Predicting spatial distribution of Asian Horned Frog
(*Megophrys montana* Kuhl & Van Hasselt 1882) in Java Island using citizen science’s data

M Rohman1*, L B Prasetyo1, M D Kusrini2

1Environmental Analysis and Geospatial Modeling, Department Conservation and Ecotourism, Faculty of Forestry and Environment, IPB University, Bogor, Indonesia
2Wildlife Ecology and Management Laboratory, Department Conservation and Ecotourism, Faculty of Forestry and Environment, IPB University, Bogor, Indonesia

E-mail: mausulur75@gmail.com

**Abstract.** Citizen science is a tool that has been used globally to gather data on species, recently, this effort is gaining popularity in Indonesia. Asian horned frog (*Megophrys montana*) is an amphibian endemic to Java with a significant population declining due to forest or habitat losses. The purpose of this study is to analyze the suitability of the habitat and to estimate the potential habitat of *Megophrys montana* in Java using maximum entropy (maxent). Ninety-four coordinates data from iNaturalist, a citizen science app, were used in modeling along with altitude, slope, rainfall, distance from rivers, Normalized Difference Vegetation Index (NDVI), and land cover categories. *Megophrys montana* habitat suitability model produced an excellent accuracy with an AUC value of 0.962. Altitude, rainfall, and slope were the most important environmental variables that affect the suitability of the species habitats. The characteristics of *Megophrys montana* habitat in Java are mountainous forest, wet rainfall, primary or secondary forest with steep slopes, and near to the rivers. West Java and Banten are provinces with the most suitable areas for their habitat, especially within the conservation areas, i.e. Mount Halimun Salak and Mount Gede Pangrango National Park.

1. **Introduction**

Habitat quality affects the distribution, population, and survival ability of certain species [1]. Forest, home for many wildlife, is rapidly declining especially in Java, where rapid development has reduced the forest cover [2]. However, a small pocket of suitable habitats for amphibians are still available, including habitat for the endemic Javanese amphibian, *Megophrys montana*. As a forest specialist, the population trend of this species is decreasing due to habitat degradation i.e. land-use change and pollution [3]. Currently, biodiversity data collection project conducted by amateur naturalists or citizen science has gained popularity. Citizen science data could be a promising source of information to fill the information gaps needed to model a species distribution [4]. One of the citizen science project available in Indonesia is Amfibi Reptil Kita (ARK) which use iNaturalist as a platform to collect data. Using the data available, it is possible to develop a habitat model suitable for *Megophrys montana* to analyze the suitability of the habitat and to predict the potential habitat of *Megophrys montana* in Java. This information can be used as a management base for the conservation of *Megophrys montana* in the future.
2. Methods
This research was conducted from July to August 2020 at the Laboratory of Environmental Analysis and Geo-Spatial Modeling, Department of Forest Resources Conservation and Ecotourism, Faculty of Forestry and Environment, IPB University. Secondary data were used for analyses, i.e. *Megophrys montana* presence coordinates and environmental variables predicted to have relevance on the presence of the frog, i.e. altitude, slope, rainfall, NDVI, land cover, and distance from rivers. The encounter coordinates are obtained from iNaturalist- platforms citizen science. This study uses research-grade data with open, obscured, and private geopriviation. Obscured and private data were obtained from the GO-ARK project (Gerakan Observasi Amfibi Reptil Kita) [5]. The number of *Megophrys montana* data in iNaturalist is 130 points consisting of GO-ARK project data (81 points) and outside the project (49 points). However, only 94 locality coordinates are generated (figure 1). The data came from observations of volunteers from April 2012 to August 2020. The modeling process at maxent uses 75% of the data for the model and 25% for the accurate model [6].

