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Exploring habitat characteristics and herpetofauna diversity in the Kamojang and Darajat Geothermal Power Plants, West Java, Indonesia

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Abstract. *Megantara EN, Husodo T, Mutaqin AZ, Kendarto DR, Wulandari I, Pujianto MP, Shanida SS, Afriyanti F. 2025. Exploring habitat characteristics and herpetofauna diversity in the Kamojang and Darajat Geothermal Power Plants, West Java, Indonesia. Biodiversitas 26: 212-230.* Considering their vital role in preserving ecological stability, herpetofauna are essential indicators of the environment's health. From 2019 to 2023, this project examines the herpetofauna's habitat and variety surrounding the Kamojang and Darajat Geothermal Power Plants, West Java, Indonesia. The study's objectives were to monitor species diversity, evaluate habitat conditions, and understand how land use changes affect these species. Data were gathered by vegetation analysis and visual and auditory encounter surveys in various land cover types, including natural forests, mixed gardens, pine plantations, shrubs, swamps, riparian, artificial gardens, craters, and replanting areas. The results identified 37 species of herpetofauna, including 18 amphibians and 19 reptiles. Vegetation analysis revealed that natural forests and riparian zones supported the highest species richness. In contrast, areas with monoculture vegetation, such as pine plantations, had lower biodiversity. Natural habitats tend to have lower temperatures and high humidity, creating ideal conditions for specialist species requiring a stable and humid environment. In contrast, artificial habitats have warmer temperatures and lower humidity, favoring generalist species, which are more adaptable to variable environmental conditions. Artificial habitats also provide diverse microhabitats, such as open areas for basking and shade from plant canopies, which favor certain reptiles and amphibians. Adapting species to these different conditions reflects the importance of maintaining a balance between natural habitats to support specialist species and artificial habitats for more flexible species. This combination of abiotic factors and habitat structure is key to the sustainability of herpetofauna diversity in both areas. Habitat quality was affected by human activities such as land conversion and agriculture, which decreased the diversity of herpetofauna and the vegetation structure. This study emphasizes the significance of habitat conservation and sustainable land management in maintaining biodiversity in geothermal areas.

Keywords: Amphibian, rapid survey, reptile

INTRODUCTION

Java is currently experiencing rapid infrastructure development that produces degradation of natural environments (Kusrini et al. 2021). Amphibians can indicate biodiversity and local pressure on the environment because amphibians are sensitive to environmental changes, e.g., water pollution (Carlsson and Tydén 2018; Priambodo et al. 2019) and road development (Hamer et al. 2015). Road development can have various adverse effects on amphibians as it can fragment amphibian habitats, cutting off access to breeding and foraging areas as well as isolate populations and reduce genetic diversity, making amphibian populations more vulnerable to environmental changes and diseases (Hamer et al. 2015). These effects can be particularly significant because amphibians often need to migrate between aquatic breeding habitats and terrestrial environments, and roads can create barriers and hazards for them. The construction of roads usually requires the clearing of vegetation and alterations to the landscape (Flores et al. 2024). Herpetofauna has also declined in abundance and diversity. Some species are even threatened with extinction because of rapid urbanization and agriculture intensification, leading to the invasion of alien species and habitat loss (Carpio et al. 2015; Cassani et al. 2015) and over-exploitation of herpetofauna for industry, consumption, and pet trading (Shaney et al. 2017).

The food chain depends heavily on amphibians as consumers, predators, prey, and bioindicators of environmental conditions (Hocking and Babbit 2014; Kanagavel et al. 2017; Carlsson and Tydén 2018; Priambodo et al. 2019). Their existence in the natural world is noteworthy and interesting, emphasizing the importance of prioritizing the conservation of the species and its environment. Gillespie et al. (2015) revealed that different habitat conditions have implications for differences in amphibian community composition because each amphibian species responds differently to changes in existing environmental conditions. In amphibian habitats, heterogeneity affects amphibian species richness (Luja et al. 2017). Habitat heterogeneity can provide amphibian species with quantitative information on different vegetation types related to food resources, space, and microhabitat types (Badillo-Saldaña et al. 2016). However, human activity may influence habitat variability through land use change (e.g., deforestation), pollution, and degradation, leading to cascading effects on amphibian communities, such as taxonomic homogenization and decreased species richness (Berriozabal-Islas et al. 2018). Even in disturbed areas, such as rice fields, the potential to discover new species remains very high (Riyanto and Kurniati 2014).

PT. Indonesia Power Kamojang Power Generation O&M Services Unit (POMU), West Java, Indonesia, aims to produce environmentally friendly, clean, and green energy. It is committed to environmental sustainability, particularly protecting biodiversity around the Kamojang and Darajat Geothermal Power Plants, West Java, Indonesia. POMU manages and monitors the environment to reduce negative impacts and enhance positive ones, especially regarding operational activities. Environmental issues, such as land cover changes due to forest conversion, have affected both the biophysical environment and socioeconomic aspects, influencing the habitats of protected species (UNPAD 2023 Unpublished Data).

Research on amphibians and reptiles in Java that had been conducted, e.g., Riyanto and Kurniati (2014); Riyanto et al. (2015), et al. (2019); Hartmann et al. (2016); Kieckbusch et al. (2016); Hamidy et al. (2018); Cahyadi and Arifin (2019); Erawan et al. (2021); Kusrini et al. (2021); Megantara et al. (2022), had revealed that amphibian and reptile diversity in Java is still underestimated. Therefore, it is essential to show the diversity of herpetofauna species to support conservation efforts. Herpetofauna research at the Kamojang and Darajat Geothermal Power Plants was conducted by Erawan et al. (2021) and Megantara et al. (2022), revealing the presence of herpetofauna in 2017 and 2018. Their presence was monitored annually from 2019 to 2023 through this study to provide updated information on biodiversity. Additionally, the study includes vegetation structure data, offering comparisons to previous research.

Knowledge of herpetofauna diversity is essential because these animals: (i) Play a vital role in maintaining the sustainability of ecosystems; (ii) Aid human socio-economics through utilization as tourism objects (Riyanto et al. 2019); (iii) Act as pest controllers (rat and insect eaters); (iv) Provide germplasm (Cahyadi and Arifin 2019). Detailed knowledge of the spatial distribution of amphibians and reptiles on Java and Bali is also needed to aid decision-making regarding landscape changes and species management. This knowledge will support many applications in the future, including spatial planning, environmental impact assessments, and implementation of conservation measures (Kusrini et al. 2021).

MATERIALS AND METHODS

Study area

The herpetofauna data collection was conducted in the operational areas of Indonesia Power's Geothermal Power Plants-Kamojang and Darajat Geothermal Power Plants, Garut District, West Java, Indonesia. The Kamojang Geothermal Power Plant (hereon referred to as Kamojang) is located at 1,485-1,661 masl. This area comprises various land covers, including natural forests, mixed gardens, pine plantations, shrubs, swamps, riparian zones, and artificial gardens (Figure 1). Darajat geothermal power plant (hereon referred to as Darajat) consists of several land cover types, including replanting areas, craters, riparian zones, lakes, and natural forests. The details of the sampling areas and land cover types can be seen in Table 1.

Procedures

Surveys were conducted in April 2019, October 2020, February 2021, and June 2022 and June 2023 at the Kamojang Geothermal Power Plant and in October 2019, June 2020, June 2021, June 2022, and August 2023 at the Darajat Geothermal Power Plant. Specifically, vegetation analysis was carried out in 2023 to describe herpetofauna's most recent habitat conditions (still within the same timeframe as the herpetofauna study). No changes or unusual phenomena, such as natural disasters, occurred that could have significantly affected vegetation changes, so the vegetation conditions from 2019 to 2023 are assumed to be largely unchanged.

Visual and auditory encounter surveys

The herpetofauna data collection was conducted using a rapid assessment approach, utilizing the Visual and Auditory Encounter Survey method (Das 2016). Following the established transect paths, data was collected during the day and at night with two repetitions for each path in each land-use type. Observations were conducted from 7:00 PM to 11:00 PM. Observations started from the track's zero point. We focused on areas suspected to be nests or hiding places for amphibians, such as tree branches, under rotten logs, between tree roots, in rock crevices, in soil holes, under piles of debris, or along riverbanks.

The data recorded included the species and number of individuals found. Species identification of the herpetofauna encountered was carried out by referring to the following sources: Iskandar (1998) and Das (2010), while the taxonomic systematics and scientific naming of species referred to Frost (2019) and Uetz et al. (2019).

A secondary method called opportunistic exploration was also used to support the detection and discovery of herpetofauna, especially those that are fossorial, small in size, and hidden. Boruah et al. (2016) revealed that a survey covered forest paths, woodlands, plantations, stream edges, agricultural fields, and bushes. For amphibians and nocturnal snakes, surveys were done thoroughly in all suitable habitats, such as village roads, ponds, drains, and surroundings of old buildings, bushes near streams, under rocks and logs, and arboreal habitats with the help of lights. Wherever possible, the species found were identified and documented in situ.

