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# Application of Climate Envelope Model in the Control of *Fasciola gigantica* Prevalence in Nigeria

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**Abstract:** Mapping the potential areas for pathogen prevalence is a repetitive process and this research is an initial attempt to model the nation-wide prevalence of *Fasciola gigantica* in Nigeria. Data on *Fasciola gigantica* occurrence localities were obtained from published literature together with bioclimatic variables, the climate envelope model (MaxEnt) was utilized to analyze and predict its spatial range and to create suitable areas for *Fasciola gigantica* prevalence in Nigeria. The results show that the predicted areas of high risk included parts of northwestern Nigeria in Sokoto, Kebbi, Katsina, and some patches of Kano State. Likewise, Bauchi, Gombe, Borno, and large portions of Plateau State. Other areas of high risk as indicated by the model included Ekiti, Ogun, and Lagos State in the southwest. Similarly, infection risks covered the southeastern Nigeria in some parts of Rivers, Akwa Ibom and Cross rivers. The three most important variables with the highest training gain as revealed by the model are isothermality, minimum temperature of the coldest month, and precipitation seasonality. The performance of the MaxEnt model was better than a random prediction with training AUC scores of 0.891. This shows that MaxEnt is a suitable modelling technique for predicting the spatial range of fascioliasis prevalence in Nigeria based on its very good predictive accuracy.

**Keywords:** *Fasciola gigantica*, Bioclimatic Variables, Climate Envelope, MaxEnt, AUC, Predictive Accuracy

## 1. Introduction

*Fasciola gigantica* is a climate-sensitive pathogen that has spread across 61 nations of the world [1-4]. Cattle, horses, goats, and even humans are predisposed to its infection and hence it is regarded as zoonotic [5]. There are two species of fascioliasis and these include *Fasciola gigantica* and *Fasciola hepatica* that thrive in tropical and temperate areas respectively. According to Elelu & Eisler [6] *Fasciola gigantica* and the snail, its intermediate hosts coexist at the same locations across the globe. Infected livers lose taste and nutritional value and as such prone to condemnation by meat inspectors at abattoirs. However, these condemned livers are sold to the public by butchers [7] which greatly undermines the nation's public health.

Nigeria is a large country in West Africa that supports a high population of domestic animals [8] (FAOSTAT, 2013) that are being used as a major source of protein. The economic gains of raising livestock reach 12.7% out of the total of Nigerian agricultural gross domestic products as reported by CBN [9]. The productivity of the fasciola-infected animals is greatly reduced and the losses have been approximated to cost over £30 million [10]. In most of the Nigerian abattoirs over 80% of the condemned livers were as a result of fascioliasis [11]. The pathogen, therefore, demands special attention as it ravages the national economy and public health.

Many studies reported the influence of seasonality in the outbreak of fascioliasis in different parts of Nigeria [12, 13]. These seasons bring about variation in terms of climatic and environmental conditions which include rainfall, temperature, topography as well as the nature of vegetation over a given period. In this regard climatic models have been developed and are termed species distribution models (SDM) and or ecological niche models (ENM) which combine climatic and environmental data at a particular location with spatial coordinates of species presence data [14]. This is to produce maps of the realized distribution [15] of species to design appropriate strategies in the control of pathogens and also as an effective guide in scientific surveys. These models have also been found to be very useful tools in determining the geographical distribution of fascioliasis prevalence over different parts of the world [16-18]. However, in Nigeria, only a few known studies applied climate models in the control of fascioliasis which includes Niger State [19] and Sokoto State [4]. Generally, in Nigeria, this is the first effort at using SDM in the design of control measures against fascioliasis prevalence.

Maximum entropy is described as having very accurate predictive ability in SDM [20-23]. Its performance surpasses other modelling techniques in SDM such as BIOCLIM, GARP, BIOMAPPER, DOMAIN, CLIMEX, GLM, and GAM [24, 25, 14]. According to Phillips et al., [14] maximum entropy utilizes background points that are drawn at random and then species presence records to generate an estimation of a species probability of occurrence at a given location.

In line with the foregoing, this paper attempts for the first time the application of maximum entropy in determining the geographic range of *Fasciola gigantica* prevalence using presence-only records at the national level in Nigeria.

