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Utilization of sago plants (*Metroxylon* spp.) as a bioindicator of water springs

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Abstract. *Botanri S, Uluputty MR, Kamsurya M, Kamaruddin, Latuponu H, Habi ML, Djumat JL, Kaliky F. 2024. Utilization of sago plants (*Metroxylon *spp.) as a bioindicator of water springs. Biodiversitas 25: 1682-1690.* Sago plants (*Metroxylon* spp) in Maluku, Indonesia are often used as an indication of a water spring. If an area grows sago, there is most certainly a spring exists. However, this anecdotal evidence has never been empirically tested. The research aims to investigate the use of sago plants as bioindicators of water springs and to analyze the relationship between water spring discharge and sago plant characteristics and environmental factors. The research was carried out on the island of Ambon, Maluku, for 12 months from January to December 2023. This research used a survey method by conducting a census of all water springs in most areas of Ambon Island. Observations of root characteristics, sago population density, and microclimate were conducted in 3 sample areas using the purposive sampling method. Observation data were analyzed using Principal Component Regression Analysis (PCRA). The research results show that sago plants can be used as bioindicators to indicate the existence of water springs. Spring water discharge was influenced by the characteristics of sago roots, including root diameter, fresh root weight, root water content, and sago population density. Collectively, the influence of root characteristics and sago stand density reached 73.4% (R-square 0.734) with a correlation between the independent variables (X1-X4) and variable Y (spring discharge) R = 0.857. Spring discharge was also influenced by microclimate characteristics, including temperature, air humidity, intensity of solar radiation, and rainfall. The contribution of the influence of microclimate characteristics to spring discharge reached 88.2% (R-square 0.882). The correlation is very strong, with a value of R = 0.939. The findings of our study imply that sago can be used as a water spring conservation plant.

Keywords: Bioindicator, microclimate, root properties, sago plants, springs

INTRODUCTION

Sago (*Metroxylon* spp) is a palm group with geographic distribution in the wet tropics of Southeast Asia and the Pacific and has an adaptability that falls into the medium (meso tolerance) to high (eury tolerance) category (Botanri 2010). With this high adaptability, sago plants can be found growing in various habitat conditions. Botanri et al. (2011a) stated that sago plants grow well on marginal land, freshwater swamps, peat swamps, swamp forests, brackish water, areas along rivers, and around water sources. Botanri et al. (2022) stated that, in general, sago plants grow in two habitat conditions, namely dry land and wetland habitats. Wetland habitat consists of several categories, namely land that is permanently inundated with fresh water (e.g., pond habitats and on the left and right sides of rivers), land that is semi-permanently flooded with fresh water (e.g., areas inundated during the rainy season), and land that is semi-permanently flooded with brackish water (e.g., coastal areas with temporary inundation when the sea water is high).

Maluku is an archipelagic province in Indonesia, consisting of many small islands with hilly, mountainous, sloping, and valley characteristics. In some areas in Maluku, sago plants are found growing and developing on the left and right sides of the hill, whereas at the bottom of the sago stands, a water source is emerging, indicating the presence of a water spring. From this spring, the water then flows into the river and becomes a source of water for the community. Sago plants are also found on the sides of rivers, and they play an essential role in maintaining the hydrological functions of the river. A study by Botanri et al. (2011b) concluded that sago plants could be used as plants for conserving water sources. Based on such facts, hypothetically, the sago plant might have the potential to be used as a bioindicator for the presence of a water spring.

Bioindicators are defined as the use of living organisms such as plankton, animals, microbes, and plants to monitor environmental conditions and the quality of air, water, or land in an area or ecosystem. These organisms are used to assess environmental health and biophysical changes occurring in the environment. Each organic entity in a biological system indicates environmental health. For example, plankton can quickly respond to changes that occur in the surrounding environment and function as important biomarkers for assessing water quality and indicators of water pollution (Parmar et al. 2016). Kovasi et al. (2022) conducted a series of studies in California, United States, which used epiphytic moss species to monitor air quality by focusing on nitrogen and sulfur deposition on various tree trunks. Research on the use of the plant species *Byrsonima basiloba* A.Juss. (Malpighiaceae) as a bioindicator was carried out by Rodrigues et al. (2020) in Brazil to monitor the amount of fluoride released into the atmosphere from the ceramic, phosphate mineral, and aluminum industries. Fluoride is known to have the highest level of phytotoxicity when compared to other air pollutants because it can damage various tree species.

The use of living organisms as bioindicators for monitoring river water quality has been carried out, among others, by Buenfil-Rojas et al. (2022) through the use of Morelet's crocodiles as indicators of river environmental pollution in Mexico due to anthropogenic impacts. Kulas et al. (2021) have utilized Ciliata, single-celled eukaryotes, which are aquatic ecosystem microbes, as bioindicators for environmental monitoring of freshwater habitats in Croatia. Changes in soil quality in Swiss vineyards have been studied by Fournier et al. (2022) using soil protist communities as bioindicators to monitor agricultural soil stress as a result of increased copper concentrations and changes in other soil properties such as soil moisture, pH, and respiration rate.

While there are various organisms used as bioindicators of environmental state and degradation, there is limited knowledge on the use of high-level plants as indicators of water sources. Such knowledge is important since many communities in rural areas still heavily rely on springs as water sources for their daily life. In the context of Maluku, the local people often identify and relate the presence of sago plants with the presence of water sources. Nonetheless, such indigenous knowledge is never empirically tested. Therefore, this study aimed to investigate the use of sago plants as bioindicators of spring sources in Ambon Island, Maluku. It is hoped that the results of this research can be used as input for relevant stakeholders in utilizing sago plants in the conservation of water springs, especially in small island areas.