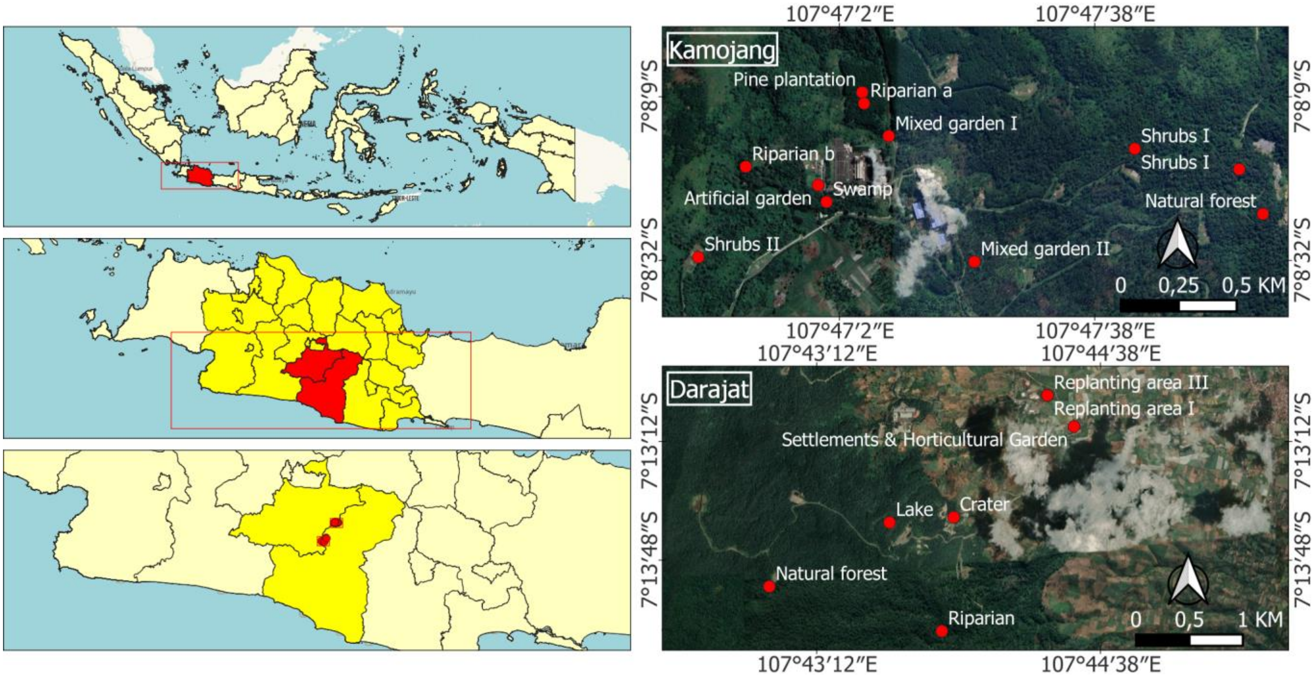


Figure 1. Study area in the Kamojang and Darajat Geothermal Power Plants, Bandung and Garut, West Java, Indonesia

Table 1. Sampling areas and land cover types in the Kamojang and Darajat Geothermal Power Plants, West Java, Indonesia

Land cover types	Description	Elevation	Coordinates
Kamojang			
Natural forest	Aquatic and terrestrial natural forests	1,661-1,645	7° 8'19.48"S 107°47'58.71"E; 7° 8'25.73"S 107°48'2.06"E
Mixed garden I	The middle section of the Cisurian River is a mixed garden	1,485-1,628	7° 8'14.83"S 107°47'9.34"E
Mixed garden II	The flow of the Cukang Lemah River, composed of mixed gardens	1,485-1,628	7° 8'32.42"S 107°47'21.40"E
Pine plantation	The pine forest is intercropped with coffee plants (*Coffea* sp.)	1,576	7° 8'8.71"S 107°47'5.59"E
Shrubs I	The upstream section of the Cisurian River consists of degraded natural forest and shrubs	1,485-1,628	7° 8'16.67"S 107°47'44.00"E; 7° 8'16.61"S 107°47'44.00"E
Shrubs II	Shrubs found on the slope of *Pasir Jawa*	1,501	7° 8'31.78"S 107°46'42.48"E
Swamp	Cikaro Lake	1,493	7° 8'24.06"S 107°47'0.57"E
Riparian	• The Cisurian River's downstream section still contains remnants of degraded natural forest	1,485-1,628	• 7° 8'10.27"S 107°47'5.83"E
	• The Cikaro River is composed of mixed gardens		• 7° 8'19.12"S 107°46'49.18"E
Artificial garden	Consists of aesthetic plants	1,522	7° 8'21.69"S 107°46'59.38"E
Darajat			
Replanting area I	Typically used as mixed gardens during the rainy season, and after use, the land is left to grow into shrubs during the dry season	1,713-1,726	7°12'58.08"S 107°44'22.21"E
Replanting area II	Typically used as mixed gardens during the rainy season, and after use, the land is left to grow into shrubs during the dry season	1,713-1,726	7°12'58.08"S 107°44'22.21"E
Replanting area III	Typically used as mixed gardens during the rainy season, and after use, the land is left to grow into shrubs during the dry season	1,713-1,726	7°12'58.08"S 107°44'22.21"E
Lake	Cibeureum Lake, covered with shrubs, is used for fishing.	2,051	7°13'36.60"S 107°43'34.01"E
Crater	Shrubs and natural stands dominate the vegetation. Near the crater, water reservoirs channel hot water to tourist areas	1,956	7°13'35.01"S 107°43'53.61"E
Natural forest	Footpaths near Mount Kendang swamp	2,172	7°13'56.01"S 107°42'57.31"E
Riparian	Cipandai River, with rocky and sandy substrates	1,983	7°14'9.52"S 107°43'49.97"E
Settlements & Horticultural Garden	Karyamekar Village. No vegetation study was conducted in this area	1,500-1,679	7°13'7.53"S 107°44'30.31"E

Vegetation survey

Habitat vegetation data was collected using the quadratic plot method. Plots were established in each cover type. Plot sizes varied depending on vegetation habitus and tree growth stages: 20x20 m for trees, 10x10 m for poles and shrubs, 5x5 m for saplings, and 2x2 m for herbaceous plants. Tree growth stages were categorized as trees for Those with a Diameter at Breast Height (DBH) greater than 20 cm, poles (DBH between 10 and 20 cm), and saplings (DBH less than 10 cm and height greater than 1.5 m). Data on plant species, diameter at breast height (DBH), and abundance (number of individuals) were recorded for each plot. Abiotic factor measurements were taken in each land cover type, including temperature, water humidity, soil pH, soil moisture, and the percentage of litter cover.

Data analysis

The identified species were tabulated using Microsoft Excel and categorized by class, order, and family. We also categorized the species by conservation status according to the International Union for Conservation of Nature (IUCN) Red List. Their presence is categorized by year of study in 2019-2023 and land cover types.

Data obtained through the quadrat method and factor abiotic measurements were tabulated using Microsoft Excel, including the species diversity of trees, poles, and saplings. Species diversity was analyzed using the Relative Frequency (RF), Relative Density (RD), Relative Dominance (RC), Importance Value Index (IVI), and Shannon-Wiener's diversity index (H') (Dharma et al. 2021). The data obtained through the profile diagram were analyzed descriptively and qualitatively.

$$Frequency\ (F) = \frac{The\ number\ of\ plot\ which\ is\ found\ a\ species}{The\ total\ number\ of\ plots}$$

$$Density\ (D) = \frac{All\ number\ of\ individual\ species}{The\ total\ width\ of\ plots}$$

$$Dominance = \frac{The\ total\ of\ basal\ area\ of\ a\ species}{The\ total\ width\ of\ plots}$$

$$Relative\ Frequency\ (FR) = \frac{Frequency\ of\ species}{The\ total\ frequency\ of\ all\ species}\ x\ 100\%$$

$$Relative\ Density\ (RD) = \frac{Density\ of\ a\ species}{The\ total\ number\ of\ all\ species\ density}\ x\ 100\%$$

$$Relative\ Dominance\ (RC) = \frac{Dominance\ of\ a\ species}{The\ total\ dominance\ of\ all\ species}\ x\ 100\%$$

$$IVI = RF + RD + RC$$

$$H' = -\Sigma({}^{ni}/_{N}) \ln({}^{ni}/_{n})$$

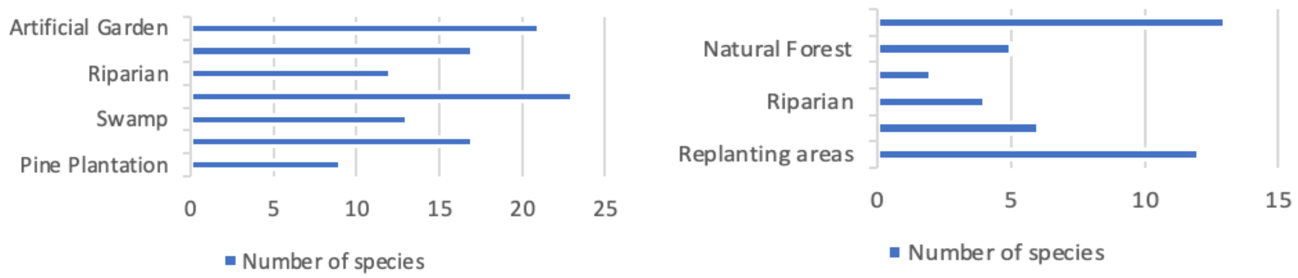
IVI is the sum of RF, RD, and RC with a value range of 0-300. p is the proportion of individuals of a certain plant species (n/N) divided by the total number of individuals (N), ln is a natural logarithmic value, Σ is the sum of calculations, and s is the number of species. The amount of species variety is categorized as high (H'>3), moderate (1≤H'≤3), or low (H'<1).

