PREDICTING THE DISTRIBUTION OF GROUNDNUT PHYTOPATHOGENS UNDER CURRENT AND FUTURE CLIMATIC SCENARIOS IN ZIMBABWE
#11736

[1]Hardlife Chinwa, [1]Elizabeth Ngadze, [1]Juliet Murimwa, [2,3]Eliel Belchrist Sossou, [4]Clara Machokoto, [1]Regis Chikowo, [1*]Casper Nyaradzai Kamutando
e-mail: Kamutandocn@gmail.com; 00263713232033

ABSTRACT

Groundnut (*Arachis hypogaea* L.) is an important oil seed crop with immense nutritional and economic benefits, but its productivity in sub-Saharan Africa (SSA) is threatened by a plethora of phytopathogens such as groundnut rosette virus, Alternaria leafspots, early leafspots and peanut rust. In Zimbabwe, ecological niches and epidemiology of these pathogenic microbial strains, particularly under the current and predicted climate change scenarios, are still poorly understood. Yet, this information is vital in crafting effective and sustainable disease management approaches for production of this important crop. Here, a field survey was conducted on small-scale farms across a climate gradient during the 2023-24 and 2024-25 summer cropping seasons, to predict the current and future (2050) distribution of groundnut phytopathogens in Zimbabwe. Three out of the five main agro-ecological regions (AER) of Zimbabwe (i.e., AERII, AERIII and AERIV) were used as sampling sites. Georeferenced data was subjected to maximum entropy (MaxEnt) algorithm for species distribution modelling. The model identified isothermality, precipitation and temperature seasonality as the major environmental variables governing suitability of groundnut phytopathogens occurrence across the diverse agro ecologies of Zimbabwe. Distribution of groundnut phytopathogens in Zimbabwe was predicted to vary with change in climatic conditions, in particular, rainfall and temperature-based bio-climatic variables. In conclusion, groundnut phytopathogens are widely distributed in Zimbabwe and climate change under current and future climate scenarios will influence their distribution posing significant threat to food security.

Keywords: Phytopathogens; Groundnut; Zimbabwe; Climate change; MaxEnt

INTRODUCTION

Foliar diseases are one of the major biotic stresses impacting the productivity of groundnuts, a potential crop widely grown for food and nutrition security by small scale farmers in sub-Saharan Africa (SSA) [1]. Renown biotypes of economic importance are (1) groundnut rosette virus (GRV), the most devastating viral phytopathogen cosmopolitan to SSA, (2) *Nothopassalora arachidicola* (late leafspot), (3) *Passalora arachidicola* (early leafspot), (4) *Puccinia arachidis* (peanut rust) and (5) Alternaria species (i.e., *A. alternata* (Fr.) Keissler., *A. tennuissima*, *A arachidis* and *A. longipse* (leaf blights)) [2-5]. Groundnut rosette alone can cause 100% yield losses while leafspots can cause >50% yield losses [6, 7]. In Ghana, yield losses between 78-88% due to GRV on groundnuts was reported by Appiah, Offei (3). In 2003, Nutsugah, Oti-Boateng (8) reported yield loss of up to 80% on pod yield due to early and late leafspot in Ghana. Mau and Ndiwa (9) reported yield loss of up to 57% due to the co-infection of peanut rust and late leafspot in Indonesia. As groundnut is a cash crop and source of nutrition for thousands of smallholder farmers in Zimbabwe, groundnut phytopathogens through yield losses can obscure the roadmap towards food and nutrition security patronaged by the sustainable development goals (SDG2 and SDG3) of the United nations [10-12].

Due to wide range of hosts, exchange of planting materials, spatial production of landraces, evolution of pathogens as well as the inadvertent sporadic weather patterns, and lack of resistant varieties, the environmental suitability of groundnut phytopathogens in Zimbabwe is likely to increase significantly [13, 14]. Exacerbated by climate change, various agro-ecological regions in Zimbabwe are likely to share similar environmental characteristics favoured by foliage disease-causing microbes for groundnuts.

Understanding the epidemic and conducive environmental conditions promoting the pathogenicity of groundnut diseases in Zimbabwe is a first line of defence against future potential yield losses and inoculum build-up as it helps policy makers in deciding whether to go for new varieties or improved plant and soil health. State-of-the-art species distribution models such as correlative (also referred to as bioclimatic), and mechanistic models have been developed to pacify our comprehension on the spread of a species as a function of environmental variables through the use of computer algorithms [15]. Predicting the distribution of species under climate change using mathematical models is useful in: (i) revealing the biogeographical patterns of a species, (ii) finding suitable areas of re-introduction of endangered species, (iii) assessing how environmental conditions influence the occurrence or abundance of species, and (iv) ecological forecasting [13, 14]. In this study, a field survey was conducted on smallholder groundnut farmers across a climate gradient in Zimbabwe to predict the potential spatial distribution of groundnut phytopathogens under current and future climates. We hypothesize that, the distribution of groundnut phytopathogens in Zimbabwe is influenced by current and future climates.

MATERIALS AND METHODS

Occurrence data

Presence only (PO) data were collected as input data across a climate gradient, encompassing three out of the five agro-ecological regions of Zimbabwe from a total of 445 occurrence points during the 2023-24 and 2024-25 summer cropping season.