MATERIALS AND METHODS

Study area and period

The research was conducted on Ambon Island, Maluku Province, Indonesia, for 12 months from January to December 2023. Geographically, the island of Ambon is located between 03°29'S - 03°38'S and 127°59'E - 128°22'E with an area of 743.4 km^2, the altitude ranges from 0 - 1,225 m above sea level. Administratively, Ambon Island is divided into two regions, namely the southern part of the Ambon City area and the northern part of Central Maluku Regency (Google, 2024). Climatic conditions are included in the climate type B category, according to Schmidt-Ferguson, with an average rainfall of around 1500-2000 mm per year (FASC Region IX of Ambon, 2006). The average rainfall is 257.9 mm per month, the average temperature is 25.9°C, and the average air humidity is 76.37% (MGA Pattimura Ambon, 2023). A map of the research location is presented in Figure 1, and the geographical position of the sample points is presented in Table 1. The topographic conditions of the sample area are hilly and sloping, dominated by sago plants mixed with secondary forest vegetation. The adjacent area is a secondary forest, and there are some mixed gardens.

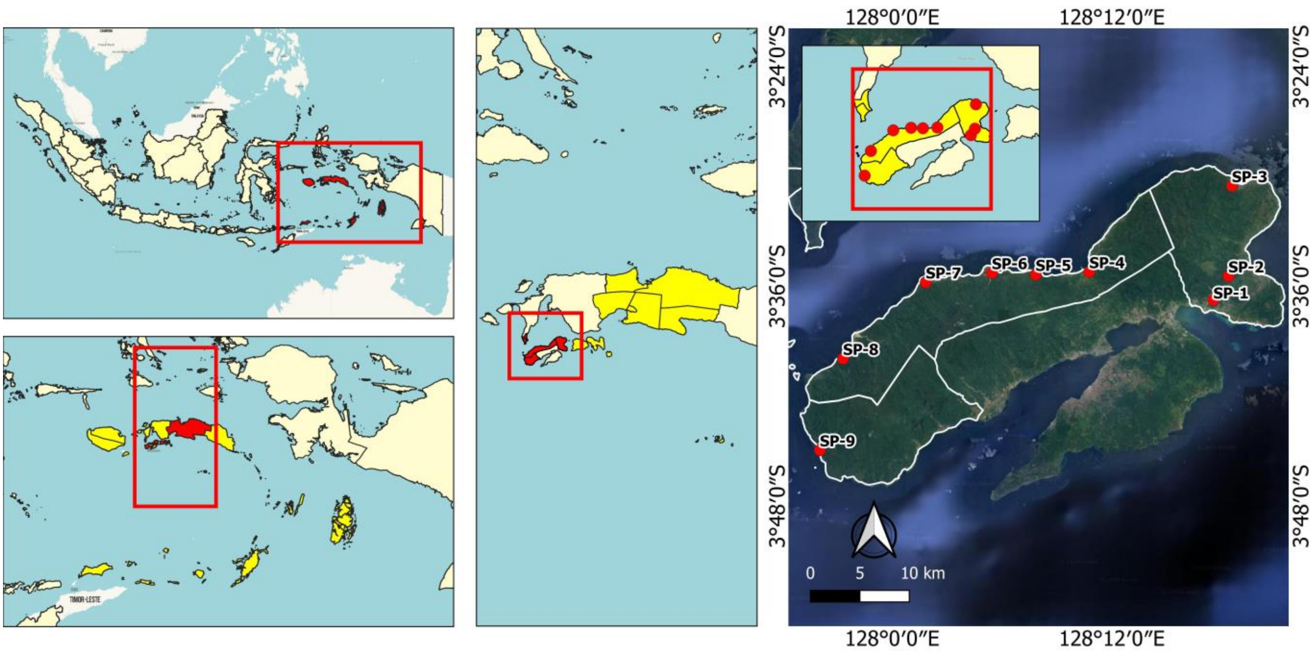

Figure 1. Map of research locations on the island of Ambon, Maluku, Indonesia

Table 1. The position of nine sample points at the research location for observing the characteristics of sago roots

Sample Point (SP)	SP-1	SP-2	SP-3	SP-4	SP-5
Name of the sample point	Suli*	Tulehu*	Liang*	Hitu**	Wakal**
Geographical coordinates	03°36'58''S 128°10'42''E	03°30'01''S 128°19'13''E	03°29'43''S 128°16'33''E	03°30'12''S 128°14'44''E	03°30'29''S 128°14'14''E
Altitude	6 m asl	8 m asl	44 m asl	12 m asl	15 m asl
Sample Point (SP)	**SP-6**	**SP-7**	**SP-8**	**SP-9**	
Name of the sample point	Hila**	Seith**	Ureng***	Wakasihu***	
Geographical coordinates	03°30'31''S 128°12'38''E	03°32'34''S 128°12'12''E	03°41'31''S 128°12'21''E	03°41'25''S 128°13'21''E	
Altitude	8 m asl	12 m asl	18 m asl	16 m asl	

Note: *: Salahutu Sub-district; **: Leihitu Sub-district; ***: West Leihitu Sub-district; m asl: meters above sea level; S: South; E: East

