Biota
Biologi dan Pendidikan Biologi
http://biota.ac.id/index.php/jb
DOI: http://dx.doi.org/10.20414/jb.v16i2.481

Research Article

Bioremediation potential of tree-level plant vegetation UIN Raden Mas Said Surakarta campus as an alternative solution to environmental problems towards a green campus

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Abstract

Environmental problems become actual and interesting issues to discuss. Environmental problems are not only in water, soil and living things but also include air pollution. One of the environmental solutions can use bioremediation, Educational Institutions can also participate in environmental solutions by becoming a green campus. The purpose of this study is to see the potential of bioremediation of tree-level plant vegetation UIN Raden Mas Said Surakarta as an alternative solution to environmental problems towards a green campus. This research was conducted from July-October 2023, plant classification was carried out thoroughly in the campus area, then a meta-analysis was carried out for its potential as bioremediation and green campus potential. Based on the results of research at the UIN Raden Mas Said Surakarta campus, there are 58 types of plants with a total of 670 plants with the most types of plants red shoots (*Syzygium paniculatum Gaertn.)* 12% and Ketapang kencana (*Terminalia mantaly)* 11%. Furthermore, the results of the meta-analysis found that the potential for vegetation bioremediation at UIN Raden Mas Said Surakarta as phytoremediation where plants act as bioremediation agents, while the potential of UIN Raden Mas Said Surakarta as a green campus based on the UI GreenMetric Guidelines 2022 Standards has met several criteria and indicators of green campus achievements, but to become a green campus requires the participation of various parties, both leaders and the academic community and students so that UIN Raden Mas Said Surakarta can get the title of green campus.

Keywords: *Bioremediation, Vegetation, Green campus.*

1. Introduction

Environmental problems become actual and interesting issues to discuss. Environmental problems are not only in water, soil and living things but also include air pollution. Previous to recent research shows that almost worldwide air pollution is a hot topic that is always discussed. Around 6.5 million tragedy deaths are caused by air pollution and poor air quality worldwide every year (Engels et al., 2018). Not only in developed countries, in the Asian region which is included in developing countries, the results of research show that the level of air pollution in developing countries exceeds the standards of the World Health Organization (Nakao et al., 2018). 75% of $CO2$ is contributed by land transportation (Damara et al., 2017). The results of combustion in motor vehicles have

exhaust results or commonly known as emissions, motor vehicle emissions consist of various air pollutants, one of which is carbon dioxide. The higher the number of land transportation users, the higher the emissions contributed to the air in line with the increasing carbon dioxide content in the air (Handayani et al., 2017).

CO_2 gas plays an important role in the greenhouse effect, having a greater influence in determining the temperature of the earth than any other. Although it has the lowest level of global warming, CO_2 gas in excess concentrations can cause large changes in the earth's surface temperature because the concentration is higher than H_2O gas. CO_2 gas has a long lifespan in the atmosphere, which is several tens of thousands of years. (Daniel, 1999 in (Fathiyah et al., 2020).

Universitas Islam Negeri (UIN) Raden Mas Said is a campus with great potential to transform into a green campus. This is in line with the activities that have been carried out by UIN Raden Mas Said towards a green campus such as efficient use of electricity, by turning off all electrical power when office hours are over and with the establishment of a universal incandescent waste bank managed by Dharma Wanita Persatuan (DWP) UIN Raden Mas Said Surakarta along with lecturers and environmental activist employees. According to (Artisna et al., 2018) Green campus is a sustainable environmental management effort that can be applied in overcoming environmental problems. The implementation of an environmentally friendly campus emphasizes the implementation of campus policies in an environmentally friendly concept such as sufficient greening, efficient use of energy, water, waste management, transportation and education. One of the environmental problems found at UIN Raden Mas Said Surakarta is the limited parking space that is not comparable to the number of motorized vehicles brought by students, provided that each student brings their own vehicle so that this can cause air pollution from carbon dioxide (CO_2) emissions.

