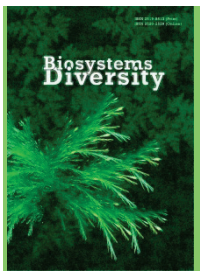

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Natural aspect of the megalithic cultural heritage area of the Bada Valley (Central Sulawesi): Vegetation composition and biodiversity analyses

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The Bada Valley is one of the Lore Lindu Megalithic Cultural Heritage areas, which is one of the first four biosphere reserves in Indonesia. The Bada Valley area offers cultural attractions that combine with nature in the form of cultural landscapes such as handicrafts from bark, hilly landscapes that offer panoramic beauty, and preserve dozens of megalithic sites from prehistoric times as well as tourist cruising areas. The area is surrounded by densely forested mountains and forms one of the most important water catchment areas for the Watershed. However, there is a lack of studies on the vascular flora. No data on plant diversity has been reported, including plant inventory, plant identification, vegetation composition, and biodiversity analyses (diversity index, evenness index, and plant species richness index). The study aimed to determine the diversity index, evenness index, and plant species richness index in the Bada Valley cultural area, Poso Regency, Central Sulawesi. This study used an exploring technique with purposive sampling. Additional information was recorded in the form of the collector's name, collection number, collection date, location, and habitus, which were recorded in the observation sheet that had been prepared. Identification of plants was carried out using the procedure for observing plant morphological characters, which included special features in each class and family or genus down to the species level. The results of the study found the vegetation composition for herbaceous strata (555 individuals), trees (91 individuals), shrubs (64 individuals), and vines (57 individuals). The diversity index value of each stratum is different for trees (H' = 1.20), herbs (H' = 1.92), shrubs (H' = 1.32), and vines (H' = 0.62). The diversity of plants in the Bada Valley in the tree, herb, and shrub strata was moderate ($1.0 < H' < 3.0$), and the encroaching plant stratum had low diversity ($H' < 1.0$). The evenness index at the level of shrubs, vines, herbs, and trees has values of 0.95, 0.90, 0.83, 0.61, respectively. The species richness index of plants in the Bada Valley is in a low category ($R < 3.5$), with R values for herbaceous plants (1.42), trees (1.33), shrubs (0.72), and vines (0.24). Information on plant biodiversity is used as a database for ecotourism development in the Bada Valley Cultural Heritage area. Research data can be used to support the local government in regulating the utilization of the Bada Valley Cultural Heritage area.

Keywords: diversity index; evenness index; richness index; plant species; invasive alien species; ecology; Central Sulawesi.

Introduction

Indonesia is a country that is very rich in biodiversity and has won an important position on the world biodiversity map. Indonesia, together with Brazil and Zaire, is in the top three countries in the world that have the highest biodiversity (megadiversity countries), with 17% of the total bird species in the world found in Indonesia (1,531 species), of which 381 species are endemic (Scales & Marsden, 2008; Murray et al., 2015; Boedhirtano, 2017) Indonesia has around 30,000 species of plants and a number of these have been used as a source of medicinal raw materials (Silalahi et al., 2015; Budiarti et al., 2017; Kasmawati et al., 2019). Diversity is the variation and variability of life on earth (Hooper et al., 2005), and diversity is a characteristic difference between communities (Lausch et al., 2016; Harrison et al., 2020).

One area in Indonesia with high biodiversity is Central Sulawesi, one of the provinces in Sulawesi. This province is located in the Wallacea region, a biogeographical area between the Sunda Shelf and the Sahul Shelf, which has a high diversity of endemic floras and faunas. However, the plant abundance of this region is insufficiently explored (Baderan et al., 2021). The Bada Valley is one of the cultural heritage areas in Central Sulawesi, together with the Behoa Valley and the Napu Valley, as well as the Palu Valley and Lake Lindu, which comprise the Lore Lindu Megalithic Area (KMLL) which has important scientific, historical and cultural values. This area has the oldest cultural chronology in Indonesia. It is currently in submission to the United Nations Educational, Scientific and Cultural Organization (UNESCO) for designation as a world cultural heritage (World Heritage).

