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The Potential Distribution Prediction of The Invasive Alien Species *Acacia decurrens* Wild., in Indonesia

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Abstract

Acacia deccurens Wild. has been reported as invasive alien species (IAS) in several areas of Indonesia. Climate change may impact IAS to be more invader. The study aimed was to develop a species distribution model of *A. deccurens* to depict the potential distribution under climate change in Indonesia. Biodiversity and Climate Change Virtual Laboratory (BCCVL) was used to examine a species distribution model (SDM) of *A. decurrens* in Indonesia based on climate variables and its naturalized distribution to predict the project distribution under current and future climate conditions. The data was collected from Global Biodiversity Information Facility (GBIF) to identify the species occurrences. The climate variables used in this study were temperature and precipitation layers based on WorldClim, current climate (1950-2000), 2.5 arcmin (~5km). The SDM of the Generalized Linear Model (GLM) was utilized to predict the response variable as a function of multiple predictor variables. We selected four IPCC Representative Concentration Pathways (RCP) 2.6, 4.5, 6.0, and 8.5 for 2050. The prediction of the distribution of A. deccurens in 2050 showed that it was likely to decrease in Indonesia (mostly found only in Sumatra and Sulawesi Island). Almost all climate variables used in this study were responsive to *A. decurrens* distribution, except B09 - mean temperature of the driest quarter. The ROC plot showed excellent values (0.99). The information of the potential distribution on IAS under current and future climate scenarios can be used for policymakers and stakeholders to manage and handle the invasion.

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Keyword
Acacia deccurens, climate change, invasive alien species, special distribution model.

Introduction

The genus of Acacia worldwide includes ± 1300 species and about 960 species come from Australia and it spreads in the tropics to the temperate area, namely Europe, Africa, South Asia, and America (Wrigley & Fagg, 2013). One of the Acacia species spread in Indonesia is *Acacia deccurens* Wild. This species, commonly known as black wattle or green wattle, is a fast-growing tree species of the Fabaceae family (Bamidele *et al.*, 2017). This species can grow about 6-12 m and easily adapt to acidic soil conditions (Endalew *et al.*, 2014). Naturally, *A. deccurens* grows in a lower mountain valley (Molla & Linger, 2017).

A. deccurens is widely planted because it has benefits both for economic and environmental in forestry, agricultural, and ecosystem forestry (Nigussie *et al.*, 2016; Wondie & Mekuria, 2018; Nigussie *et al.*, 2020; Chanie & Abewa, 2021; Nigussie *et al.*, 2021). Several studies have reported that *A. deccurens* cultivated in degraded land can improve soil fertility, increase water quality, and prevent soil erosion (Reubens *et al*., 2011; Molla & Linger, 2017; Bazie *et al*., 2020). Furthermore, according to CABI (2021), *A. decurrens* can be used as fuels (charcoal and fuelwood), ornamental plants, and materials (tanning and timber) (Richardson *et al*., 2015).

On the other side, several publications have reported that *A. decurrens* is a severe invasive problem (i.e., Hawai, New Zealand, Africa, and Indonesia) that this species spreads rapidly through root suckers and seed (Richardson and Rejma´nek 2011; Richardson *et al*., 2015). The invasion by an alien species of *A. decurrens* can proliferate as a pioneer plant in an area where the native species can not to adapt to environmental conditions (Sunardi *et al*., 2015; Sunardi *et al*., 2017). It creates negative consequences, especially for native biodiversity (Sunardi *et al*., 2017). In Indonesia, the invasiveness of *A. decurrens* is found several areas such as Mount Merapi after eruption 2006 (Suryanto *et al*., 2010 a,b) and 2010 (Afrianto et al. 2016; Sunardi *et al*., 2017; Afrianto *et al*., 2017, Afrianto *et al*., 2020), Mount Merbabu (Purwaningsih, 2010; Untoro et al. 2017), Kawah Ijen Nature Tourism Park (Hapsari et al. 2014), and Mount Panderman Nature Tourism (Septiadi. 2018).