Some alternative problems that can be done to reduce pollution in the campus environment, in addition to reducing the number of vehicles, namely by greening, UIN Raden Mas Said Surakarta includes campuses with a variety of tree-level plant vegetation, where plants can carry out photosynthesis and produce oxygen (O_2) which has the opposite role to carbon dioxide, where oxygen plays an important role in human breathing. Vegetation itself is a grouping of plants that have a role in biotic and abiotic environments, meaning that if you want to create a cool and comfortable environment and, in an effort, to reduce air pollution in order to go to a green campus, a classification process is needed on plants and vegetation analysis so that the results of any plants that have the potential to solve environmental problems, especially in air pollution (Rahman, 2019).

2. Material and Method

Plant vegetation classification is carried out on the main campus of Raden Mas Said State Islamic University Surakarta which includes the Faculty of Sharia, Faculty of Ushuluddin and Da'wah, Faculty of Islamic Economics and Business, Faculty of Adab and Language, Building A, B, C, D and E, Student Center, Sport Dome, Rectorate Building, Library, LP2M Building, LP2M BUILDING, LPM, PTIPD, Laboratory Building, Graha Building, and all buildings within the scope of the main campus of UIN Raden Mas Said Surakarta. Furthermore, the potential of the plant is obtained using the *In-Silico Technique*.

Analysis of bioremediation potential using bioremediation indicators according to Vidali in (Hardiani, et al., 2011: 32). Based on biological process agents as well as engineering implementation, bioremediation can be divided into four groups, namely: at. Phytoremediasis; Bioremediasi in situ; Bioremediasi ex situ; Bioagumentation. The green-

campus potential uses the UI Green Metric Guidelines 2022 standard as presented in table 1.

Table 1. UI Green Metric Guidelines 2022 Standard

No	Category	Indicator
1.	Governance and infrastructure	1. The ratio of green opening area and conservation.
		2. Availability of water absorption areas.
		3. Availability of operational costs for building maintenance.
		4. Availability of facilities for disabled and special needs.
		5. Availability of security and health facilities.
2.	Utilization of energy resources	1. Availability of energy saving tools.
		2. Have buildings and facilities that are able to save energy.
		3. Save electricity.
		4. Reduction of greenhouse gas emissions.
		5. Take an active role in energy innovation and weather change programs.
3.	Waste Management	1. Has a waste recycling movement program.
		2. Have a paper and plastic reduction program.
		3. Have organic and inorganic waste management programs.
		4. Have toxic waste management.
		5. It has good drains and drains.
4.	Water governance and utilization	1. Have a water conservation program.
		2. Able to reuse waste water.
		3. Provide potable water for the academic community.
		4. There are efforts to control water pollution in the campus area.
5.	Transportation	1. Restrictions on the use of cars and motor vehicles.
		2. Public transportation is available.
		3. The implementation of zero emission policies in the campus environment.
		4. The ratio of parking spaces to the number of campus residents.
		5. Pedestrian areas available
6.	Education and Research	1. There are courses on environmental sustainability.
		2. Funding for research on environmental

	sustainability.
3.	There are activities themed on environmental sustainability.
4.	The existence of student activities based on environmental sustainability.
5.	The existence of a community of environmental conservation services.
6.	There are programs that improve learning based on environmental sustainability.
7.	There are reports and websites regarding the implementation of environmentally Friendly campuses.

3. Results and Discussion

3.1. Results

Based on the results of the classification of tree-level plant vegetation in the main campus environment of UIN Raden Mas Said Surakarta, 58 types of gardens with a total of 670 plants were obtained, this is presented in table 2.

