ECOLOGICAL NICHE MODELLING OF LEPTOSPIROSIS AS A CONTRIBUTOR FOR STRENGTHENING HEALTH RESILIENCE IN PUBLIC HEALTH SYSTEM

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Abstract. Model implementation of health programs and commitment to build human resilience are closely related. The ecological niche modeling (ENM) of leptospirosis could build an integrated public health system. This study attempted to describe the relationship between leptospirosis risk factor control programs and the environmental science approach. The ENM of leptospirosis was employed as the main method followed by extracting information related to alternative control efforts. Natural, built, and social environment variables were employed as proxies for the indicators. The results showed that each area had distinctive characteristics. Moreover, natural environmental factors in almost all areas studied could significantly predict the distribution of leptospirosis. A study in Demark has revealed that natural environmental factors were quite dominant. Meanwhile, a study in Boyolali has shown that the natural environmental factor contributed the most to the density of vegetation. The biggest contributing factor to the built-environmental factor was the use of land. In Semarang City, natural environmental factors with the biggest contribution were vegetation density and maximum temperature. Meanwhile, in Ponorogo, the natural environmental factor with the biggest contribution was the density of vegetation. Meanwhile, the contributing-built environment factors were land use and distance to major rivers. This study has also found that social factors insignificantly contributed to these four areas. This study concluded that a broad multidisciplinary-scientific study should consider the local wisdom of each region to build community resilience against outbreaks before and after the recovery.

Keywords: ecological niche modeling; leptospirosis; health resilience, public health system

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INTRODUCTION

The implementation of health program's model and commitment to building human resilience are related (Wulff *et al*, 2015). The ecological niche modeling (ENM) of leptospirosis could contribute to build an integrated public health system, specifically integrated control efforts by multi-sciences and cross sectors. Leptospirosis is still a health problem in various regions in various parts of the world. The cycle of transmission and spread is very complex and involves many factors. Leptospirosis is one of neglected disease based on dynamic environment, including the natural, built and social environment. Determinant, frequency, and leptospirosis distribution are specifically localized in several areas with different environmental conditions. Various models of transmission and control cycles have been researched and carried out to find the most appropriate and efficient intervention efforts (Dhewantara *et al*, 2022; Djati *et al*, 2019; Ikawati and Puspitaningsih, 2012; Khan *et al*, 2014; Lau *et al*, 2017; Minter *et al*, 2019; Mohammadinia *et al*, 2019; Sunaryo *et al*, 2021; Triampo *et al*, 2007; Zhao *et al*, 2016). However, the modeling rarely involves the three elements including with an environmental science approach, namely natural environment, built, and social environment.

The novelty of this research could be seen from two scientific perspectives. Based on health science, the novelties of this research included the integration of information, approaches and methods as well as the interpretation of non-health sciences including environmental, ecological, spatial, and social sciences, into health sciences, especially in efforts to control the disease, namely leptospirosis. In terms of environmental science, the environmental science approach can be applied to specific and specific health sciences. Thus, in general, the novelty of this research is the understanding of disease problems using a broader environmental science approach. From the point of view of the method used, ENM is generally used to investigate patterns of species presence for conservation purposes. Ecological niche modeling had been used to explore the distribution of disease. Several diseases that have been studied using ENM are dengue fever, chikungunya, cutaneous leishmaniasis, fungal wound contamination, avian influenza, tularemia, anthrax, and also leptospirosis (Ashby *et al*, 2017; Bodbyl-Roels *et al*, 2011; Chalghaf *et al*, 2016; Dhewantara *et al*, 2022; Nakazawa *et al*, 2010; Pittiglio *et al*, 2022; Richman *et al*, 2018; Tribble *et al*, 2015; Zhao *et al*, 2016). But, on the other hand, ENM is still rarely used to see the distribution of disease based on various environmental factors, included social factors.

In many endemic areas, efforts to control leptospirosis have not been based on risk factors that mutually interact. An environmental science perspective enables leptospirosis and current issues of environmental and social dynamics to link and crucially understand. This study aimed to describe the relationship between leptospirosis risk factor control programs and the environmental science approach. Leptospirosis using multi-disciplinary science, in this case, environmental science, should be understood. Environmental science is slightly different from the perspectives of health and environmental health. The results of this study are expected to complete the understanding of leptospirosis; thus, leptospirosis has to be controlled comprehensively.

MATERIALS AND METHODS

The ecological niche modeling (ENM) of leptospirosis was employed as the main method followed by extracting information related to alternative control efforts. This study used mix methods, that was quantitative and qualitative methods, because of its spatial design. First, both quantitative and qualitative data were collected and analyzed separately; results were compared to see whether the findings confirm or disconfirm each other (Creswell, 2014). The variables of the natural, built, and social environment were employed as proxies for the indicators. This study analyzed 12 environmental variables. Seven factors of the natural environment included elevation, vegetation density, rainfall, average temperature, area wetness, rodent density, and big cattle density. The built environment consisted of five factors, namely, land use, rice field distribution, settlement distribution, settlement pattern, and distance from the main river. Meanwhile, social environmental factors consisted of two factors, population density and income per capita.

This study was conducted in Demak, Boyolali, Semarang City (Central Java), and Ponorogo (East Java). The secondary data on coordinates of human cases from District Health Office of four research areas have been collected for ten years (2008-2018). All variables were collected in the same period.