Species distribution models (SDMs) can predict the effect on potential species distributions under climate change at the single-species and community levels (Sung *et al*., 2018). The study aimed to develop a SDM of *A. deccurens* to project the potential distribution under climate change in Indonesia. Therefore, understanding the SDM of the potential distribution of the invasive species under and future climate change can be used as early preventive and management strategies for managing and handling the invasion.

Materials and Methods

Data collection

This study was analyzed by the Biodiversity and Climate Change Virtual Laboratory (BCCVL) (http://www.bccvl.org.au/). BCCVL is cloud-based, providing access to modeling tools, large species distribution, climate, the collection of biological and other environmental datasets, and diverse experiment categories to carry out a study into the relationship between biodiversity and climate change (Hallgren *et al*., 2016). The Global Biodiversity Information Facility (GBIF) (http://www.gbif.org/) dataset of *A. decurrens* was used to conduct the species occurrence (GBIF 2021). Worldclim current conditions (1950-2000) at 2.5 arcmin was used in this simulation. Based on the database, *A. decurrens* has about 17,917 occurrence records and 17,232 geo-referenced. Then, this data was imported in BCCVL. The climate and environmental data used WorldClim, current climate (1950-2000), 2.5 arcmin (~5km). These bioclimatic variables were generated using 1950 to 2000 from an array of global climate layers (except Antarctica). Eight climate variables were chosen in the BCCVL, such as:

1. B04 (temperature seasonality, standard deviation)
2. B05 (max temperature of warmest month)
3. B06 (min temperature of coldest month)
4. B08 (mean temperature of wettest quarter)
5. B09 (mean temperature of driest quarter)
6. B13 (precipitation of wettest month)
7. B14 (precipitation of driest month) and,
8. B15 (precipitation seasonality, coefficient of variation).

The temperature and precipitation data were chosen because they are important factors to impact vegetation range and abundance of species (Krebs, 1985). Afrianto *et al*., (2017) state that the habitat preferences of *A. decurrens* were strongly correlated with temperature conditions. Because we do not have a true absence dataset for the experiment, we used the pseudo absence configuration (PA models) with the absence-presence ratio of 1, the random pseudo-absence strategy, and the number of background points of 10,000. Pseudo-absence points were used to generate for the experiment.

Data analysis

The experiment was conducted by the primary experiment of SDM experiment. For the algorithm of SDM, we used Generalized Linear Model (GLM). The GLM is a linear regression model to predict the response variable as a function of multiple predictor variables. The GLM was used because it has several advantages, namely (1) the response variable be able to all form of the exponential distribution model, (2) can be used in categorical predictors, (3) easy to interpret and understand how each of the indicators is impacting the outcome, (4) less vulnerable to overfitting than for instance CTA or MARS algorithms. The area under the curve (AUC) of the receiver operating characteristics (ROC) curve was used to examine model robustness. This curve is a non-parametric threshold-independent measure of accuracy used to assess SDM (Bertelsmeier & Courchamp. 2014). The x-axis of the ROC plot is a graph of the false positive rate (1- specificity), and the y-axis is an actual positive rate (sensitivity). The values above 0.5 means prediction better than random, and the value of 0.5 means a random prediction. The AUC score was classified as follow (Crego *et al*., 2014):

A. Value above 0.9 is excellent
B. Good 0.9 > AUC > 0.8
C. Fair 0.8 > AUC > 0.7
D. Poor 0.7 > AUC > 0.6, and
E. Fail 0.6 > AUC > 0.5