Table 2. Results of Plant Vegetation Classification Tree level in the campus environment of UIN Raden Mas Said Surakarta

No.	Plant Name	Total	No.	Plant Name	Total
1.	*Terminalia catappa* L.	**44**	30.	*Terminalia mantaly*	**73**
2.	*Bambusa vulgaris* Schrad.	**1**	31.	*Swietenia mahagoni* (L.) Jacq.	**6**
3.	*Pterocarpus indicus*	**63**	32.	*Dimocarpus longan* Lour.	**9**
4.	*Wrightia religiosa*	**18**	33.	*Mangifera indica* L.	**19**
5.	*Saraca indica*	**2**	34.	*Pometia pinnata* J.R.& G.Forst	**7**
6.	*Averrhoa carambola* L	**2**	35.	*Rosa hybrida*	**1**
7.	*Ficus benjamina*	**3**	36.	*Jasminum sambac* L.	**1**
8.	*Averrhoa bilimbi* L.	**1**	37.	*Jasminum sambac* L. varigata	**7**
9.	*Bougainvillea spectabilis* Willd.	**5**	38.	*Artocarpus heterophyllus* Lam	**3**
10.	*Platycladus orientalis* (L.) Franco	**8**	39.	*Dypsis lutescens* (H. Wendl.).	**8**
11.	*Casuarina equisetifolia* L.	**3**	40.	*Adonidia merrillii* (Becc.)	**1**
12.	*Erythrina crista-galli* L.	**30**	41.	*Areca catechu* L.	**11**
13.	*Syzygium cumini* (L.) Skeels	**1**	42.	*Syzygium paniculatum* Gaertn.	**78**
14.	*Delonix regia* (Bojer ex Hook.) Raf.	**1**	43.	*Alstonia scholaris* R. Br.	**5**
15.	*Polyalthia longifolia* Sonn.	**32**	44.	*Codiaeum variegatum* (L.)	**3**
16.	*Syzygium aqueum*	**7**	45.	*Syzygium polyanthum* (Wight)	**4**
17.	*Psidium guajava* L.	**2**	46.	*Elaeis guineensis* Jacq.	**13**
18.	*Psidium guajava* L. var. kristal	**2**	47.	*Manilkara zapota*	**3**
19.	*Syzygium malaccense* (L.)	**3**	48.	*Manilkara kauki* (L.) Dubard	**10**
20.	*Anacardium occidentale* L.	**2**	49.	*Falcataria moluccana* (Miq.)	**2**
21.	*Syzygium jambos* (L.) Alston	**1**	50.	*Duranta erecta* L.	**1**
22.	*Citrus* sp.	**4**	51.	*Annona muricata* L.	**9**

23.	*Citrus limon* (L.) Burm. f.	**2**	52.	*Pleomele angustifolia*	**22**
24.	*Acanthocereus tetragonus* (L.) Humm	**13**	53.	*Tabebuia aurea*	**29**
25.	*Plumeria acuminata* Ait	**30**	54.	*Tabebuia rosea* (Bertol.) DC.	**15**
26.	*Cocos nucifera* var. eburnea	**2**	55.	*Mimusops elengi* L.	**16**
27.	*Muntingia calabura* L.	**8**	56.	*Schefflera grandiflora*	**1**
28.	*Ficus lyrata* Warb.	**7**	57.	*Hibiscus similis* Bl	**11**
29.	*Coccoloba uvifera* (L.) L.	**4**	58.	*Annona squamosa* L.	**1**
Total Number of Plants					**670**
Total Plant Types					**58**

Based on Table 1, an analysis was then carried out by processing the data into percentages to see the most dominant plant types on the UIN Raden Mas Said Surakarta campus and see their potential for environmental bioremediation based on In Silico analysis, a diagram of the percentage of plant vegetation is presented in figure 1.