Environmental factors were analyzed in the ENM as well as being collected and converted into several steps. The initial steps of the ENM in this study started by preparing the spatial data in the raster format

(Young *et al*, 2011). The steps were:

1. Producing a comma-separated value (.csv) file from location coordinate data for leptospirosis sufferers, in an Excel Worksheet;

2. Modifying the environmental factor layer (altitude, rainfall) rain, temperature, humidity, land use, so it has a wide extension the same (geographical boundaries and cell size) using ArcGIS (Esri, Zurich, Switzerland);

3. Converting environmental raster data into ASCII format;

4. Running the MaxEnt modeling using MaxEnt version 3.3.3e (Young *et al*, 2011);

5. Modeling begins with determining the background, followed by set Run, set up MaxEnt by doing replication, reduction, test data, determine the number of iterations, regulation, bias, run simulation modeling, interpretation of outputs, and determination of thresholds;

6. Running modeling was carried out 15 times for each location, with maximum iterations for each location is 5000, convergence the threshold for each location is 0.00001, and the default prevalence of 0.5.

7. Converting MaxEnt output in ASCII format to raster by specifying symbols so that the final map can be read and easy to understand.

The sources of variables employed in this study are presented in Table 1.

The modeling was carried out three times to investigate and compare the analysis results or predictive results. In the first modeling, all environmental variables were included in the model. This study neither conducted the multicollinearity test nor deleted and disposed of variables in the model. This modeling was carried out by considering the opinion that the variable deletion was not necessary unless it was ecologically irrelevant to the research object (Elith *et al*, 2011). The model distributions, such as Maxent, worked well to deal with the collinearity (De Marco and Nóbrega, 2018). In the second modeling, the multicollinearity test, deletion, and removal of one variable have indicated a correlation coefficient of 0.9. The multicollinearity analysis was carried out to determine the correlation or strength of the relationship between environmental variables used. The existence of multicollinearity would negatively affect the results of the modeling. The negative effect of the multilinearity would make the resulted model overconfident due to the influence of two or more interrelated variables (Putri *et al*, 2019). In the third modeling, the second modeling variable contributed to the model for less than 2% and was then excluded from the model (Chalghaf *et al*, 2016). In addition, the final results of ecological niche modeling were expected to show and predict the distribution and incidence of leptospirosis in the research sites. In 2018, further modeling was also carried out to predict the distribution and incidence of leptospirosis in 2030-2040. The results of the modeling were in the form of colored visual maps. Color and gradation show the probability distribution. A high probability of species distribution was marked by an increasingly red color while the low species distribution was marked by an increasingly blue color (Chalghaf *et al*, 2016).

Then the modeling results were compared using several indicators. List of indicators to compare the modeling results in this study is presented in Table 2.

This study was conducted with ethical approval by Komisi Etik Penelitian Kesehatan, Badan Penelitian dan Pengembangan Kesehatan (Health Research Ethics Commission, Health Research and Development Agency) No. LB.02.01/2/KE.203/2019 dated 29 May 2019 which was valid from 29 May 2019 to 28 May 2020.

Table 1
Variables of research

Variable	Data	Data source
Leptospirosis occurrences	Geocode of cases' address	District health services
Land use	Land use of Ministry of Environment and Forestry 2017	Ministry of Environment and Forestry
Elevation	ASTER GDEM	https://earthexplorer.usgs.gov/
Normalized difference vegetation index	Landsat 8 OLI (120/065) [22 Aug 2017]	https://earthexplorer.usgs.gov/
Normalized difference wetness index	Landsat 8 OLI (120/065) [22 Aug 2017]	https://earthexplorer.usgs.gov/
Precipitation (Rainfall)	Bioclimatic variable	http://worldclim.org/version2 Fick and Hijmans, 2017
Average temperature	Bioclimatic variable	http://worldclim.org/version3 Fick and Hijmans, 2017
Rodent density	Trap success	Several result studies and rodent surveys in area studies 2008-2018 (Djati *et al*, 2015; Wahyuni and Yuliadi, 2010; Pramestuti *et al*, 2014; Primaningtyas, 2014; Dewi, 2015)

Table 1 (cont)

Variable	Data	Data source
Big cattle density	Density of beef cattle, dairy cattle, horses, goats, sheep	District Central Bureau of Statistics 2008-2018
Population density	Models the distribution of human population (counts and densities) on a continuous global raster surface	https://sedac.ciesin.columbia.edu/data/collection/gpw-v4
Income per capita	Gross domestic product	Kummu *et al*, 2018

ASTER GDEM: Advance Spaceborne Thermal Emission Radiometer-Global Digital Elevation Model; Landsat 8 OLI: Land Satellites 8 Operational Land Imager

Table 2
Comparison indicators

Indicators	Comparison method	Note
Probability of leptospirosis occurrences and distribution	Visual based on map	Highest possible distribution among the other research areas (color close to red)
	Probability value	Highest possible distribution among the other research areas (values close to 1)
Contribution of predictors to the model	Value based on response curves	Highest contribution (values close to 100%)

RESULTS

The results showed that each area has distinctive characteristics. The ecological niche modeling in the four research areas has discovered different predictions for Models 1, 2, and 3, predictions for 2018, and predictions for distribution in 2030-2040. All models produced in this study had predictive capabilities of 0.607-0.929 (60.7-92.9% accuracy). The modeling results in the four research sites are presented in Fig 1.

The results of comparing four predictions show that Demak was the area with the highest possible distribution among the other three research areas. Values of possible distribution close to 1 had shown by color of area close to red. Overall, the probability of leptospirosis in 2018 and 2030-2040 was fairly predicted even in all districts in the Boyolali region. Meanwhile, the prediction in Semarang City in 2030-2040, areas with high probability will be lessened in many districts. Overall, Boyolali and Ponorogo were predicted to have almost fixed locations and the probability of case distribution in 2030-2040.