## 2. Study Area

Nigeria (Figure 1) is located at Latitudes 4° and 14° north of the Equator and between Longitudes 2° 2' and 14° 30' east of the Greenwich Meridian. And also it lies on the west coast of Africa, at the extreme inner corner of the Gulf of Guinea. The country covers an area of 923,768 square kilometers (356,669 square miles), extending 1,127 kilometers (700 miles) east–west and 1,046 kilometers (650 miles) north–south. It is bounded on the North-East by Chad, on the East by Cameroon, on the South by the Atlantic Ocean (Gulf of Guinea), on the West by the Benin, and on the NW and North by the Niger Republic, with a total boundary length of 4,900 km, of which 853 km is coastline. The borders between Nigeria and Chad, as well as Nigeria and Cameroon, are disputed, and there have been border clashes on occasion [26].

Among all livestock in Nigeria, ruminants, which include sheep, goats, and cattle, are the farm animals most commonly reared by farm families in the country's agricultural system. Nigeria has a goat population of 34.5 million, a sheep population of 22.1 million, and a cattle population of 13.9 million [27]. However, a greater proportion of these animals' population is concentrated in the northern region of the country than in the southern region. Specifically, the northern region of the country is a home to approximately 90% of the country's cattle population and 70% of the sheep and goat populations. The northern region of Nigeria has the highest concentration of livestock [28].