The report from the Gorontalo Cultural Heritage Preservation Center (2018) mentions potential threats to archaeological remains in the Bada Valley. Threats caused by natural factors include weathering caused by interactions between archaeological remains and their environment; environmental factors such as climate, temperature, humidity, and sunshine; organisms such as insects, fungi, lichens, and bacteria. Other natural factors are erosion, landslides and floods, and the activities of large animals that can potentially damage these objects. In addition to natural factors, human activities also have the potential to threaten the existence of these archaeological remains; destruction and theft, vandalism, mining activities, agricultural land clearing, plantations and development (Satrija et al., 2015).

Mining activities in the Bada Valley Cultural Heritage area are spread over four villages: Bulili Village, Badangkaia Village, Bewa Village and Gintu Village, which was discovered in 2017. The perpetrators of this illegal mining are not only the local people of the Bada Valley but also

come from outside the Bada Valley or the Poso Regency. Use of trammels, mercury, and other materials in mining will damage the environment. The impact of this activity is frequent flooding, landslides, and destruction of the habitat of various species of animals, including endemic wildlife such as the Maleo Bird, Babirusa, and Anoa, also hundreds of other species of animals that have been living and breeding in the forest in the Lore Lindu National Park area.

In addition to human activities, one of the causes of the decline in biodiversity is the invasion of alien species. Invasive alien species are species of flora, fauna, microorganisms and pathogens originating from outside their original habitat that enter new areas and can cause harm to ecosystems or the environment, the economy and public health. Approximately 300 species of weeds have become invasive and have been found in Indonesia (Widjaja et al., 2014; Setyawati & Tjitrosoedirdjo, 2021). The percentage of successful weed species becoming dominant and causing negative impacts on new habitats is 10% (Sitepu, 2020).

The lack of attention to plant biodiversity has become the reason for researching the biodiversity index of the Bada Valley cultural reserve area. Data on plant diversity is complementary to realizing the development of ecotourism in Central Sulawesi Province.

Material and methods

Study area. This research was conducted in the Bada Valley cultural heritage area, Poso Regency, Central Sulawesi Province. The Bada Valley is located in South Lore and West Lore Districts, Poso Regency. Gintu is the capital city of South Lore District, and Langkeka is the capital city of West Lore District. Administratively, the Bada Valley is bordered to the north by Lore Tengah District, Poso Regency; to the east by Pamona Puselemba and West Pamona Districts, Poso Regency; to the south by Rampi Seko District, North Luwu Regency, South Sulawesi, and to the west by the District Kulawi, Poso Regency (Fig. 1). The total area of the Bada Valley is 997.7 km^2 (Central Bureau of Statistics, 2022).

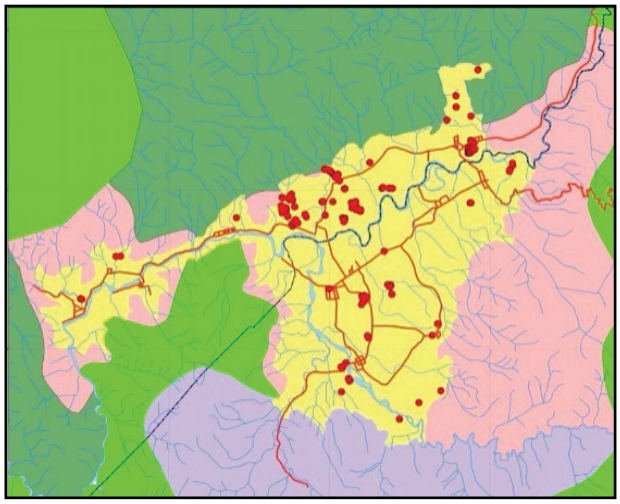

Fig. 1. Research observation points in the Bada Valley Cultural Heritage Area

The Bada Valley is a valley surrounded by mountains with an altitude between 750 and 1250 meters above sea level with a tropical climate with an average temperature of 22–31 °C with average air humidity reaching 90%, with an average rainfall of 2000 to 4000 mm per year. The geological composition of Poso district, especially in the Bada Valley area, consists of rocks of the Tinemba Volcano Formation in the form of Andesite and Andesite Basalt lava rocks resulting from the eruption of submarine volcanoes in the Pliocene to Pleistocene period aged 15 to 2 million years ago. The existence of volcanic activity in the Bada Valley area can still be found in the presence of hot springs in Kagerao Village and Langkeka Village, West Lore District.