Frog presence data is changed to a comma-separated value (csv), while the environmental variable is converted into ascii (asc). In addition, the environmental variables used must have a similar coordinate system, outer boundary, and cell size. This study uses WGS 1984 coordinate system and cell size is 1 km². The first data analysis is the multicollinearity test to determine the relationship between the variables [7]. Multicollinearity test is performed using band collection statistics in ArcMap, if multicollinearity value is less than or equal to -0.75 or exceeds +0.75 will mean multicollinearity. After the multicollinearity test, overlay analysis is used to determine the overlap of the *Megophrys montana* encounter points with the environmental variables that using. Overlay analysis using intersect in Arc Map. Maxent calculations result in habitats indicated by a range of values of 0 to 1 [8], divided into four conformity classes i.e., non-conforming (0–0.3), low (0.3–0.4), medium (0.4–0.6) and high (0.6–1.0) [9]. A good model can be defined with curves that maximize specificity. This condition can be measured using the Area Under Curve (AUC) value [10]. The accuracy of the model based on AUC values is divided into a poor grade (0.6–0.7), medium (0.7–0.8), good (0.8–0.9), and excellent (0.9–1.0) [11]. The percentage of sample data used to test the accuracy of the model is 25%.

![Figure 1. Megophrys montana presence data based on iNaturalist data from April 2012 to August 2020.](image)

3. Result and discussion
3.1 iNaturalist coordinates and environmental variables
In general, *Megophrys montana* are found in mountainous areas, elevation above 500 m asl. However, there are four outliers of encounter points in low lands (0-300 m asl), located in residential areas, rice fields, and ponds. We considered these data as spatial bias because citizen science data is drawn flexibly with varying observer expertise, collected across a wide range of spatial resolutions and sampling attempts that are often not standardized [12]. This bias has the potential to inhibit the ability of citizen
science data to be maximally used in making habitat models [13,14], thus we omit these four data in the modeling process.

Spatial data processing produces maps of environmental variables that are used in modeling, i.e. maps of altitude, slope, rainfall, NDVI, land cover, and distance from rivers (figure 2). These are the variable considered affecting the presence of *Megophrys montana* on the island of Java.

![Figure 2](image) Environmental variables are: a) altitude; b) rainfall; c) slope; d) land cover; e) NDVI; f) distance from rivers.

Java Island has an altitude from 0 to 3,636 masl and is almost evenly distributed in every province in Java. The slope variable varies from 0 to 163.59%. The mountainous areas in Java tend to be dominated by moderate slopes, especially in the western part. Rainfall shows a value of 1.055 to 4.417 mm/year. Eastern parts of Java have lower levels of rainfall than western and central parts. NDVI values vary from -0.6 to 0.83. The land cover classification consists of 19 types, but only 5 types are used in the modeling, i.e. shrubs, secondary forest, primary forest, plantation forest, and agriculture. The determination of the land cover is based on the value of the greatest influence in modeling. The distance from the river to 1.18 km shows the importance of river presence to the habitat of *Megophrys montana*.

### 3.2. Multicollinearity test

Temperature and altitude data have a cross-correlated relationship because it has a multicollinearity value of -0.97527 (table 1). Therefore, the temperature was not included in the modeling because the altitude is the variable that has the highest effect.
Table 1. Multicollinearity test on environmental variables.

|   | 1   | 2   | 3   | 4   | 5   | 6   | 7   |
|---|-----|-----|-----|-----|-----|-----|-----|
| 1 | 1   | 0.40486 | 0.38878 | 0.00014 | 0.36747 | -0.45269 | -0.02838 |
| 2 | 0.40486 | 1   | 0.36056 | -0.28982 | 0.60215 | **-0.97527** | 0.02707 |
| 3 | 0.38878 | 0.36056 | 1   | 0.01171 | 0.39417 | -0.41894 | 0.02772 |
| 4 | 0.00014 | -0.28982 | 0.01171 | 1   | -0.24028 | 0.28787 | -0.09281 |
| 5 | 0.36747 | 0.60215 | 0.39417 | -0.24028 | 1   | -0.60924 | 0.04831 |
| 6 | -0.45269 | -0.97527 | -0.41894 | 0.28787 | -0.60924 | 1   | -0.01465 |
| 7 | -0.02838 | 0.02707 | 0.02772 | -0.09281 | 0.04831 | -0.01465 | 1   |

Note: rainfall (1), altitude (2), NDVI (3), landcover (4), slope (5), temperature (6), and distance from rivers (7)

3.3. Accuracy of the model

The results of *Megophrys montana* habitat suitability model produce an AUC value of 0.962 with a standard deviation of 0.009 (figure 3). This indicates that the accuracy of the model is very good [11].

