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Using Machine Learning to Model Future Distributions of Babandotan *Ageratum conyzoides* L. Under Climate Change Scenarios (CMIP 5: RCP 2.6 and RCP 8.5) until 2070 in Bandung Areas

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Abstract

Ageratum conyzoides L., locally known as Babandotan, is an important plant in particular in West Java, including in Bandung, due to its medicinal uses. Currently, climate change is known to influence the distribution of organisms by altering climates and making habitats suitable or not suitable. Then, this present study is aiming to use machine learning to model future distributions of *A. conyzoides* under climate change scenarios CMIP 5 RCP 8.5 until 2070 in Bandung areas. The *A. conyzoides* occurrences were sampled from nine locations in Bandung and its surrounding areas. Machine learning using the R platform and MaxEnt algorithm was used to develop species distribution modeling (SDM). The model was then simulated using RCP 2.6 and 8.5 scenarios for the years 2050 and 2070. The quality of the model was assessed using AUC values. The current SDM model shows suitable habitats for *A. conyzoides* are sizing 1250 km^2, mostly located in Bandung (56%), Kota Bandung (24%), and Sumedang (16%). The AUC value was 0.964, showing that the resulting model is good. Climate change will affect *A. conyzoides* in the future. Based on the RCP model, suitable habitats for *A. conyzoides* will be shifted northward, eliminating the suitable habitats in the south of Bandung, as can be seen in 2070.

Keywords: *AUC, Babandotan, RCP, suitable*

1. Introduction

Ageratum conyzoides or locally known as Bandotan or Wedusan is a type of agricultural weed belonging to the Asteraceae family [1]. This annual herb originates from tropical America, especially Brazil, but has long been introduced and wild in the archipelago. In Indonesia, this species has various local names according to its locality. In West Java, it is called as Babandotan or Babadotan; in most of Java Island, it is called as Wedusan; in Madura Island, it is called as Dus-Bedusan; and Rumput Balam in Pontianak, West Kalimantan Island. While in english name, *A. conyzoides* is known as Billygoat weed, Goat weed [2, 3], Chick weed, or White weed. This species plant acquires its name because the smell odor it emits resembles the smell odor of a goat.

This plant is widespread throughout tropical regions, even to the subtropics. Imported to Java before 1860, now this weed has spread widely in Indonesia. In South America, this plant is even cultivated. This plant is often found as a nuisance plant in dry rice fields, fields, yards, roadsides, embankments, water edges, and bushy areas. This plant is found up to an altitude of 3,000 m, this herb flowers all year round and can produce up to 40,000 seeds per individual plant. In West Java, this species is widely use as medicinal plants for particular wound remedy [4].

Recently, large scale patterns of species distribution including plants and medicinal plants were impacted by climate change and greenhouse gas concentration determines. Intergovernmental Panel on Climate Change (IPCC) has created several climate scenarios based on greenhouse gas concentrations known as Representative Concentration Pathways (RCP). RCP 8.5 is an emission scenario without policies to reduce emissions with a rapid increase in methane, high use of fossil fuels, and the slow development of technology to reduce the impact of climate change. Then, RCP 8.5 climate scenario is considered suitable to simulate the impacts of climate change on the species' distribution [5]. Recent research has indicated the role of model species distribution. As a result, several methods have been developed

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to model species distribution at spatial scale. One approach that has been used widely to model the potential spatial distributions of a species is known as machine learning based species distribution modeling (SDM). This model has been used widely to estimate potential distributions of animal [6], ticks [7], vegetation [8], and crops. Among SDMs, there are a growing variety of methods for estimating habitat suitability, including MaxEnt (Maximum Entropy), Bioclim, Domain, generalized additive model (GAM), GLM, and Biomapper. Each machine learning tool is unique, with its own set of pros and downsides. According to Marcer et al. [9], SDM is one of the best and is most often used habitat suitability modeling tools. Several advantages of SDM include the need for only species presence data, the capacity to run with a limited quantity of data, the high accuracy of prediction results, the high reproducibility, and the ability to predict the most discriminating environmental factors [10].