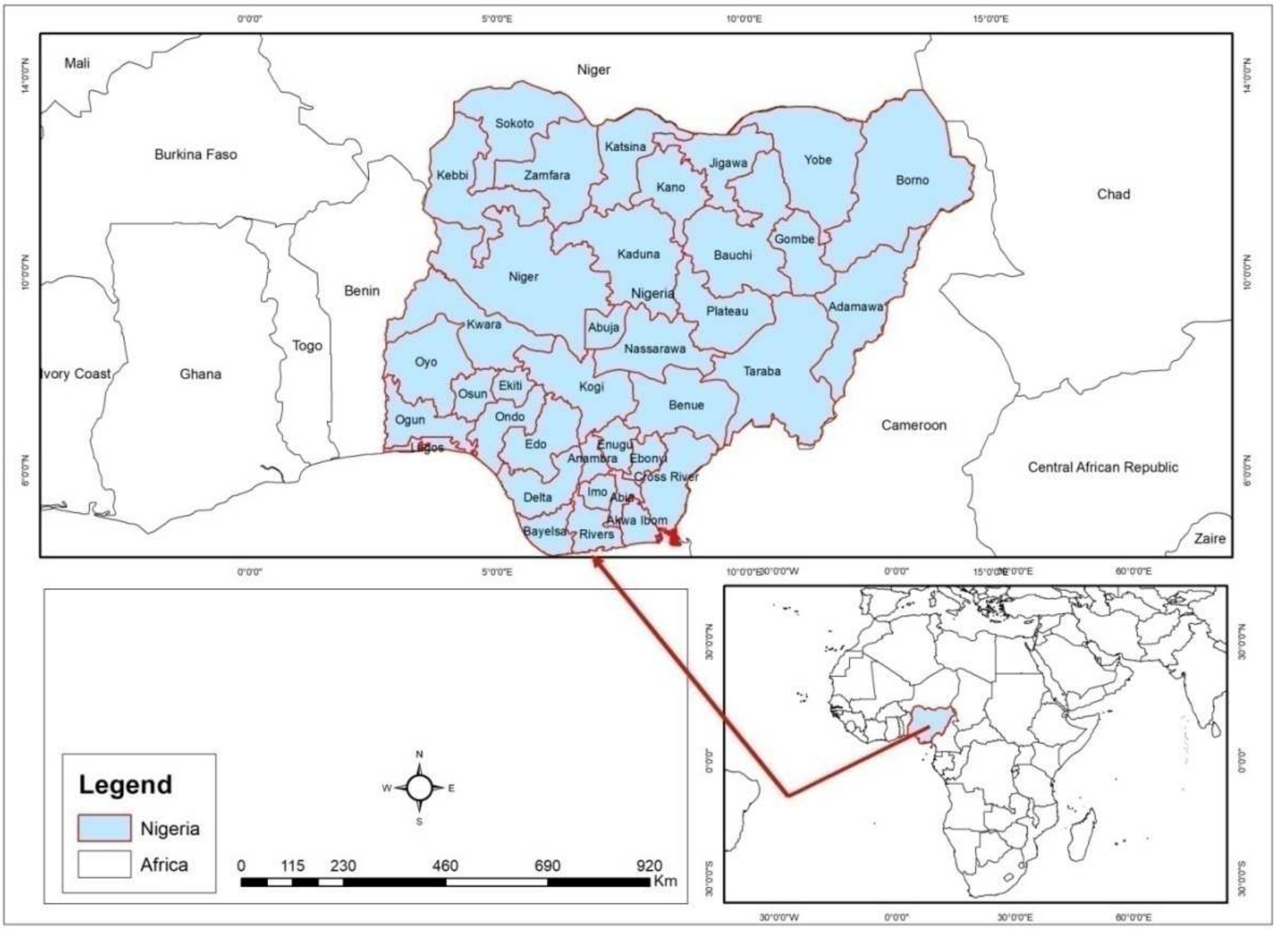


*Figure 1. The study area.*

### *2.1. Fascioliasis Distribution Data*

This study compiled fifty (50) fascioliasis presence records based on field surveys in Nigeria from published literature through reputable journals across the globe (Table 1) (attached separately). The authors of these journals are specialists in various fields such as Parasitology, Biology as well as Veterinary Science. Their researches focused on examining the prevalence of fascioliasis among slaughtered definitive hosts at the abattoirs from different localities that covered all the geopolitical zones of Nigeria. The spatial coordinates of the occurrence locations were obtained through the application of ArcMap 10.3 using the identifier function. This software is designed to perform geographic information system operations through spatial data analysis and manipulations.

***Table 1.*** *Occurrence locations of Fasciola gigantica in Nigeria used for MaxEnt analysis.*

| S.No. | Species | Geographic coordinates | |
|---|---|---|---|
| | | Latitude | Longitude |
| 1 | F_gigantica_NIG | 5.816705 | 13.295536 |
| 2 | F_gigantica_NIG | 5.306182 | 13.099181 |
| 3 | F_gigantica_NIG | 5.44363 | 12.372666 |
| 4 | F_gigantica_NIG | 5.325817 | 11.449796 |
| 5 | F_gigantica_NIG | 4.344041 | 12.667199 |
| 6 | F_gigantica_NIG | 3.95133 | 12.156676 |
| 7 | F_gigantica_NIG | 4.481489 | 12.038862 |
| 8 | F_gigantica_NIG | 6.582491 | 11.724694 |
| 9 | F_gigantica_NIG | 7.662445 | 12.981368 |
| 10 | F_gigantica_NIG | 8.526409 | 11.921049 |
| 11 | F_gigantica_NIG | 7.721352 | 11.03745 |
| 12 | F_gigantica_NIG | 10.038344 | 12.431573 |
| 13 | F_gigantica_NIG | 11.177205 | 11.626516 |
| 14 | F_gigantica_NIG | 13.180029 | 11.822872 |
| 15 | F_gigantica_NIG | 11.15757 | 10.232394 |
| 16 | F_gigantica_NIG | 9.861625 | 10.173487 |
| 17 | F_gigantica_NIG | 10.606461 | 12.173457 |
| 18 | F_gigantica_NIG | 10.406586 | 11.688047 |
| 19 | F_gigantica_NIG | 10.147604 | 11.402511 |
| 20 | F_gigantica_NIG | 10.255265 | 12.087796 |
| 21 | F_gigantica_NIG | 12.43387 | 9.146782 |
| 22 | F_gigantica_NIG | 13.361877 | 10.403138 |
| 23 | F_gigantica_NIG | 11.919923 | 9.389487 |
| 24 | F_gigantica_NIG | 11.353925 | 8.897177 |
| 25 | F_gigantica_NIG | 8.879848 | 9.72187 |
| 26 | F_gigantica_NIG | 9.72187 | 9.584421 |
| 27 | F_gigantica_NIG | 6.266324 | 9.303827 |
| 28 | F_gigantica_NIG | 5.75236 | 10.517352 |
| 29 | F_gigantica_NIG | 7.034108 | 9.132804 |
| 30 | F_gigantica_NIG | 7.008716 | 8.8898 |
| 31 | F_gigantica_NIG | 6.661033 | 9.604057 |
| 32 | F_gigantica_NIG | 7.839165 | 8.44556 |
| 33 | F_gigantica_NIG | 8.546044 | 7.758317 |
| 34 | F_gigantica_NIG | 6.582491 | 8.092121 |
| 35 | F_gigantica_NIG | 5.26691 | 8.799 |
| 36 | F_gigantica_NIG | 5.600714 | 7.69941 |
| 37 | F_gigantica_NIG | 4.540396 | 7.758317 |
| 38 | F_gigantica_NIG | 5.306182 | 7.287064 |
| 39 | F_gigantica_NIG | 7.348277 | 6.756905 |
| 40 | F_gigantica_NIG | 8.114062 | 6.20711 |
| 41 | F_gigantica_NIG | 6.425407 | 6.815811 |
| 42 | F_gigantica_NIG | 7.485725 | 5.539502 |
| 43 | F_gigantica_NIG | 7.505361 | 5.441324 |
| 44 | F_gigantica_NIG | 7.898072 | 4.989707 |
| 45 | F_gigantica_NIG | 6.975202 | 4.793352 |
| 46 | F_gigantica_NIG | 8.349689 | 4.911165 |
| 47 | F_gigantica_NIG | 6.346865 | 5.009342 |
| 48 | F_gigantica_NIG | 5.365088 | 5.85367 |
| 49 | F_gigantica_NIG | 3.637161 | 6.835447 |
| 50 | F_gigantica_NIG | 3.342628 | 6.462372 |