Further analysis was conducted by the secondary experiment that is the climate experiment, to investigate the distribution of a species under potential future climatic conditions. A climate change experiment predicted *A. decurrens* distribution with the climate information under climate change scenarios. In this study, we selected four IPCC Representative Concentration Pathways (RCP) 2.6, 4.5, 6.0, and 8.5 for the 2050s. Furthermore, we evaluated by (1) WorldClim, future projection using IPSL-CM5A-LR RCP 2.6 10 arcmin (2050), (2) WorldClim, future projection using IPSL CM5A-LR RCP 4.5, 10 arcmin (2050), (3) WorldClim, future projection using IPSL-CM5A-LR RCP 6.0, 10 arcmin (2050), and (4) WorldClim, future projection using IPSL-CM5ALR RCP 8.5, 10 arcmin (2050). The prediction results based on the current climate condition indicate distribution of suitable habitat.

RESULTS AND DISSCUSSION

Present distribution of *A. decurrens* in Indonesia

The introduction of *A. decurrens* in Indonesia is for industrial purposes. This exotic plant species is planted as crops plants or plantations such as mahogany, pine, agathist, coffee, cocoa, palm oil, acacia, African wood, and others. Exotic species introduced in Indonesia are listed as industrial plants. including *A. decurrens* since ancient times of Dutch colonialism (Purwaningsih, 2010).

The prediction of the current distribution of *A. decurrens* showed that mostly this species occurred in Sumatra and Sulawesi Island. In Sumatra Island, *A. decurrens* distributed to several provinces Banda Aceh, North Sumatera, West Sumatera, and Bengkulu. In contrast, in Sulawesi Island, this invasive species spread to West Sulawesi, Central Sulawesi, and some parts of along with Southeast Sulawesi (Figure 1). However, until now, no scientific documents and reports explain the occurrence of *A. decurrens* in these areas. Mostly, the studies of *A. decurrens* is only found in Java Island, especially in Mount Merapi National Park. Based on the report GBIF, in Indonesia *A. decurrens* has less for the invasiveness impact with 42 occurrences reported (GBIF, 2021). On the other hand, the highest occurrence is found in Colombia of 12,725 occurrences and has the highest invasiveness impact of *A. decurrens*.

Figure 1. Map of current distribution of IAS of *A. decurrens* under current climate condition in Indonesia using GLM algorithm in BCCVL. Darker areas represent a higher potential distribution of *A. decurrens*.

By "invasion pathway" or the stages of invasion, there are five nonexclusive consequences of climate change for invasive species, namely (1) modified transport and initiation mechanisms, (2) establishment stage by new invasive species in the area, (3) modified impact of existing invasive species, (4) the spreading of invasive species, and (5) modified effectiveness of control approach (Hellman *et al*., 2008). The distribution of invasive species under climate change is found more invader in outside protected areas of Europe's marine and terrestrial because of the low human accessibility (Gallardo *et al*., 2017). Panda *et al*., (2017) state the phenology and capacity of species to adapt quickly in climate are potentially related to the invasion stage in the future climate.

Potential future distribution under climate change of *A. decurrens* in Indonesia

Climate change condition is likely to decrease the potential of the distribution of *A. decurrens* in Indonesia. Figure 2 shows that *A. deccurens* in Sumatra Island was only found in Banda Aceh Province based on IPCC RCP 2.6, 4.5, 6.0, and 8.5 for 2050, and some part of North Sumatera (Pemantang Siantar) based on IPCC RCP 2.6 and 4.5 for 2050. Moreover, Figure 3 shows that *A. decurrens* in Sulawesi Island were only found in Central Sulawesi and South Sulawesi based on IPCC RCP 2.6, 4.5, and 6.0 for 2050.