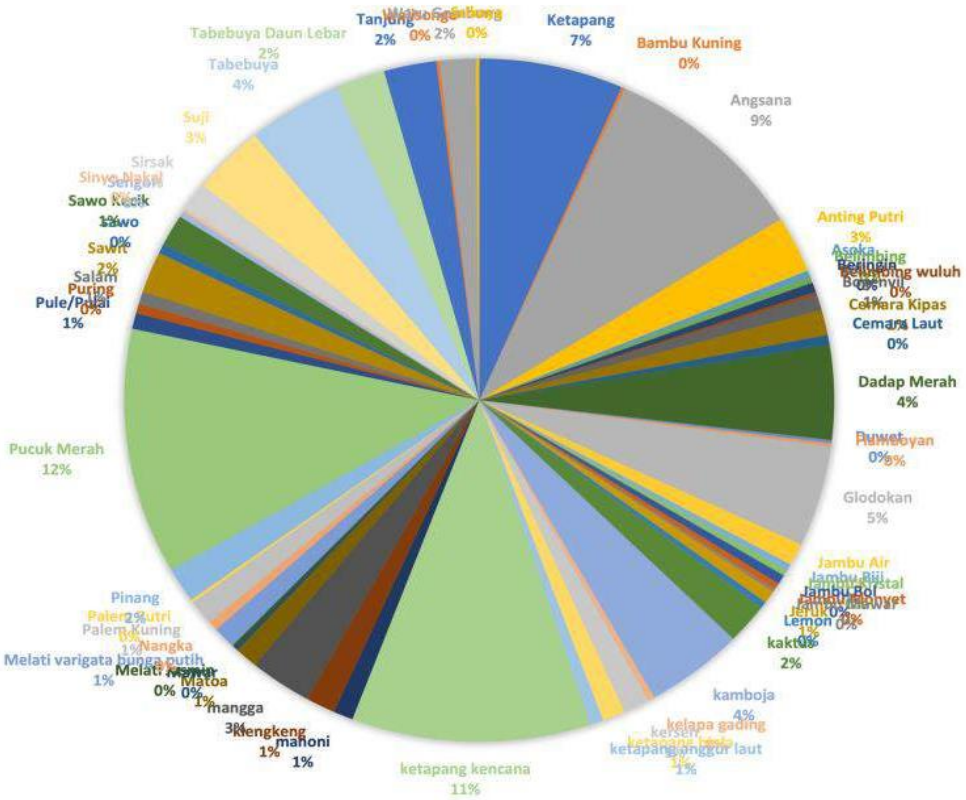

Figure 1. Vegetation chart of tree plants at the main campus of UIN Raden Mas Said Surakarta

Based on figure 1, the highest percentage of red shoot plants was obtained with 12% and Ketapang kencana plants as much as 11%.

3.2. Discussion

3.2.1 Bioremediation Potential of Tree Level Plants at UIN Raden Mas Said Surakarta Main Campus

The process of biologically decomposing organic waste under controlled conditions into a substance that is safe to handle or whose concentration is below the upper limit set by the authorities is known as bioremediation. According to the US Environmental Protection Agency, bioremediation is a natural method to remove harmful chemicals (Surikatchi, 2011: 143). These harmful substances are broken down by microorganisms, producing harmless gases such as $CO2$ and water.

A technological technique called phytoremediation uses plants to remediate polluted soil at the site (Surtikanti, 2011: 144). Improving the growth medium and increasing the availability of soil microbes can help these technologies work more effectively by degrading pollutants. Plant roots are the first step in the phytoremediation process because they absorb contaminants in water. Water containing impurities is then circulated throughout the plant body during the transportation process, so that the water becomes pure. These plants can contribute directly or indirectly to the process of cleaning up contaminated areas. It is more likely that plants that thrive in contaminated areas contribute indirectly to contaminant removal than actively. Certain bacteria are agents that play an active role in the biodegradation of pollutants, and plants can facilitate the growth of soil microbes by acting as a growth medium for plant roots (Surtikanti and Surakusumah, 2011: 145).

