

Analysis of Plant Species as Noise Barriers in Air Transportation Activities at Sam Ratulangi Airport, Manado, North Sulawesi, Indonesia

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ABSTRACT

Plants serve as natural noise barriers at airports, particularly in areas surrounding runways and airport terminals. This research aims to analyse plant species that function as noise barriers in response to air transportation activities at Sam Ratulangi Airport, Manado, North Sulawesi, Indonesia. The research was conducted within and around the vicinity of Sam Ratulangi International Airport and its surrounding areas. The research methodology utilised both primary and secondary data. Plant inventories were carried out using purposive sampling. All plant species relevant to the research were recorded and documented, including the species identity and the number of individual specimens. The collected data were analysed using qualitative descriptive methods. The research findings indicate that in the airside area, there are 27 species of understory plants (including grasses, sedges, and broad-leaved species) within the plots, and 12 species found outside the plots. Outside the airside area, 26 species of tree-form plants and one epiphytic species were recorded. *Ficus rumphii* exhibited the highest relative density among the plant species outside the airside area, with 88 individuals (21.89%), followed by

Polyalthia longifolia with 86 individuals (21.39%), and *Mimusops elengi* with 64 individuals (15.92%). These three species, which function as noise barrier plants, were found outside the airside area and demonstrated higher relative densities compared to other plant species. The noise barrier understory plant species identified in the airport's airside area with the highest relative density were *Poaceae* 1 (8.76%), followed by *Paspalum* sp. (2.78%) and *Carex* sp. (0.09%).

Keywords: Plants, Noise barriers, Sam Ratulangi Airport, North Sulawesi, Indonesia.

INTRODUCTION

The concept of an eco-airport refers to the planning, development, and operation of airports to create environmentally friendly transportation infrastructure, both within the airport premises and in its surrounding areas. The eco-airport framework encompasses several environmental components, including noise, vibration, air quality, water, soil, waste materials, energy, aviation safety zones, and community health.^(1,2)

Airports and their surrounding environments serve as habitats for a variety of flora and fauna. A habitat is defined as a space where

living organisms reside and reproduce. Within a habitat, environmental conditions are conducive to the survival and propagation of living beings. Animals require specific locations to forage, mate, and produce. For plants, a suitable habitat is characterised by the presence of adequate sunlight, water, air, and soil conditions necessary for growth. ^(3,4)

Vegetation plays a significant role in natural noise reduction around airports, particularly in areas near runways and terminals. Certain plant species with dense canopies and broad leaves—such as *Samanea saman* (rain tree) and *Pterocarpus indicus* (narra tree)—are especially effective at absorbing sound waves due to their physical characteristics, including thick foliage and sturdy stems. ^(5,6)

Samanea saman possesses a wide canopy and dense foliage, making it highly capable of absorbing sound waves. *Pterocarpus indicus* also demonstrates strong noise-reducing properties, especially at specific distances from the noise source. *Swietenia mahagoni* (mahogany) is effective at attenuating sound over greater distances. Other plant species, including *Syzygium paniculatum* (red tip) and *Saraca asoca* (ashoka tree), have been demonstrated to significantly attenuate noise levels.

Plant leaves, particularly those that are dense and expansive, can absorb a portion of acoustic energy, thereby reducing sound reflection and transmission. When sound waves encounter leaves and branches, they may be reflected or deflected, altering the direction of propagation and diminishing sound intensity. The shape and density of a plant's canopy significantly influence its ability to dampen noise. Dense and compact canopies are more effective than sparse ones. In addition to functional benefits,

airport greening contributes to visual aesthetics and enhances environmental comfort. ^(5,6)

The integration of vegetation as a natural noise barrier in airport environments presents an effective and environmentally sustainable approach to noise mitigation. The morphological and physiological characteristics of specific plant species—such as leaf size, canopy density, and stem rigidity—play a critical role in their capacity to absorb, deflect, or scatter sound waves. When combined with strategic planting layouts, these vegetative features can significantly reduce the propagation of aircraft noise, particularly in zones adjacent to runways, taxiways, and terminals. In addition to acoustic benefits, this green infrastructure contributes to the overall environmental quality and comfort of the airport setting. ^(5,6) Therefore, it is necessary to research the analysis of plant species used for noise barriers in response to air transportation activities at Sam Ratulangi Airport, North Sulawesi, Indonesia.

