Model

To maintain the quality of the project's outcome, Software Testing Life Cycle (STLC) methodology is adopted in this project. There are six phases in STLC which are:

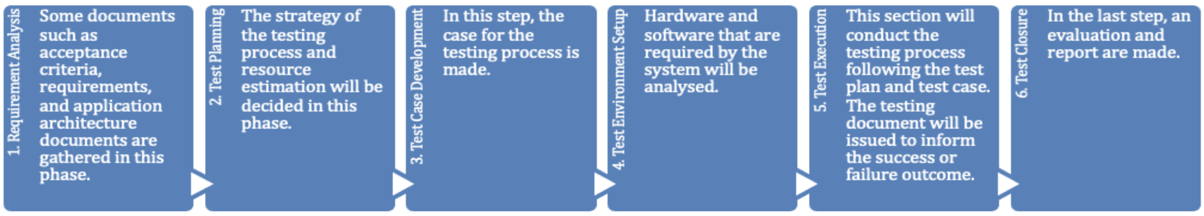


Figure 3. STLC Diagram Model

Results and Discussion

A. Result

The new system is designed to replace the function of the existing system in every Indonesian botanical garden. Every botanical garden can access the new system to operate and manage its own pages. The data in this system is stored in a database to make it easy the maintenance and integration data. Hence, all requirements and data from stakeholders should be gathered. This data is confirmed with the users in the gathering requirements session. The analysis phase results are used to generate the first design of the future system.

1. Analysis of the existing business process

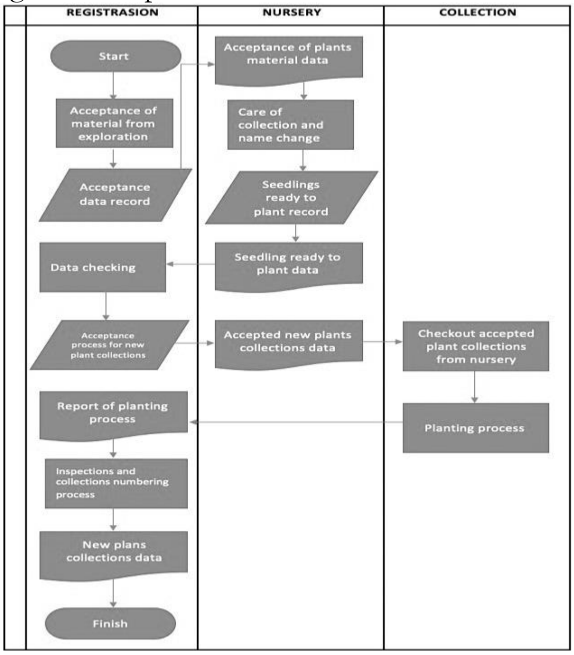


Figure 4. The Existing Business process in the Indonesian Botanical Garden

Business process management relates to the quality of an organisation to provide a great performance [18]. Thus, the existing business process is the essential main data to develop a proper information system.

The existing business process data has been gathered from interviews with internal users and discussion forums with Indonesian botanical gardens communities. According to the analysis of the existing business process, the backend system that is used to manage all data will be developed in some group services based on the roles which are:

a. System Administrator
A system administrator manages main data such as the master role module, master group menu module, user access module, and role menu module.

b. National Administrator
The national administrator manages all transaction modules at the national level such as the user access module for botanical garden administrator (registration, nursery, and collections), Province data, spatial data, IUCN category data, collector data, and type of acceptance data.

c. Registration
The registration division has the responsibility to manage more than 16 transaction modules. They are collector data modules, exploration data modules, vak data modules, spatial data modules, acceptance data modules, verification of planting requests, verification of number requests, verification of seeds name changes, Index Seminum Module, verification of relocation module, verification of death collections, historical transaction data, plants collections data, and verification of new number from relocation.

d. Nursery
Nursery is a division that is responsible to manage new material plants from exploration and care of seeds.

e. Collections
The collections unit has responsibilities to plant, manage, and record all data about plant collections.

2. System Design and Architecture

The system design and architecture phase are a bridge between the data analysis stage and the development process. According to Udi [19], the design database, design interface, and system architecture are generated from analysed data in the system design process.

a. Use case diagram of the public homepage

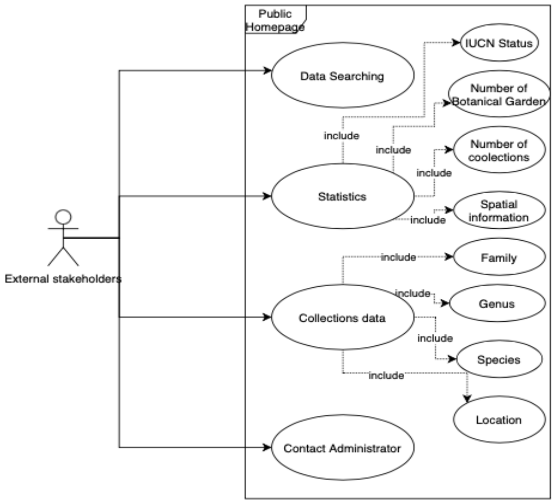


Figure 5. The Existing Business process in the Indonesian Botanical Garden

b. Use case diagram of administrator homepage

In the Backend system, some roles handle some modules such as system administrator, national administrator, nursery, registration, and collections. Use case diagram of the administrator can be seen below:

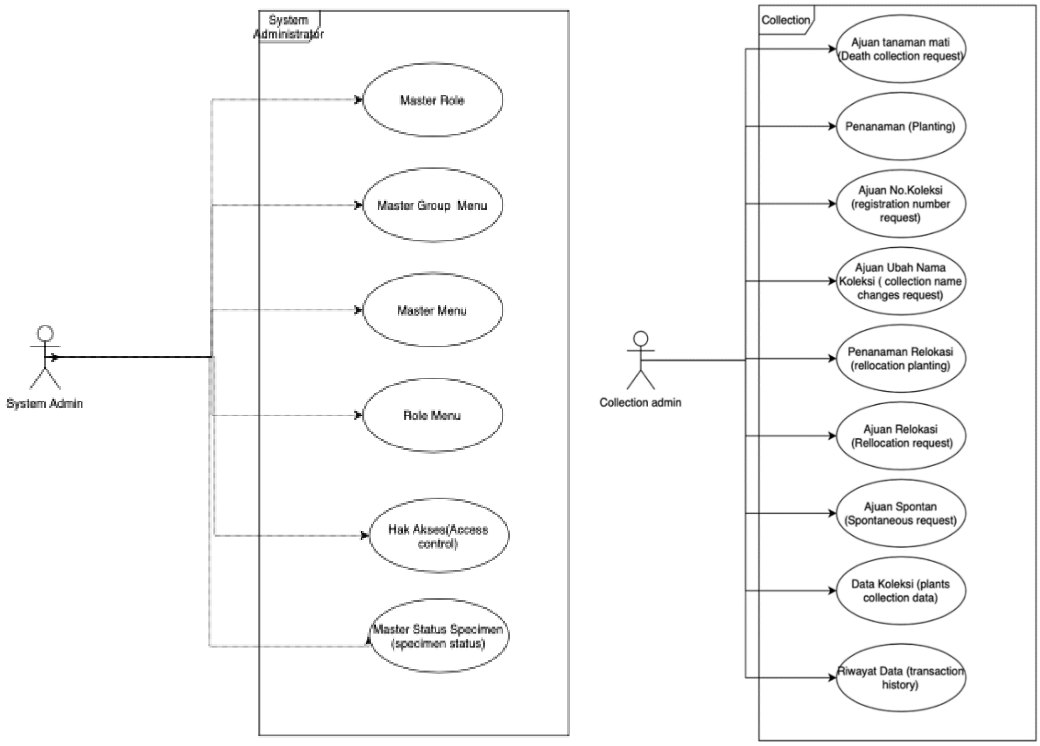


Figure 6. Use case diagram of administrator homepage (1)