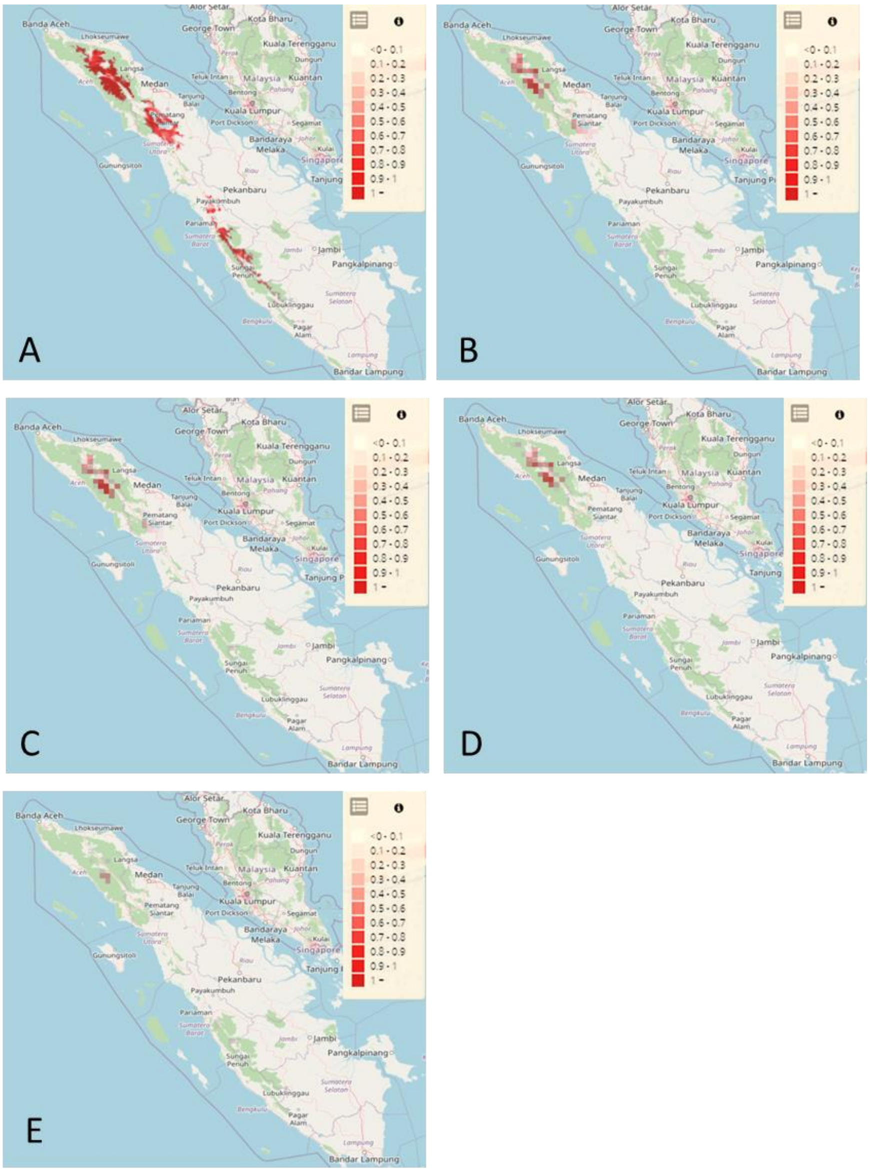

Figure 2. Comparison of climate change models of *A. decurens* for current and 2050 in Kalimantan Island. (A) Current distribution, and (B-2) IPCC RCP 2.6, 4.5, 6.0, and 8.5 for the 2050 were evaluated with WorldClim data and 10 arcmin resolution. Darker areas represent a higher potential distribution of *A. decurrens*.