The research method uses exploring methods for the exploration of plant species. Exploration of the Bada Valley cultural heritage area and observation of all existing plant species, accompanied by digital photographs taken with a digital camera, was used to collect plant data. Additional information was recorded in the form of the collector's name, collection number, collection date, location, and habitus, which were recorded in the observation sheet that had been prepared. Identification of plants was carried out using the procedure for observing plant morphological characters, which included special features in each class and family or genus down to the species level and then compared with the books Tjitrosoepomo (1985), Harris & Harris (2001), Pitopang et al. (2008) and Steenis (2008). Identification results were then analyzed by descriptive qualitative methods. For plant species that were not identified, herbarium specimens were made by taking plant parts cleaned of soil, fungus or foreign material adhering to them. Identification of invasive plant species was carried out based on the Guide to The Naturalized and Invasive Plants of Southeast Asia (Witt, 2017).

Data on the diversity of plant species was identified through the Diversity Index (H') (Shannon & Wiener, 1963). The value of H' determines the level of species diversity in an area, where the definition of the value of species diversity according to Shannon-Wienner is: $H' > 3$: high species diversity, $1 \leq H' \leq 3$: medium species diversity, $H' < 1$: Low species diversity. The evenness index of species refers to the Pielow evenness indices formula (Ludwig & Reynolds, 1988). The species richness index uses the Margalef formula (Magurran, 1988).

Results

The herbaceous stratum dominates the vegetation composition in the Bada valley area with with a total of 555 individuals, then the ree stratum of 91 individuals, shrubs of 64 individuals, and vines of 57 individuals (Table 1).

The value of the diversity index in the Bada Valley Cultural Conservation Area has differences in diversity in each stratum. The tree stratum had a diversity index of 1.20, the herbaceous stratum 1.92, the shrub strata 1.32 and the vines stratum 0.62 (Table 2). Based on the criteria for the value of species diversity according to Shannon-Wienner, the diversity of plants in the Bada Valley in the strata of trees, herbs and shrubs is included in the criteria of moderate diversity because the value is $1.0 \leq H' \leq 3.0$, and the strata of vines has low diversity criteria because $H' < 1.0$.

The evenness index for the shrub stratum had the highest value, namely 0.95, followed by vines at 0.90, herbaceous plants at 0.83 and trees at 0.61. Herbaceous plants had the highest species richness index with a value of 1.42, tree stratum 1.33, shrub stratum 0.72 and vines stratum 0.24. Based on the species richness index criteria, plants in the Bada Valley area have low species richness criteria because the R-value < 3.5.

Discussion

The herbaceous stratum comprises the plants with the highest diversity index value in the Bada Valley. The herbaceous stratum dominates the area with a total of 555 individuals. Herbaceous plants have a height or stem length of 0.3–2.0 meters and have wet or soft stems because they have a high water content. The high composition of herbaceous plants is closely related to the excellent adaptability of these plants in both tropical and subtropical environmental conditions. Herbaceous plants can be dispersed easily in groups with the same individual or solitary in a variety of different habitat conditions, such as moist or watery soil dry, rocks and habitats with less dense or open shade (Zelnik, 2012; Aguilar et al., 2019; Lelli et al., 2019). Herbaceous plants have strong competitiveness and high adaptation to the surrounding plants (such as bushes, shrubs, and even trees), so they can grow in empty places. Herbaceous plants in different habitats are very different in the amount that an area can produce occupying different habitats, such as habitats with high humidity to dry areas (Litza & Diekmann, 2019; Träger et al., 2019; Spicer et al., 2022).

The dominating plant is the *Ageratum conyzoides* (L.) L. This plant can be spread quickly from the wind and by insects and human activity. This plant also has speedy growth and is relatively small compared to other herbaceous plants. According to Shen et al. (2019), herbaceous plants whose body size is relatively tiny could gain a more expansive living space, thus enabling the life of more individuals (wealth) and more species (diversity).