![Figure 3. Illustration of model accuracy test result with AUC values.](image)

3.4. The effect of environmental variables on modeling

Based on the jackknife curve, the order of the variables with the highest effect is altitude, rainfall, and slope (figure 4). Altitude is the most important variable in the modeling process because it has the greatest value when processed with other variables and when omitted it reduces the yield the most. This indicates that the *Megophrys montana* are very sensitive to altitude changes. *Megophrys montana* are found in higher areas and the name of these species indicates their habitat, which is mountainous areas [15,16].
3.5. The effect of environmental variables on the probability of *Megophrys montana* presence

The effect of environmental variables on the probability of *Megophrys montana* presence is illustrated by the independent response curve in figure 5.

The response curve shows the probability presence of *Megophrys montana* increased at an altitudinal range of 0 - ± 1800 masl, and response will turn negative where altitude > ± 1800 masl. The differences in altitude will cause differences in climate, especially temperature, rainfall, and humidity. An increasing altitude will decrease the air temperature and increase the rainfall. Habitats with low air temperatures are preferred by amphibians because they can retain moisture on their skin [17]. Air temperature in Indonesia decreases by 5-6 °C for each additional 1000 masl [18]. However, altitude can be a natural barrier for amphibians so that it has an influence on community structures such as density [19]. Therefore, the probability presence of *Megophrys montana* is smaller when altitude is above 1800 masl.

The rainfall response curve shows the probability of *Megophrys montana* presence increases when the rainfall is in the range 1000 - ± 4000 mm / year and the lowest probability is when the rainfall is > ± 4400 mm/year. Areas with low air and surface temperatures are suitable habitats for amphibians because they can avoid the loss of water on the surface of the skin [20].

![Figure 4. Jackknife test results in modeling.](image-url)
The response curve shows the probability of *Megophrys montana* presence increases with the increasing value of the slope. There is a possibility that areas with high slopes are protected areas with good vegetation cover conditions to provide sustainable benefits [21]. However, the slope is a variable that can limit the presence of amphibians because it can hinder movement [22].

The response curve shows the probability of *Megophrys montana* presence decreases with increasing distance from the river. It indicates that the existence of a water source is important for *Megophrys montana*, especially as amphibians are always associated with water [16]. The presence of water causes the surrounding area to have high humidity due to evapotranspiration [23]. This condition keeps amphibian skin moist to help with the process of exchanging air and water through the skin, which beneficial to amphibians that need sufficient moisture to protect themselves from drought [16].

The response curve shows that the probability of *Megophrys montana* presence increases with an increase of NDVI. The NDVI curve shows a decrease from negative values to 0 and increases when $\geq 0$ and increasing significantly in the range $+0.4 - +0.7$. Overlapping results also show an increase when the NDVI value gets bigger. This is influenced by the NDVI value which has a positive relationship with land cover; when NDVI is greater, the vegetation cover is denser. Vegetation can reduce air and surface temperature because the canopy can reduce the intensity of solar radiation. This condition will form a microclimate with high humidity [18]. In addition, humidity affects the presence of amphibians due to the presence of mucus glands that function to keep the skin moist [24].

The land cover used consists of five types, i.e. shrubs, primary forest, secondary forest, plantation forest, and agriculture. The land cover response curves show that the highest probability of *Megophrys montana* presence is in primary and secondary forests (see figure 6).

![Figure 6. Response curves to land cover](image)

**Figure 6.** Response curves to land cover is a) shrubs; b) primary forest; c) secondary forest; d) plantation forest; e) agriculture.

This result is consistent with the previous report, that *Megophrys montana* occupy the litter of both primary and secondary forest floors [15,16]. Primary and secondary forests have dense vegetation cover and the forest floor is filled with leaf litter. Asian horned frogs are also rarely found on disturbed lands such as plantation forests and agriculture [15].

### 3.6. Potential habitat for *Megophrys montana* on the island of Java

Areas with high suitability for *Megophrys montana* are within highlands with high rainfall rates, steep slopes, and primary or secondary land cover types (figure 7). In general, areas with high suitability are mountainous areas. This result is consistent with the etymology of *Megophrys montana*, referring to its habitat in mountainous areas [16]. In addition, the results of the jackknife test showed that *Megophrys montana* was sensitive to altitude changes.
Figure 7. The suitability of the *Megophrys montana* habitat on the island of Java a) overall areas; b) within conservation areas (yellow color).