In almost all areas studied, natural environmental factors had the greatest contribution to predict the distribution of leptospirosis. This present study revealed that Demak had natural environmental factors quite dominantly contributed to the distribution of leptospirosis while the social environmental factors did not have an overall contribution. In Boyolali, the natural environmental factor that contributed the most was the density of vegetation and the biggest contributing factor to the built environment factor was land use. In Semarang City, the natural environmental factor that had the biggest contribution was the vegetation density, followed by the maximum temperature. In Ponorogo, the natural environmental factor with the biggest contribution was the density of vegetation while the contributing built environment factors were land use and distance to major rivers. Social factors slightly contributed to the four research sites. Overall, the social and environmental factors that showed very little contribution was the population density factor.

Demak model had the greatest predictive power among the three other locations while the lowest predictive power was found in the

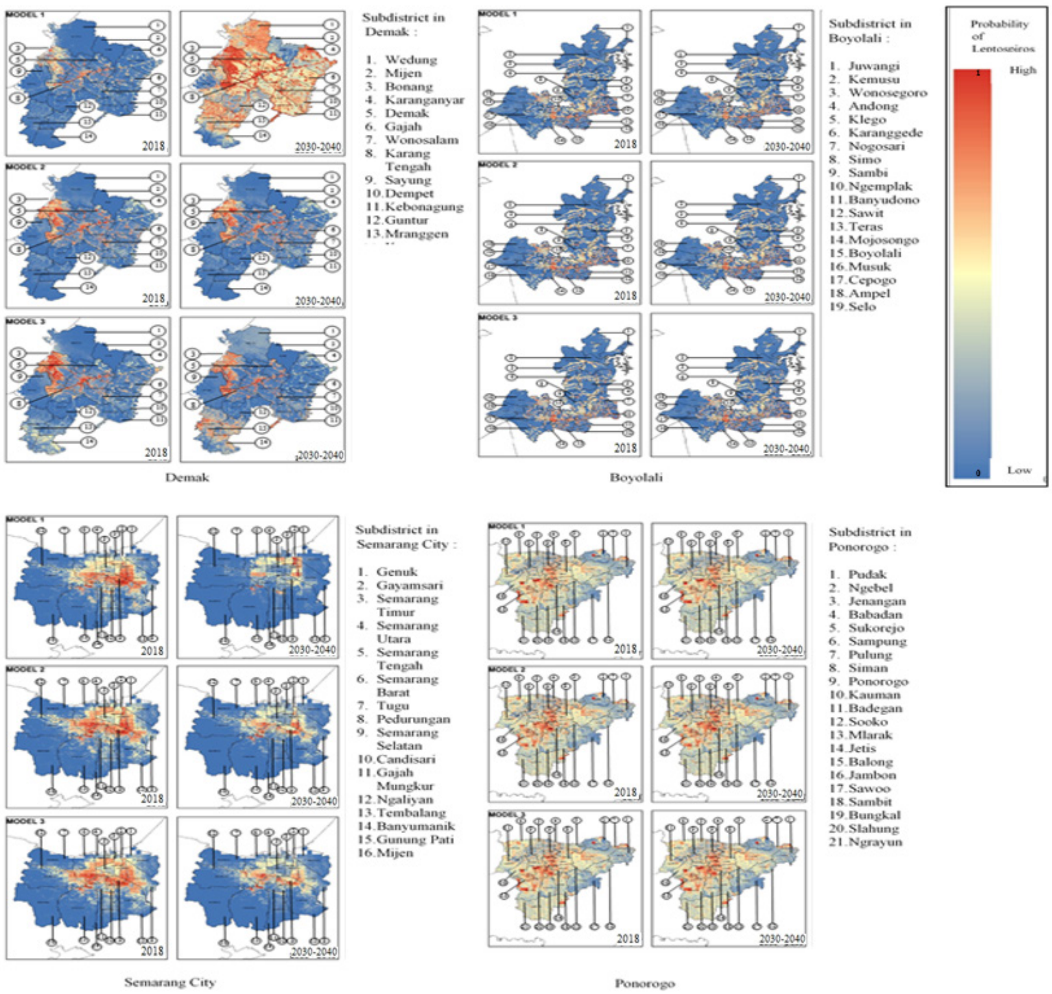

Fig 1 - Visualization of ecological niche modeling of Demak, Boyolali, Semarang City, and Ponorogo

Ponorogo model. Area under the curve (AUC) figured for Demak and Semarang models decreased in Model 3 as the environment variable decreases and was incorporated into the model. Boyolali model had a better contribution with the decrease in environmental variables. The Ponorogo model showed poor performance when the disposal variable was in Model 2 (maximum temperature, minimum temperature, and area wetness). Moreover, the AUC number become smaller. Some environment variables which were dumped back in Model 3 and entered into the model, were vegetation density, big cattle density, land use, and distance to a major river. The model's performance become slightly better, and the best performance was found in Ponorogo. In general, the built model could provide information about the distribution of suitable leptospirosis habitats in the research sites.

Furthermore, the detailed values and conditions of each environmental factor are presented in the form of a curve response. The response curves are shown in Fig 2.