West Java is on of regions known to have high diversity of plants including *A. conyzoides* and those regions including Bandung and its surrounding areas. Around Bandung, *A. conyzoides* in its natural habitats has been reported in the Purwakarta, in north of Bandung. While Azka et al. [11] have reported the presences of *A. conyzoides* in the Cileunyi, west of Bandung. Despite numerous studies are reporting the presences of *A. conyzoides* in Bandung, while there is still a lack of information on how this species can adapt to the climate change in long terms. Then the novelty of this study is using machine learning to model future distributions of *A. conyzoides* under climate change scenarios CMIP 5 RCP 8.5 until 2070 in Bandung areas. The results in the forms of potential future distributions of A. *conyzoides* then can inform the future conservation strategy required for this species.

2. Methodology

2.1. Study Area

The study area is in terrestrial ecosystems of Bandung and its surrounding areas (Figure 1). Those areas including Bandung, Kota Bandung, and Cimahi. In the North, it was bordered by Subang and Purwakarta. In the South, it was bordered by Cianjur and Garut. While, Sumedang was located in the East. Bandung and it surrounding areas were located in the highland with elevation ranging from 675 m above sea level to 1,050 m above sea level. Due to its highland landscape, the climate in Bandung and its surrounding areas is cold weather with average temperature of 23.5 ^{o}C and receiving average precipitation rates of 200.4 mm and 21.3 days with rain every month.

2.2. A. conyzoides *Surveys*

Survey activities were performed for 2 months in 2023 in 9 sampling sites as can be seen in Figure 1. The sampling sites were selected based on the presences of natural habitats that were considered suitable for *A. conyzoides*. The presence of *A. conyzoides* was recorded using direct visual observation or also known as visual encounter survey (VES) and a database provided and gathered from literature reviews sourced from journal articles and reports provided by government agencies, including the agency for agriculture and forestry at the Indonesian Ministry of Environment and Forestry. VES was implemented purposefully by visiting natural habitats including forests and plantations where *A. conyzoides* may grow. The geographical coordinates of *A. conyzoides* presences in the field were recorded using the Garmin Etrex 30 type Global Positioning System (GPS). The data were converted to Microsoft Excel and saved in CSV format for use in SDM habitat suitability modelling. The species identification guideline to determine *A. conyzoides* was based on identification keys [12, 13, 14].

2.3. A. conyzoides *Environmental Variables*

This study followed Dong et al. [15] and Arshad et al. [16] by included a variety of environmental variables (Table 1). In recent years, habitat suitability modeling has made considerable use of bio-climatic variables (Bio 1–Bio 19) from the worldwide climate database WordClim (www.worldclim.org, the new version 2.0) [17], particularly in the Asian region [18, 19]. The dataset variables represent the climatic variables affecting species, including temperature and precipitation. The climatic variables include warm and cold and dry and cold seasons.

In order to produce an accurate and instructive habitat suitability model, those environmental variables were selected based on the selection and exploitation of environmental aspects that had a major influence. Each environmental variable's contribution to the final model was assessed using Jackknife analysis. A few environmental variables that came from the Jackknife analysis were not included in the model since they made no impact whatsoever (percentage contribution = 0). According to reference [20], the environmental variables had a low average contribution (<6%) or low permutation relevance (<6%). Two crucial elements for comprehending and quantifying the environmental variable's contribution and significance to the SDM model are the contribution percentage and permutation.

2.4. Multicollinearity Test

By utilizing Pearson's correlation tests [21] on 19 environmental variables (Bio 1 – Bio 19) (Table 1), a multicollinearity test was carried out to create a model that performs better with fewer variables and to prevent collinearity between the variable. Highly cross-correlated variables ($r^2 > 0.8$) were eliminated, while variables with $r^2 < 0.8$ were retained for additional examination in the context of geographical distribution modeling. When multicollinearity arises, a variable's predictive capacity is unstable and