RESULTS AND DISCUSSION

We found 37 species of herpetofauna in the Kamojang and Darajat Geothermal Power Plants (Table 2, Figures 2 and 3). Of these, 18 are amphibians and 19 are reptiles. The amphibians are most represented by the family Ranidae, with five species, while the reptiles are most commonly represented by the family Gekkonidae, with seven species. Compared to Kusrini et al. (2021), 29 amphibians and 56 reptiles were recorded in the Halimun Salak National Park, 27 amphibians and 56 reptiles in the Gede Pangrango National Park, 19 amphibians and 57 reptiles in the Ujung Kulon National Park, and 14 amphibians and 34 reptiles in the Alas Purwo National Park.

Out of the 37 species found, Javan torrent frog (*Huia masonii*), The Indonesian false bloodsucker (*Pseudocalotes tympanistriga*), and Reinwardt's frog (*Rhacophorus reinwardtii*) are endemic to Java Island (Figure 4) (Kusrini et al. 2021). Generally, the species presence did not differ significantly (Figures 2 and 3). Some species were consistently found every year in both Kamojang and Darajat Geothermal Power Plants, including Asian common toad (*Duttaphrynus melanostictus*), palmated chorus frog (*Microhyla palmipes*), nicobar frog (*Amnirana nicobariensis*), schlegel's frog (*Chalcorana chalconota*), common house gecko (*Hemidactylus frenatus*), common sun skink (*Eutropis multifasciata*), and temminck's forest skink (*Tytthoscincus temmincki*). These species can be found in human-modified land and forests, indicating their adaptability to human-modified and natural environments.

Several amphibians found in the Kamojang and Darajat Geothermal Power Plants are also present in Bali (Kusrini et al. 2021), including *D. melanostictus*, Asian Grass Frog (*Fejervarya limnocharis*), Java spadefoot toad (*Leptobrachium hasseltii*), *M. palmipes*, *A. nicobariensis*, *C. chalconota*, and white-lipped tree frog (*Polypedates leucomystax*). Several reptiles found in the Kamojang and Darajat Geothermal Power Plants are also present in Bali (Kusrini et al. 2021), including green crested lizard (*Bronchocela cristatella*), great crested canopy lizard (*Bronchocela jubata*), marbled bow-fingered gecko (*Cyrtodactylus marmoratus*), four-clawed gecko (*Gehyra mutilata*), *H. frenatus*, flat-tailed house gecko (*Hemidactylus platyurus*), common dwarf gecko (*Hemiphyllodactylus typus*), *E. multifasciata*, *T. temmincki*, gunther's whip snake (*Ahaetulla prasina*), linnaeus's reed snake (*Calamaria linnaei*), yellow-striped trinket snake (*Coelognathus flavolineatus*), copper-headed trinket snake (*Coelognathus radiatus*), speckle-bellied keelback (*Rhabdophis chrysargos*), and flat-nosed pit-viper (*Trimeresurus puniceus*).



A B

Figure 2. Herpetofauna presences based on land cover types in the Kamojang (A) and Darajat (B) Geothermal Power Plants, West Java, Indonesia

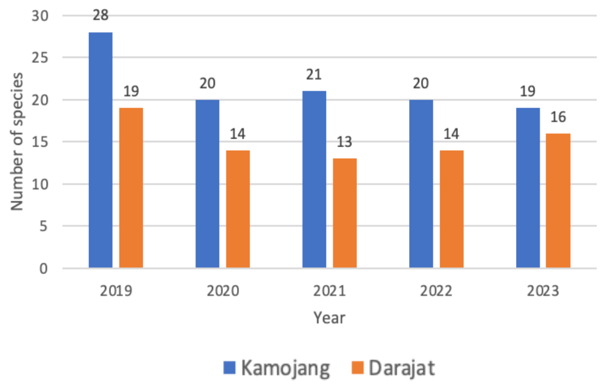


Figure 3. Trend of species in the Kamojang and Darajat Geothermal Power Plants, West Java, Indonesia in 2019-2023.

Herpetofauna's habitat in the Kamojang, West Java, Indonesia (Figure 5)

Based on the IVI (Table 3), herpetofauna habitats are dominated by several plants, including pine (*Pinus merkusii*), mara (*Macaranga rhizinoides*), timor white gum (*Eucalyptus urophylla*), avocado (*Persea americana*), sea hibiscus (*Hibiscus tiliaceus*), needlewood (*Schima wallichii*), great malay bean (*Engelhardia spicata*), ko rian (*Sloanea sigun*), and Javan chestnut-oak (*Castanopsis javanica*). The plant families with the most species are found in four families: Poaceae, Asteraceae, Fabaceae, and Lauraceae. The Poaceae and Fabaceae families comprise 13 species, while Asteraceae and Lauraceae comprise 12 species each. Poaceae and Asteraceae are cosmopolitan groups that can grow in various habitats. These two families are commonly found in open areas, such as shrubs, plantations, and agricultural lands. This is also supported by their seed dispersal mechanisms, primarily wind, which makes them easily spread. Furthermore, most of the data collection sites are plantation ecosystems and disturbed ecosystems. Lauraceae is a family known to dominate montane forest stands in Java. The Lauraceae family is quite dominant in the Kamojang area because it is located at an altitude of 1,400-1,600 masl.

Pine plantations

Table 5 shows that the diversity index for herpetofauna in pine plantations is among the lowest, especially for saplings and seedlings. The IVI values (Table 3) show that the plantation is dominated by *P. merkusii*, making it the most dominant species in this land cover type. This suggests that the vegetation in pine plantations is highly homogenous, offering limited ecological niches for herpetofauna. The uniformity of the plant species and structure in this habitat makes it less favorable for species that depend on varied microhabitats for foraging, breeding, and shelter. The dominant presence of *P. merkusii* (as shown by the high IVI) reduces undergrowth, which many amphibians and reptiles rely on. The lack of diversity in the vegetation, particularly the absence of a significant understorey, limits the types of species that can survive in this habitat. For herpetofauna, the lack of a complex ground layer or moist environments (e.g., streams or ponds) is detrimental, especially for amphibians, which depend on water sources for reproduction.

Aside from *Pinus*, other tree stands in this area include red calliandra (*Calliandra calothyrsus*), East Africa mahogany (*Khaya anthotheca*), and *S. wallichii*. This pine forest is located near a horticultural garden. The understory vegetation includes doveweed (*Murdannia nudiflora*) and palm grass (*Molineria capitulata*). In this vegetation, *Microhyla achatina*, Asian grass lizard (*Takydromus sexlineatus*), *E. multifasciata*, and *T. temmincki* were found. The low presence of amphibians is attributed to the absence of flowing water or standing water in the area.

The abiotic factors (Table 6) in the pine plantation further explain the low species richness. Table 6 shows that the temperature in the pine plantation is 19.6°C, which is relatively moderate, but the soil pH is slightly acidic (6.4), and soil humidity is low (60%). Additionally, the leaf litter cover is minimal (10-20%), which affects ground-dwelling herpetofauna, such as skinks or frogs that use leaf litter for cover and foraging. The lack of adequate soil moisture and cover reduces the suitability of this habitat for many amphibians that need high humidity and a stable microclimate for survival.

The combination of a monoculture dominated by *P. merkusii*, low plant diversity and unfavorable abiotic conditions (low humidity, sparse leaf litter, and limited understorey) create an environment that is less supportive for herpetofauna. This results in the pine plantation having the lowest recorded species richness compared to other land cover types in Kamojang, where more diverse and structurally complex habitats, such as riparian zones and natural forests, support a richer herpetofauna community.

Shrubs

Several amphibian species thrive in these shrubs, including *M. achatina*, *M. palmipes*, *F. limnocharis*, large-headed frog (*Limnonectes kuhlii*), *C. chalconota*, and Java bubble-nest frog (*Philautus aurifasciatus*). These species utilize the shrubs for foraging and shelter, indicating the importance of this land cover in maintaining herpetofauna populations. Additionally, reptile species such as *B. cristatella*, are also found in these areas, underscoring the ability of the shrubland to provide adequate microhabitats for both amphibians and reptiles.

Abiotic factors (Table 6) play a significant role in shaping the quality of these habitats. The shrubs' temperature ranges from 18.2°C to 22.9°C, with a soil pH of 6.6 to 6.8, soil moisture of 40% to 60%, and air humidity of 59.5% to 71.2%. These variations in temperature and humidity significantly impact the presence and behavior of herpetofauna, as amphibians are particularly sensitive to such environmental changes. Moderate biodiversity and favorable abiotic conditions in these shrublands allow them to sustain stable herpetofauna populations.