Plants can actively or passively degrade contaminants during the cleaning process. Different plants actively participate in phytoremediation in different ways. Some carry out transformation processes, such as rhizofiltration (which filters heavy metals into the root system), phytoextraction (which is the extraction and recovery of contaminants from underground biomass), phytovolatilization, phytodegradation, and phytostabilization (which stabilizes waste areas by controlling discharge and evapotranspiration) (Kelly in Surtikanti, 2011: 145). Physical and biological processes form the basis for distinguishing the six processes. Meanwhile, plants produce carbon, transmit oxygen, act as passive biofilters, and form an environment (habitat) that supports the proliferation of microorganisms.

According Vaid., et al (2022) The field of bioremediation has undergone an impactful revolution in recent years due to an exponential increase in various issues related to soil and water pollution. Bioremediation is an advanced and efficient technology, which involves the use of biological means such as microorganisms and plants to degrade heavy metal contaminants. Among the millions of microbes present in the ecosystem, the highest metal adsorption ability is possessed by species belonging to genus *Penicillium, Streptomyces, Bacillus, Rhizopus, Chlorella, Ascophyllum, Sargassum,* and *Aspergillus.* Among different

plant species, *Allium, Eucalyptus, Helianthus*, and *Hibiscus* are the main heavy metal absorbers.

The process by which plants absorb nutrients and pollutants made from organic matter from soil or groundwater and convert them is known as phytotransformation. Pollutants in plants have the ability to change from toxic to non-toxic. This transformation causes metabolites to accumulate inside the plant. The process by which contaminants are absorbed by soil or aquatic plants and then collected or stored in plant parts (leaves or stems) is known as phytoextraction. We call this plant a hyperaccumulator. After the accumulation of pollutants, the crop can be harvested; However, they should be buried in landfills or destroyed in incinerators rather than eaten.

In general, all tree-level plants at the main campus of UIN Raden Mas Said Surakarta have the potential for phytoremediation bioremediation by collaborating with microorganisms that live in plant roots and produce oxygen through burning carbon dioxide in the environment. Based on table 2, and figure 1 obtained at the main campus of UIN Raden Mas Said Surakarta, 58 types of tree-level plants were obtained, then research restrictions were carried out by analyzing plant bioremediation with percentages of 12%, 11% and 9%, so that red shoot plant types, Ketapang kencana and angsana were obtained which would be analyzed for their potential as bioremediation agents as follows:

1. Pucuk Merah Plant (*Syzygium paniculatum* Gaertn.)

   Red shoot plants have several benefits including being able to be a natural air purifier because it is able to absorb more carbon dioxide compared to other plants, the leaves of red shoot plants can be processed into herbal teas that have natural antioxidants to ward off free radicals. The content of flavonoids, polyphenols, steroid active compounds and terpenoids found in red shoots can also prevent various diseases such as diabetes. Red shoots can also store water reserves during the dry season because of the large taproot structure so that it can absorb and store large amounts of water. In addition, sturdy roots can also prevent landslides. So that this plant can not only be used as an ornamental plant but also has benefits for the environment. Its expanding branches can be used as a habitat for other living things such as insects and small birds (Adman, 2012).

Figure 2. Pucuk Merah Plant

2. Ketapang Kencana Plant (*Terminalia mantaly*)

Based on the classification results, four types of Ketapang trees were obtained, namely ordinary Ketapang, Ketapang laut, Ketapang violin and Ketapang kencana. Ketapang trees are very important for the maintenance of the surrounding ecosystem. The fallen leaves of these trees break down into humus, which increases soil fertility and aids water conservation. In addition, the roots of this tree effectively hold the soil so as to prevent landslides and erosion. This reduces the possibility of damage from natural disasters and preserves the environment. This tree contributes to lowering the concentration of CO_2 in the atmosphere by acting as an efficient carbon sink. Ketapang trees maintain the surrounding air quality by reducing weather variations and air pollution.

In addition to its environmental advantages, Indonesian people value the Ketapang Tree more because of its cultural and historical significance. This tree is revered by many local communities as a representation of their cultural heritage and local wisdom. There is something mystical and magical about this tree because of the beliefs and stories of the people who surround it. This tree has played an important role in the history of society. A tree that has stood there for centuries has given significant religious significance to several locations in Indonesia, making it a monumental site (Bardan et al., 2023).