MATERIALS & METHODS

This research was conducted within the premises and surrounding areas of Sam Ratulangi International Airport, Manado. The research area was divided into specific zones, determined based on the geographical coordinates of each observation point.

The data used in this research consists of primary and secondary data. Primary data were obtained from within and around the airport area through observation and documentation. Secondary data were collected by reviewing literature and various documents related to the research (Table 1).

Table 1. Parameters, Data Collection Methods, and Plant Data Analysis

No.	Parameters	Data Collection Method	Data Analysis Methods
1	Land use around the airport related to plants and animals	Direct field observation and interviews	Ground checking
2	Plant inventory within the airport	Sampling plot design	Analysed using a plant density formula applied to the airport area. ^(7,8)

3	Mechanisms of plant resource utilisation: in the airside area, outside the airside area	Direct field observation and interview methods	Descriptive analysis using a Likert Scale ^(9,10)
4	Socio-Cultural conditions of the community regarding plant utilisation	Direct field observation and interview methods	Descriptive analysis using a Likert Scale ^(9,10)

Relative density of a species is calculated using the formula $RD = Ni / Nt \times 100\%$, where Ni represents the number of individuals of a particular species, and Nt is the total number of individuals of all species observed within the research area.^(9,10) This value indicates the percentage contribution of the species to the total plant population in the research site. The data collected through observation, interviews, documentation, and literature review were subsequently analysed using a descriptive approach.^(9,10)

RESULT AND DISCUSSION

Based on ground verification of satellite image interpretation, nine land use types

were identified in the area surrounding Sam Ratulangi Airport, Manado: mixed gardens, grasslands, residential areas, rice fields, coconut plantations, teak plantations, lakes, agricultural land, and wetlands (Table 2). The predominant land use is coconut plantation, covering approximately 494 hectares or 28% of the total area around the airport. Mixed gardens and agricultural land cover approximately 444 hectares (25%) and 207 hectares (12%), respectively. In contrast, land uses such as lakes, rice fields, wetlands, and grasslands each account for less than 10% of the total area.

Table 2. Land Use Information in the Airport Area

Land use category	Area (Ha)	Percentage (%)
Buildings	10.61	0.62
Parking Area	8.16	0.47
Mixed Gardens	444.88	25.89
Agricultural Land	207.80	12.09
Runway	41.91	2.44
Grassland	150.91	8.78
Coconut Plantation	494.88	28.80
Residential Area	179.58	10.45
Swamp	12.69	0.74
Rice Fields	117.25	6.82
Teak Plantation	3.48	0.20
Pond	46.28	2.69
Total	1,718.42	100.00

Land use within the airport area consists primarily of grassland, with six distinct types of plant habitats and vegetation zones identified within the airport premises: (1) Grassland areas, (2) Garden/landscaped areas, (3) Tree-lined grassland areas functioning as noise buffers, (4) Roadside areas with shade trees, (5) Wetland areas, and (6) Drainage areas.

Land conversion, including the transformation of forested areas into coconut plantations, is the primary driver of land use change. This process is also influenced by the socio-economic dynamics

of the local community, which drive competition over the use of relatively limited land resources. Other mixed-crop plantation commodities, such as clove, also contribute to land use changes; however, coconut remains the dominant land use in the area.^(11,12)

Tree and Palm Species as Noise Barriers Outside the Airside Area

The research findings indicate that in the airside area, there are 27 species of understory plants (including grasses, sedges, and broad-leaved species) within the plots,

and 12 species found outside the plots. Outside the airside area, 26 species of tree-form plants and one epiphytic species were recorded. *Ficus rumphii* exhibited the highest relative density among the plant species outside the airside area, with 88 individuals (21.89%), followed by *Polyalthia longifolia* with 86 individuals (21.39%), and *Mimusops elengi* with 64 individuals (15.92%) (Table 3). These three species, which function as noise barrier plants, were found outside the airside area and demonstrated higher relative densities compared to other plant species.