Shrubs I and Shrubs II experienced changes due to the expansion of agricultural land, replaced with horticultural crops such as cabbage (*Brassica oleraceae*), common bean (*Phaseolus vulgaris*), and chilli pepper (*Capsicum annum*). This conversion highlights the vulnerability of shrublands to rapid changes, as their relatively short growth cycles make them susceptible to being replaced by other vegetation types. Despite these changes, some remnants of natural tree cover, such as charcoal tree (*Trema orientalis*), *E. spicata*, and *C. javanica*, were retained, although their canopies were pruned. The opening of these lands significantly reduced the composition of saplings in the area. Structurally, Shrubs I was dominated by *S. sigun* for trees, gispang (*Claoxylon longifolium*) for poles, southern magnolia (*Magnolia blumei*) for saplings, and winter-hazel (*Distylium stellare*) for seedlings (Table 3). *Hibiscus tiliaceus* dominated shrubs II for trees, *E. spicata* for poles, orange wild rhea (*Debregeasia longifolia*) for saplings, and *P. americana* for seedlings (Table 3). The conversion of shrubland into agricultural fields threatens the biodiversity area, as the rapid turnover of vegetation types disrupts the habitat stability that species like amphibians and reptiles rely on, raising concerns about the long-term impact of agricultural expansion.

Natural forests

Natural forests provide the specific conditions necessary to support the life cycle of *H. masonii*, a Vulnerable species that depends on intact, moist environments, typically near water sources, for breeding. The IVI (Table 3) for the natural forests indicates that the area is dominated by species that create a stable and diverse habitat. In these forests, *C. javanica* and *D. stellare* dominate the tree layer. At the same time, ki leho (*Saurauia bracteosa*) and *E. spicata* are prevalent in the pole layer, providing canopy cover and maintaining the microclimate essential for amphibians like *H. masonii*. The sapling layer is dominated by *D. stellare*, while the common yellow-stem fig (*Ficus fistulosa*) dominates the seedling layer. These dominant species create suitable microhabitats with sufficient moisture and shelter for amphibians to thrive. The well-structured vegetation in natural forests supports a more complex ecosystem, providing a conducive habitat for *H. masonii*.

The abiotic factors in the natural forest further explain its suitability for *H. masonii*. The temperature is moderate, around 19.4°C, with relatively high humidity (52.7%) and slightly acidic soil with a pH of 6.4, creating an ideal environment for amphibians. The leaf litter cover, ranging from 70-80% (Table 6), provides shelter and foraging grounds for amphibians like *H. masonii*, which often rely on moist and covered ground layers.

However, parts of the natural forest, such as the Pasir Jawa area, have been damaged due to deforestation and conversion into horticultural farmland. Additionally, temporary access roads that can accommodate vehicles have contributed to the degradation of herpetofauna habitats. Farmers also use these roads to transport fertilizers, crops, timber, and non-timber forest products, as well as for access to tourist areas; the understory vegetation in these disturbed forests is dominated by impatiens species. Despite the habitat disturbance, several species, such as *L. kuhlii*, *C. chalconota*, *R. reinwardtii*, and *B. cristatella*, can still be found, indicating that these species are capable of associating with disturbed habitats.

Swamp

The swamp area is a seasonal wetland filled with water during the rainy season and partially drying up during the dry season. During the rainy season, the vegetation is dominated by *Caliandra* shrubs, while in the dry season, the land is often converted into horticultural gardens, such as potato farms. However, some natural tree stands are left intact. Structurally, the swamp vegetation is dominated by *E. spicata* in the tree and pole layers and *D. stellare* in the seedling layer (Table 3). The absence of saplings is attributed to land conversion for agriculture, which affects the overall plant composition. The lack of vegetation diversity in some layers, especially seedlings, has prevented the diversity index from being recorded in these plant strata. The swamp serves as a habitat for several herpetofauna species, including *M. achatina*, *M. palmipes*, Malayan Wart Frog (*Limnonectes macrodon*), and *A. nicobariensis*. These species thrive in the wet conditions during the rainy season but are affected by the habitat changes brought about by land conversion in the dry season.

Regarding abiotic factors, the swamp area has an average temperature of 21.1°C, air humidity of 56.2%, soil pH of 6.8, and soil moisture reaching 68% (Table 6). These abiotic conditions, particularly the high soil moisture and relatively neutral pH, are favorable for both amphibian life and plant growth during the wet season. However, the seasonal drying of the swamp and its conversion into agricultural land during the dry season significantly impacts the ecosystem's stability and biodiversity.

Mixed garden

The mixed garden area in Kamojang is characterized by a combination of tree species and cultivated crops, creating an agroforestry system closely resembling a forest structure. In Mixed Garden I (Table 3), the vegetation is dominated by *P. merkusii* at the tree level, with *S. wallichii* and *K. anthotheca* at the pole level, while Arabian coffee (*Coffea arabica*) dominates the sapling and seedling layers. The exclusive presence of coffee in the sapling and seedling layers results in no diversity index for these layers, indicating a monoculture in the understory. However, the diversity index for trees and poles is moderate to low, reflecting a relatively diverse but not highly rich composition of these strata.

In Mixed Garden II (Table 3), the structure is slightly different, with *E. urophylla* dominating the tree and pole layers and *C. arabica* dominating the sapling and seedling layers. The coffee plants are over three years old, with an average height of 1.5 to 2 meters and dense canopies, which indicates infrequent pruning. Large trees alongside coffee plants create an agroforestry system miming a forest structure. The ground cover in this area is dominated by mistflower (*Ageratina riparia*) and billygoat weed (*Ageratum conyzoides*), which thrive in the shaded understory.

In Mixed Garden I and Mixed Garden II, temperatures range from 21.2°C to 21.3°C, with air humidity between 59.6% and 61.4% and soil pH varying from 6.2 to 6.8. Soil moisture levels differ more significantly, ranging from 30% in Mixed Garden I to 51% in Mixed Garden II (Table 6). These variations in humidity and moisture create distinct microhabitats that may influence species composition.

In terms of herpetofauna, these mixed gardens support a diverse array of species, including *D. melanostictus*, *M. achatina*, *F. limnocharis*, *L. kuhlii*, *L. macrodon*, *C. chalconota*, *A. nicobariensis*, Red-webbed white-lipped frog (*Chalcorana rufipes*), and *P. leucomystax*. Among the reptiles found in these areas are *B. cristatella*, *H. frenatus*, and *E. multifasciata*.

Riparian

The riparian zone is found along the Cikaro River and Cikaro Lake, extending toward the foothills of Pasir Jawa. *Macaranga rhizinoides* and *E. spicata* are prevalent in these riparian areas, indicating their crucial role in stabilizing the ecosystem near water bodies, essential for amphibian survival. The temperature remains moderate, around 19.6°C, with higher humidity at 66.2% and slightly acidic soil with a pH of 6.9 (Table 6). The combination of soil moisture and a high leaf litter cover (80-90%) creates an ideal habitat for species that rely on water bodies and moist conditions for breeding and survival. This habitat is home to several species, including *L. kuhlii*, *C. chalconota*, *B. cristatella*, and Kuhl's angelhead lizard (*Gonocephalus kuhlii*).

Artificial garden

The IVI (Table 3) for the artificial garden reflects moderate diversity for trees and poles, with *P. americana* dominating both strata. However, the diversity index for saplings and seedlings is lower due to the dominance of Indonesian cinnamon (*Cinnamomum burmanii*) and *C. arabica*, limiting the species' variety in these layers. The abiotic conditions in the artificial garden include a temperature of around 23.5°C, air humidity of 54.4%, and a soil pH of 6.2, which is slightly acidic. Soil moisture levels are around 30%, and the leaf litter cover ranges from 40-50% (Table 6). These conditions create a moderately dry environment compared to riparian or natural forest areas. However, they are still sufficient to support a variety of plant species and provide suitable habitats for the amphibians found in the garden.

Herpetofauna's habitat in the Darajat, West Java, Indonesia (Figure 5)

Based on The IVI (Table 4), several plant species dominate herpetofauna habitats, such as white gum (*Eucalyptus alba*), Monterey cypress (*Cupressus macrocarpa*), blue tree fern (*Cyathea contaminans*), *S. wallichii*, and rasamala (*Altingia excelsa*). The families with the most species are Orchidaceae, Poaceae, and Asteraceae.

Replanting areas

Replanting areas in the study site are structurally dominated (Table 4) by *E. alba* and *C. macrocarpa* in the tree layer. The pole and sapling layers are similarly dominated by *E. alba*, while the seedling layer is dominated by *C. macrocarpa* and *S. wallichii*. This dominance of a few species across multiple strata indicates a lack of diversity, as shown by the absence of a diversity index (DI) for trees, poles, saplings, and seedlings. The low diversity reflects that these replanting areas were designed for revegetation with limited species variation, aiming more at land stabilization rather than biodiversity enrichment.

The IVI data (Table 4) highlights the overwhelming dominance of *E. alba* and *C. macrocarpa* in all vegetative layers, reinforcing the lack of species richness. The homogeneity of plant species across the various layers of vegetation suggests that these replanting areas have a simplified vegetation structure, offering fewer ecological niches for different species. Despite the low plant diversity, these areas still support several herpetofauna species, including *D. melanostictus*, *A. nicobariensis*, *C. rufipes*, *C. chalconota*, *P. leucomystax*, *G. mutilata*, *E. multifasciata*, and *T. temmincki*.