Some of the benefits of ketapang trees for life and the environment are as follows: a. Shading tree, first. The most popular use of ketapang is as a shade tree for roads or parks. Because Ketapang has the ability to grow big and has a header like an umbrella. Therefore, it gives a dubious and quite shady impression. However, Ketapang trees lose a lot of leaves in the dry season, which sometimes causes the area around the tree to become unclean.

Figure 3. Ketapang Kencana Plant

In mountainous and coastal areas, Ketapang's taproot system is resistant to soil movement and erosion. But the construction of roads and buildings can also be degraded because of their strong roots. b. Organic dyes. The use of Ketapang as a natural dye is the next advantage. The plant has tannin-containing compounds in the bark of its stems and leaves. When dissolved, tannin compounds are often used as organic black dyes. This black color can be used as a textile raw material and as ink. In addition, the bark can produce an olive to brownish-yellow color. c. Helps balance the pH of water. The pH level of water can be adjusted with ketapang leaves.

3. Angsana Plant (*Pterocarpus indicus)*

One type of molt tree plant (two-housed) is the angasana tree. With a trunk diameter exceeding two meters, this plant can reach a height of thirty to forty meters. Angsana trees generally have an ugly, short, and banir shape. Formononetin, Isoliquiritigenin, Hydroxy Hydra Topic Acid, and Aryl Benzofuran are some of the substances found in its stems. The leaves of the angasana tree are pinnate and compound, with five to eleven leaves. The leaves are 12–13 centimeters long, with alternating feathers and seating. Loliolide and Paniculata diols are compounds found in leaves. Angsana trees produce bright yellow bisexual flowers 6–13 cm long. Fragrant flowers grow on the tips of the leaves or in their armpits. This plant produces Python esters and luteol in its flowers. The crown of angasana flowers is yellow- orange measuring from 7 to 11 centimeters long. The petals of the flower are 6 mm in diameter and resemble bells. This tree produces fruit in the form of pods. Large wings enclose unopened pods (samara). Pods are spherical in shape 4-6 cm in diameter and light brown in color (Waryanti et. al., 2015).

Figure 4. Angsana Plant

Here are some of the benefits of angsana trees for the environment:

a. Providing shade and beautifying the surrounding environment

   The ability of Angsana trees to provide excellent shade is its main benefit to the environment. Angsana trees can provide good shade if they have reached a large size because as we know they can grow large and have dense leaves.

b. As an effective pollutant absorber

   According to some studies, angasana trees are able to absorb lead from the air, a pollutant that is harmful to humans and the environment (Istiaroh et al., 2014).

c. As an organic textile dye

   Angsana trees also have other uses as natural textile dyes. Kino red sap is extracted from Angsana trees. Usually natural textile dyes are made from the sap of the Angsana tree. In addition, Angsana Tree sap is also commonly used as a basket dye in the Kalimantan region itself.

3.2.2 Analysis of Adequacy of Plant Availability with Fulfillment of *Green Campus Criteria* UIN Raden Mas Said Surakarta

Eco green campus is a campus that prioritizes environmental values and sustainability in all aspects of campus activities. Developing an environmentally friendly campus is one way to improve environmental quality and reduce negative impacts on the environment (Muzzaki et al., 2023). The concept of a green campus in the context of environmental conservation is not only a campus environment filled with green trees, but also the extent to which campus residents can effectively and efficiently utilize existing resources in the campus environment such as the use of paper, stationery, the use of electricity, water, land, waste management, and so on (Nor, 2017). A green campus can be the first step to start a more environmentally friendly life. In terms of spatial planning

and infrastructure, a green campus is a lesson for campus managers to truly realize a green campus if they want to maximize the role of universities in supporting environmental conservation. The campus needs to provide a large enough green open space for the academic community. The campus needs to ensure that the drainage system can work to reduce the negative effects caused by environmental damage. In terms of water management, the campus must be able to reduce clean water consumption. Campuses are rewarded when they are able to save water and have more recycled water available. Campus mosques are often used as indicators of the use of recycled water (Amrina & Suryani, 2019).