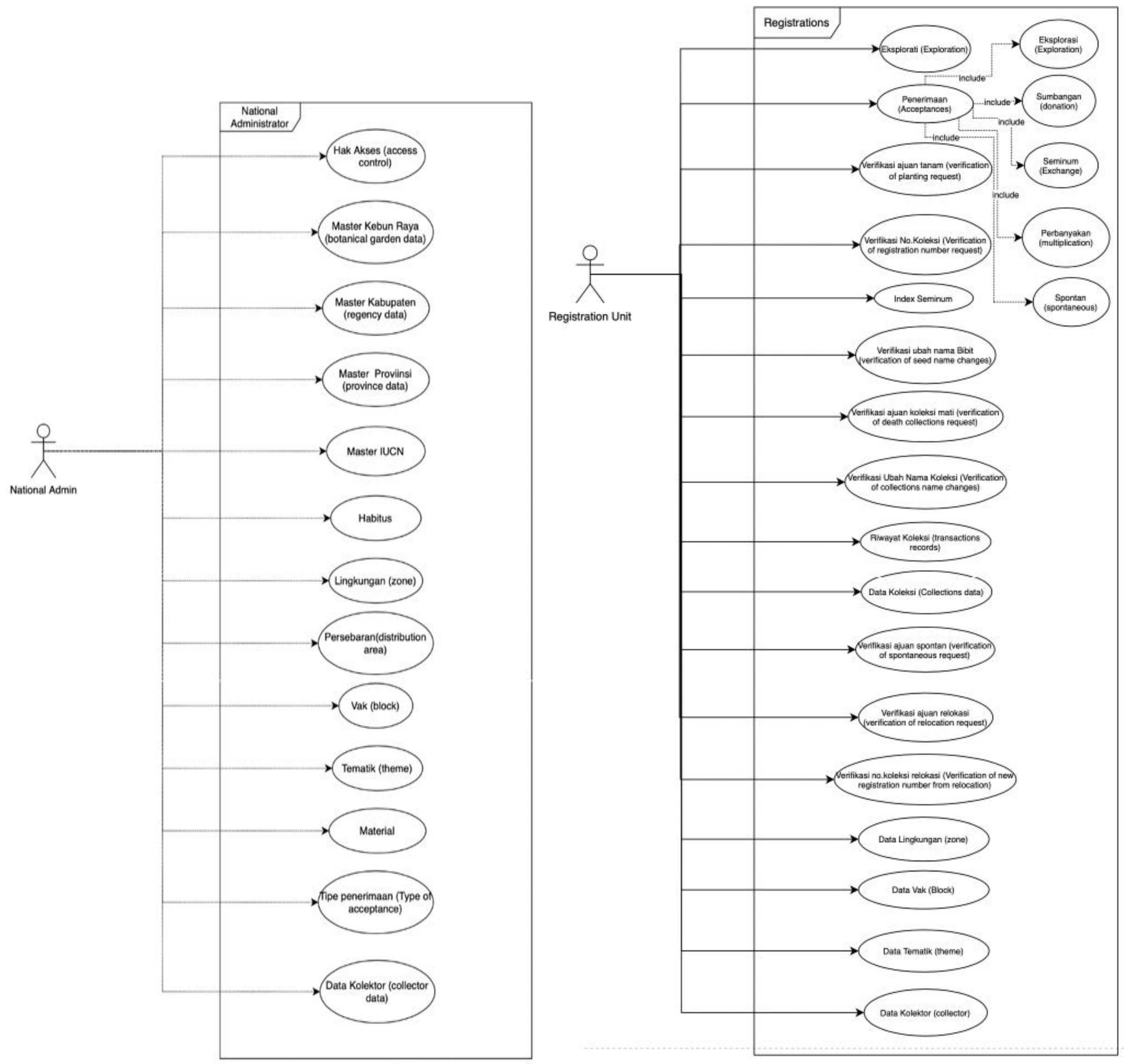


Figure 7. Use case diagram of administrator homepage (2)

c. System Architecture

The system will be deployed in the cloud platform. Cloud platforms provide an easy way to access and maintain the system. It also supports national integration data for plant collections data in Indonesian Botanical Gardens.

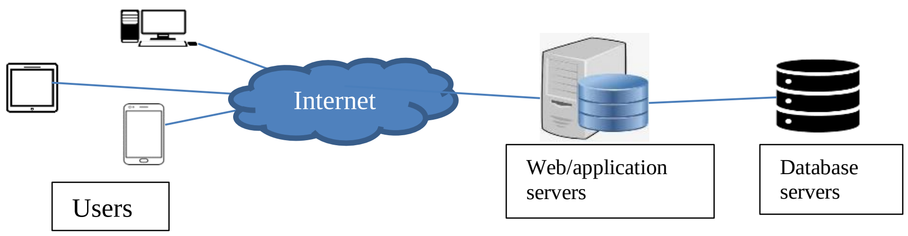


Figure 8. The system architecture of Makoyana

d. Entity Relationship Diagram (ERD)

The Entity-Relationship Diagram (ERD) is based on the business process that is implemented in almost all Indonesian botanical gardens. The flow of data follows the business process flow that is used in the current business process.