### *2.2. Climate Data*

Bioclim variables used in this study were generated from WorldClim version 1.4 climate data set [29] available at hptt://www.worldclim.org. WorldClim is a suite of climate layers that covered the world at 1 km spatial resolution indicating both present and future climate scenarios. These represent long-term climatic layers that consist of monthly averages of mean, maximum and minimal temperature and precipitation. The climate surfaces produced were a result of an interpolation procedure involving temperature and altitude and long-term records of precipitation (1950-2000). The generated bioclim variables (19) are very relevant biologically in species distribution modeling than yearly or monthly means of precipitation and temperature. This is due to their feature of capturing both the effects of seasonal fluctuations, trends and extremities associated with climatic adaptation of each species of animals or plants [30, 23].

### *2.3. MaxEnt Modelling*

Maximum model was constructed through the application of MaxEnt program (Version 3.3.3e) downloaded from http://www.cs.princeton.edu/~schapire/maxent/ [14]. The software was applied in determining the geographic range of suitable areas for *Fasciola gigantica* prevalence over Nigeria using the presence records together with the WorldClim dataset. It has an inbuilt algorithm that uses regularization of *Fasciola gigantica* prevalence to regulate over-fitting. MaxEnt displays visually different grades of facioliasis prevalence using logistic output format with the aid of a continuous map. This map uses an approximation of the probability of getting an infection with the pathogen in question between 0 and 1. Consequently, areas of high and low risk would be highlighted using graded colors.

In this study, all the available data were used for training and the performance of the model was also based on the same sample points as were utilized for model training as previously applied in other studies [31, 17]. However, in a model appraisal, this did not contradict the convention of partitioning the overall sample points into testing and training if a large dataset is available [32]. In our situation sample points are limited but the main driving force for the application of MaxEnt modeling was its uniqueness in producing a better performance with even a small number of samples compared to other models in SDM [14].

### *2.4. Model Evaluation*

An assessment of model performance is a fundamental step in ascertaining the relevance of a model to a given purpose. Area Under the Curve (AUC) of Receiver Operating Characteristics Curve (ROC) is an independent threshold technique that was applied in this study in the evaluation of MaxEnt model performance. According to Swets [33], AUC is calculated by differentiating between the true-positive fraction (assessing the accuracy of the model's prediction of species presence) versus the false-positive fraction (appraising the accuracy of the model's prediction of absence) through the ROC plot [32]. Result interpretations of AUC scores are: 0.5 is synonymous to random guessing, >0.7 implies reasonable performance and is 'potentially significant', while >0.8 indicates excellent score and a value of 0.9 or greater shows an outstanding performance [22, 34, 35].