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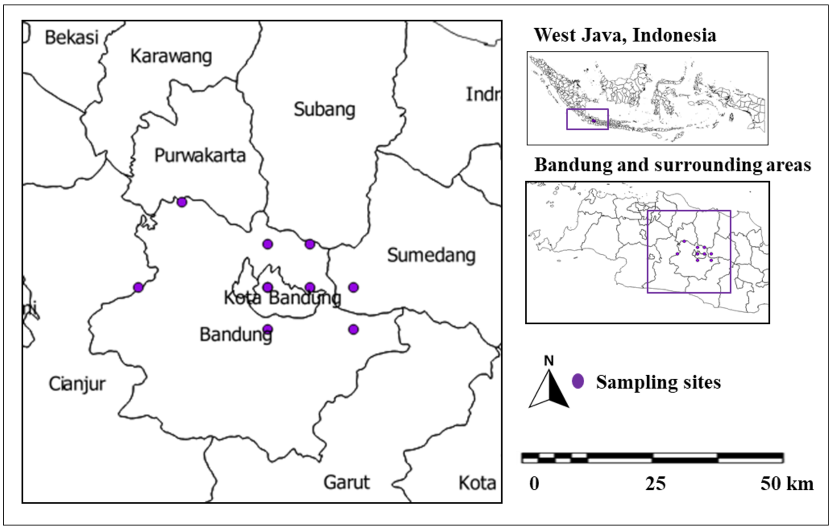

Figure 1. Sampling sites in Bandung and its surrounding areas.

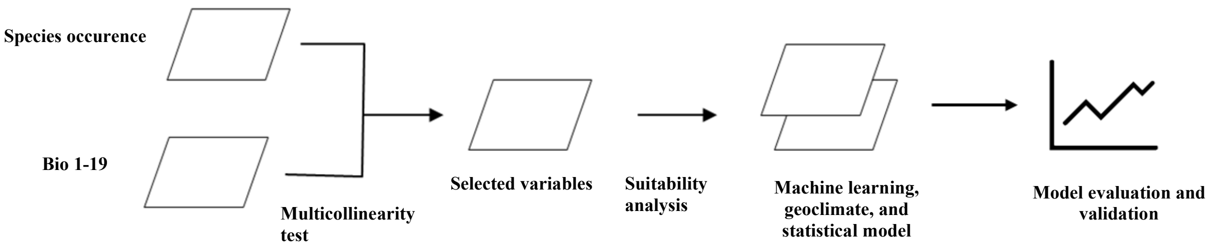

Figure 2. Schematic flowchart showing the SDM pipeline.

inaccurate due to its significant correlation with other variables in the model [22]. The chosen environmental variables to be employed were Bio 1, 3, 5, 11, 12, 13, 14, 15, 16, 17, and 19 based on the results of the multicollinearity test.

2.5. A. conyzoides *Suitability Analysis*

This study generated predicted suitability maps of *A. conyzoides* in Bandung and its surrounding areas using machine learning SDM tools in particular MaxEnt algorithm within R platform version 3.6.3 [23]. The particular MaxEnt algorithm is as follows: Pr(y=1|z) = f1(z) Pr(y=1)/ f(z),

Let the Pr(y=1|z) is the probability of presence of the *A. conyzoides,* conditioned on study areas;

Pr(y=1) is the prevalence of the *A. conyzoides* (proportion of occupied areas) in the study areas;

f(z) is the probability density of environmental variables across study areas;

f1(z) is the probability density of environmental variables within study areas where the *A. conyzoides* is present.

The pre-processing steps for preparing species suitability analysis include data cleaning, data reduction, data transformation, and data integration. The data cleaning and data reduction to avoid and remove duplication of *A. conyzoides* occurrence. The data transformation and integration to transform and integrate the *A. conyzoides* occurrence with environmental variables. The SDM pipeline started with performing the multicollinearity test to retrieve the bioclimatic variables with less potential of autocorrelation. The next stage is the habitat suitability modeling using several models. The obtained model was then evaluated (Figure 2). Within the SDM pipeline, the feature engineering steps include selecting, transforming, and manipulating *A. conyzoides* occurrence data to create features and training *A. conyzoides* occurrence data that are suitable for training machine learning models. A number of R application including sp, dismo [24], library("maptools"), rgdal [25], and raster [26], are needed to create the suitability maps. SDM received 19 environmental variables as inputs (Bio 1 – Bio 19).The performance model was assessed using the receiving operating curve (AUC) area as threshold-independent and correlation coefficient, sensitivity, specificity, The True Skill Statistic (TSS) and Kappa as threshold dependents, and the contribution and influence of each environmental variable on the *A. conyzoides* habitat suitability model were ascertained using a Jackknife test [27]. AUC values range from 0 (least suitability) to 1, with a value less than 0.5 suggesting that the resulting model is no better than random and uninformative data and a value more than 0.5 showing that the resulting model is highly good and informative.

The prediction map resulting from SDM models was

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Table 1. Sampling sites in Bandung and its surrounding areas.