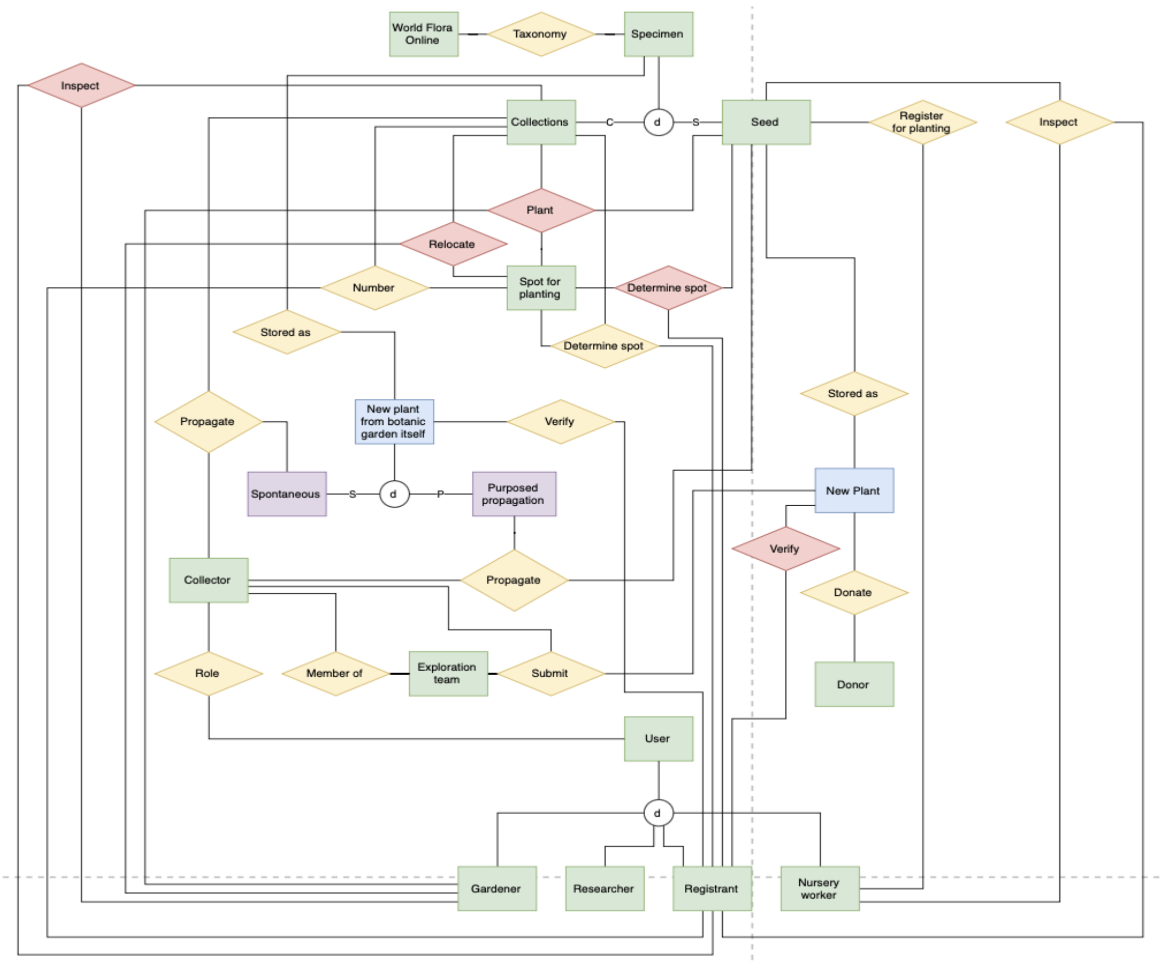


Figure 9. Entity Relationship Diagram of Makoyana

3. System Interfaces

a. Homepage for external stakeholders/public users

On the Home page, simple design and user-friendly concepts are adopted to provide users with an effective and efficient experience to find out plant collections data. Real-time data about plat collections can be searched by filling the search form in the middle of the page.

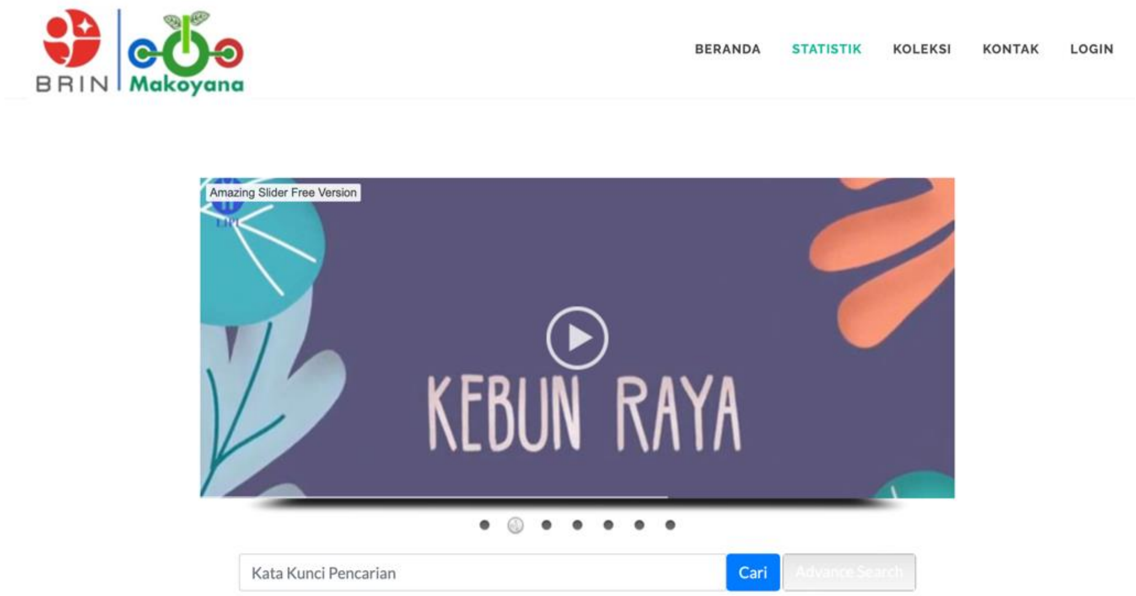


Figure 10. Homepage interface for public

b. Statistical interfaces for public users
The external stakeholders can explore the statistical data of plant collections from all Indonesian botanical gardens on this page. The number of gardens that are connected, the number of species, and IUCN status can be directly monitored on the statistical interface page.