Ficus rumphii (Rumph's fig.1), also known as the Mock Bodhi tree, is native to South and Southeast Asia and typically reaches 12–15 m in height with a dense, rounded crown of large leaves. Frequently used as an ornamental shade tree, it is well-suited for utilisation in airport landscapes. Dense belts of trees, such as *F. rumphii*, can attenuate mid- to high-frequency noise by absorbing and scattering sound waves across multiple foliage layers, a mechanism analogous to that observed in effective urban vegetation noise buffers.^(13,14)



Figure 1. *Ficus rumphii*, a noise-buffering tree in the Sam Ratulangi Airport area

The canopy of *Polyalthia longifolia* grows vertically and symmetrically, with dense, pendulous foliage that forms an effective physical barrier capable of blocking and absorbing ambient environmental noise. The

thick foliage increases the surface area available for sound interaction, thereby enhancing the absorption and diffusion of sound waves.⁽¹⁵⁾

Table 3. Tree and Palm Species Outside the Airside Area

No	Trees and Palms	Number of individuals	Relative Density (%)	Noise barrier
1	<i>Alstonia scholaris</i>	11	2.74	√
2	<i>Anacardium occidentale</i>	2	0.49	-
3	<i>Casuarina</i> sp.	7	1.74	√
4	<i>Chrysophyllum cainito</i>	1	0.25	√
5	<i>Citrus</i> sp.	1	0.25	√
6	<i>Cocos nucifera</i>	9	2.24	√
7	<i>Durio zibethinus</i>	1	0.25	-
8	<i>Eugenia</i> sp.	1	0.25	-
9	<i>Ficus benjamina</i>	23	5.72	√
10	<i>Ficus rumphii</i>	88	21.89	√
11	<i>Ficus septica</i>	1	0.25	√
12	<i>Mangifera indica</i>	17	4.23	-
13	<i>Mimusops elengi</i>	64	15.92	√
14	<i>Morinda citrifolia</i>	42	10.48	-
15	<i>Nephelium lappaceum</i>	8	1.99	-
16	<i>Polyalthia longifolia</i>	86	21.39	√

17	<i>Pometia pinnata</i>	1	0.25	√
18	<i>Pterocarpus indicus</i>	18	4.48	√
19	<i>Roystonea regia</i>	6	1.49	√
20	<i>Samanea saman</i>	2	0.49	√
21	<i>Spathodea campanulata</i>	1	0.25	√
22	<i>Swietenia mahagoni</i>	1	0.25	√
23	<i>Syzygium oleana</i>	1	0.25	√
24	<i>Terminalia catappa</i>	2	0.49	√
25	<i>Wodyetia bifurcata</i>	7	1.74	√
26	<i>Chrysophyllum cainito</i>	1	0.25	√
	Total	402	100	

This characteristic makes *P. longifolia* highly suitable as a sound-absorbing plant species in urban landscapes. Vegetation studies have shown that plants with dense canopy structures and multiple leaf layers, such as *P. longifolia*, can reduce environmental noise levels by approximately 5 to 10 decibels at a given distance from the sound source. ⁽¹⁵⁾

Mimusops elengi is a tree species with high potential as noise-reducing vegetation in airport areas. It possesses thick, coarse, and trichome-covered leaves, along with a dense and lush canopy—morphological traits that align with the physiological criteria of effective noise-reducing plants (through sound wave absorption and diffraction). Research in the fields of landscape architecture and environmental studies suggests that vegetation, such as *Mimusops elengi*, can significantly reduce noise levels through mechanisms of diffraction, reflection, and absorption. Therefore, the strategic planting of *Mimusops elengi* in airport surroundings can contribute to creating a more comfortable environment, while simultaneously supporting other ecological functions, such as air pollution mitigation and enhancement of landscape aesthetics. ^(16,17)

Ficus religiosa is one of the most widely planted plant species due to its effectiveness in mitigating noise generated by aircraft. However, the presence of *F. religiosa* has also been linked to an increase in wildlife activity, particularly among birds, within airport areas. This is primarily because the species produces fruit that serves as a food source for frugivorous bird species. ^(18,19)

Understory Plant Species as Noise Barriers in the airside area

The research findings revealed that 27 species of understory vegetation were recorded across 72 distinct plots in the airside area. *Centrosema pubescens* Benth. has the highest relative density, with 902 individuals (20.63%). In contrast, the species with the lowest relative densities were *Melanolepis multiglandulosa* and *Spathodea campanulata*, each represented by a single individual (0.02%). (Table 4).