MaxEnt model also uses a jacknife to explain the contribution of each parameter (BIO1-19) in the modeling of fascioliasis prevalence in Nigeria. The algorithm performs tripartite operations by a) running the model with all the variables, then b) running the model with one variable excluded, and c) finally using the excluded variable only in running the model. Consequently, variable with much influence in the modeling process is depicted by having the highest training gain when included or decrease training gain tremendously when excluded.

## 3. Results

### *3.1. The Predicted Geographic Range of F. gigantica Risk in Nigeria*

The MaxEnt model's prediction reveals that the risk of fascioliasis infection is not homogeneous across Nigeria (Figure 2). Hence regions were categorized into high, moderate, and low risk zones. Areas or zones of high risk covered parts of northwestern Nigeria in Sokoto, Kebbi, Katsina, and some patches of Kano State. Likewise, Bauchi, Gombe, Borno, and large portions of Plateau State. Other areas of high-risk as indicated by the model included Ekiti, Ogun, and Lagos State in the southwest. Similarly, infection risks cover the south eastern Nigeria in some parts of Rivers, Akwa Ibom, and Cross rivers. In all these high-risk areas the probability of fascioliasis infection was between 0.5-0.9.

Areas of moderate risk include some parts of Kwara, Niger State, FCT, Kogi, Osun, Edo, Ebonyi, Cross Rivers and also Taraba State. The probability of fascioliasis infection as predicted by the model was 0.4-0.5. However, the probability of low-risk areas between 0.1-0.18 as predicted by the model cover some parts of Yobe, Borno, Zamfara, Kaduna, and Niger State.

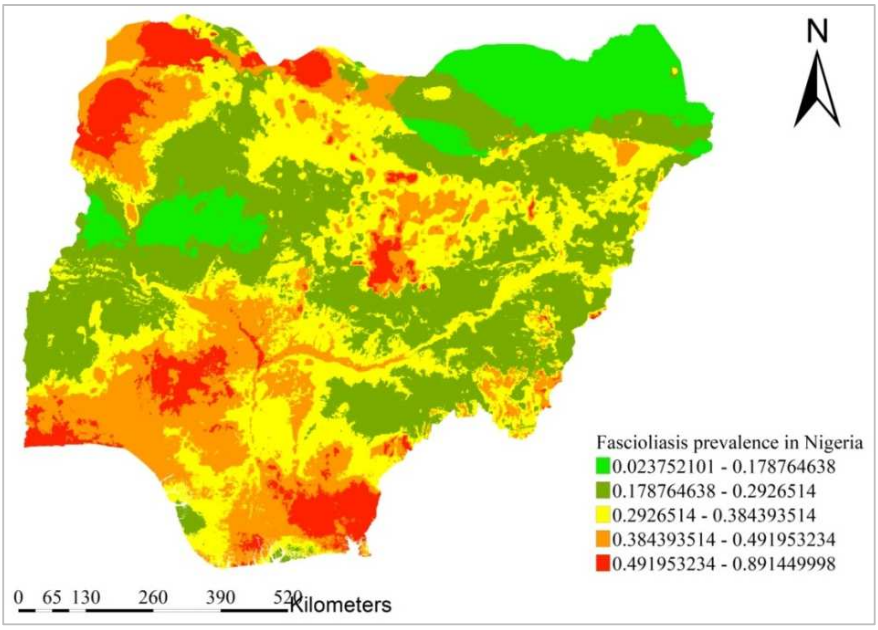


***Figure 2.*** *Predicted spatial distribution of fascioliassis prevalence in Nigeria.*

### *3.2. Model Evaluation*

The MaxEnt model for the prediction of suitable areas for fascioliasis prevalence in Nigeria performed remarkably more than a mere random prediction with a high AUC average and standard deviation of >0.8 (Figure 3). The AUC value was attained as a mean of 10 replicates. This performance of the model indicates a reliable score for high sensitivity and specificity for the occurrence of fascioliasis parasites in Nigeria.