The size of high suitability habitat in Java is 2,913 km² or 1.89% of the total size of the island. Provinces with the highest high level of habitat suitability are West Java (1,566.96 km²), followed by Central Java (626.97 km²) and Banten (139.03 km²). Although East Java is the largest provincial area in Java Island, it only has high suitability area of 30.20 km² or 0.06% of the total area. The factor that might influence this low size area is its relatively dry climatic conditions compared to West Java. The annual rainfall of West Java in 2019 is 3555 mm [25], while East Java is 1727 mm [26]. In addition, another factor that can influence is the low presence data of the *Megophrys montana* collected in the eastern part of Java. There is only one presence coordinate in East Java, a private geotype data located in Batu, Malang.

Locations with a high percentage of suitability areas are the western part of Java, i.e. West Java and Banten except for DKI Jakarta which is a dense modern city, an area incompatible with the *Megophrys montana* habitat. Geographically, West Java has complex natural conditions and geological structures with mountainous areas in the middle and southern part with an average height of 1,000 masl and the highest level of elevation at 3,078 masl. The province also has forested areas, both primary and secondary, that serve as conservation forest, protection forest, and production forest covering an area of 695 and 658.9 hectares. Rainfall ranges from 1,000-4,000 mm / year with an average temperature of 16-34 °C. In addition, there are 41 river basins with surface water discharge of 81 billion m³/ year [27].

The conservation area with high suitability for *Megophrys montana* habitat is 900.43 km² or 18.42% from the total conservation area of Java. The western part of Java has the highest suitable habitat for *Megophrys montana* in conservation areas. This indicates that the potential for the protection of the
Megophrys montana habitat in the western part is the greatest in Java, especially in the Mount Halimun Salak and Mount Gede Pangrango National Parks. Areas with high suitability in Central Java, the largest is Mount Slamet, are not conservation areas. In addition, part of the area of high habitat suitability in Java included in the conservation area is only 30.9%. Conservation area managers need to pay attention in protecting the Megophrys montana in the future, as it only occurs in Java.

4. Conclusion

Altitude, rainfall, slope are important environmental variables in modeling the habitat suitability of Megophrys montana. The characteristics of the Megophrys montana habitat in Java are mountainous forest, wet rainfall, primary forest or secondary forest with steep slopes, and close to rivers. Areas in Java Island that have high potential as Megophrys montana habitat are located in the West, i.e West Java and Banten provinces. The protection area potential for its habitat is also very large, especially in Mount Halimun Salak National Park and Mount Gede Pangrango National Park.