The response curves denoted that the environmental factors had suitable values for leptospirosis habitat in the four research sites. Climate variables that contributed greatly to the modeling of the four research sites were rainfall and temperature. Leptospirosis was mainly found in Demak because the heavy rainfall in this area ranged from 2.275-2.350 mm/year. The rainfall in Semarang is 2,230-2,250 mm/year and the average temperature was between 27.50-27.52°C. Based on the response curve (Fig 2) to the Normalized Difference Vegetation Index (NDVI) at the four research sites, the habitat of leptospirosis showed that leptospirosis was found in habitat conditions with vegetation indexes between 0.00 to 0.40 in Demak, -0.20 to 0.20 in Boyolali, 0.19 to 0.30 in Semarang, and -0.10 to -0.03 in Ponorogo. The very low NDVI score was found in Ponorogo indicating that the habitat was suitable for the distribution of leptospirosis

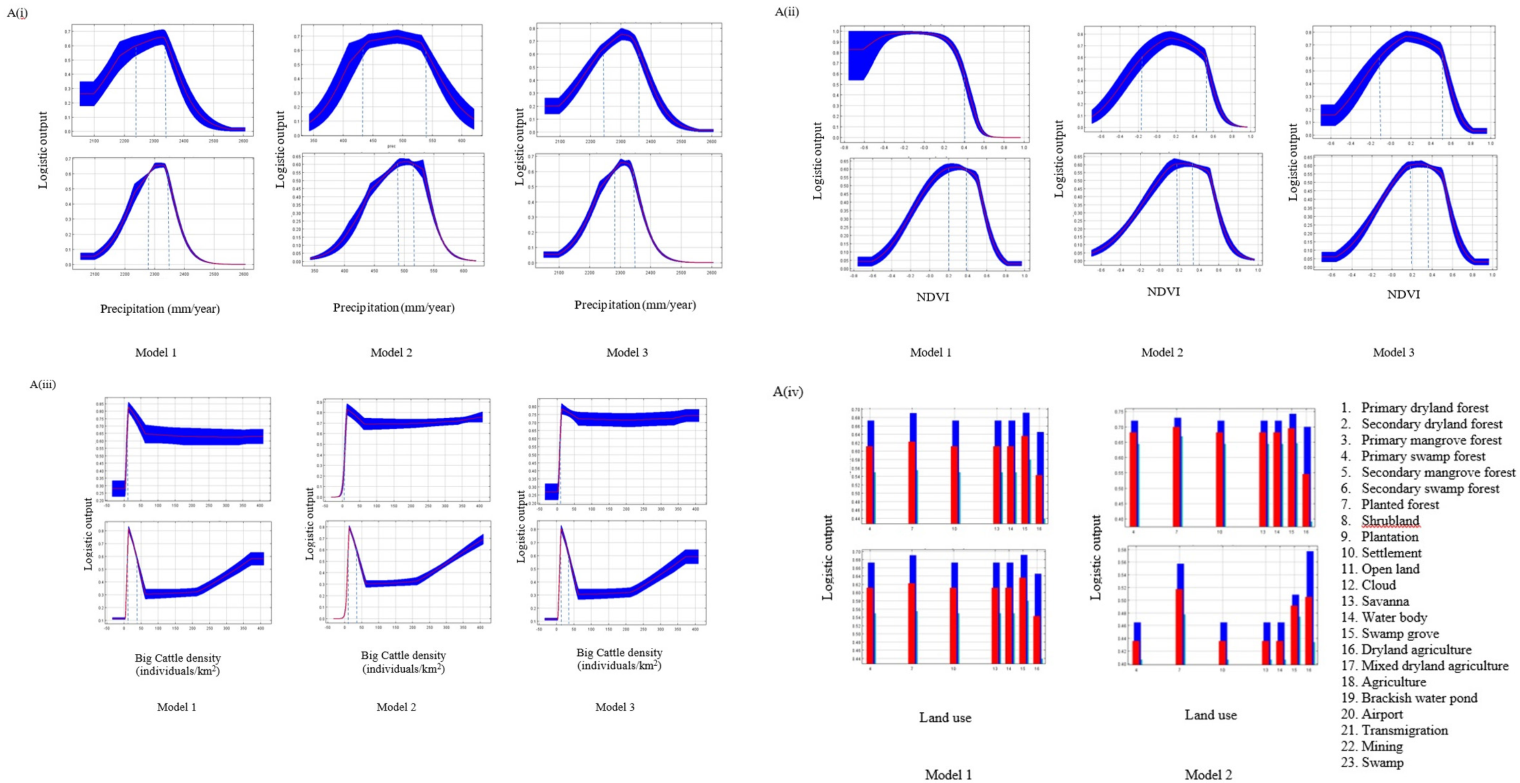

Fig 2 - Response curves of Demak, Boyolali, Kota Semarang, and Ponorogo

A(i): response curves of precipitation in Demak; A(ii): response curves of NDVI in Demak; A(iii): response curves of big cattle density in Demak; A(iv): response curve of land use in Demak