These species, many generalists, can adapt to disturbed environments and thrive even in less complex ecosystems. The abiotic conditions in the replanting areas are characterized by moderate temperatures ranging from 19.2°C to 19.5°C, with relatively high air humidity of 65% to 78%. The soil pH ranges from 6.4 to 6.8, slightly acidic, and the soil moisture is moderately high. The leaf litter cover varies between 30% and 70% (Table 6), providing sufficient ground cover and shelter for amphibians and reptiles that use the leaf litter for breeding and hiding.

These abiotic factors favor herpetofauna, particularly amphibians such as *D. melanostictus* and *P. leucomystax*, which thrive in moist, slightly acidic environments. The moderate temperatures and relatively high humidity create suitable conditions for thermoregulation in reptiles like *E.*

multifasciata. At the same time, leaf litter enhances the habitat's suitability for amphibians and other ground-dwelling species.

Lake

The IVI for the lake area vegetation (Table 4) highlights the dominance of a few key species such as *E. spicata*, stone oaks (*Lithocarpus javensis*), and *S. wallichii* across all strata. This dominance, particularly in the sapling and seedling layers, suggests a low diversity index for these strata, indicating limited species richness and a simplified vegetative structure. The low diversity index suggests that the vegetation in the lake area is less heterogeneous, which can affect the variety of ecological niches available to herpetofauna.

Despite this low diversity, the presence of amphibians such as *M. achatina*, *M. palmipes*, *A. nicobariensis*, and *P. aurifasciatus*—species known for their ability to survive in various environments—suggests that the habitat still provides the necessary resources for species that can tolerate less diverse plant communities.

The lake area's abiotic conditions contribute significantly to its ability to support herpetofauna populations. The temperature in this area averages around 20.1°C, with relatively high humidity levels ranging from 72% to 80% (Table 6), providing a moist microclimate essential for the amphibians inhabiting the area. The soil is quite acidic, with a pH of 6.5, which is ideal for plant growth and supports the moisture-retentive properties amphibians need for breeding and survival.

Soil moisture in the lake area is consistently high due to the proximity to the water body, creating a suitable habitat for amphibians, which depend on moist environments. The extensive leaf litter cover, ranging between 60% and 80%, further enhances the microhabitat by providing shelter and foraging grounds for amphibians and reptiles.

Crater

The IVI in the crater area (Table 4) highlights the dominance of *E. spicata* (tree), *M. blumei* (pole), and cantigi (*Vaccinium varingiaefolium*) (sapling and seedling). The diversity index for the tree layer is categorized as low, indicating limited species richness in this stratum. However, the diversity index for the pole, sapling, and seedling layers is moderate, suggesting that these layers support a more varied species composition than the tree layer.

The low diversity index in the tree layer reflects a simplified vegetation structure, which can limit the variety of ecological niches available to species that rely on more complex forest structures. In contrast, the moderate diversity index in the other layers provides slightly more heterogeneity, which may support species adaptable to varying conditions within the crater's environment.

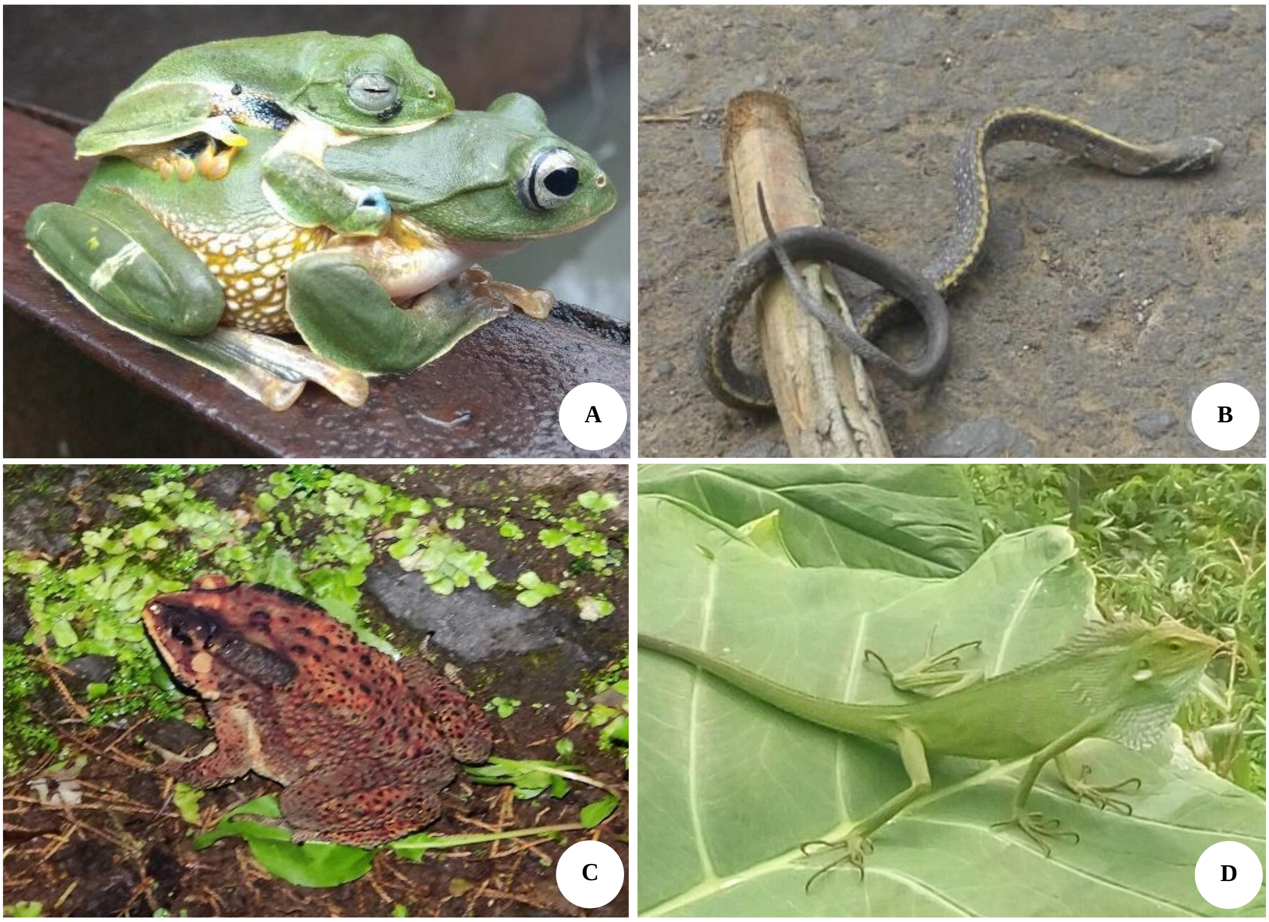


Figure 4. A. *Rhacophorus reinwardtii*; B. *Coelognathus flavolineatus*; C. *Duttaphrynus melanostictus*; D. *Bronchocela jubata*. Photographs by: Iwandarajat and Jirjizjauhan

Table 2. Trend of herpetofauna species in the Kamojang and Darajat Geothermals, West Java, Indonesia

Class | Order | Family | Species	Common name	Kamojang (Year)					Darajat (Year)					Cons.
		2019	2020	2021	2022	2023	2019	2020	2021	2022	2023	IUCN
AMFIBIA												
ANURA												
Bufonidae												
Duttaphrynus melanostictus (Schneider, 1799)	Black-spectacled Toad	+	+	+	+	+	+	+	+	+	+	LC
Dicroglossidae												
Fejervarya limnocharis (Gravenhorst, 1829)	Asian Grass Frog		+	+	+	+						LC
Limnonectes kuhlii (Tschudi, 1838)*	Large-headed Frog	+	+	+	+	+						LC
Limnonectes macrodon (Duméril & Bibron, 1841)	Malayan Wart Frog	+	+	+	+	+						LC
Limnonectes microdiscus (Boettger, 1892)	Indonesian Wart Frog	+		+								LC
Megoprhyidae												
Leptobrachium hasseltii (Tschudi, 1838)	Java Spadefoot Toad	+										LC
Megophrys montana (Kuhl & Van Hasselt, 1822)*	Asian Spadefoot Toad	+					+	+		+	+	LC
Microhylidae												
Microhyla achatina (Tschudi, 1838)*	Javan Chorus Frog	+	+	+	+	+	+				+	LC
Microhyla palmipes (Boulenger, 1897)	Pengalengan Rice Frog	+	+	+	+	+	+	+	+	+	+	LC
Ranidae												
Amnirana nicobariensis (Stoliczka, 1870)	Nicobar Island Frog	+	+	+	+	+	+	+	+	+	+	LC
Chalcorana chalconota (Schlegel, 1837)	Schlegel's Frog	+	+	+	+	+	+	+	+	+	+	LC
Chalcorana rufipes (Inger, Stuart & Iskandar, 2009)	Red-webbed white-lipped frog	+	+	+	+		+				+	LC
Huia masonii (Boulenger, 1884)*	Javan Torrent Frog	+	+	+	+		+	+	+	+	+	LC
Odorrana hosii (Boulenger, 1891)	Hose's Frog	+	+	+	+	+						LC
Rhacophoridae												
Philautus aurifasciatus (Schlegel, 1837)*	Java Bubble-nest Frog	+				+	+	+	+	+	+	LC
Polypedates leucomystax (Gravenhorst, 1829)	White-lipped Tree Frog	+	+	+	+		+	+	+	+	+	LC
Rhacophorus margaritifer (Schlegel, 1837)*	Java Flying Frog	+										LC
Rhacophorus reinwardtii (Schlegel, 1840)*	Reinwardti's Frog	+	+	+		+						LC
REPTILIA												
SQUAMATA												
Agamidae												
Bronchocela jubata (Duméril & Bibron, 1837)	Great Crested Canopy Lizard	+	+		+	+		+	+	+	+	LC
Bronchocela cristatella (Kuhl, 1820)	Green Crested Lizard				+	+						LC
Gonocephalus kuhlii (Schlegel, 1851)	Kuhl's Anglehead Lizard	+				+						NE
Pseudocalotes tympanistriga (Gray, 1831)*	Indonesian False Bloodsucker	+										LC
Colubridae												
Calamaria linnaei (Boie, 1827)	Linnaeus's Reed Snake	+	+	+		+	+				+	LC
Coelognathus flavolineatus (Schlegel, 1837)	Yellow-striped Trinket Snake						+					LC
Coelognathus radiatus (Boie, 1827)	Copper-headed Trinket Snake						+					LC