Variables	Sources	Format	Unit
Annual mean temperature (Bio 1)*	www.worldclim.org	Image data in Raster	^{0}C
Mean diurnal range (Bio 2) (mean of monthly (max temp - min temp))	www.worldclim.org	Image data in Raster	^{0}C
Isothermality (Bio 3)*	www.worldclim.org	Image data in Raster	%
Temperature seasonality (Bio 4) *	www.worldclim.org	Image data in Raster	^{0}C
Max temperature of warmest month (Bio 5)	www.worldclim.org	Image data in Raster	^{0}C
Min temperature of coldest month (Bio 6)	www.worldclim.org	Image data in Raster	^{0}C
Temperature annual range (Bio 7)	www.worldclim.org	Image data in Raster	^{0}C
Mean temperature of wettest quarter (Bio 8)	www.worldclim.org	Image data in Raster	^{0}C
Mean temperature of driest quarter (Bio 9)	www.worldclim.org	Image data in Raster	^{0}C
Mean temperature of warmest quarter (Bio 10)	www.worldclim.org	Image data in Raster	^{0}C
Mean temperature of coldest quarter (Bio 11)*	www.worldclim.org	Image data in Raster	^{0}C
Annual precipitation (Bio 12)*	www.worldclim.org	Image data in Raster	mm
Precipitation of wettest month (Bio 13)*	www.worldclim.org	Image data in Raster	mm
Precipitation of driest month (Bio 14) *	www.worldclim.org	Image data in Raster	mm
Precipitation seasonality (Bio 15) *	www.worldclim.org	Image data in Raster	dimensionless
Precipitation of wettest quarter (Bio 16)*	www.worldclim.org	Image data in Raster	mm
Precipitation of driest quarter (Bio 17)*	www.worldclim.org	Image data in Raster	mm
Precipitation of warmest quarter (Bio 18)	www.worldclim.org	Image data in Raster	mm
Precipitation of coldest quarter (Bio 19)*	www.worldclim.org	Image data in Raster	mm

*: selected variables based on multicollinearity test including Bio 1, 3, 4, 11, 12, 13, 14, 15, 16, 18, and 19.

imported into GIS for presentation and additional study [28]. According to Wei et al. [20], habitat suitability levels on the SDM model map can be classified into five suitability level included 0: unsuitable,1: low suitability, 2: medium suitability, 3: high suitability, 4: very high suitability.

2.6. CMIP 5 Future Scenario

Three situations were used in this investigation. The first scenario is the situation as it is in 2023; the second is a future scenario based on the RCP 2.6 and RCP 8.5 estimates from the 5th Coupled Model Intercomparison Project (CMIP) for 2050; and the third scenario is for 2070. The future scenario is based on the Fifth Assessment Report (AR5) [29] of the Intergovernmental Panel on Climate Change (IPCC) using downscaled global climate model data from CMIP5. The IPCC's 2014 AR5 adopted multiple Representative Concentration Pathways (RCPs) for the CMIP 5, which depict trajectories of greenhouse gas concentrations rather than emissions. The forecasts from the Special Report on Emissions Scenarios (SRES) issued in 2000 [30] have been replaced by this. Four potential future climates are described by these routes in climate modeling and study, all of which are thought to be feasible depending on the quantity of greenhouse gases released in the near future. The four RCPs—RPP2.6, RCP4.5, RCP6, and RCP8.5—are called after potential ranges of Radiative Forcing values in the year 2100 in comparison to pre-industrial values (+ 2.6, + 4.5, + 6.0, and + 8.5 W/m2, respectively), according to [31]. In order to simulate the habitat suitability distributions of *A. conyzoides* by the years 2050 and 2070, this study chose the RCP 2.6 and RCP8.5 models representing optimistic and pessimistic scenarios.

3. Result and Discussion

This study assessed the habitat suitability of *A. conyzoides* in Bandung and its surrounding areas in present time and in future time by year 2050 and 2070 under RCP 2.6 and RCP 8.5 climate scenario. The detailed results were explained as follows.