NDVI: Normalized Difference Vegetation Index

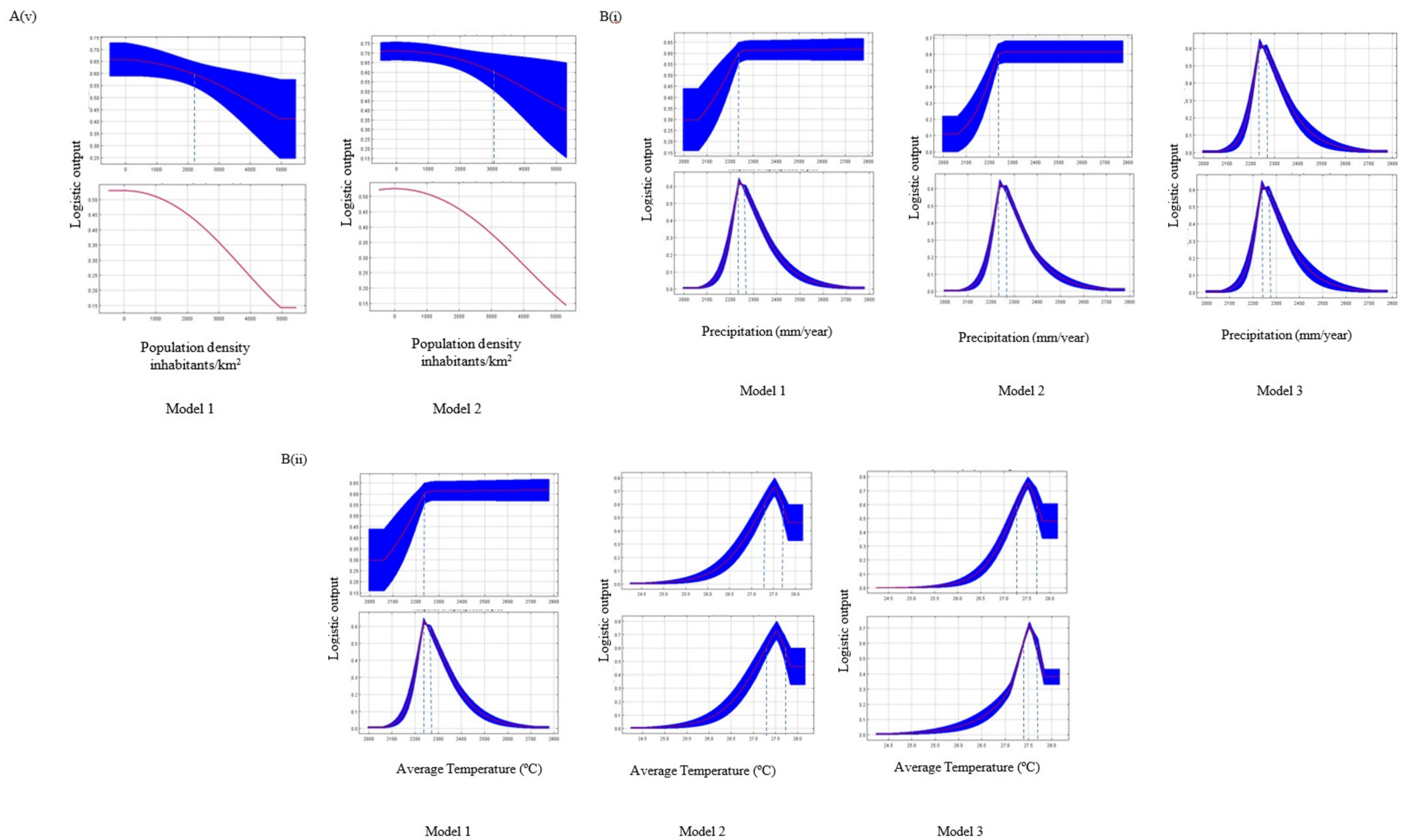

Fig 2 - cont

A(v): population density in habitants in Demak; B(i): response curves of precipitation in Semarang; B(ii): response curves of average temperature in Semarang