Table 1
Composition of Plants in the Bada Valley Area

Stratum	Species	Local name	Individual number	Uses
Tree	*Antidesma ghaesembilla* Gaertn.	Tumbuhan Buni.	62	Buni plants are widely used as a traditional medicine to treat high blood pressure, palpitations, anaemia, syphilis
	Cryptocarya sp.	Kayu masohi	6	This plant treats fever and stomach cramps and relieves joint pain
	Bischofia javanica Blume	Bintungan	3	The bark of the plant is used to lower blood cholesterol levels and treat diarrhoea
	Premna serratifolia L.	Bebuas	4	Water decoction of the leaves of this plant is used to treat fever
	Casearia sp.	Hulu tulang	3	This plant are used as a natural dye and also used as an ornamental plant
	Melia azedarach L.	Renceh	8	Medication to lower high blood pressure
	Psidium guajava L.	Jambu biji	6	Diarrhoea and cough medicine
	Total individual number		91	–
Herbs	*Euphorbia hirta* L.	Tanaman asma	34	This plant can be used to treat asthma, as an antimalaria drug and wound-healing drug
	Ageratum conyzoides (L.) L.	Babandotan	183	The benefits of this plant can be used as a wound healer, leprosy and ulcers
	Chromolaena odorata (L.) R. M. King & H. Rob.	Krinyuh	88	This plant can be used as a wound healing drug and can stop bleeding quickly
	Stachytarpheta cayennensis (Rich.) Vahl	Pecut kuda	56	Used as a medicine for malaria, fever and diabetes
	Crotalaria trichotoma Bojer	Orok-orok	16	Utilized as animal feed and potentially as green manure
	Erigeron sp.	Jabung	13	Can treat pain caused by rheumatism, has a soothing effect, and heals wounds, so now it is widely used in cosmetic products
	Melastoma malabathricum L.	Senduduk	9	It can be used to treat burns
	Tridax procumbens L.	Songgolangit	104	It can be used to treat gout, aching rheumatic pain and gout
	Euphorbia heterophylla L.	Daun katemas	24	Used to treat asthma, constipation and bronchitis
	Crassocephalum crepidioides (Benth.) S. Moore	Daun sintrong	28	Can increase immunity
	Total individual number		555	–
Shrub	*Syzygium paniculatum* Gaertn.	Pucuk merah	20	This plant can improve immune function and can lower blood sugar levels
	Ixora coccinea L.	Asoka	10	Used for wound healing
	Ricinus communis L.	Daun jarak	11	It can be used as a laxative
	Broussonetia papyrifera (L.) L'Hér. ex Vent.	Pohon saeh	23	The bark of this plant is used as a primary ingredient in making traditional clothes for the people of the Bada Valley
	Total individual number		64	–
Vines	*Calopogonium mucunoides* Desv.	Kalopo	39	It can be used as green manure and as a land cover plant
	Scurrula parasitica L.	Benalu	18	This plant has potential as an anticancer, antimalarial and medicine for haemorrhoids and diarrhoea
	Total individual number		57	–

Table 2
Species diversity index, species richness index, and evenness index of stratum composition in Bada Valley Cultural Conservation Area

Stratum	Diversity index (H')	Evenness index (E)	Richness index (R)
Tree	1.20	0.61	1.33
Herbaceous	1.92	0.83	1.42
Shrub	1.32	0.95	0.72
Vines	0.62	0.90	0.24

The role of herbaceous plants in the region is significant, not least, when experiencing succession, marked by many pioneer plants and small herbaceous plants. Herbs play an essential role in the annual nutrient cycle; the herb litter that is returned to the soil contains high levels of nutrients. In addition, herbs are also used as a source of animal feed, medicine and wealth in germplasm. For example, preserving wild animals as a component of an ecosystem is influenced by the presence and diversity of undergrowth as a place to live and a high source of food and many other functions (Schmidt et al., 2019; Álvarez et al., 2022).

The diversity of plants in the Bada Valley area is included in the medium and low diversity index criteria. The low diversity is caused by several factors, including the control of the area in the cultural heritage area, soil type, climate, and biotic influences (living things). This actual condition is supported by the statement of Compant et al. (2019), which states that plant diversity is influenced by several factors, including climate, soil type, altitude and biotic influences (living things). Furthermore, Dar & Reshi (2020) states that diversity is synonymous with the stability of an ecosystem; that is, if the diversity of an ecosystem is relatively high, the condition of the ecosystem tends to be stable. Ecosystem environments that are disturbed tend to have moderate diversity. In the case of polluted ecosystem environments, species diversity tends to be low.