3.1. A. conyzoides *Current Occurrence*

Figure 1 shows current occurrences of *A. conyzoides* across in Bandung and its surrounding areas. This species was observed common in north parts of Bandung mainly in

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areas bordered with Purwakarta and Subang. An occurrence was also recorded in East near Sumedang and in West near Cianjur. While 44% of occurrences were in Bandung and 33% of occurrences were in north parts. *A. conyzoides* was rare and has limited occurrences in the southernparts. This finding is in agreement with a research reporting the presences of *A. conyzoides* in the northern parts in Purwakarta areas [4]. While Putri et al. [32] have report *A. conyzoides* in Sumedang areas and its use as remedy for wound. The community in here used leaf parts and apply as application.

3.2. A. conyzoides *Current Distribution Model*

Figure 3 shows the current estimated distribution and potential suitable habitats for *A. conyzoides* across Bandung and its surrounding areas. As can be seen in Figure 4, the current SDM model shows suitable habitats for *A. conyzoides* are sizing 1,250 km^2, mostly located in Bandung (56%), Kota Bandung (24%), and Sumedang (16%). The suitable habitats were divided into unsuitable, low suitability, medium suitability, high suitability, and very high suitability areas. West of Bandung, these areas were dominated by areas classified as unsuitable and having low suitability. This is also similar to the eastern parts of Bandung in Sumedang. While areas considered highly suitable and very suitable were actually located in the two parts, the first parts were concentrated in the northern parts of Kota Bandung, where these areas were dominated by very high suitable areas. The second parts were concentrated in the Bandung, where these areas were dominated by very suitable areas. South of Subang and West of Sumedang, which were bordered by Bandung, were also considered suitable for *A. conyzoides* at the current time. Based on the AUC analysis (Figure 5), the AUC value

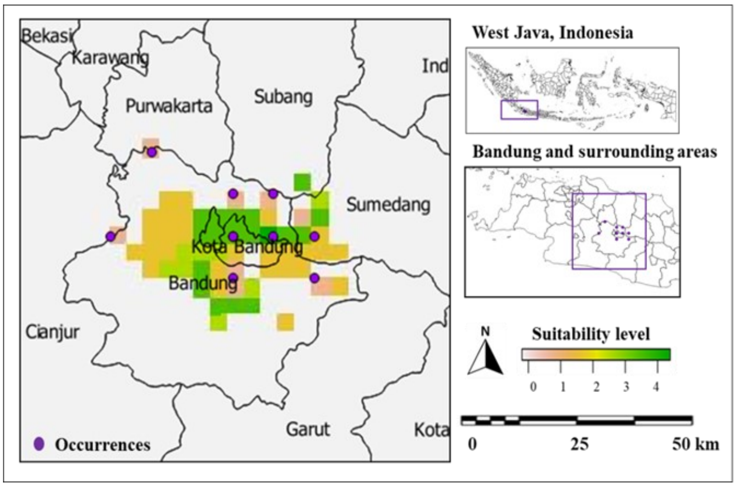

Figure 3. *A. conyzoides* current distribution model (Suitability level 0: unsuitable, 1: low suitability, 2: medium suitability, 3: high suitability, 4: very high suitability).

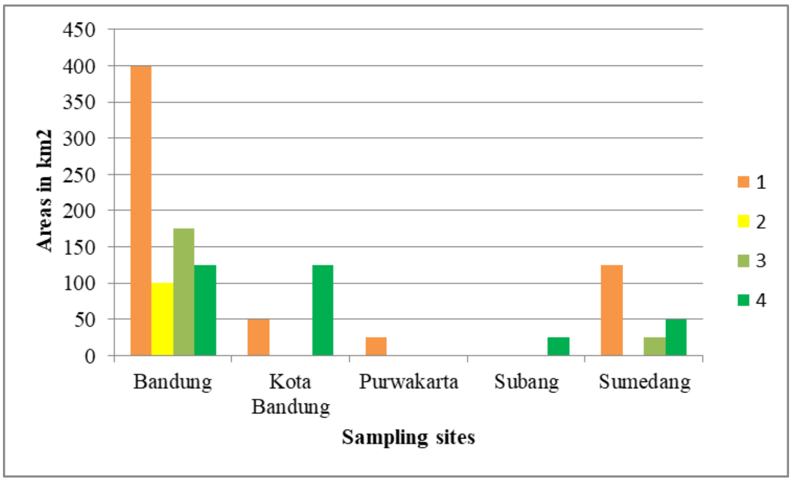

Figure 4. Areas (km^2) of *A. conyzoides* current distribution model (Suitability level 1: low suitability, 2: medium suitability, 3: high suitability, 4: very high suitability).