This pattern reflects a typical distribution in plant communities, where a few species dominate in terms of abundance while many others occur at low frequencies. The dominance of *Centrosema pubescens* may be attributed to its adaptive growth habit, rapid vegetative propagation, and tolerance to open, disturbed environments such as those commonly found in airport airside areas. Conversely, the rarity of *Melanolepis multiglandulosa* and *Spathodea campanulata* suggests that these species either have limited ecological niches within the site or face competition from more aggressive ground-cover species. These findings are consistent with previous studies highlighting the uneven distribution of understory species across anthropogenically influenced landscapes. ^(20,21)

The noise barrier understory plant species identified in the airport's airside area with the highest relative density were *Poaceae* 1 (8.76%), followed by *Paspalum* sp. (2.78%) and *Carex* sp. (0.09%). The high relative density of these grass and sedge species is ecologically significant, as members of the

Poaceae and Cyperaceae families are well-documented for their dense foliage and structural characteristics that contribute to sound absorption and attenuation, particularly in open and semi-open landscapes. ^(22,23) Thus, the high relative density of *Poaceae* 1 and *Paspalum* sp. within the airport area not only reflects their ecological adaptability but also supports their effectiveness as natural noise attenuators through acoustic mechanisms that have been experimentally documented. *Poaceae* 1 serves as an effective natural noise barrier due to its dense leaf structure and fibrous stem composition, which enhance its ability to absorb and attenuate sound waves. Members of the *Poaceae* family have been extensively studied and documented for their acoustic properties, demonstrating significant sound reduction capabilities in open and semi-open environments. ^(22,23) The structural traits of *Poaceae* 1, including high foliage density and surface roughness, contribute to scattering and dissipating noise energy, thereby reducing ambient noise levels. Consequently, *Poaceae* 1 plays a vital ecological role as a bioacoustic buffer in landscapes exposed to anthropogenic noise pollution. *Paspalum* sp., as understory grasses, have been recognised for their contribution to noise attenuation in natural and semi-natural

environments. Their dense and tufted growth form creates a physical barrier that disrupts and absorbs sound waves, reducing noise propagation. Studies on grass species including *Paspalum*, have demonstrated their effectiveness in lowering ambient noise levels due to their leaf morphology and canopy structure, which enhance sound scattering and absorption. ^(22,23) Therefore, *Paspalum* sp. plays an important ecological role as a natural noise dampener, especially in open landscapes where vegetation serves as a primary buffer against anthropogenic noise.

Carex sp., commonly found as understory plants in airport environments, contribute significantly to noise reduction due to their dense foliage and robust structural characteristics. Members of the *Cyperaceae* family, including *Carex*, have been shown to possess high sound absorption capacities, which are critical in attenuating anthropogenic noise in open and semi-open landscapes such as airports. ^(22,23) The thick leaf layers and compact growth habit of *Carex* sp. facilitate the scattering and damping of sound waves, thereby serving as an effective natural acoustic barrier. Consequently, the presence of *Carex* species in airport vegetation supports ecological noise management strategies by mitigating noise pollution at the understory level.

Table 4. Understory Plant Species in the airside area

No.	Species name	Number of individuals	Relative Density (%)	Noise Barrier
1	<i>Poaceae</i> 1	383	8.76	√
2	<i>Antigonon</i> sp.	64	1.46	-
3	<i>Bidens</i> <i>spilosa</i>	4	0.09	-
4	<i>Carex</i> sp.	4	0.09	√
5	<i>Centrosema</i> <i>pubescens</i> Benth.	902	20.63	-
6	<i>Comelina</i> sp.	151	3.46	-
7	<i>Cucurbita</i> sp.	26	0.59	-
8	<i>Cyperus</i> <i>kyllingia</i> L.	52	1.19	-
9	<i>Cyperus</i> <i>rotundus</i>	6	0.14	-
10	<i>Desmodium</i> sp.	7	0.16	-
11	<i>Digitaria</i> <i>violascens</i>	3	0.07	√
12	<i>Echinochloa</i> <i>esculenta</i>	707	16.17	-
13	<i>Imperata</i> <i>cylindrica</i>	490	11.21	-
14	<i>Ipomea</i> sp.	79	1.81	-
15	<i>Leersia</i> <i>hexandra</i> Swartz	78	1.78	-
16	<i>Leersia</i> sp.	293	6.70	-
17	<i>Melanolepis</i> <i>multiglandulosa</i>	1	0.02	-