Abroad, the term *green campus* began to resonate since the late 90s and its implementation began to flourish in the early 2000s, when universities began to prioritize environmental sustainability in their operations and curriculum. The green campus concept was first popularized by *the Association for the Advancement of Sustainability in Higher Education* (AASHE) in the United States. AASHE began identifying and reporting on university sustainability efforts in 2005 by launching the *Sustainability Tracking, Assessment & Rating System* (STARS), which serves as a guideline for universities to measure their sustainability performance. The Green *Campus concept* was adapted from the *Development and Validation of Environmental Literacy Scale for Adults* (ELSA) and *UNESCO's 1978* Intergovernmental Conference on Environmental Education.

Green Campus Criteria from the Ministry of Research, Technology, and Higher Education In addition to the University of Indonesia, the Ministry of Research, Technology and Higher Education (currently named the Ministry of Education, Culture, Research, and Technology) also sets several criteria for universities to be considered green campuses. These criteria include:

1. Energy and water management: These criteria measure a university's efforts to save energy and water, including things like the use of renewable energy sources and the application of water conservation technologies.
2. Waste management: This criterion measures a university's efforts to reduce, recycle, and compost waste, including things like implementing waste sorting programs and promoting recycling.
3. Green transport: This criterion measures the university's efforts to promote sustainable transport options, such as cycling and public transport.
4. Green buildings and infrastructure: These criteria measure a university's efforts to design and construct buildings and infrastructure in environmentally friendly ways, such as using sustainable materials and implementing green building standards.
5. Education and research: This criterion measures a university's efforts to incorporate sustainability into its curriculum and research activities, such as offering courses on environmental sustainability and conducting research on environmental issues.
6. Community engagement and outreach: These criteria measure a university's efforts to engage with local communities and promote environmental

awareness and sustainability, such as through community service programs and public education campaigns.

Based on table 1 on the main campus of UIN Raden Mas Said Surakarta has met several criteria and indicators of green campus achievement, but to become a *green campus requires the participation of various parties, both leaders and the academic community and students so that UIN Raden Mas Said Surakarta can get the title of* green campus. As for some things that have been tried by the main campus of UIN Raden Mas Said Surakarta in meeting green campus indicators*, namely building and providing a special building for three-level motorized vehicle parking located in front of the SBSN Building, then there are waste bank activities on campus and the creation and planting of many types of plants for green open land.* This is in line with the opinion of firda (2022) which states that the transformation of UIN Raden Mas Said Surakarta not only prioritizes the tridharma value of higher education but also transforms towards an environmentally friendly campus.

In addition, in the field of Education and research, the UIN Raden Mas Said campus has scientific study programs, one of which is Environmental Science which focuses on environmental studies and several studies on the environment have been funded by the UIN Raden Mas Said Surakarta campus, including this research. Therefore, it is hoped that in the future UIN Raden Mas Said Surakarta can meet all other indicators so that it can obtain the title of *green campus*.

Conclusion

There are 58 types of tree-level plants with a total of 670 plants with the most composition of red shoot plants, namely 78 trees classified and taxonomic at the main campus of UIN Raden Mas Said Surakarta. Based on the results of classification and analysis of plant vegetation at UIN Raden Mas Said Surakarta, all tree-level plants have a role in environmental bioremediation, especially as phytoremediation with the use of the plant itself and become a place for the growth of microorganisms which further synergize in the environmental bioremediation process.

Acknowledgments

Author appreciates the support of the 2023 LITAPDIMAS financial award provided by UIN Raden Mas Said Surakarta, which helped to finance this research.

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