Table 2. The distribution of sago plants in Ambon Island, Indonesia, with the presence of water springs (Pranata et al. 2018)

City/district, Sub-district	Sago area (ha)	Percentage (%)
Ambon City		
1. Sirimau	0.00	0.00
2. Ambon Bay	9.47	2.01
3. Baguala	3.15	0.67
4. Leitimur	43.59	9.25
5. Nusanive	0.00	0.00
Sub-total	56.21	11.94
Maluku Tengah District		
6. Salahutu	168.27	35.73
7. Leihitu	238.81	50.71
8. West Leihitu	7.67	1.63
Sub-total	414.75	88.07
Total	470.95	100.00

Materials and tools

The materials used as an object in this research are the sago plants managed by local communities. The equipment included an altimeter, scales, thermohygrometer, lux meter, discharge measuring tube, stopwatch, electric oven, and datasheet.

Data collection procedure

This research used a survey method where sub-district and sampling villages were purposively selected (Moleong 2018). The springs where sago grows were determined using the snowball sampling method based on information from local communities (Nurdiani 2014). In each sample village, the researchers inventoried water springs and then determined the presence or absence of sago plants in the area around the spring. The locations of field sampling are presented in Table 2. The total sample area covered approximately 88% of the sago area on Ambon Island. The intended sample area aimed to observe the number of spring discharges, while the presence or absence of sago plants in each spring was observed using a census method that covered all springs on Ambon Island.

At each spring where sago grows, the clump population density and root system samples are observed, including Root Mass Density (RMD), root diameter, root fresh weight, root dry weight, and root water content. RMD is the root mass per unit volume of soil (g cm^{-3}) (Freschet et al. 2021). Root diameter was measured using a caliper (units are cm). Fresh weight was measured by weighing fresh roots that had been washed clean. Then, the drying root weight was done by drying the roots in an electric oven at 65°C for 24 hours. Root drying was carried out at the Biology Laboratory of the Ambon State Islamic Institute. Based on the fresh weight of the roots and the dry weight, the water content of the roots was determined using the formula (Agus 2021):

$$\textbf{Water content} = \frac{\textit{Fresh Weight} - \textit{Dry weight}}{\textit{Fresh Wieght}} \, x\ 100\ \%$$

Data analysis

The data on the presence of sago plants at water springs were subjected to qualitative statistical analysis. To elucidate the influence of sago root properties and microclimate properties, including rainfall, on spring discharge, Principal Component Analysis (PCA) was employed. PCA is a technique for reducing data to a smaller size while retaining most of the variance (diversity) from the initial data. Data reduction was carried out using the Kaiser-Meyer-Olkin (KMO) and Measured Sampling Adequacy (MSA) test statistics, with statistical criteria >0.5 (Stang 2017).

The influence of sago root parameters and microclimate on spring discharge was analyzed using Principal Component Regression Analysis (PCRA) (Gaspersz 1995). The principal component regression model, which explains the influence of the independent variable on the dependent variable, was analyzed using the following model:

$$Y = w_o + w_1 K_1 + w_2 K_2 ..... + w_m K_m + v \qquad (1)$$

Where :

Y : indenpendent variable

K_j : principal component independent variable, which is a linear combination of all standard variables Z (j : 1, 2, …, m)

w_o : constante

w_j : regression model parameter (coefisient regression), (j : 1, 2, …, m)

v : error

In the analysis process, all independent variables were transformed into standard variables Z. This data transformation is necessary because there are unit differences between the independent variables. Data transformation used the following formula:

$$Z_i = (\frac{x_i - \bar{x}}{s_i}) \quad (2)$$

Where :
Z_i : the ith independent variable is in standard form

x_i : the i-th independent variable in its original form
$\bar{x}$: the average value of the independent variable x_i
S_i : standard deviation (standard deviation) of x_i

After going through the algebraic computing process, a regression equation can be formed in the form of the original variable 'X', as follows:

$$Y = b_o + b_1 x_1 + b_2 x_2 ... + b_p x_p \quad (3)$$

Where :
Y : dependent variable
x_i : the i-th independent variable specified from the start, i = 1, 2,...,p
b_o : constante (intercept)
b_i : regression coefficient of the i-th variable, i = 1, 2, …, p.

RESULTS AND DISCUSSION

The presence of sago plants and springwater

The results of the research show that based on data from observations of 135 springs on Ambon Island, there were 126 springs (93.3%) with the presence of sago, while sites with the presence of sago plants but the springs were no longer active were 9 sites (6.7%) (Table 3).

There are active springs, meaning that the springs are still producing water. Meanwhile, there are a small number of springs where, at the time the research was carried out, the springs were no longer active, meaning that the springs only flowed water when it rained, if environmental conditions changed to the dry season, the springs no longer flowed water (Figure 2).

Most of the springs were found in the Salahutu and Leihitu Sub-districts, which reach 75.6% of the total number of springs on Ambon Island, Maluku. This is in line with the area of sago plantations in these two regions, which is around 407.08 ha, equivalent to 86.4% of the total area of sago plantations on Ambon Island, which is 470.95 ha. The condition of sago plants and water flow in the studied area is presented in Figure 3.