18	<i>Mimosa indica</i>	88	2.02	-
19	<i>Panicum</i> sp.	264	6.04	-
20	<i>Paspalum conjugatum</i>	3	0.07	-
21	<i>Paspalum distichum</i> Linn.	139	3.18	-
22	<i>Paspalum</i> sp.	121	2.78	√
23	<i>Phyllanthus niruri</i>	53	1.21	-
24	<i>Pseodoelephantopus spicatus</i>	2	0.04	-
25	<i>Rostellularia procumbens</i>	415	9.49	-
26	<i>Spathodea campanulata</i>	1	0.02	√
27	<i>Wedelia chinensis</i> (Osbeck) Merr.	36	0.82	-
	Total	4372	100	

Furthermore, the large canopy trees serve as roosting trees (Figure 2) and nesting sites for various bird species, including *Mimusops elengi*, *Polyalthia longifolia*, *Spathodea campanulata*, *Pterocarpus indicus*, *Ficus benjamina*, and *Syzygium paniculatum*. These trees can have both

negative and positive impacts. The negative effects include potential interference with flight operations, increased safety risks, and possible damage to airport facilities. Conversely, the positive effects include the potential enhancement of biodiversity and certain ecological functions.



Figure 2. Dormant Trees within the Airport Area

Environmental Factors

The measurement of environmental factors in the airport area revealed an average wind speed of 0.62 m/s, an average air temperature of 33.98°C, an average relative humidity of 64.77%, and an average light intensity of 11,764 Lux. These results indicate that the low wind speed in the airport area can be attributed to its location within a valley (Mapanget Valley).

The air temperature in the area is categorised as high, which is likely due to the dominance of grassland vegetation in the surrounding environment. Air humidity tends to have an inverse relationship with temperature; as temperature increases, humidity tends to decrease, and vice versa. The relatively low humidity in this context

is considered favourable for the growth of grassland vegetation. ⁽²⁴⁾ The low light intensity suggests a reduced amount of photon energy reaching the ground surface. This condition is likely a result of frequent cloud cover observed during the research period.

The sociocultural context of communities outside the airport area in utilising plants

Based on observations and interviews with 30 community respondents from five villages located outside the airport area, 22 individuals (73.33%) reported maintaining a home medicinal garden (*apotik hidup*) in their yard, while 8 individuals (26.67%) reported not having one (Figure 3).



Figure 3. Interviews with Community Respondents Regarding Home Medicinal Gardens (*Apotik Hidup*) in Household Yards

Within the household yards of the community, there are 11 types of traditional medicinal plants, also known as “living pharmacies,” namely: turmeric, ginger, cat’s whiskers (*Orthosiphon aristatus*), thick leaf, guava, tiger grass, sesewanua, duck’s claw, tungkara, chives, and saketa. Various parts of these plants—including roots, leaves, fruits, seeds, and stems—have been traditionally used as medicine passed down through generations. The majority of respondents expressed a very positive attitude toward cultivating medicinal plants in their home yards, with 24 individuals (80%) rating it as very good and 6 individuals (20%) as good. Gardens and home yards should not be viewed solely in terms of the biodiversity of the flora growing within them and the fauna interacting with it. More broadly, the abiotic aspects of gardens and home yards are also of critical importance. These abiotic factors play a dominant role in determining the diversity, structure, and dynamics of the plant life present in these spaces.²⁵ Improvements in community structure through education on medicinal conservation contribute to meeting health-related needs.²⁶ The conservation and integration of medicinal plants as landscape elements serve to support the preservation of endemic species while simultaneously creating functional green spaces within the airport area.

CONCLUSION

The research findings indicate that in the airside area, there are 27 species of

understory plants (including grasses, sedges, and broad-leaved species) within the plots, and 12 species found outside the plots. Outside the airside area, 26 species of tree-form plants and one epiphytic species were recorded. *Ficus rumphii* exhibited the highest relative density among the plant species outside the airside area, with 88 individuals (21.89%), followed by *Polyalthia longifolia* with 86 individuals (21.39%), and *Mimusops elengi* with 64 individuals (15.92%). These three species, which function as noise barrier plants, were found outside the airside area and demonstrated higher relative densities compared to other plant species. The noise barrier understory plant species identified in the airport’s airside area with the highest relative density were *Poaceae* 1 (8.76%), followed by *Paspalum* sp. (2.78%) and *Carex* sp. (0.09%). The high relative density of these grass and sedge species is ecologically significant, as members of the Poaceae and Cyperaceae families are well-documented for their dense foliage and structural characteristics that contribute to sound absorption and attenuation, particularly in open and semi-open landscapes.

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