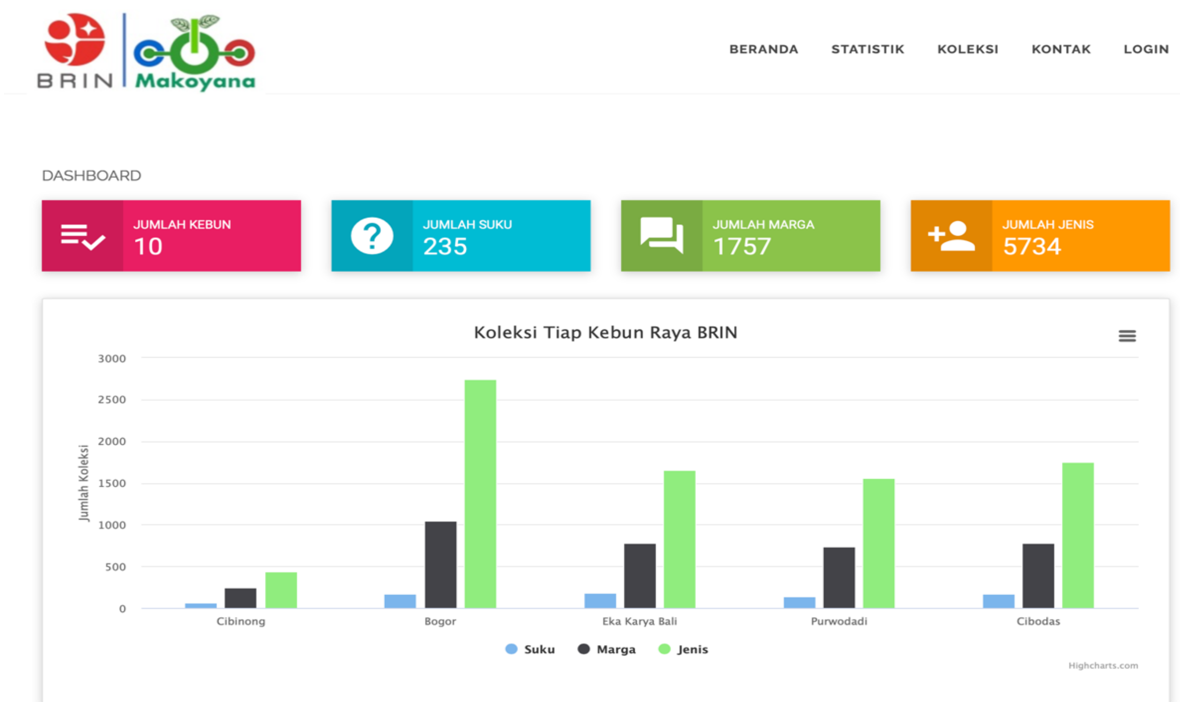


Figure 11. Statistics interface for public

c. Searching page of plants collections data
The searching page provides an advanced search option for external users. Stakeholders can search data based on some categories such as family or genus. The shown data can also be

ordered based on location, genus, or family depending on stakeholders' requirements.

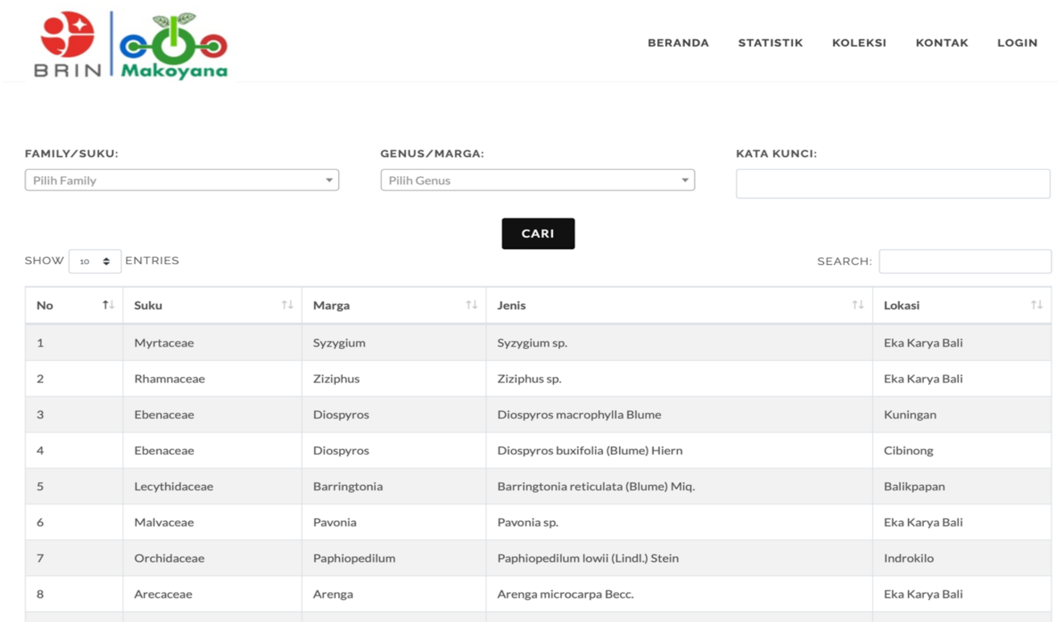


Figure 12. Searching page

d. Administrator homepage
There are some roles for internal stakeholders in the system such as national administrator, system administrator, registration division, nursery, and collections division. On the administrator homepage, the internal stakeholders can monitor the daily transactions in each botanical garden, knowing the real-time data about IUCN status, and the number of specimens.
In every role, the modules are arranged based on the responsibilities in the business process that is implemented to manage plant collections in Indonesian Botanical Gardens.
The data also implement the server-side method that can improve the accessibility rate because of the data that is shown based on the user's requests. This method also can decrease the use of memory on the client-side.

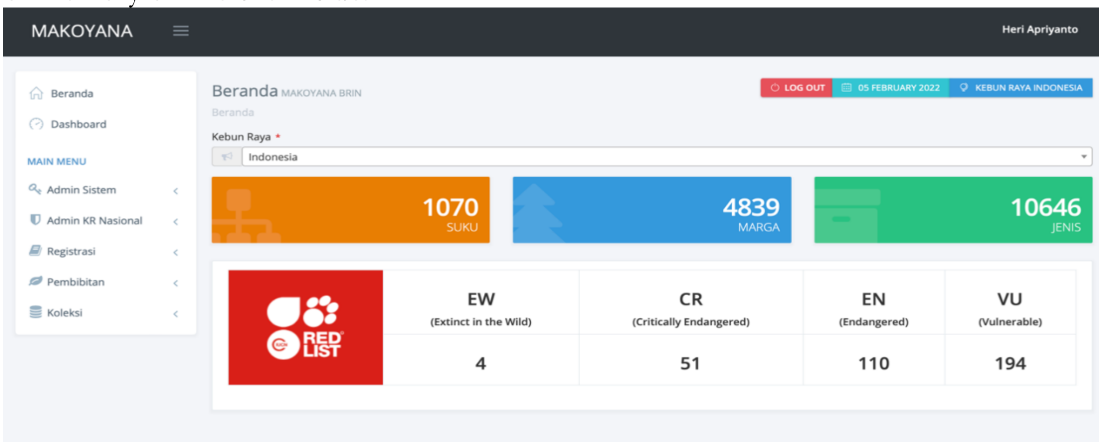


Figure 13. Administrator Homepage

e. Exploration Module interface
The exploration module interface records all data about the history of exploration activities that have been done by Indonesian Botanical Gardens. This data is essential to map the area

that was already explored in the past and to identify the origin of the plant collections.