NDVI: Normalized Difference Vegetation Index

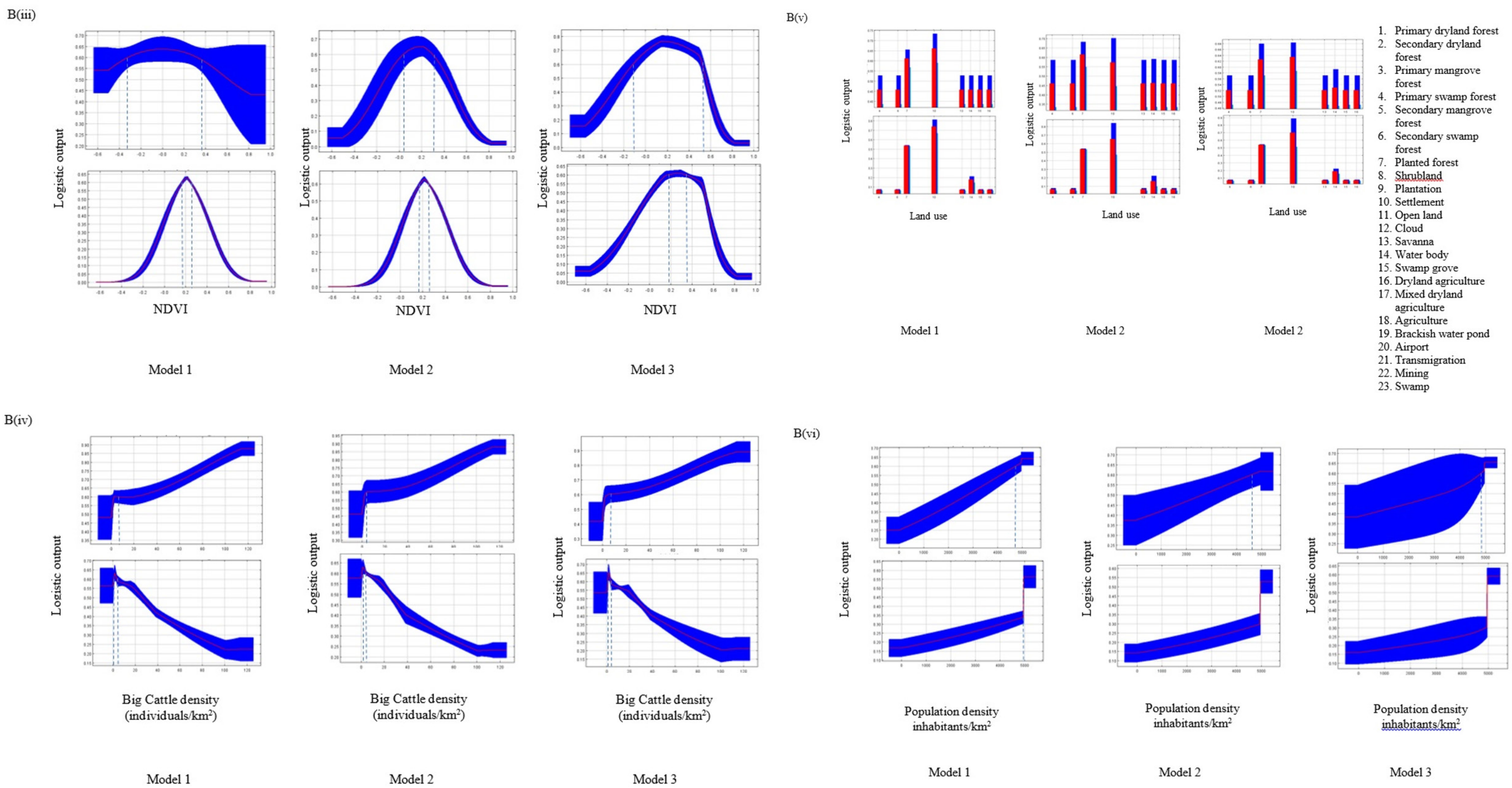

Fig 2 - cont

B(iii): response curves of NDVI in Semarang; B(iv): response curves of big castle density in Semarang; B(v): response curves of land use in Semarang; B(vi): response curves of population density in Semarang

NDVI: Normalized Difference Vegetation Index

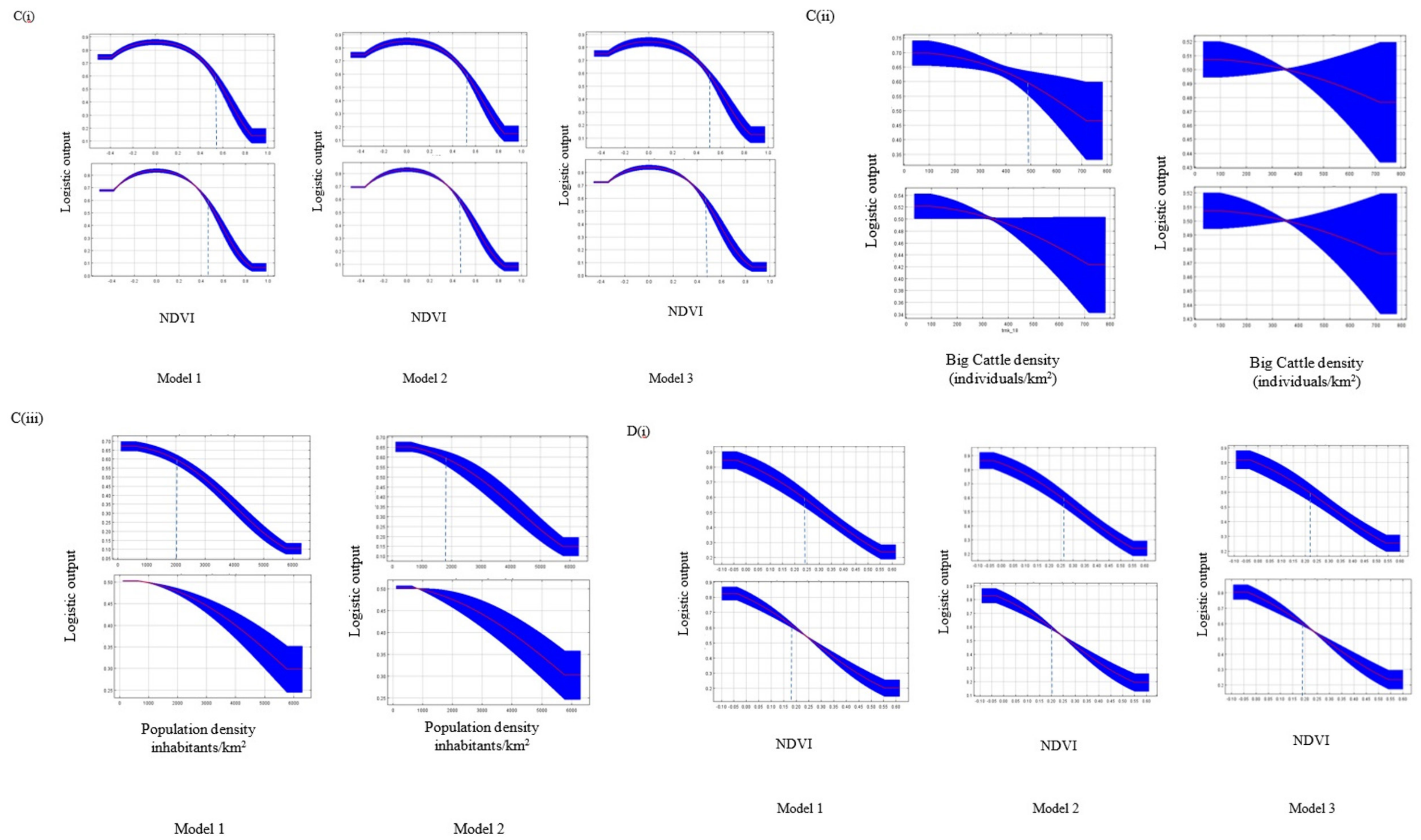

Fig 2 - cont

C(i): response curves of NDVI; C(ii): response curves of population density; C(iii): response curves of big cattle density; D(i): response curves of NDVI

NDVI: Normalized Difference Vegetation Index

in the area dominated by rice fields. The highest vegetation density in leptospirosis was found in the Demak area. Overall, the Demak and Semarang showed nearly similar thickness degrees of the cover vegetation. However, Semarang had a smaller value than Demak. The factor of the biotic natural environment that contributed to the modeling of this study was the density of large big cattle. The four consecutive research sites had large response curves of the big cattle density from all over modeling, ranging from 15-25 individuals/km^2 (Demak), 100-700 individuals/km^2 with a decreasing curve (Boyolali), 5-115 individuals/km^2 with an inclined curve (Semarang), and 55-75 individuals/km^2 (Ponorogo).