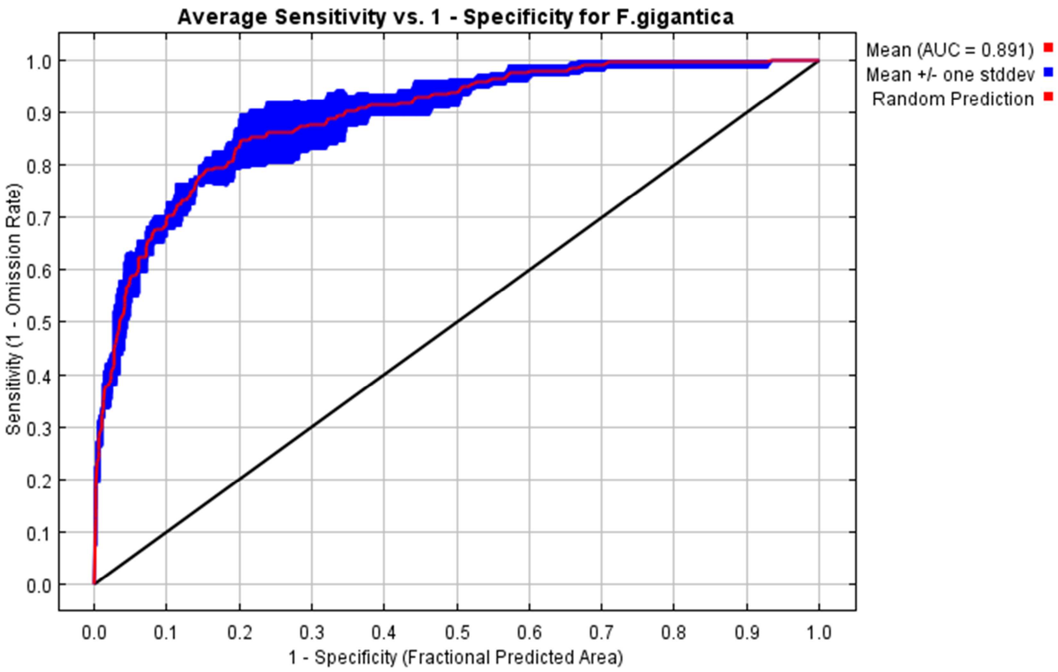


***Figure 3.*** *Area Under the Curve (AUC) (Red and Blue indicate the average of 10 model replicates runs and standard deviation respectively).*

### *3.3. The Role of Climatic Variables on the MaxEnt Model*

The three most important variables that influenced the prevalence of fascioliais in Nigeria in terms of having the highest training gain as revealed by the model (Figure 4) are isothermality, minimum temperature of the coldest month and precipitation seasonality. These variables contain more valuable information when used in isolation in the prediction of fasciolaisis. Other variables that indicated training gain when used alone in running the model encompassed: 'precipitation of wettest month' (BIO_13), 'precipitation of coldest quarter' (BIO_19), 'precipitation of driest month' (BIO_14), and 'mean temperature of driest quarter'' (BIO_9).