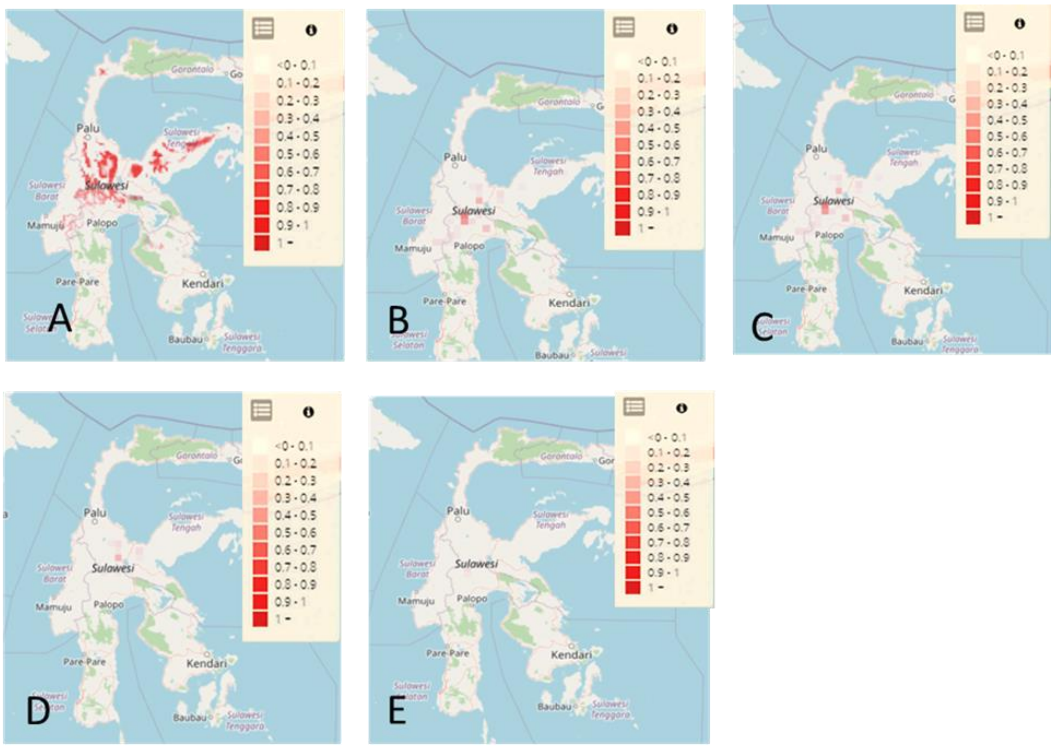

Figure 3. Comparison of climate change models of *A. decurens* for current and 2050 in Sulawesi Island. (A) Current distribution, and (B-2) IPCC RCP 2.6, 4.5, 6.0, and 8.5 for the 2050 were evaluated with WorldClim data and 10 arcmin resolution. Darker areas represent a higher potential distribution of *A. decurrens*.

Except for B09 (mean temperature of driest quarter), all climate variables used in this study are responsive to *A. decurrens* distribution (Figure 4). *A. decurrens* was found in areas that have moderate frost tolerance. It grows in the warm sub-humid to the humid climatic zone. The environmental requirement of *A. deccurens* needs annual rainfall of 900-1150 mm. It can grow with a mean minimum of the coolest month of 1-5°C, or it will even tolerate temperatures as low as -6°C. On the other hand, the mean maximum of the hottest month is 26-30°C. In general, the ROC plot showed excellent values (0.99) (Figure 5).

The climate change predicted will make several species losses in 2050 (Gallagher et al. 2012). This phenomenon is because climate change will make a warmer condition where it may impact the flowering and seedling of several plant species (Germishuizen and Gardner 2015; Booth 2017). The short term of climate change is predicted to affect abundance and distribution (Blyth et al. 2021). In a different result, Sutomo et al. (2017) shows that the distribution prediction of *A. nilotica* in 2045 will increase, especially in eastern Indonesia. Kriticos *et al*., (2003), also state SDM of *A. nilotica* might rising significantly because of climate change. It is because *A. nilotica* can grow in temperature around ~35 °C or 5°C warmer rather than *A. deccurens*.

This model prediction does not include other factors that are considered to impact the distribution of *A. decurrens*. Those factors are edaphic, topographic, and dispersal agent. It is because this species has values both economically and ecologically, thence social aspects are also required to be analysed (Sutomo *et al*., 2021 a,b). By adding those variables, it will make the prediction more powerful (Booth, 2018).