Table 3. Water springs with the presence of sago on Ambon Island, Maluku, Indonesia

Sub-district	Number of springs	Status	
		Active	Not active
Salahutu	25	25	-
Leihitu	77	73	4
West Leihitu	11	9	2
Sirimau	7	7	-
Ambon Bay	15	12	3
Amount	135	126	9

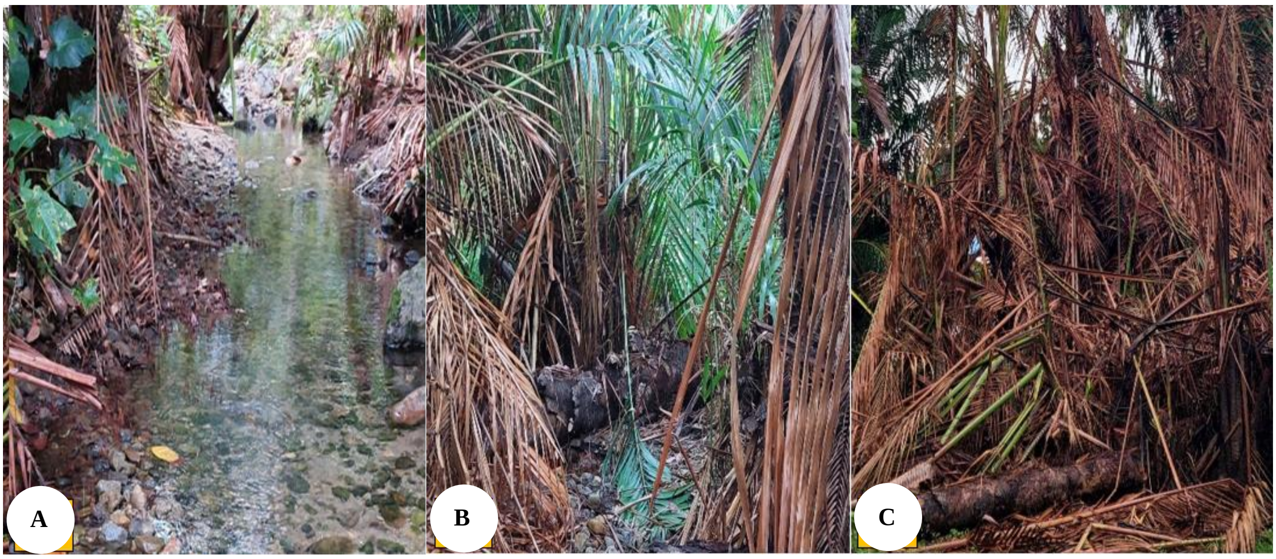

Figure 2. Conditions of active, inactive springs and fragmentation of sago plants on Ambon Island, Maluku, Indonesia. Where: A. Active spring, B. Inactive spring, C. Sago fragmentation

Figure 3. The condition of sago plants and spring water flow is in Ambon Island, Maluku, Indonesia. Where: A. Condition of sago population density water sources; B. Water flows from a spring to a tributary; C. Water flows from a spring source under a sago stand

Influence of the sago root system on spring discharge

Based on the results of Principal Component Analysis (PCA), it is known that there are 5 variables out of 6 parameters of sago growth characteristics that influence spring discharge at the studied area, namely: 1) root diameter (X1), 2) root density (X2), 3) fresh root weight (X3), 4) root water content (X4), and 5) population density (X5). The variable with no significant influence was root dry weight. Based on the results of Principal Component Regression Analysis (PCRA), it is known that the influence of sago growth parameters on spring discharge reaches 73.4% (R-square 0.734). Collectively, the water discharge (Y1) can be modelled using the independent variables (X1, X2, so on) on regression equation as formulated below:

$$Y1 = 1.152 + 0.464X1 + 0.0011X2 + 0.1109X3 + 0.6136X4 + 0.0077X5 \quad (4)$$

R = 0.857 R-square = 73.4 %

Where:
Y1 : Spring discharge (liters/second)
X1 : Root diameter (mm)
X2 : Root mass density (g cm^{-3})
X3 : Fresh weight of roots (gram)
X4 : Root water content (%)
X5 : Population density (clumps/per ha)

According to the results of the analysis, sago growth parameters influence spring discharge. From the equation above, it can be seen that if there is an increase in root diameter, density, fresh weight, root water content, and population density of sago groves, the spring discharge will experience an increase in flow. The variables that have the greatest influence on spring discharge are sequentially root water content > root diameter > root fresh weight > clump population density > root mass density. If there is an increase in root water content by one percent, the spring discharge will increase to 1.77 liters/second (Eq. 4). If there is an increase in the root diameter by one millimeter, the spring discharge flow rate will increase to 1.62 liters/second. Apart from that, if there is an increase in the fresh weight of the roots by one gram, the population density of the clumps increases by one clump per hectare, and the root density increases by one clump per m^2, then the spring discharge can increase by 1.26, 1.16 and 1.15 liters/second respectively. As a comparison of the characteristics of sago roots, the nipah plant (*Nypa fruticans* Wurmb.) was used because the two types of plants originate from tropical regions, have clump growth characteristics, and have similar habitat types. The differences in several variables of sago root properties compared to nipah palm are presented in Table 4.