Gekkonidae												
Ahaetulla prasina (Boie, 1827)	Gunther's Whip Snake				+							LC
Cyrtodactylus marmoratus (Gray, 1831)**	Marbled Bow-fingered Gecko	+	+	+	+							NE
Gehyra mutilata (Wiegmann, 1834)	Four-clawed Gecko	+					+	+	+	+	+	NE
Hemidactylus frenatus (Duméril & Bibron, 1836)	Common House Gecko	+	+	+	+	+	+	+	+	+	+	LC
Hemidactylus platyurus (Schneider, 1797)	Flat-tailed House Gecko	+	+	+					+			NE
Hemiphyllodactylus typus (Bleeker, 1860)	Common Dwarf Gecko							+		+		NE
Oligodon purpurascens (Schlegel, 1837)	Purple Kukri Snake				+							LC
Lacertidae												
Takydromus sexlineatus (Daudin, 1802)	Asian Grass Lizard					+						LC
Natricidae												
Rhabdophis chrysargos (Schlegel, 1837)	Speckle-bellied Keelback	+		+			+					LC
Scincidae												
Eutropis multifasciata (Kuhl, 1820)	Common Sun Skink	+	+	+	+	+	+	+	+	+	+	NE
Tytthoscincus temmincki (Duméril & Bibron, 1839)	Temminck's Forest Skink	+	+	+	+	+	+	+	+	+	+	NE
Viperidae												
Trimeresurus puniceus (Boie, 1827)	Flat-nosed Pit-viper						+					LC

Note: *: Endemic to Java Island; **: The species is believed to be endemic to Java and its surroundings, but its status is still considered to have a wide distribution due to the lack of research and data supporting the endemicity status of the species; Cons.: Conservation Status; IUCN: International Union for Conservation of Nature; LC: Least Concern; NE: Not Evaluated; +: Presence.

Table 3. IVI (%) of herpetofauna's habitat in the Kamojang, West Java, Indonesia

Scientific name	Common name	Land cover types								
		PP	MG I	MG II	NF	Sh I	Sh II	Sw	Ri	AG
Tree										
Castanopsis javanica A.DC.	Javan Chestnut-oak				68.66		128.12			
Distylium stellare S.Vidal	Winter-hazel				60.96					
Engelhardia spicata Blume	Great Malay Bean			57.16		51.9		87.97		
Eucalyptus urophylla S.T. Blake	Timor White Gum	21.92	32.99	126.51						51.4
Falcataria moluccana (Miq.) Barneby & J.W. Grimes	Moluccan Albizia									80.1
Hibiscus tiliaceus L.	Sea Hibiscus						171.88			
Lithocarpus sp.	-			29.34		43.2				
Macaranga rhizinoides Elmer	Mara								144.03	
Magnolia sp.	-								34.39	
Ostodes paniculate Blume	Panicled Bone-Tree							68.26		
Persea americana Mill.	Avocado									114.4
Pinus merkusii Jungh. & de Vriese	Pine	278.08	267.01							
Schima wallichii (DC.) Korth.	Needlewood				48.40					
Sloanea sigun K. Schum.	Ko Rian					78.5		40.13	33.60	
Pole										
Alangium chinense (Lour.) Harms	Chinese alangium					17.08				
Castanopsis javanica A.DC.	Javan chestnut-oak								49.18	
Claoxylon longifolium (Blume) Endl. Ex Hassk.	Gispang					52.26				
Engelhardia spicata Blume	Great Malay Bean				59.68		59.86	111.61	93.36	
Eucalyptus urophylla S.T. Blake	Timor White Gum			153.82						
Falcataria moluccana (Miq.) Barneby & J.W. Grimes	Moluccan Albizia									82.72
Khaya anthotheca (Welw.) C.DC.	East African Mahogany		97.73							
Lithocarpus indutus (Blume) Rehder	Pasang Balung									21.55
Lithocarpus sp.	Stone Oaks							32.98		
Macropanax dispermus (Blume) Kuntze	Pampung							36.83		
Magnolia blumei (Korth.) Figlar & Noot.	Southern Magnolia					24.69				
Persea americana Mill.	Avocado									119.33
Pinus merkusii Jungh. & de Vriese	Pine	284.73	80.79	36.70						
Pittosporum ferrugineum Aiton	Rusty Pittosporum						30.12			
Saurauia bracteosa DC.	Ki Leho				64.59					
Saurauia pendula Miquel	Ki Leho								38.48	
Schima wallichii (DC.) Korth.	Needlewood	15.27	98.04							
Syzygium densiflorum Wall. Ex Wight & Arn.	Jambu kopo				29.02					
Toona sureni (Blume) Merr.	Suren toon			49.29						
Trema orientalis (L.) Blume	Charcoal tree						32.37			

Sapling										
Alangium chinense (Lour.) Harms	Chinese alangium					53.29				
Cinnamomum burmannii (Nees & T. Nees) Blume	Indonesian cinnamon									
Claoxylon longifolium (Blume) Endl. Ex Hassk.	Gispang					53.29				
Coffea arabica L.	Arabian Coffee	300.00	300.00	300.00						
Debregeasia longifolia (Burm.f.) Wedd.	Orange Wild Rhea						96.59			
Distylium stellare S.Vidal	Winter-hazel				53.27					
Ficus ribes Reinw. Ex Blume	Walen				26.26					
Ficus rostrata (Miq.) Miq.	Fig tree				29.09					
Hibiscus tiliaceus L.	Sea Hibiscus						66.35		76.91	
Magnolia blumei (Korth.) Figlar & Noot.	Southern Magnolia					160.45	63.74		45.93	
Oreocnide rubescens (Blume) Miq.	Sembarak								33.64	
Persea americana Mill.	Avocado									175.60
Syzygium densiflorum Wall. Ex Wight & Arn.	Jambu kopo									53.08
Syzygium polyanthum (Wight) Walp.	Indonesian Bay Leaf									34.61
Seedling										
Alstonia scholaris (L.) R. Br.	Blackboard tree						73.33			
Claoxylon longifolium (Blume) Endl. ex Hassk.	Gispang		55							111.90
Coffea arabica L.	Arabian Coffee		245	242.50		100.00				164.41
Debregeasia longifolia (Burm.f.) Wedd.	Orange Wild Rhea			45.13						
Distylium stellare S.Vidal	Winter-hazel				36.50	200.00		300.00		
Ficus fistulosa Reinw. ex Blume	Common Yellow-stem Fig				81.97					
Macropanax dispermus (Blume) Kuntze	Pampung								49.14	
Oreocnide rubescens (Blume) Miq.	Sembarak								70.32	
Ostodes paniculata Blume	Panicled Bone-Tree								70.55	
Persea americana Mill.	Avocado						124.44			
Syzygium densiflorum Wall. ex Wight & Arn.	Jambu Kopo				36.50					
Syzygium polyanthum (Wight) Walp.	Indonesian Bay Leaf						51.11			
Trema orientalis (L.) Blume	Charcoal tree									23.69

Note: PP: Pine Production; MG I: Mixed Garden I; MG II: Mixed Garden II; NF: Natural Forest; Sh I: Shrubs I; Sh II: Shrubs II; Sw: Swamp; Ri: Riparian; AG: Artificial Garden.