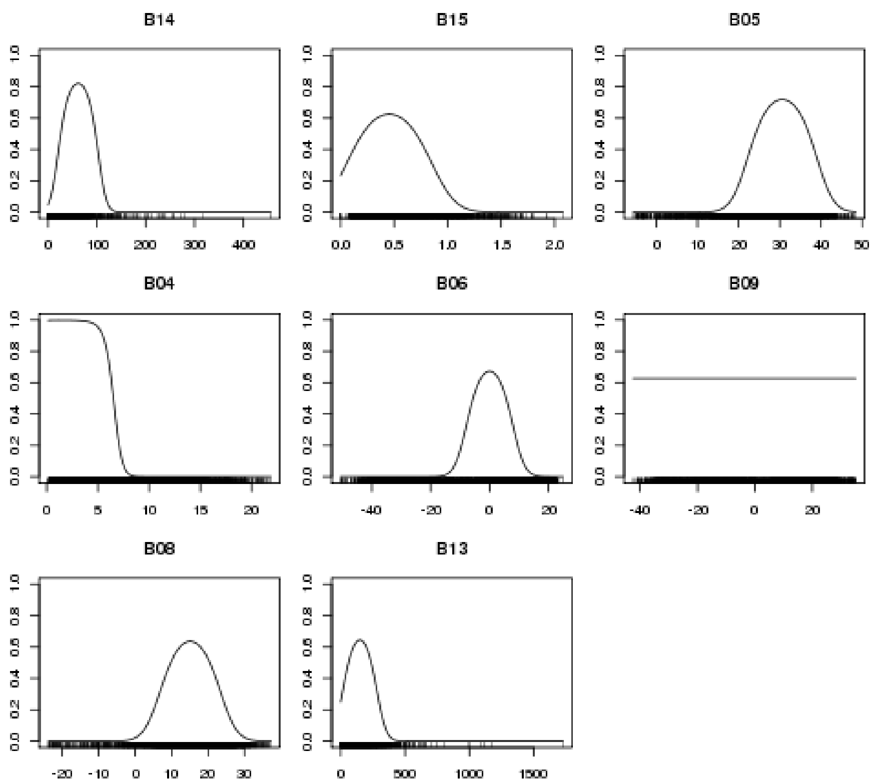

Figure 4. The response curve for *A. decurrens* distribution model.

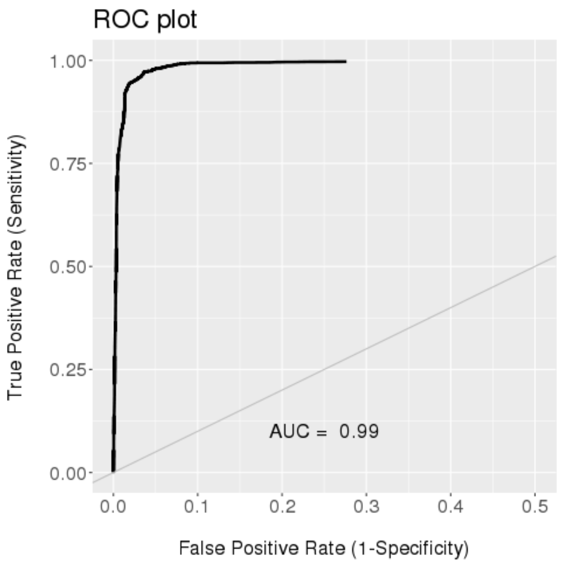

Figure 5. ROC plot of *A. decurrens* model using GLM in BCCVL.

CONCLUSIONS

A. decurrens will decrease in 2025 based on the current and future climate variables conditions. Except for the mean temperature of the driest quarter, all climate variables used in this study were responsive to *A. decurrens* distribution, and the ROC plot showed excellent values (0.99). This study provides great tools to determine the impacts of climate change on the IAS of *A. decurrens* for management purposes.

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