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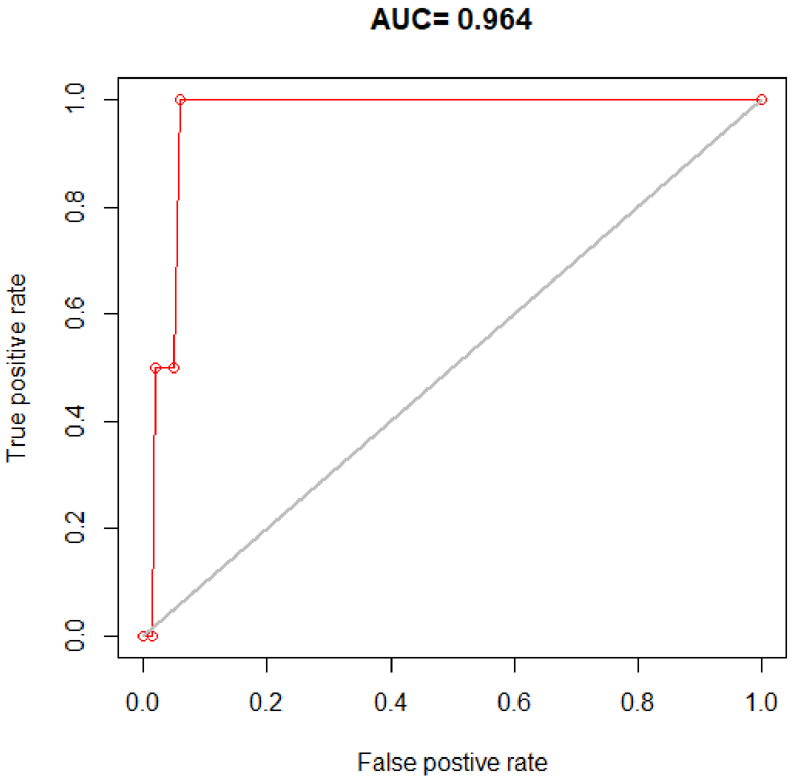

Figure 5. The Receiver Operating Characteristic (ROC) curve result of the model.

of this model is 0.964 (Table 2) and considered this model is highly good and informative.

3.3. A. conyzoides *Bioclimatic Variables*

Figure 5 shows the response curves of *A. conyzoides* towards several selected bioclimatic variables. Among those variables, and as can be seen in Table 3, Bio 18 followed by Bio 12 and Bio 11 were bioclimatic variables that contributed more to the distributions of *A. conyzoides* than other bioclimatic variables. According to the permutation importance analysis, Bio 11, followed by Bio 3, and Bio 18, has significant effects on the model. Bio 18 is the precipitation of the warmest quarter, and this means that an area is considered suitable habitat for *A. conyzoides* if, during the warm season, it is receiving rainfall with a range of 70–75 mm, as informed by the response curves in Figure 6. While *A. conyzoides* will prefer mostly habitats with temperature ranging from 22 to 23 °C during the cold season, as can be seen in the Bio 11 response curve. In the tropical regions and in Indonesia, the precipitation of the warmest quarter is considered as a significant variable affecting plant distribution as reported by Gunawan et al. [33] and other study at global scale [34].

3.4. A. conyzoides *Future Distribution Model*

Climate change is predicted to impact the future distribution model of *A. conyzoides.* The RCP 2.6, known as the optimistic scenario, as predicted, will yield larger areas suitable for *A. conyzoides* than the pessimistic scenario under RCP 8.5 (Figure 7). RCP 2.6 yields areas similar to the current distributions. While under the pessimistic scenario in RCP 8.5, suitable areas in Bandung are less than in RCP 2.6 scenarios. In 2070, only suitable habitats in the northern parts remained for both scenarios (Table 4) as can be observed in Subang. According to the model, in the future, *A. conyzoides* will shift northward to the mountainous areas nearby Tangkuban Perahu Mountain and Bukanegara Hills. Those hilly areas are characterized by low temperatures and rainfall. Those areas characterized by low temperatures will provide a refuge for

Table 2. The evaluation variables.