Geng et al. (2019) state that the higher the species diversity, the more stable the community and that it will have a higher ability to deal with disturbances. Furthermore, van der Plas (2019) argued that high species diversity indicates a community that has high complexity because the species interactions in that community are very high. A community is said to have high species diversity if the community is composed of many species. Conversely, a community is said to have low species diversity if the community is composed of a few species and only a few dominant species, in line with the statement of Pitopang & Ihsan (2014), which explains that the higher the value of the diversity index, the better the ecosystem in the region.

Based on the analysis of the evenness index of species, the Bada Valley area has plants included in the criteria for high species distribution. Evenness index values or Evenness (E) range from 0 to 1 (Magurrann, 1988), meaning that the plants in the area can grow and spread throughout the observation sites. The even distribution of plants in this location cannot be separated from the influence of environmental factors. The high level of biodiversity is because Indonesia is a tropical country with high levels of rainfall, temperature and humidity. According to Fattorini et al. (2021), Indonesia has a diversity of flora and fauna due to its geographical location around the equator and between the continents of Asia and Australia, giving rise to the emergence of particular characteristics and characteristics in resources in the form of tropical forest ecosystems. Furthermore, according to Kitayama et al. (2021), tropical forests are located along the equator, that is, in areas with high radiation intensity, with small daily and annual amplitudes.

The value of the Diversity index relates to the value of species richness but is also influenced by the distribution of species abundance. Midolo et al. (2019) state that species richness is the number of species in a community. The greater the number of species found, the greater the wealth index. The richness of plant species in the Bada Valley area is classified as low. It has been explained above that the number of species will affect species richness. The number of plant species for each stratum in the Bada Valley area is still relatively small, thus affecting species

richness. This follows the opinion of Roswell et al. (2021) that a community has high species diversity if the community is composed of many species. Conversely, if the community comprises very few species and only a few dominant species, then the species diversity is low.

Species richness shows all the variations found in living things between species. Differences between species of organisms in one or more families will be visible, making it easier to observe than differences between individuals in one species. Richness at the species level occurs because of the variety of these species. The species richness index is the most straightforward measure because it only considers differences in the number of species in a particular area. Species richness determines the amount of species richness in each community. This was confirmed by Mahaut et al. (2020), who stated that species richness refers to the number of species in a community. The quantity of species in the field determines the size of the richness index. In the context of cultural heritage sites or areas, the presence of certain plant species at the site or area strongly supports the concept of preservation by local values and traditions. Sites identified as places of worship, such as the Sepe Site in Kolori Village and the Suso Site in Lengkeka Village, Lore Barat District, are, of course, closely related to the use of certain plant species in carrying out worship ceremonies or rituals following the beliefs that developed at that time. In addition, a tradition continues today, namely the use of the bark of the *Broussonetia papyrifera* (L.) L'Hér. Ex Vent., better known as the Saeh tree, to be used as traditional clothing for the people of the Bada valley.

Based on the results of the identification of the plant species composition, several species were identified as invasive species (Table 3). Some of these species are foreign species whose natural habitat is outside the Southeast Asian region.