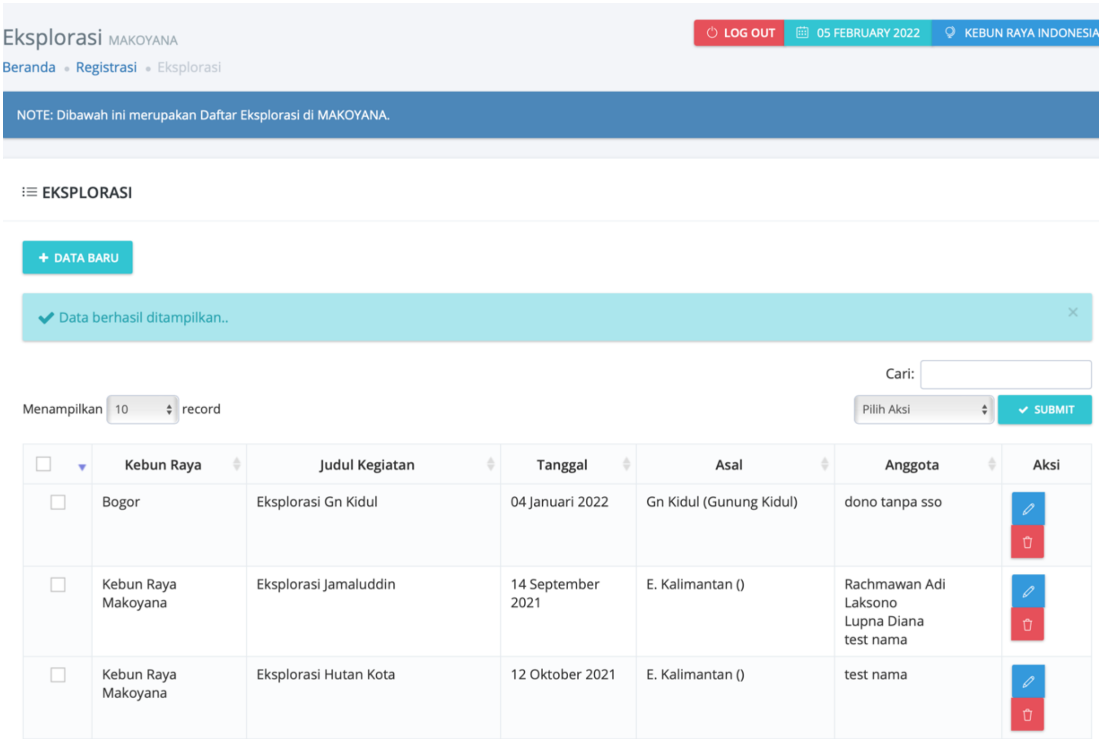


Figure 14. Exploration Module Interface

f. Accepted material plants module interface
The first form that should be input by the administrator is the accepted material plants form. This form is essential to record the basic data of plant collections and to provide a registration number for plant collections.