Evaluation variables	Threshold-independent	Threshold dependent				
	Area under the receiver operator (AUC) curve	Correlation coefficient	Sensitivity	Specificity	The True Skill Statistic (TSS)	Kappa
Values	0.964	0.522	0.694	0.680	0.374	0.370

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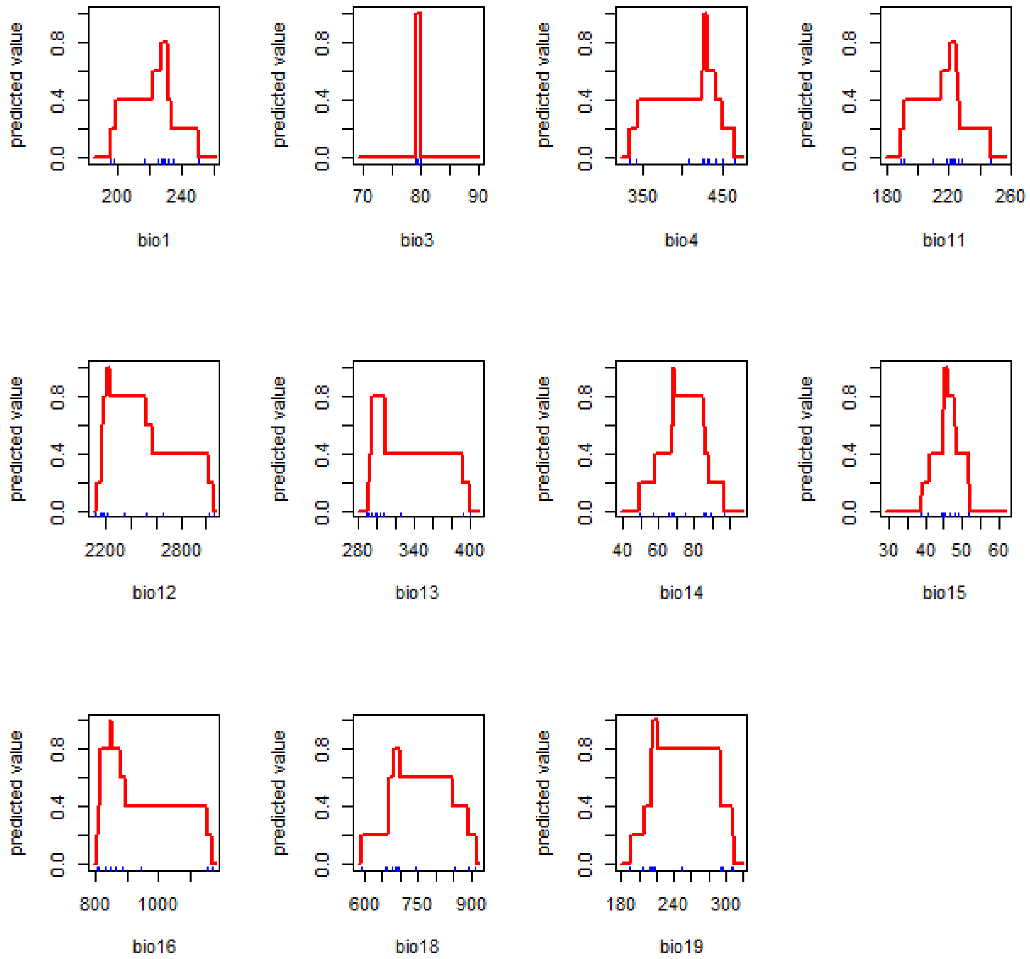

Figure 6. The Receiver Operating Characteristic (ROC) curve result of the model.