Table 4. IVI (%) of herpetofauna's habitat in the Darajat, West Java, Indonesia

Scientific name	Common name	Land cover types						
		RA I	**RA II**	**RA III**	**La**	**Cr**	**NF**	**Ri**
Tree								
Astronia spectabilis Ridl.	Gembirung							38.31
Cupressus macrocarpa Hartw. ex Gordon	Monterey cypress		226.44	61.90				
Engelhardia spicata Blume	Great Malay Bean		35.63		141.73	152.08	95.45	84.89
Eucalyptus alba Reinw. ex Blume	White Gum	300		176.19				
Lithocarpus javensis (Blume) A.Camus	Stone oaks				26.28			
Metadina trichotoma (Zoll. & Moritzi) Bakh.f.	Angrit						80.06	
Podocarpus neriifolius D. Don	Ki Putri					35.43		
Schefflera rugosa (Wall. ex Harv.) Harms	Ramogiling						30.26	57.03
Schima wallichii (DC.) Korth.	Needlewood		37.93	61.90	38.42	112.49		
Pole								
Cyathea contaminans (Wall. ex Hook.) Copel.	Blue Tree Fern	37.4	73.14	28.64				47.71
Engelhardia spicata Blume	Great Malay Bean				56.47	60.22	34.43	
Eucalyptus alba Reinw. ex Blume	White Gum	244.07	109.31	164.13				
Homalanthus populneus (Geiseler) Pax	Bangki							44.49
Lithocarpus javensis (Blume) A.Camus	Stone oaks				72.77			
Magnolia blumei (Korth.) Figlar & Noot.	Southern Magnolia						48.87	
Schefflera rugosa (Wall. ex Harv.) Harms	Ramogiling						41.14	76.12
Schima wallichii (DC.) Korth.	Needlewood	18.54	48.67	52.61	51.35	84.90		
Sapling								
Aporosa arborea (Blume) Müll.Arg.	Sebasah						24.16	
Cupressus macrocarpa Hartw. ex Gordon	Monterey cypress		50.71					
Cyathea contaminans (Wall. ex Hook.) Copel.	Blue Tree Fern							27.62
Elaeocarpus serratus L.	Ceylon Olive			25.78				
Engelhardia spicata Blume	Great Malay Bean				52.82			
Eucalyptus alba Reinw. ex Blume	White Gum	217.65	72.27	108.13				
Lasianthus laevigatus Blume	Smooth Lasianthus						66.4	
Lithocarpus javensis (Blume) A.Camus	Stone Oaks				44.47			
Melastoma malabathricum L.	Indian Rhododendron					69.71		
Psychotria montana Blume	Wild Coffee							55.32
Schima wallichii (DC.) Korth.	Needlewood	82.35	69.88	26.33	55.31	43.60		
Strobilanthes cernua (Blume) J.R.I. Wood	Bubukuan							39.92
Syzygium lineatum (DC.) Merr. & L.M.Perry	Common Kelat						63.61	
Vaccinium varingiaefolium (Blume) Miq.	Cantigi					77.24		

Seedling							
Altingia excelsa Noronha	Rasamala	50.75					
Castanopsis argentea (Blume) A.DC.	Saninten			28.02			
Cupressus macrocarpa Hartw. ex Gordon	Monterey Cypress	52.94					
Lasianthus laevigatus Blume	Smooth Lasianthus					57.02	
Litsea cubeba (Lour.) Pers.	Mountain pepper				38.90		
Litsea fulva (Blume) Fern.-Vill.	-			34.14			
Magnolia blumei (Korth.) Figlar & Noot.	Southern Magnolia		25.40				
Mussaenda frondosa L.	Dhobi Tree					26.74	
Pilea melastomoides (Poir.) Blume	Melastome Clearweed						54.64
Psidium guajava L.	Guava		80.95				
Psychotria montana Blume	Wild Coffee						46.58
Schima wallichii (DC.) Korth.	Needlewood	47.47	108.73	111.57	56.67		
Strobilanthes cernua (Blume) J.R.I. Wood	Bubukuan						50.28
Syzygium lineatum (DC.) Merr. & L.M.Perry	Common Kelat					67.02	
Vaccinium varingiaefolium (Blume) Miq.	Cantigi				73.00		

Note: RA I: Replanting Area I; RA II: Replanting Area II; RA III: Replanting Area III; La: Lake; Cr: Crater; NF: Natural Forest; Ri: Riparian.

Table 5. Diversity index of plants in the Kamojang and Darajat Geothermal Power Plants, West Java, Indonesia

Land cover types	Tree	Pole	Sapling	Seedling
Kamojang				
Natural forest	1.97	2.36	2.84	2.08
Mixed garden I	1.76	1.24	0	0.48
Mixed garden II	0.33	1.29	0	0.48
Pine plantation	0.26	0.2	0	-
Shrubs I	1.9	2.1	1.15	0.64
Shrubs II	0.68	1.62	1.54	1.31
Swamp	1.75	1.75	-	0
Riparian	1.6	1.98	2.15	1.84
Artificial garden	1.47	1.58	1.14	0.83
Darajat				
Replanting area I	0.00	0.39	0.47	-
Replanting area II	0.17	1.18	1.63	1.86
Replanting area III	0.80	0.81	1.72	1.34
Lake	1.53	1.99	2.08	1.94
Crater	0.97	1.81	1.98	2.22
Natural forest	1.78	2.67	2.41	2.45
Riparian	1.96	2.01	2.46	2.14

Note: red: No plant/ a plant only/ have no diversity index; yellow: Low diversity index; green: Moderate diversity index

Table 6. Measurement of abiotic factors in each land cover

Location | Land cover types	Temperature (°C)	Air humidity (%)	Soil pH	Soil humidity (%)	Leaf litter cover (%)
Kamojang					
Natural forest	19.4	52.7	6.4	40	70-80
Mixed garden I	21.2	61.4	6.8	30	20-30
Mixed garden II	21.3	59.6	6.2	51	0
Pine plantation	19.6	59.7	6.4	60	10-20
Shrubs I	18.2	71.2	6.8	60	10-20
Shrubs II	22.9	59.5	6.6	40	20-30
Swamp	21.1	56.2	6.8	68	50-60
Riparian	19.6	66.2	6.9	65	80-90
Artificial garden	23.5	54.4	6.2	30	40-50
Darajat					
Replanting area I	19.2	65	6.8	70	30
Replanting area II	19.5	78	6.4	80	60-70
Replanting area III	19	77	6.8	70	30-40
Lake	16.5	79	6.9	70	70-80
Crater	18.4	67	6.8	30	30-40
Natural forest	18	60	6.8	52	80-90
Riparian	17.3	59.8	6.9	59	0

The level of temperatures in the crater is 18.4°C (Table 6), with air humidity at 67%. These moderate conditions suit certain amphibians and reptiles, although the humidity is lower than in other parts of Darajat. Soil pH is 6.8, which is neutral and favorable for the growth of species such as *E. spicata* and *V. varingiaefolium*. However, the soil humidity is relatively low at 30%, which makes the ground drier than in areas like riparian zones or lakes. This reduction in moisture could limit the abundance of amphibians that rely heavily on consistently moist environments. The leaf litter cover around the crater is sparse, ranging from 30% to 40%. While this cover provides some shelter for ground-dwelling species, it is less extensive than natural forests. In this vegetation, *P. aurifasciatus* and *E. multifasciata* were found.

Natural forests

The IVI data (Table 4) shows the high diversity reflected in the diversity index, which ranks the natural forest as having the highest species richness compared to other land cover types. This rich and balanced plant community creates a variety of ecological niches, making the natural forest a more stable and supportive environment for herpetofauna. This diversity helps maintain a resilient ecosystem that supports species with varying habitat preferences, ensuring that both amphibians and reptiles can thrive. *Engelhardia spicata* dominates the natural forest in the tree layer, *M. blumei*. in the pole layer, smooth lasianthus (*Lasianthus laevigatus*) in the sapling layer, and *Syzygium lineatum* in the seedling layer. Several herpetofauna species have been found, including *M. palmipes*, Asian horned frog (*Megophrys montana*), *P. aurifasciatus*, and *T. temmincki*.

Figure 5. Vegetation in the Darajat, West Java, Indonesia: A-B. Replanting area; C. Crater; D. Cipandai River; E. Cipandan River spring; F. Forest around Cibeureum Lake; G. Cibeureum Lake; H. Kendang Mountain Swamp; I. Natural Forest. Vegetation in the Kamojang, West Java, Indonesia: J. Pine plantation; K. Mixed gardens; L. Former shrubs turned into a horticultural garden; M. Swamp used as a horticultural garden in the dry season; N. Shrubs; O. Riparian; P. Natural forests; Q. Disturbed natural forest. Photographs by Suroso and Nugrahaputramaulana

The abiotic conditions in the natural forest contribute to its ability to support diverse flora and fauna. The temperature in the natural forest is moderate, averaging around 18°C, with air humidity of 60% (Table 6). Soil pH is 6.8, which is neutral and favorable for plant growth. Soil humidity is relatively lower than other areas, at 52%, but it still supports the forest's diverse plant and animal life. The leaf litter cover ranges from 80% to 90%, providing a rich layer of decomposing organic matter that offers many species shelter, breeding grounds, and foraging opportunities.

Riparian

The IVI in the riparian area (Table 4) highlights the dominance of key species like *E. spicata*, ramogiling (*Schefflera rugosa*), and eumachia montana (*Psychotria montana*) across the vegetation strata. Despite the dominance of these species, the diversity index remains moderate, indicating that the riparian zone supports a variety of plant species across the tree, pole, sapling, and seedling layers. This moderate diversity suggests that the riparian zone offers a range of microhabitats essential for supporting diverse amphibian species.