Table 4. Differences in root properties of sago plants compared to nipah palms

Rooting properties	Plant type		Information
	Sago	Nipah	
Root diameter / RD (mm)	8.66	4.27	RD sago 2 times > nipah
Root density / RD (per m^2)	155.16	ND	-
Fresh weight of roots / FWR (g)*	21.15	7.93	FWR sago 3 times > nipah
Root dry weight / RDW (g)*	4.04	1.23	RDW sago 4 times > nipah
Root water content / RWC (%)	418.37	220.11	RWC sago 2 times > nipah

Note: Research results (2023). ND: no data; *based on fresh and dry weight of root samples

Influence of microclimate on spring discharge

Based on the results of principal Component Analysis (PCA), it is known that all microclimate variables analyzed affected spring discharge. After continuing with Principal Component Regression Analysis (PCRA), it was found that the magnitude of the influence of microclimate parameters, namely air temperature (X1), air humidity (X2), solar radiation (X3), and rainfall (X4) on spring discharge had a large influence reaching 88.2% (R-square 0.882). Collectively, the spring discharge can be modeled using the independent variables (X1, X2, etc.) on the regression equation formulated as follows:

$$Y1 = 1.152 - 0.3056X1 + 0.0863X2 - 0.0610X3 + 0.0025X4 \quad (5)$$

R = 0.939 R-square = 88.2 %

Where:
Y1 : Spring discharge (liters/second)
X1 : temperature (ºC)
X2 : relative humidity (%)
X3 : solar radiation (lux)
X4 : rainfall (mm)

Based on the results of the analysis, microclimate parameters affect spring discharge. From the equation above, if X = 0, meaning there is no influence of microclimate parameters, then the spring discharge will flow at a speed of 1.15 liters/second (Eq. 5). There are two variables whose influence is positive, and the other two variables are negative. The influence of the variables air humidity and rainfall is positive, meaning that if there is an increase in air humidity and rainfall, the spring discharge will increase, and conversely, if there is an increase in air temperature and solar radiation, the spring discharge will decrease. The magnitude of the increase in spring discharge as a result of increasing air humidity by one percent and rainfall of one millimeter, respectively, spring discharge will increase by 1.24 and 1.16 liters/second. In the opposite condition, if there is an increase in air temperature by one degree and an increase in solar radiation by one lux, then the spring discharge will decrease by 0.85 and 1.09 liters/second, respectively.

Discussion

This study revealed that across the island of Ambon, Maluku, Indonesia, there were 135 springs existed; 93.3% of the springs were active with the presence of sago and 7.6% of the springs were no longer active. This finding suggests that the sago plant can be used as a guide or bioindicator for the existence of springs. This means that if there are sago plants, there is a high possibility of the presence of spring. In several places where the springs were inactive, there was damage to sago plants, mostly as a result of the activities of local communities, causing the population to decrease. Community activities that might damage the sago plants include converting land that was originally sago forest into agricultural land, residential areas, or other uses. The research by Pugara et al. (2021) found that changes in land cover as a result of development activities had an impact on reducing spring water discharge in the Pekalongan District, Central Java, Indonesia. The research by Rafee et al. (2022) in Brazil shows that changes in land use and cover over the years have caused a decrease in water discharge in the upper reaches of the Parana River. This decrease in the upstream section has led to a reduction in the water discharge of the middle river and the estuary. Gule et al. (2023) conducted research in the Addis Ababa City area of Ethiopia, Africa, and found that changes in land cover use not only affect the reduction in quantity but also changes in water quality. These facts, among other things, provide an argument that changes in land cover will always be followed by a decrease in water source discharge. Likewise, the reduction of the sago plant population in Ambon Island Maluku, Indonesia, resulted in a decrease in the discharge of springs. Ekhuemelo et al. (2016) said that forests as vegetation have long been seen as an important water source. Forest water catchments provide the vast majority of all water used for human needs. Forest vegetation recycles moisture in the atmosphere through the process of transpiration to increase the amount of rainfall. The importance of forest vegetation to water supply includes improving the water cycle, reducing runoff, increasing river water discharge, filtering water pollutants, and controlling floods. Therefore, a recommendation is made to increase water supply sustainably through land protection, aggressive reforestation, forest conservation, good management, and policy formation and implementation.

The use of plants as bioindicators has been carried out and reported by various researchers. Khalil et al. (2021) conducted research in Pakistan using microalgae and macroalgae as bioindicators of water quality and found that the use of algae can determine the level of water pollution as the impact of community activities. Pico et al. (2023) stated that plants can assimilate compounds in the air, water, and soil and respond to changes in surrounding conditions so that they can be used as bioindicators of pollution. Based on the results of research conducted in several areas in Saudi Arabia, it was found that wild plants can be used as bioindicators to explain the level of air, water, and soil environmental pollution as a result of anthropogenic contaminants in the terrestrial environment. The results of this research can be used as a reference to explain that sago plants are appropriate for use as bioindicators for the existence of springs. Roy (2022) identified 70 plant species as bioindicators with *Phragmites australis* (Cav.) Trin. ex Steud., *Sorghum saccharatum* (L.) Moench, *Lepidium sativum* L., *Sinapis alba* L., *Apium nodiflorum* (L.) Rchb.fil., *Arundo donax* L., *Bolboschoenus maritimus* (L.) Palla, *Juncus acutus* L., *Nasturtium officinale* R.Br., *Typha angustifolia* L. and *Typha domingensis* Pers. were the most studied bioindicators. Such plants are bioindicators for monitoring the level of metal pollution in urban wastewater as well as a phytoremediation plant.