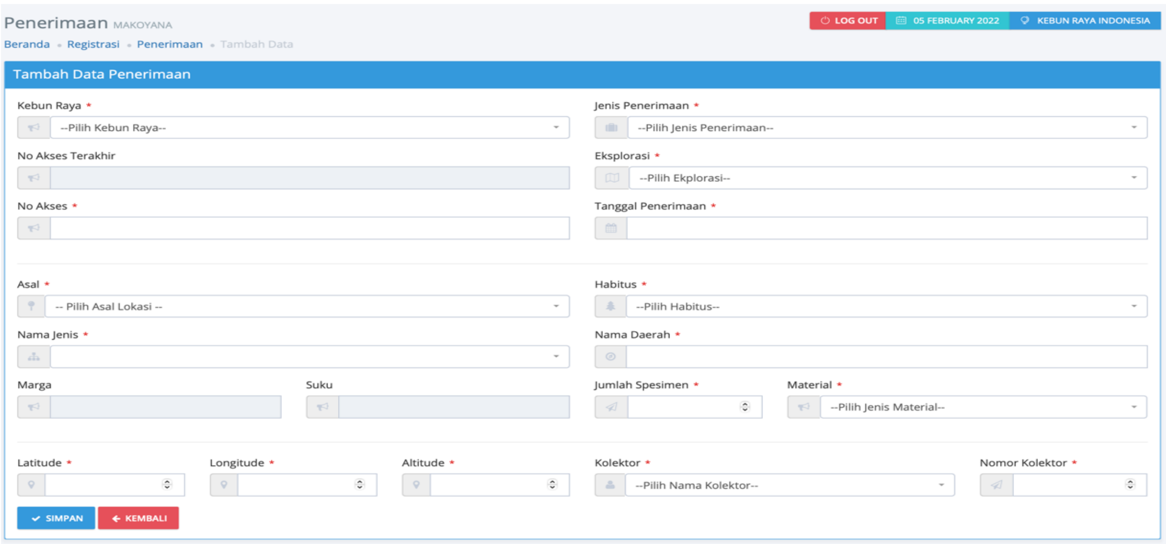
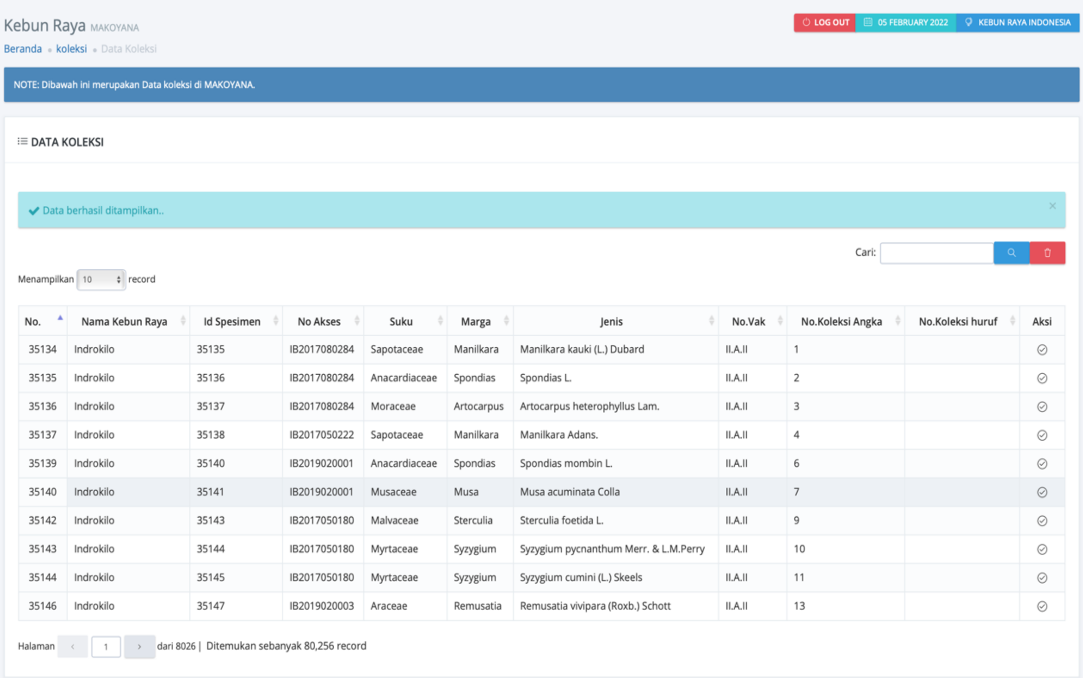


Figure 15. The material plant acceptance page

g. Plant collections data interface

All records of plant collection data are shown on this page. The plant collection data can be accessed by all roles in the system.