The diversity index shows that no single species dominates the ecosystem, allowing for a balanced plant community that provides ecological stability. The abiotic conditions in the riparian zone are highly favorable for the growth of diverse vegetation and the presence of amphibians. The average temperature in the riparian area is 17.3°C, with air humidity at 59.8%, providing a cool and moist microclimate ideal for amphibians. The soil pH is 6.9, slightly acidic to neutral, which is beneficial for the growth of riparian vegetation. Soil moisture is moderate at 59% (Table 6). The riparian zone supports a notable variety of amphibians. Species like *M. montana*, *H. masonii*, and *P. aurifasciatus* are commonly found here. These species are particularly adapted to moist environments with minimal human disturbance.

Settlements & horticultural garden

No vegetation study was conducted in this area. However, several herpetofauna species were observed, including *D. melanostictus*, *M. achatina*, and *P. aurifasciatus*. Among the reptile species found were *B. jubata*, *G. mutilata*, *H. frenatus*, and *E. multifasciata*.

In Kamojang, the presence of herpetofauna species is higher in mixed and artificial gardens (human-modified lands) compared to the natural forest habitat (Figure 3). In mixed and artificial gardens, the IVI suggests that the dominant plant species create environments that might favor certain herpetofauna species, particularly those more adaptable to disturbed habitats. In mixed gardens, for example, species like *C. arabica* dominate the sapling and seedling layers, while trees such as *P. merkusii* provide a canopy cover (Table 4). This combination of plant layers offers a variety of microhabitats, such as shade, ground cover, and open areas, which can attract a diverse range of herpetofauna species, including both reptiles and amphibians, showcasing the remarkable variety of life forms that can be found in these habitats.

In contrast, natural forests are dominated by a few species with high IVI values (Table 4), such as *C. javanica* and *E. spicata*, which form a more closed canopy and dense forest floor. While these habitats are critical for species requiring more stable and intact environments (e.g., *H. masonii*), they may offer various ecological niches than the more heterogeneous environments in human-modified lands.

Although natural forests tend to have higher diversity indices for trees, poles, and saplings, this can sometimes lead to more specialized ecosystems, where certain species are more dominant, and competition for resources can be higher. In contrast, mixed gardens and artificial gardens, despite their relatively lower plant diversity, offer more open and variable environments, allowing generalist species (species that can survive in various conditions) to thrive.

For instance, in mixed gardens, the moderate to low diversity index (sapling: 0; pole: 1.24; tree: 1.76) suggests a more simplified vegetation structure, which can be favorable for species like *D. melanostictus*, and *E. multifasciata*; these species are highly adaptable and can exploit open, disturbed areas. These species can take advantage of the open spaces and the less complex vegetation to forage and move around more freely.

The abiotic factors in human-modified lands may also play a role in supporting higher herpetofauna presence. Table 6 shows mixed and artificial gardens tend to have slightly warmer temperatures (around 21.2°C to 23.5°C) and lower humidity than natural forests (Table 6). These conditions may be more favorable for reptiles, which often prefer drier and warmer conditions for thermoregulation. In comparison, amphibians that can tolerate these conditions, such as *M. palmipes* and *A. nicobariensis*, also benefit from occasional water sources or shaded areas within these modified habitats. In comparison, the natural forest has cooler temperatures (19.4°C) and higher humidity (52.7%), which are more suitable for sensitive amphibian species that require consistently moist and cooler environments. However, this habitat may not be as favorable for species that thrive in more open or disturbed environments.

In Darajat, replanting areas and settlement and horticultural gardens (no vegetation sampling was conducted) are also dominated by species that provide open and varied microhabitats, as seen in the IVI data; for example, trees like *E. alba* used in replanting areas have a high IVI (300) (Table 4), creating open canopies that allow sunlight to penetrate the lower layers. This environment benefits certain reptiles and amphibians that prefer open areas for basking or hunting, such as *D. melanostictus* and *E. multifasciata*. Similarly, in settlement & horticultural gardens, various cultivated plants create diverse microhabitats with open and shaded areas, supporting herpetofauna species that can adapt to disturbed environments. In addition, the horticultural garden is located near a small stream, which may have contributed to the increased presence of herpetofauna.

On the other hand, the natural forest in Darajat is characterized by a dominance of more closed-canopy species such as *E. spicata* and *S. wallichii*. This dominance results in less variation in light and shelter, potentially limiting the number of herpetofauna species that can thrive in this more specialized environment. The relatively high diversity index for trees (1.78) and poles (2.67) (Table 5) in natural forests in Darajat might lead to more competition for resources and less variability in habitat structure. This, in turn, favors more specialized species but may not support a high number of generalist species that thrive in disturbed or open environments, highlighting the crucial role of habitat structure in influencing species coexistence.

Moreover, replanting areas demonstrate a promising potential, showing moderate diversity for poles and saplings. This provides a more heterogeneous environment supporting a greater variety of species. The diversity index in replanting areas is lower for trees but higher for saplings and poles, indicating that while the mature tree layer may be uniform, the undergrowth provides more ecological niches for herpetofauna. These more open, transitional habitats offer various levels of vegetation cover, allowing species with different habitat preferences to coexist.

The abiotic factors (Table 6) in human-modified lands, such as replanting areas, further explain the higher presence of herpetofauna. In Table 6, replanting areas in Darajat have moderate temperatures (19.2-19.5°C) and relatively high humidity (65-78%), favorable conditions for many amphibians and reptiles. The soil pH (6.4-6.8) is slightly acidic, which is also suitable for amphibians. The leaf litter cover is moderate (30-70%) (Table 6), providing sufficient ground cover for species like *M. palmipes* and *P. leucomystax*, which use leaf litter for shelter and breeding. Similarly, settlement and horticultural gardens have more varied environmental conditions due to human activities. These areas often have access to water sources (irrigation systems) and food resources (insects attracted by crops), which can support higher biodiversity. These human-modified lands' fragmented and transitional nature creates microclimates ideal for herpetofauna species that thrive in less stable environments. In contrast, the natural forest in Darajat has cooler temperatures (18°C), higher humidity, and denser canopy cover, which may be more suitable for a limited number of specialized species but less favorable for generalist species that prefer open, disturbed habitats.

In both Kamojang and Darajat Geothermal Power Plants, the increasing dominance of human-modified lands underscores the crucial role of environmental scientists, conservationists, and policymakers in addressing this issue. This primarily involves cutting down natural forests, removing native vegetation, and introducing invasive species. These activities disrupt the natural landscape, fragmenting it into isolated patches more favorable to generalist species of herpetofauna. The conversion of natural forests to human-modified lands often changes abiotic factors, such as increased temperatures due to reduced canopy cover and decreased humidity. The fertilizers and pesticides used in areas adjacent to Kamojang and Darajat Geothermal Power Plants, particularly in horticultural gardens and agricultural lands, directly affect herpetofauna by reducing their prey (such as insects) and exposing them to harmful chemicals. These synthetic inputs are particularly disruptive to amphibians and are highly sensitive to environmental changes.

The presence of roads and vehicle access through these areas further fragments the landscape and as mentioned, increases herpetofauna mortality through vehicle strikes; roads fragment populations, creating smaller, isolated groups that are more vulnerable to local extinction. In general, there are three common patterns of negative impacts from the presence of roads and traffic on wildlife: (i) increased mortality; (ii) degradation of habitat, both in terms of quantity and quality; (iii) fragmentation of populations into sub-populations, each of which is more vulnerable to local extinction compared to the larger initial population (Rytwinski and Fahrig 2015).

In conclusion, the research conducted in Kamojang and Darajat reveals significant insights into the biodiversity and challenges faced by herpetofauna in these areas. Thirteen-seven herpetofauna species were recorded, comprising 18 amphibians and 19 reptiles. The composition of species across different habitat types varies, with human-modified areas such as mixed gardens and artificial gardens showing higher adaptability for generalist species. At the same time, natural forests remain critical for specialized species like *H. masonii*, and *P. aurifasciatus*, which rely on stable and intact environments.

Despite the overall diversity, several factors threaten the long-term sustainability of herpetofauna populations, including habitat fragmentation, land conversion for agriculture, and the presence of roads. Human activities such as deforestation, expansion of horticultural gardens, and vehicle access have led to the degradation of natural habitats, creating smaller, isolated populations more vulnerable to local extinction. The research also highlighted the increased mortality of herpetofauna, particularly from vehicle strikes, as many species cannot avoid fast-moving vehicles due to their slower movement speeds and small body size.

The conservation of natural forests is critical to protect the biodiversity in Kamojang and Darajat. Strict regulations on deforestation and the prevention of further land conversion into agricultural areas must be enforced. Maintaining large, contiguous areas of natural habitat is essential for supporting specialized species that cannot survive in human-modified environments. Areas cleared for agriculture or other uses should be prioritized for restoration. Replanting native vegetation and reducing the use of chemical fertilizers and pesticides in adjacent agricultural lands improve the habitat quality and minimize the impact on herpetofauna populations.

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