The sago plant can be used as a bioindicator for springs due to the influence of the plant itself and climate factors, especially the microclimate. The results of this study show that spring discharge can be inferred using root characteristics and microclimate factors. We found that there is a strong correlation between spring discharge and the root properties of sago plants, where the correlation reaches 0.86 ($R = 0.86$). The subsequent statistical analysis resulted in a coefficient of determination value of 0.734 ($R^2 = 0.734$), meaning characteristics of sago roots contribute to spring discharge at 73.4%. This is due to the nature of sago roots, which have relatively large diameters compared to other types of palms. For example, when compared to the diameter of nipah palm roots, the diameter of sago plants is twice as large as nipah palm roots.

Based on Table 4, it appears that sago plants have several advantages compared to other plants because sago plants have very high water storage capacity, reaching four times their weight and two times greater than the roots of nipah plants. Apart from that, this plant has a fairly high density and weight of fresh roots. This fact, among other things, makes sago plants able to protect the condition of springs so that the existence of sago plants is synonymous with springs. With the superiority of this root system, collectively, the properties of sago plant roots influence spring discharge. Apart from that, population density also has a positive effect on spring discharge, meaning that the higher the population density, the spring discharge will increase. The dense population of sago plants resembles forest conditions, so the role of sago plants is very good in storing and protecting spring discharge. Nugrahanto et al. (2019) and Amaliah et al. (2020) stated that the percentage of forest cover plays an important role in water regulation in river basins and forests, with its hydrological function influencing spring discharge, which in turn influences river discharge. Research by Pfeiffer et al. (2021) in Mongolia shows that the presence of forest cover in the Kharaa River land area has a positive effect on the discharge and quality of the water. A study by Gorgoglione et al. (2020) conducted in Uruguay, South America, found that land cover plays an important role in influencing the quantity and quality of Santa Lucia River water. Likewise, research by Suroso et al. (2020) conducted on the Brantas River, East Java, Indonesia concluded that good vegetation influences groundwater storage, which in turn has an impact on river water discharge. Research by Tague and Moritz (2019) in the Sierra Nevada Mountains of southern California found that disturbances affect the density of forest vegetation, resulting in a decrease in groundwater content in the vegetation root zone. This reduction in water content is then related to a reduction in the discharge of the spring water produced.

Besides the characteristics of the roots of sago plants, spring discharge is also influenced by microclimate, including temperature, humidity, solar radiation, and rainfall, where the contribution reaches 88.2% with a correlation coefficient of 0.939. Based on Equation 5, it appears that the influence of temperature and solar radiation is negative on the spring discharge conditions, meaning that if the temperature and solar radiation increase, the spring discharge will decrease. On the other hand, air humidity and rainfall have a positive relationship with spring discharge. The research by Bastiancich et al. (2022) in Italy shows that there is a positive relationship between rainfall and spring discharge, meaning that an increase in the amount of rainfall will be followed by an increase in spring discharge. The negative influence of temperature and solar radiation begins with solar radiation reaching the surface of the sago plant canopy, resulting in the increased temperature around sago plants. The reduction in spring discharge is more due to evapotranspiration through the canopy of sago plants. Evaporation occurs due to changes in the temperature of the macro environment. At the same time, transpiration also occurs in the form of water loss from the plant canopy as a result of the increasing water content on the leaves due to the continuous transport of water from the soil to the canopy. Singh et al. (2022) have conducted a study on climate change and global warming and the sustainability of springs in the Himalayan city of Almora, India. Climate change, including changes in temperature and air humidity, plays a role in the sustainability of water sources. Based on the results of their research, it was concluded that in Almora, India, over the last 20 years, there has been a reduction in spring discharge, and on average, every year, there is one inactive spring. Apart from the influence of climate change, the transformation of these springs is also triggered by anthropogenic activities. Watanabe (2023) states that the movement and storage of water in the root system of forest vegetation are influenced by various factors, including forest structure, topography, and climate.

Water loss from the canopy of sago plants is generally low. This is because water that evaporates from the canopy of sago plants is trapped inside due to a very dense canopy, resulting in the air humidity inside the canopy of sago plants increasing as the solar radiation entering the canopy of the sago stands is very low. The research by Botanri et al. (2011b) found that the intensity of solar radiation entering the canopy of sago plants was only around 12.4%, with an air temperature of around 22.69 - 23.94°C and air humidity reaching 91.13%. This condition of high air humidity indicates that the water content in the air is very high. As a result, the water content in the soil is maintained, and it then flows to the ground surface in the form of springs. The results of Vasconcelos and Sacht's (2020) research conducted in Brazil show that forest trees play a role in influencing the microclimate. The presence of canopy cover reduces the maximum and minimum daily temperatures and narrows the daily temperature range. As daily temperatures decrease, water loss from the canopy decreases. A study by Chen et al. (2023) in Shanghai, China, reported that the vegetation canopy plays a role in changes in air temperature, relative humidity, wind speed, and direction. Solar radiation is the main variable that influences changes in air temperature. Even though the daily temperature increases with the presence of vegetation canopy, the air temperature inside the canopy is lower than the surrounding temperature. This low air temperature inhibits the evaporation of water from the canopy, resulting in the amount of water on the soil surface being maintained. This water condition then becomes a source of spring water.

In conclusion, the sago plant is a type of palm plant that can be used as a bioindicator to predict the existence of springs. The use of sago as a bioindicator is supported by sago roots, which can bind water more than four times their weight and the densely closed canopy system, which is indicated by the population density, thus inhibiting water loss from the soil surface. The presence of sago plants maintains spring discharge. The condition of the spring, which continues to be maintained, is also influenced by climatic conditions, especially air humidity, which reaches 81%, and rainfall, which averages around 244.9 mm/month.