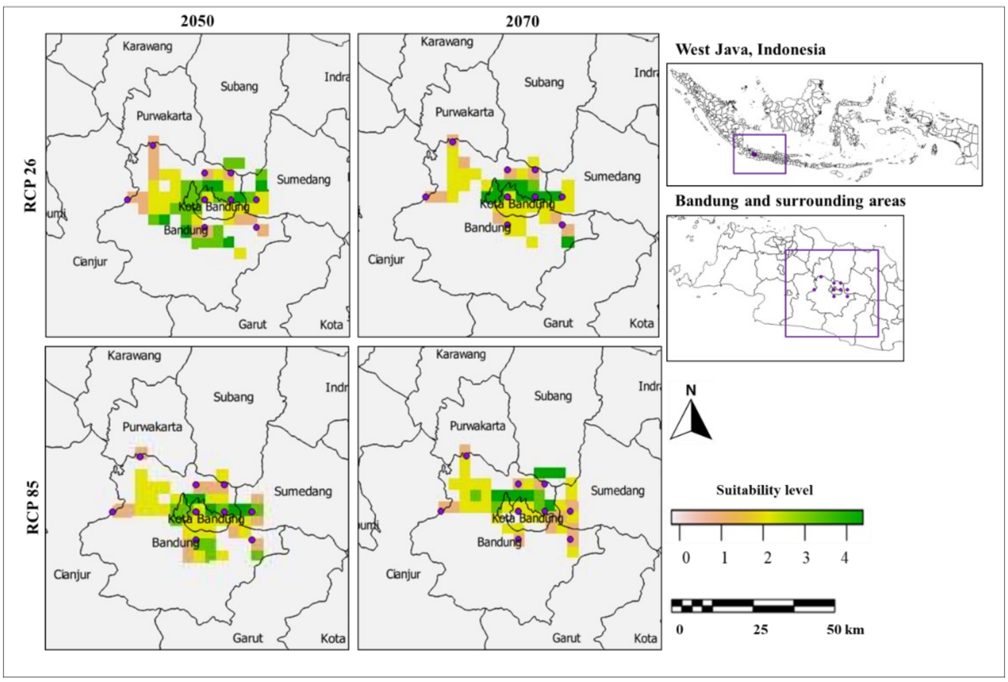

Figure 7. *A. conyzoides* future distribution model for RCP 2.6 and 8.5 climate scenario for year pf 2050 and 2070 (Suitability level 0: unsuitable, 1: low suitability, 2: medium suitability, 3: high suitability, 4: very high suitability).

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Table 3. Bioclim variables and their percent contribution and percent permutation importance reported by model

Bioclim	Variable contribution	Permutation importance
1	10%	9%
3	9%	15%
4	8%	10%
11	11%	16%
12	12%	8%
13	6%	11%
14	1%	10%
15	7%	10%
16	7%	11%
18	17%	12%
19	8%	11%

Table 4. Estimated loss or gain areas in km² between the current period and future projections (2050 and 2070) under each RCP scenario for habitat have a very high suitability.

Sampling sites	Current	2050		2070	
		RCP 2.6	RCP 8.5	RCP 2.6	RCP 8.5
Bandung	125	-75	-125	-100	-125
Kota Bandung	125	-25	-50	-50	-75
Purwakarta	0	0	0	0	0
Subang	25	+25	0	0	+50
Sumedang	50	0	-25	-50	-50

species sensitive to temperature rises due to climate change. In agreement with this, those areas are preferable for *A. conyzoides* since its growth is best suited to temperatures ranging from 20–25 °C [35]. This explains the shifting of *A. conyzoides* to the North of Bandung in the future and the disappearance of suitable habitats in the South. The shifting of suitable habitat to the north then encourages some areas in the northern region to need to be protected, including Tangkuban Perahu Mountain and Bukanegara Hills.

3.5. Limitations of the study

There are certain limits to this study's methodology. The VES is used in this study to record the species' presences that could compromise the model's correctness. Potential drawbacks of VESs include biases associated with habitat features, observer experience, and species detectability, especially for low-density or cryptic species. Besides that, the duration of this study, which was quite short, only 2 months, also limited the number of samples that were required for the model.

4. Conclusion

The current SDM model shows suitable habitats for *A. conyzoides* are sizing 1,250 km^2, mostly located in Bandung (56%), Kota Bandung (24%), and Sumedang (16%). Based on the model, at the current time, there are two locations that are suitable for *A. conyzoides*. The first locations were in the northern parts of Kota Bandung, where these areas were dominated by very suitable areas. The second location was concentrated in Bandung, where these areas were dominated by very suitable areas. *A. conyzoides* prefers habitats with rainfall with range of 70-75 mm during warm season and temperature ranging from 22 to 23 °C during the cold season. Climate change is predicted to impact the future distribution model of *A. conyzoides*. In 2070, only suitable habitats in the northern parts of Bandung remained for both scenarios. The result is considered very useful in contributing to the particular local government's zoning policy and climate-resilient agriculture strategies. It provides empirical evidence about suitable areas for *A. conyzoides*. It is strongly recommended to prioritize northwards of Bandung, covering Subang and including the Tangkuban Perahu Mountain and Bukanegara Hills regions.

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