Furthermore, based on the comparison of all environmental factors, response curves of built contributing to the modeling were settlement patterns and land use. Four research sites had nearly similar species that were suitable for land use as leptospirosis habitats. The settlement patterns of dominant lands were settlements (53-67%) and rice fields (54-62%). The settlement pattern index was found in Demak with scores ranging from 3.0 to 3.5. This finding showed that leptospirosis habitats in areas with settlement patterns were evenly distributed (dispersed). This study had found that 71.43% of the settlement patterns in 14 districts in Demak were evenly distributed, 21.43% were unevenly distributed (random), and 7.14% were clusterily distributed. Meanwhile, the other three locations showed different distribution patterns of settlements from that of Demak. All districts in Boyolali had an evenly distributed pattern. None of the districts in Semarang had a random pattern, and none of the districts in Ponorogo had a clumped pattern. Therefore, Demak had the most varied settlement patterns among the other three research sites.

The response curves for social environmental factors (Fig 2) in all models in three study areas showed that the predicted range of population density constitutes suitable habitat for leptospirosis because these areas had fewer than 600 inhabitants/km^2 (Boyolali), 2,600-5,000 inhabitants/

km^2 (Semarang), and 400 inhabitants/km^2 (Ponorogo). The population density factor in Demak did not contribute to the modeling. Another social environmental factor studied was the income of the population. The contributing variables showed that the research population did not contribute to all models in all research sites.

DISCUSSION

The results of this study indicated that natural and environmental factors dominate the ecological niche modeling. The results of this study were almost equal to the results of Zhao *et al* (2016) in China. However, in this study, the natural environmental factors that contribute the most are the annual average temperature and annual rainfall (Zhao *et al*, 2016). The natural environmental factor that had the largest contribution to all research sites was the density of vegetation. The vegetation density index was suitable for leptospirosis habitat and was low. However, if the vegetation density index was below -0.60, the case distributions would decrease; similarly, if the index was above 0.60. This result was almost similar to that of Sunaryo and Widiastuti (2012) who conducted a study in Tembalang, Semarang City and discovered that leptospirosis cases were more dominant in areas with a low vegetation index. A low vegetation density index was followed by a decrease in temperature so that in the range of temperature was moderate or not too high, leptospirosis could develop more optimally. The research sites of this study had the following factors. First, the natural environment that contributes greatly was Semarang City; this finding was similar to that of Zhao *et al* (2016). Semarang was one of the areas with high-temperature characteristics. Therefore, in certain areas and certain seasons, Semarang had moderate temperature with normal conditions. The difference in a leptospirosis habitat was most clearly found in Semarang than in the other three research sites. Moderrate to high rainfall factors in this study contributed to the modeling of leptospirosis in the areas of Demak and Semarang. The results of this study were supported by the results of Setyorini *et al* (2017) who conducted a study in City Semarang in 2014-2016 and discovered that the majority of the cases are found in areas with moderate rainfall of approximately 1,212-3,600 mm/year. In this modeling and two areas, rainfall did not contribute to the prediction of leptospirosis. This finding was supported by other studies, which had discovered that in certain areas and conditions, rainfall was not related to the distribution of certain leptospirosis (Hacker *et al*, 2020; Melani, 2010; Pavey and Nano, 2013; Rahayu *et al*, 2018). The relationship between rainfall and leptospirosis was indirect. The intermediate and supporting factors were flood events, behavioral factors, and the presence of rats as leptospirosis-transmitting animals. Behavioral factors were associated with contact risk, and water is a medium for leptospirosis transmission or contact with rats. Unlike Demak and Semarang, Boyolali and Ponorogo were two areas with quite varied topography and a quite low possibility of flooding.

The population density, land use dominated by settlements, and settlement patterns spread evenly and become social and fostered factors that supported and were suitable for the leptospirosis habitat. Three environmental factors in the modeling of this study had visible variations, large contributions, and a range of values. This condition directly supported the relationship between these factors. In other studies, these three factors were not associated with the incidence and spread of leptospirosis (Hacker *et al*, 2020; Melani, 2010; Pavey and Nano, 2013; Rahayu *et al*, 2018). The distribution pattern of the settlement spread evenly in Demak and constituted one of the characteristics of suitable habitats for leptospirosis. The habitat in 14 districts in Demak was not affected by the population density but was influenced by other factors, such as overall land use and settlement pattern trends. The other three research sites did not show as various settlement patterns as those in Demak. Although the settlement patterns in all districts in Boyolali spread evenly but did not contribute to leptospirosis habitat.

The modeling results showed that one of the variables included in and contributing to the built environment was the distance to the river. This finding was supported by several previous studies, which involved rivers in their analysis (Djati *et al*, 2015; Jagadesh *et al*, 2019; Cahyati and Kumalasari, 2019; Melani, 2010; Setyorini *et al*, 2017). The difference was in the range of risky distances or the increased probability of leptospirosis. This study had discovered that in Ponorogo, areas with a radius of less than 2 km from the river were predicted to have a high probability of developing leptospirosis. Such a condition was also related to the community's behavior and habits toward the river. Proximity distance from the river could increase the risk of contracting leptospirosis because the best transmission for leptospirosis-causing bacteria was the river water. However, the understanding, awareness, and behavior to prevent infectious leptospirosis and routine activities in the river could lessen the risk or probability of contracting leptospirosis.