REFERENCES

Agus F. 2021. Petunjuk Teknis Analisis Kimia Tanah, Tanaman, Air, dan Pupuk. Agricultural Research and Development Agency, Ministry of Agriculture of the Republic of Indonesia, Jakarta. [Indonesian]

Amaliah R, Arsyad U, Paembonan SA. 2020. Pengaruh perubahan penutupan lahan terhadap debit aliran pada daerah aliran sungai Pangkajene, Sulawesi Selatan. Jurnal Hutan dan Masyarakat 12 (1): 14-23. DOI: 10.24259/jhm.v12i1.7203. [Indonesian]

Bastiancich L, Lasagna M, Mancicni S, Falco M, De Luca DA. 2022. Temperature and discharge variation in natural mineral water springs due to climate variability: A case study in the Piedmont Alp (NW Italy). Environ Geochem Health 44: 1971-1994. DOI: 10.1007/s10653-021-00864-8.

Botanri S, Prasetyo LB, Kartono AP, Syahbuddin H. 2022. Penyebaran spasial dan potensi tanaman sagu (*Metroxylon* spp.) di Pulau Seram, Maluku. J Sci Technol 3 (1): 55-67. DOI: 10.51135/justevol3issue1page55-67. [Indonesian]

Botanri S, Setiadi D, Guhardja E, Qayim I, Prasetyo LB. 2011a. Habitat characteristics of sago palm (*Metroxylon* spp) at the Seram island, Maluku. Forum Pascasarjana 34 (1): 33-44. [Indonesian]

Botanri S, Setiadi D, Guhardja E, Qayim I, Prasetyo LB. 2011b. Studi ekologi tumbuhan sagu (*Metroxylon* spp) dalam komunitas alami di Pulau Seram, Maluku. Jurnal Penelitian Hutan Tanaman 8 (3): 135-145. DOI: 10.20886/jpht.2011.8.3.135-145. [Indonesian]

Botanri S. 2010. Spatial Distribution, Autecology, and Biodiversity of Sagoo (*Metroxylon* spp.) in Seram Island, Maluku. [Dissertation]. Institut Pertanian Bogor, Bogor. [Indonesian]

Buenfil-Rojas AM, Alvarez-Legorreta T, Gozalez-Jauregui M, von Osten JR, Cedeno-Vazquea R. 2022. Effectiveness of Morelet's crocodile as a bioindicator of metal pollution and metallothionein response to spatial variation of metal axposure. Environ Adv 8: 100251. DOI: 10.1016/j.envadv.2022.100251.

Chen H, Liu R, Zhang Y. 2023. The impact of vegetation canopy on the outdoor thermal environment in cold winter and spring. Sustainability 15 (17): 12818. DOI: 10.3390/ su151712818.

Ekhuemelo DO, Amonum JJ, Usman IA. 2016. Importance of forest and trees in sustaining water supply and rainfall. Niger J Educ Health Technol Res 8: 270-280.

FASC (Forest Area Stabilization Center) Region IX of Ambon. 2006. Climate Map of Ambon Island, Maluku Province. Forestry Planning Agency, Ministry of Forestry of the Republic of Indonesia. [Indonesian]

Fournier B, Steiner M, Brochet X, Degrune F, Mammeri J, Carvalho DL, Siliceo SL, Bacher S, Pena-Reyes A, Heger TJ. 2022. Toward the use of protist as bioindicators of multiple stresses in agricultural soil: A case study vineyard ecosystem. Ecol Indic 139: 108955. DOI: 10.1016/j.ecolind.2022.108955.

Freschet GT, Oages L, Iverson CM, Comas LH, Rewald B, Roumet C, Klimešová J, Zadworny M, Poorter H, Postma JA, Adams TS, Bagniewska-Zadworna A, Bengough AG, Blancaflor EB, Brunner I, Cornelissen JHC, Garnier E, Gessler A, Hobbie SE, Meier IC, Mommer L, Picon-Cochard C, Rose L, Ryser P, Scherer-Lorenzen M, Soudzilovskaia NA, Stokes A, Sun T, Valverde-Barrantes OJ, Weemstra M, Weigelt A, Wurzburger N, York LM, Batterman SA, de Moraes MG, Janeček S, Lambers H, Salmon V, Tharayil N, McCormack ML. 2021. A starting guide to root ecology: Strengthening ecological concepts and standardizing root classification, sampling, processing and trait measurements. New Phytol 232: 973-1122. DOI.org/10.1111/nph.17572.

Gaspersz V. 1995. Teknik Analisis dalam Penelitian Percobaan. Tarsito, Bandung. [Indonesian]

Google. 2024. Ambon Island. https://www.google.com/search?client=firefox-b-d&q=pulau+ambon

Gorgoglione A, Gregorio J, Rios A, Alonso J, Chreties Ch, Fossati M. 2020. Influence of land use/land cover on surface-water. Sustainability 12 (11): 4692. DOI: 10.3390/su12114692.

Gule TT, Lemma B, Hailu BT. 2023. Implication of land use/land cover dynaimics on urban water quality: Case study Ababa city, Ethiopia. Heliyon 9 (5): e15665. DOI: 10.1016/j.heliyon.2023.e15665.