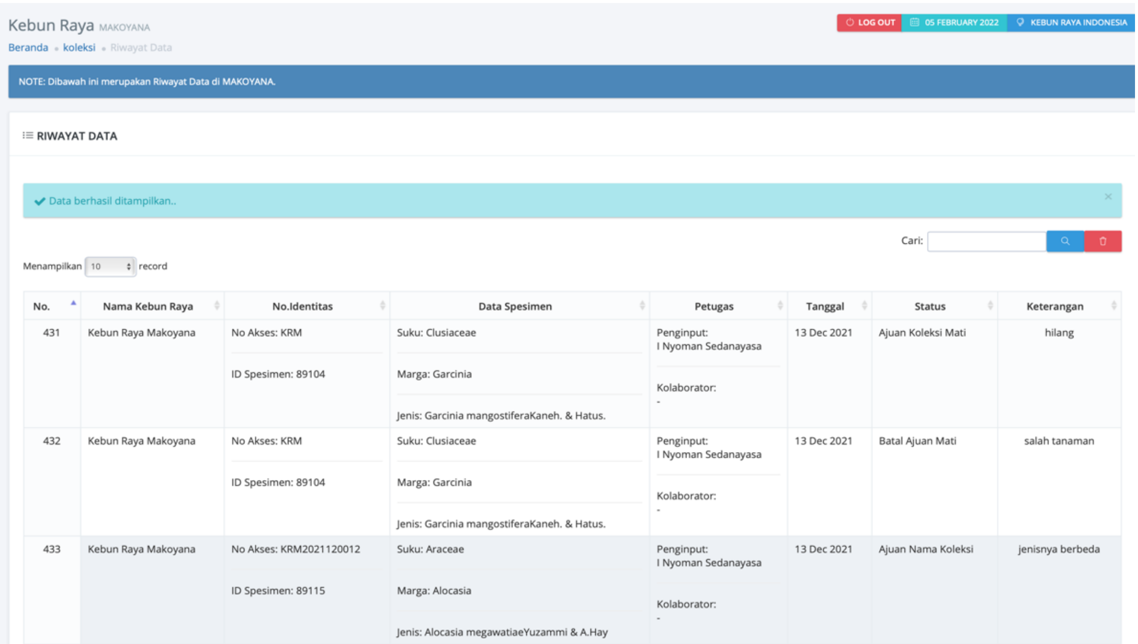


No.	Nama Kebun Raya	Id Spesimen	No Akses	Suku	Marga	Jenis	No.Vak	No.Koleksi Angka	No.Koleksi huruf	Aksi
35134	Indrokilo	35135	IB2017080284	Sapotaceae	Manilkara	Manilkara kauki (L.) Dubard	II.A.II	1		
35135	Indrokilo	35136	IB2017080284	Anacardiaceae	Spondias	Spondias L.	II.A.II	2		
35136	Indrokilo	35137	IB2017080284	Moraceae	Artocarpus	Artocarpus heterophyllus Lam.	II.A.II	3		
35137	Indrokilo	35138	IB2017050222	Sapotaceae	Manilkara	Manilkara Adans.	II.A.II	4		
35139	Indrokilo	35140	IB2019020001	Anacardiaceae	Spondias	Spondias mombin L.	II.A.II	6		
35140	Indrokilo	35141	IB2019020001	Musaceae	Musa	Musa acuminata Colla	II.A.II	7		
35142	Indrokilo	35143	IB2017050180	Malvaceae	Sterculia	Sterculia foetida L.	II.A.II	9		
35143	Indrokilo	35144	IB2017050180	Myrtaceae	Syzygium	Syzygium pycnanthum Merr. & L.M.Perry	II.A.II	10		
35144	Indrokilo	35145	IB2017050180	Myrtaceae	Syzygium	Syzygium cumini (L.) Skeels	II.A.II	11		
35146	Indrokilo	35147	IB2019020003	Araceae	Remusatia	Remusatia vivipara (Roxb.) Schott	II.A.II	13		

Figure 16. Plants collection data interface

h. Transaction history interface

This page records all transactions that are done by users in the system. The transactions history can be traced and can be monitored to improve quality control in the system.



No.	Nama Kebun Raya	No.Identitas	Data Spesimen	Petugas	Tanggal	Status	Keterangan
431	Kebun Raya Makoyana	No Akses: KRM ID Spesimen: 89104	Suku: Clusiaceae Marga: Garcinia Jenis: Garcinia mangostiferaKaneh. & Hatus.	Penginput: I Nyoman Sedanayasa Kolaborator: -	13 Dec 2021	Ajuan Koleksi Mati	hilang
432	Kebun Raya Makoyana	No Akses: KRM ID Spesimen: 89104	Suku: Clusiaceae Marga: Garcinia Jenis: Garcinia mangostiferaKaneh. & Hatus.	Penginput: I Nyoman Sedanayasa Kolaborator: -	13 Dec 2021	Batal Ajuan Mati	salah tanaman
433	Kebun Raya Makoyana	No Akses: KRM2021120012 ID Spesimen: 89115	Suku: Araceae Marga: Alocasia Jenis: Alocasia megawatiaeYuzammi & A.Hay	Penginput: I Nyoman Sedanayasa Kolaborator: -	13 Dec 2021	Ajuan Nama Koleksi	jenisnya berbeda

Figure 17. Transactions history page

4. System Testing
System testing is used to assess the success rate of the new system. In this step, the system will be analysed based on its functionality and accessibility.

Table 1. Public user interface testing

Participant	Search page	Statistic page	IUCN data access	plants collections data
Stakeholder 1	V	V	V	V
Stakeholder 2	V	V	V	V
Success rate	100%	100%	100%	100%

Table 2. Administrator interface testing

Participant	Login	National Admin module	Registration Module	Nursery Module	Collection Module
Admin 1	V	V	V	V	V
Admin2	V	V	V	V	V
Success rate	100%	100%	100%	100%	100%

B. Discussion
According to the result, the new system is designed to address the main issues that are faced by the Indonesian Botanical Garden related to data management. The first issue is about the stakeholders that find it difficult to access plant collection data from all Indonesian botanical gardens and affecting on many aspects such as flora conservation, economics, science, and health. This issue can be addressed by the new system that is designed with cloud architecture and has integrated data. As the result, the data that is provided can be monitored in real-time by stakeholders. It can be seen in the system testing phase that involves stakeholders accessing the main public user interface on the new system with 100% of pages are success to be accessible. Another issue that should be addressed is there is no integration data which causes some following issues such as a lack of accuracy, consistency, and efficiency in processing and accessing data. The system is designed using a single database that can be accessed by all Indonesian Botanical Gardens. It makes the process of monitoring and controlling data can be done regularly at the national level. Also, modules for administrators are designed to accommodate the business process that has been implemented in the Indonesian Botanical Garden. This can eliminate the possibility of inconsistent procedures that can address the issues of accuracy, consistency, and efficiency in processing and accessing data. With the result of the administrator interface testing process that achieves a perfect score, it can be claimed that the new system can be implemented to address the issues in the data management aspect in Indonesian Botanical gardens.

Conclusion

To conclude, the system can be claimed that have the ability to address issues in the Indonesian Botanical Garden. According to the system testing process, the new system has succeeded to provide some data for public users such as search page, statistic page, IUCN data, and plant collections data with the success rate of the perfect number. This system also can be accessed by the internal botanical garden to maintain some roles such as national admin, registration, nursery, and collection. The success rate in the administrator interface testing reaches 100%. It means that all modules can cover the requirements. Furthermore, some essential issues such as integration data can be addressed by the system. This system can integrate all data from all Indonesian Botanical gardens and provide complete information for stakeholders. In addition, the system that is accessed in the cloud can be accessed in the multiplatform and devices at Makoyana.brin.go.id. It is also easy to be maintained and enlarged. It means that the system is efficient to be accessed anytime and anywhere. In addition, the system provides a portal system to access the biodiversity data from all Indonesian botanical gardens. In this condition, the accuracy of data can be easy to be assessed. The system can also be used as a reference for the national standard business process in terms of botanical garden management in Indonesia. In the future, the development of big data and the use of artificial intelligence to monitor and manage plant collections are possible be done with Makoyana as a based system. The national integrated data and transactions historical data can be analysed and transformed into knowledge. The structure of data in the system is also designed to support future research.

Acknowledgement

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