The modeling predictions for the distribution of leptospirosis in Semarang in 2030-2040 had shown that risk or case distributions will be reduced in certain areas. This condition did not mean that there was no need to control measures against leptospirosis. Unlike the other three locations, Semarang had the largest number of variables or contributing factors. However, this condition did not rule out the possibility of other factors or variables that contribute to the predictive modeling of the leptospirosis distribution in Semarang. Other social factors that were more detailed and measurable possibly still exist in Semarang, for examples, matters related to densely populated settlements, slum cities, and factors related to leptospirosis-transmitting animals, especially rats, determined the incidence, and distribution of leptospirosis. Community behavioral factors in this research could not be observed, as occurring in Demak and Boyolali. Possible behavioral factors, which include structuring housing, household waste management, and food storage, were factors that should be considered in the modeling of the curve eco-social-based ecology.

Social environmental factors in this research had very small contributions to predict the distribution of leptospirosis incidence in the four research sites. This finding was supported by Zhao *et al* (2016) who conducted a study in China and had discovered that socio-economic factors include income per capita and population density. Social environmental factors were related to leptospirosis in previous studies they are population density, habits and behavior, and employment and income. However, the relationship between social environmental factors and leptospirosis is rarely examined using a spatial method because the operational definitions and methods that could convert social data into spatial data are not easily implemented. Most studies employed a spatial method that involves social environmental factors; they discovered no relationship between social factors and the incidence or spread of leptospirosis.

Another weakness of the spatial method to predict the spread and increase of leptospirosis cases is the lack of involvement of social factors in the process of in-depth analysis. Thus, apart from using this modeling, a combination of other methods is also needed to more comprehensively explore social factors. The network analysis on social media can be conducted by initially determining the right, potential, local, and specific content in the target area to control leptospirosis. The previous studies had deployed that the density of rats as animals is a main infectious agent that was very closely related to the incidence of leptospirosis (Allan *et al*, 2015; Guernier *et al*, 2016; Pui *et al*, 2017; Suryani *et al*, 2016). The results of this study were different from those of the previous studies. The modeling results at all research sites showed that the density of rats, obtained based on the trap success data (successful capture), did not contribute to all models due to several reasons.

First, the data on the rat density employed in the modeling were data on the relative density, which were also secondary data sourced from various results of surveys, research, and activities. This rat-catching method also had some drawbacks. However, the data on this rat were very limited and sporadic and were not from the results of a longitudinal survey.

Second, the results of this study indicated differences from the previous field research on health. The point of view used in this research was macro. Moreover, leptospirosis was observed and understood from a scientific point of view and a broader philosophy, namely environmental science. Rats live in almost the same habitat as humans; their existence can be an indicator that shows the level of harmony in the direct or indirect relationship between humans and the environment. In fact, rats or rodents are also a part of the ecosystem which, if their amount is reduced or excessive than the normal amount, could affect the environmental balance. The emergence of diseases or health disorders could alarm or sign the balance of the disordered environment. This understanding no longer considers humans as the center of the environment, but they are also part of the environment. Inappropriate, excessive, or indifferent human behavior to the balance of the environment could harm humans.

Other studies had discovered more specific risk factors which were directly related to leptospirosis. However, they only focused on public health, particularly environmental health and epidemiology. This research was no longer limited to certain risk factors, such as rat density, flooding, and water contact contamination. It explored and discussed the issue of leptospirosis using a broader environmental science approach. Unlike other environmental factors which result in broad and macro contributions, in this research, these specific risk factors contributed little to the spread of leptospirosis. On the other hand, it is still necessary to consider the follow-up research by involving these factors in more detail. Rat density is an important risk factor in the transmission and spread of leptospirosis. However, environmental science no longer considers humans as the center in the environment and considers the density of this rat as a part of environment that needs attention. A high density of rats in a habitat could be caused by excessive human activities that exploit and develop their environment. Several elements could indirectly affect the balance of the ecosystem and ultimately result in a negative impact on humans.

Through an environmental science approach, scientific multidisciplinary is necessary to understand the health sector, especially disease and epidemics. Comprehensive understanding, a more global point of view, and a broader scope are needed to design and develop control measures for leptospirosis as an environment-based disease. The intervention management is possibly implemented by the stakeholders' control program in regional health service units to control leptospirosis. This management should be based on the results of studies involving environmental factors as a whole. Supporting factors for successful implementation interventions include increasing understanding of leptospirosis and habitat as a common environmental problem by creating or activating formal and informal communication forums through activities as well as utilizing the role of social media.

A deeper exploration of social factors, especially the potential of local wisdom, aims to control leptospirosis in the community and is pivotal to complete a comprehensive study of leptospirosis. Furthermore, the results of this comprehensive study suggest to support strong commitments from all parties, especially the community, to develop and implement health programs sustainably.

In summary, the relationships between leptospirosis risk factor control programs and the environmental science approach are close and important. Scientific multidisciplinary is necessary to understand the health sector, especially disease and epidemics. This study concluded that a broad multidisciplinary scientific study should consider the local wisdom of each region to build community resilience to outbreaks before and after the recovery.

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CONFLICT OF INTEREST DISCLOSURE

The authors declare no conflicts of interest.

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