Khalil S, Mahnashi MH, Hussain M, Zafar N, Un-Nisa W, Khan FS, Afzal U, Shah GM, Niazi UM, Awais M, Irfan M. 2021. Exploration and determination of algal role as bioindicator to evaluate water quality-probing fresh water algae. Saudi J Biol Sci 28: 5728-5737. DOI: 10.1016/j.sjbs.2021.06.004.

Kovasi A, McCune B, Jovan S. 2022. The potential use of elemental content of saxicolous lichen as bioindicators of nitrogen deposition in the central and southern California mountains. Ecol Indic 144: 109541. DOI: 10.1016/j.ecolind.2022.109541.

Kulas A, Gulin V, Kepcija RM, Zutinic P, Peric MS, Orlic S, Kajan K, Stoeck TH, Lentendu G, Canjevac I, Martinic I, Udovic MG. 2021. Ciliates (Alveolata, Ciliophora) as bioindicators of environmental pressure: A karstic river case. Ecol Indic 124: 107430. DOI: 10.1016/j.ecolind.2021.107430.

MGA (Meteorological and Geophysical Agency) of Pattimura Ambon. 2023. Climate data. [Indonesian].

Moleong LJ. 2018. Metodologi Penelitian Kualitatif. PT. Remaja Rosdakarya, Bandung. [Indonesian]

Nugrahanto EB, Adi RN, Supangat AB, Nugroho NP. 2019. The effect of forest coverage percentage on peak discharge in the natural forest sub watershed, Tanah Laut Regency. J Watershed Manag Res 2 (2): 123-136. DOI: 10.20886/jppdas.2018.2.2.123-136. [Indonesian]

Nurdiani N. 2014. Teknik sampling *snowball* dalam penelitian lapangan. ComTech 5 (2): 110-111. DOI: 10.21512/comtech.v5i2.2427. [Indonesian]

Parmar TK, Rawtani D, Agrawal YK. 2016. Bioindicator: The natural indicator of environmental pollution. Front Life Sci 9 (2): 110-118. DOI: 10.3389/fenvs.2023.1146052.

Pfeiffer M, Kustner G, Erdenesukh E, von Tumpling W, Hofmann J. 2021. Investigation of environmental and land use impacts in forested permafrost headwaters of the Selenga-Baikal River System, Mongolia effects on discharge, water quality and macroinvertebrate diversity. Intl Soil Water Conserv Res 9: 605-623. DOI: 10.1016/j.iswcr.2021.06.002.

Pico Y, Campo J, Alfarhan AH, El-Seikh, Barcelo D. 2023. Wild and ruderal plant as bioindicator of global urban pollution by air, water and soil in Riyadh and Abha, Saudi Arabia. Sci Total Environ 888: 164166. DOI: 10.1016/j.scitotenv.2023.164166.

Pranata R, Karepesina S, Botanri S. 2018. Distribusi spasial tumbuhan sagu (*Metroxylon* spp.) di Pulau Ambon. Agrohut 9 (2): 117-126. DOI: 10.51135/agh.v9i2.10. [Indonesian]

Pugara A, Pradana B, Puspasari DA. 2021. The impact land-use changes on the water carrying capacity in Kajen, Indonesia: A spatial analysis. IOP Conf Ser Earth Environ Sci 887 (1): 012018. DOI: 10.1088/1755-1315/887/1/012018.

Rafee SAA, Uvo CB, Martins JA, Machado CB, Freitas ED. 2022. Land use and cover change versus climate shift: Who is the main player in river discharge? A case study in the Upper Parana River Basin. J Environ Manag 309: 114651. DOI: 10.1016/j.jenvman.2022.114651.

Rodrigues DA, Sales JdeF, Vasconcelos-Filho SC, Rodrigues AA, Costa AC, Rodrigues CL, e Silva FHde L, Muller C. 2020. *Spondias mombin*, a potential bioindicator of potassium frouride pollution. Ecol Indic 114: 106314. DOI: 10.1016/j.ecolind.2020.106314.

Roy GS. 2022. A review of plant bioindicators in wetlands. Adv Environ Eng Res 3 (4): 052. DOI: 10.21926/aeer.2204052.

Singh M, Parihar DS, Depak. 2022. Assesment of tradisional water source natural springs of a Lesser Himalayan town Almora, Uttarakhand. Intl J Innov Res Multidiscip Field 8 (6): 123-132. DOI: 10.2015/IJIRMF/202206019.

Stang. 2017. Aplikasi Statistik Multivariat dalam Penelitian Kesehatan. Mitra Wacana Media Publishers, Jakarta. [Indonesian]

Suroso, Krishna KP, Santoso PB. 2020. Impact of land use land cover changes on river discharge at Brantas catchment area using SHETRAN Model. IOP Conf Ser Mater Sci Eng 982 (1): 012037. DOI: 10.1088/1757-899X/982/1/012037.

Tague CL, Moritz MA. 2019. Plant accessible water storage capacity and theee-scale root interactions determine how foorest density reduction alter forest water use and productivity. Front For Glob Change 2: 1-18. DOI: 10.3389/ffgc.2019.00036.
Vasconcelos VV, Sacht HM. 2020. Influence of canopy on surface temperature. rapaRev Bras Geogr 13 (7): 3275-3286. DOI: 10.26848/rbgf.v13.07.p3275-3286.
Watanabe T. 2023. The importance of forest hydrology: Understanding the relationship between forest and water resources. Opinion 14 (2). DOI: 10.37421/2157-7587.2023.14.455.