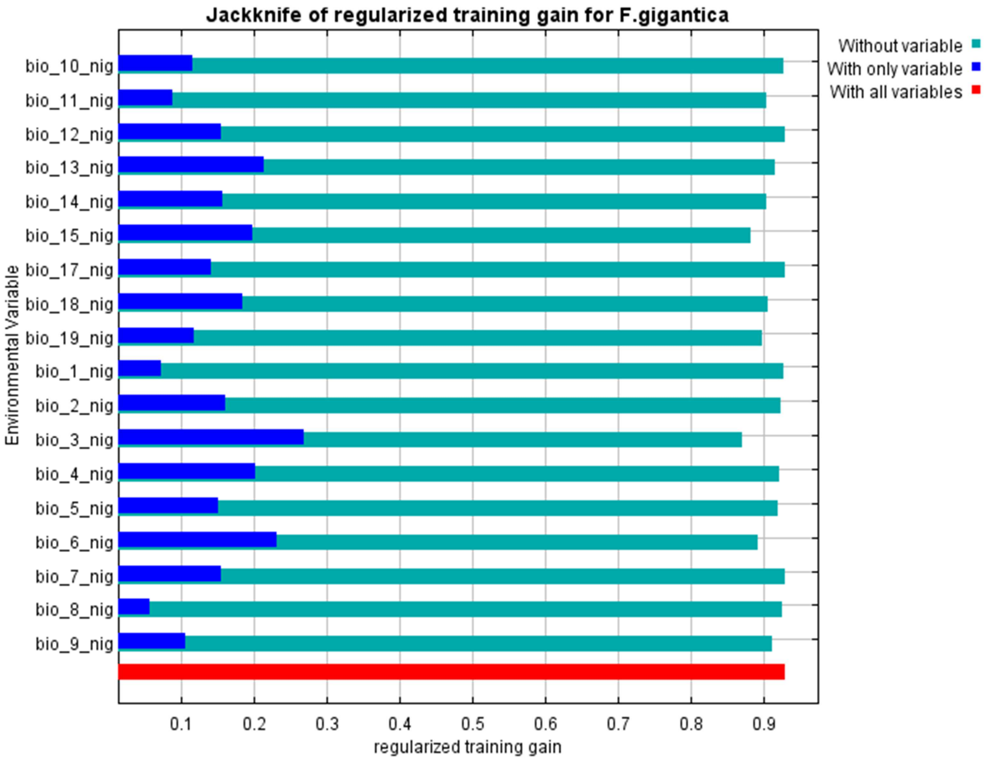


***Figure 4.*** *Jacknife tripartite operations with green indicating the run without a variable, blue with only one variable while red shows the model runs with all the variables.*

# 4. Discussion

In Nigeria like other parts of Africa, there is the existence of suitable climatic and environmental conditions that favor the survival of snails [2], an intermediate host of fascioliasis. The pathogen is taking a heavy toll on the productivity of the infected animals and hence becomes a big problem to reckon with throughout Africa. The prevalence of fascioliasis is not uniform across the country as reported by various studies and is one of the main causes of liver deterioration and condemnation at abattoirs [36]. The climate envelope techniques had been applied in the control of fascioliasis in some countries in Europe [37, 38, 17] and other parts of the world including some countries in Africa [39]. However, this is the first attempt to model the potential spatial distribution of fascioliasis prevalence in Nigeria in its entirety using maximum entropy. This is due to the concentration of a large population of animals in the country [27] and the tendency of fasciola to infect humans [40] as in other parts of the world.

The use of the limited number of presence records (<100) in the present study did not distort the accuracy of the MaxEnt model. This is because it has been proved through studies that species present records as low as 5 and other numbers less than a hundred did not interfere in the accurate performance of climate envelope models [41-43].

The regions in Nigeria with the highest risk of probability of fascioliasis infection as revealed by the model included some parts of the north-west, north-central, south-west and extreme ends of the south-east. Temperature-based variables (BIO_3 and BIO_6) and precipitation seasonality contribute significantly towards model construction. In northern Nigeria, there is the existence of extensive plain land that is adjoining the rivers referred to as fadama (wetlands) which provides a habitat for snails. These snails as intermediate hosts of fascioliasis remain viable throughout the year owing to an abundance of optimum moisture conditions. Consequently, this condition favors efficient continuity of fasciola life cycle [2] and its prevalence since the temperature in the region is not a constraint throughout the year. Thus northern Nigeria with a higher population of animals [28] has been described as the source of fascioliasis infection to other parts of Nigeria due to twofold factors. These include the viability of fascioliasis in the definitive host from the source areas to any other location as well as the fact that snail intermediate host of genus Lymneae is domiciled in most southeastern parts of the country [44].

Similarly, the ecological conditions as well as the availability of aquatic environments in the north-central, south-west, and south-east, contribute significantly to proliferation of snails throughout the year. In addition, these areas experience high amounts of rainfall that invariably create a suitable habitat for transmission of pathogens through the breeding of parasites in these agroclimatic zones [45, 46, 13].

# 5. Conclusion

The findings from this study demonstrated that the risk of fascioliasis infection covers all the agroecological zones of

Nigeria. This can be attributed to favorable climatic conditions coupled with other predisposing factors. However, the use of bioclimate variables in this study did not mean that other non-climatic factors were not significant in influencing the geographic range of fascioliaisis infection in Nigeria. This can be considered as an initial effort that shows the relevance of maximum entropy as an aspect of climate envelope models in the mapping of fascioliasis prevalence in Nigeria.

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