Table 3
Identified Invasive Species in the Bada Valley Region

No.	Species	Invasiveness	Information
1	*Melia azedarach* L.	Invasive	This species is native or originates from the Southeast Asia region but has the potential as an invasive alien species in several areas outside its natural habitat. *M. azedarach* is fast-growing and has few natural enemies. Seeds of this species are spread by birds and other animals. It has been reported as an invasive species in several locations in the Americas, Pacific and Africa, South Africa and Hawaii, USA. This species is difficult to control because of its ability to grow again vegetatively (Bhat et al., 2021).
2	*Euphorbia hirta* L.	Invasive	It is a weed or invasive species on agricultural land and hosts several pests and plant diseases (Tripathi et al., 2021).
3	*Ageratum conyzoides* (L.) L.	Invasive	*A. conyzoides* is reported as an invasive and harmful weed in agricultural fields. This species tends to invade open or degraded land. This species causes a decrease in crop yields and affects biodiversity, and is a host of pathogens and nematodes that affect several types of crops (Kohli et al., 2006).
4	*Chromolaena odorata* (L.) R. M. King & H. Rob.	Invasive	*C. odorata* is a species of herb or shrub with a wide distribution. This species is included as one of the 100 dangerous invasive species in the world. This species will quickly spread and invade new areas that are degraded through seeds easily carried by the wind (Yu et al., 2016).
5	*Stachytarpheta cayennensis* (Rich.) Vahl	Invasive	*S. cayenneensis* originates from South and Central America and the Caribbean. This species is widely introduced to various regions because it has attractive flowers. *S. cayenneensis* has a broad environmental tolerance and often invades disturbed areas, thereby overpowering native flora. This species is considered a noxious weed in the Northern Territory, Australia and is increasingly abundant in Florida, USA. According to the risk assessment, this species is considered highly invasive (score 20 = high risk) (Chandler et al., 2014).
6	*Melastoma malabathricum* L.	Invasive	*M. malabathricum* is known as a weed on mahogany (*Swietenia macrophylla*) in Sumatra, Indonesia (Master et al., 2020). It is a primary weed commonly found growing in industrial plantation forests. *M. malabathricum* is registered as a Federal Noxious Weed in the US.
7	*Euphorbia heterophylla* L.	Invasive	According to Utami et al. (2017), *E. heterophylla* is a major weed in Fiji, Ghana, Mexico, Philippines, Indonesia and Thailand, Brazil, India, Italy, Papua New Guinea, Cuba, Honduras, Peru, Uganda and the United States. This species harms several crops, including cocoa, coffee, cotton, cowpea, corn, papaya, peanuts, sorghum, soybeans, sugarcane, tea, and upland rice. It has fast growth, and it is strongly competitive in gaining access to light, water and nutrients.
8	*Crassocephalum crepidioides* (Benth.) S. Moore	Invasive	*C. crepidiodes* is an invasive species included in the Global Compendium of Weeds as one of the most aggressive weeds in tropical and subtropical regions (Dong et al., 2010). It is a pioneer species that can produce large numbers of downy seeds dispersed by the wind.
9	*Syzygium paniculatum* Gaertn.	Alien Invasive	It is an invasive foreign species. This species' original range is Australia (Ramirez & Kallarackal, 2019).
10	*Calopogonium mucunoides* Desv.	Invasive	*C. mucunoides* is a woody plant listed in the Global Compendium of Weeds that impacts agricultural and semi-natural ecosystems. *C. mucunoides* has been widely introduced as a forage legume and nitrogen-fixing plant in tropical and subtropical regions (Feitoza et al., 2018). *C. mucunoides* can potentially kill native vegetation and food crops in agricultural areas. Currently, *C. mucunoides* is classified as a noxious weed in Australia and an invasive species in Malaysia, the Philippines, Puerto Rico, and several islands in the Pacific Ocean, such as French Polynesia, Cook Islands, Samoa, Palau, and the Solomon Islands.

Developing the Cultural Conservation site or area also requires environmental management by applying the principle of authenticity. In selecting plant species, efforts are made to use and cultivate endemic or existing plant species around the Cultural Conservation site or area. Thus, the intended Cultural Conservation area can be developed under the principles of Cultural Conservation and environmental preservation.

Conclusion

The value of the diversity index in the Bada Valley Cultural Conservation Area has differences in diversity in each stratum. The tree stratum had a diversity index of 1.2, herbaceous stratum 1.91, shrub stratum 1.32 and vines stratum 0.62. The tree, herb and shrub strata are included in the medium diversity criteria, and the vine stratum has the low diversity criteria. The evenness index for the shrub stratum had the highest value, namely 0.95, followed by vines at 0.90, herbaceous plants at 0.83 and trees at 0.61. Herbaceous plants had the highest species richness index with a value of 1.42, tree stratum 1.33, shrub stratum 0.72 and vine stratum 0.24. Based on the species richness index criteria, plants in the Bada Valley area have low species richness criteria because the R-value < 3.5. Further research is needed to determine the biodiversity of flora and fauna from cultural areas in Central Sulawesi Province.

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