References

[1] Hall LS, Krausman PR, and Morrison 1997 The habitat concept and a plea for standard terminology Wildlife Society Bulletin 25 173–182
[2] Ferdaus RM, Iswari P.Kristianto ED, Muhajir M, Diantoro TD, and Septivianto S 2014 Rekonfigurasi Hutan Jawa: Sebuah Peta Jalan Usulan CSO (Yogyakarta: Biro penerbitan aRuPA) pp 1-2
[3] [IUCN] International Union for Conservation of Nature and Natural Resources SSC Amphibian Specialist Group 2018 The IUCN Red List of Threatened Species [internet]. [downloaded 2020 July 10th]. Available on: https://www.iucnredlist.org/
[4] Bruder U, Mair UL, Jonsson M, Knape J, Singer A, and Snall T 2018 Can opportunistically collected Citizen Science data fill a data gap for habitat suitability models of less common species? Methods in Ecology and Evolution 9 1667–1678
[5] Kusrini et al. 2019 Mobilizing Citizen to Document Herpetofauna Diversity in Indonesia 3rd International Conference on Tropical Biology (Bogor: Seameo BIOTROP) pp 26–35
[6] Bradsworth N, White JG, Isaac B, and Cooke R 2017 Species distribution models derived from citizen science data predict the fine scale movements of owls in an urbanizing landscape. Biological Conservation 213 27–35
[7] Pearson RG, Raxworthy CJ, Nakamura M, and Peterson AT 2007 Predicting species distributions from small numbers of occurrence records: a test case using cryptic geckos in Madagascar Journal of Biogeography 34 102–117
[8] Phillips SJ and Dudik M 2008 Modeling of species distribution with maxent: New extensions and a comprehensive evaluation Ecography 31 161–175
[9] Latifiana K 2010 Pemetaan habitat potensial herpetofauna pada daerah terdampak erupsi Gunung Merapi Seminar Nasional Geomatika: Penggunaan dan Pengembangan Produk Informasi Geospasial Mendung Daya Saing Nasional 497-510
[10] Baldwin RA 2009 Use of maximum entropy modeling in wildlife research Entropy 11 854–866
[11] Araujo MB and Guisan A 2006 Five (or so) Challenges for distribution modelling Journal Pf Biogeography 33(10) 1677–1688
[12] Robinson OJ, Ruiz-Gutierrez V, Reynolds MD, Golet GH, Strimas-Mackey M, and Fink D 2020 Integrating citizen science data with expert surveys increases accuracy and spatial extent species distribution models Divers Distrib 00 1-11
[13] Kremen C, Cameron A, Moilanen A, Phillips SJ, Thomas CD, Beentje H, and Zjhra ML 2008 Aligning conservation priorities across taxa in Madagascar with high-resolution planning tools Science 320(5873) 222–226
[14] Rondinini C, Wilson KA, Boitani L, Grantham H, and Possingham HP 2006 Tradeoffs of different types of species occurrence data for use in systematic conservation planning Ecology Letters 9(10) 1136–1145
[15] Lathrop A 2003 Asian horned frog, Megophrys montana. Grzimek’s Animal Life Encyclopedia, Volume 6, Amphibians. 2nd edition (Farmington Hills: Gale group) 115-116
[16] Iskandar DT 1998 *Amfibi Jawa Dan Bali - Seri Panduan Lapangan* (Bogor: Puslitbang-LIPI) pp 36

[17] Syazali M, Idrus AA, and Hadiprayitno G 2017 Analisis multivariat dari faktor lingkungan yang berpengaruh terhadap struktur komunitas amfibi di Pulau Lombok *Bioedukasi: Jurnal Pendidikan Biologi* **10**(2) 68–75

[18] Lakitan B 1994 *Dasar-dasar Klimatologi* (Jakarta: PT Raja Grafindo Persada) pp 37

[19] Heinen JT 1992 Comparisons of the leaf litter herpetofauna in abandoned cacao plantations and primary rain forest in Costa Rica: some implication for faunal restoration *Biotropica* **24** 431–439

[20] Churchill TA and Storey KB 2009 Dehydration tolerance in wood frog: a new perspective on development of amphibian freeze tolerance *Am. J. Physiol. Regulatory Integrative Comp. Physiol.* **265** 1324–1332

[21] [Kepres] Keputusan Presiden Republik Indonesia Nomor 32 Tahun 1990 Tentang Pengelolaan Kawasan Lindung

[22] Zawacki CLR 2009 Effects of slope and riparian habitat connectivity on gene flow in an endangered panamanian frog *Atelopus varius* *Diversity and Distributions* **15** 796–806

[23] Manik TK, Rosadi RB, and Karyanto A 2012 Evaluasi metodé Penman–Monteith dalam menduga laju evaporasi standar di dataran rendah Propinsi Lampung *Jurnal Agroteknologi* **26** 121–128

[24] Delfino G, Alvarez BB, Brizzi R, and Cespedez JA 1998 Serous cutaneous glands of Argentine phyllomedusa Wagler 1830 (*Anura Hylidae*): secretory polymorphism and adaptive plasticity *Tropical Zoology* **11** 333–351

[25] [BPS] Badan Pusat Statistik Jawa Barat 2020 Provinsi Jawa Barat Dalam Angka 2020 (Bandung: BPS Provinsi Jawa Barat) 45-46

[26] [BPS] Badan Pusat Statistik Jawa Timur 2020 Provinsi Jawa Timur Dalam Angka 2020 (Surabaya: BPS Provinsi Jawa Timur) 57-58

[27] [RPJMD] Rencana Pembangunan Jangka Menengah Daerah Jawa Barat 2018–2023 2019 2 2-13

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