Disease confirmation under compound microscope

Symptomatic diseased groundnut samples were brought to the laboratory for further confirmation through the aid of a compound microscope. Fungi specimen was cultured in an incubator at 25 °C using potato-dextrose agar until spores were developed.

Data for environmental variables

Worldclim's (www.worldclim.org) nineteen (19) bioclimatic variables (BIO1-BIO19) from 1970-2000 were downloaded from database as raster layers. Four socio-economic pathways (SSPs) namely, SSP5-8.5 (highest scenario), SSP3-7.0 (high scenario), SSP2-4.5 (medium scenario) and SSP1-2.6 (low scenario) for greenhouse gas (GHG) emissions, released by the Intergovernmental Panel on Climate Change (IPCC) in 2013, were selected from Australia ACCESS CM2 of the Coupled Model Intercomparison Project Phase 6 (CMIP6) for the year 2050 (2040-2060).

MaxEnt model simulation

To simulate the model, the maximum entropy (MaxEnt) ver 3.4.3. algorithm was employed [16]. The software is open source with high accuracy, and it can work with as little as 20 occurrences to predict the distribution of species.

Determination of suitable and unsuitable areas

Output maps from the MaxEnt software in .asc format were uploaded into QGIS together with the country shapefile downloaded from diva-gis. Uploaded layers under symbology were changed from single band Gray to single band pseudo-colour in-which turbo colour ramp was selected to generate colourful continuous maps. To generate binary maps, linear interpolation was changed to discrete. The raster calculator in QGIS was used to assign the binary values (classes) of 1 and 0 to the variables.

RESULTS

Model and variable performances

The model had an excellent performance with an accuracy value of 0.965 and a standard deviation of 0.041. The bioclimatic variables which reduced the model gain the most when excluded was BIO3 (isothermality, Figure 1).

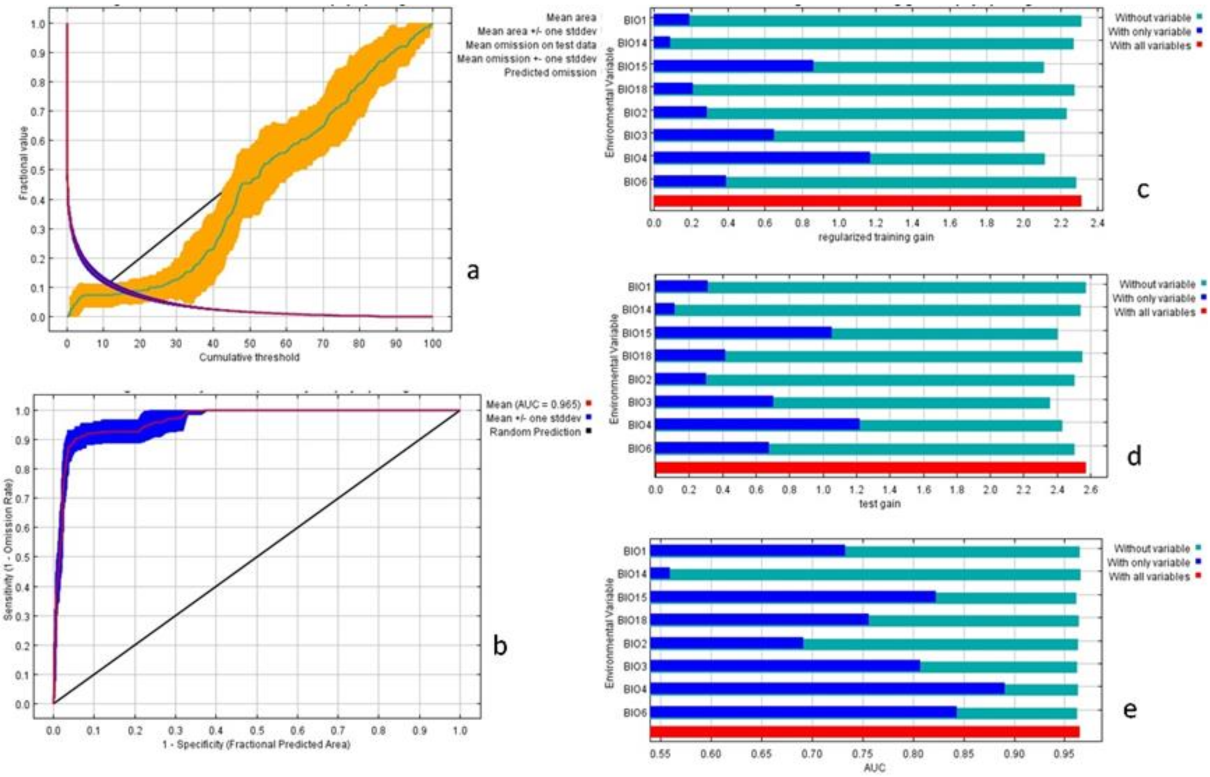

Figure 1. Model and variable performance based on area under curve (AUC) of the receiver operating curve (ROC), omission rate and Jackknife tests

Groundnut phytopathogens under current and future climatic scenarios

Under current climatic conditions, the ecological niche model (ENM) revealed that, the unsuitable area (unsuitable = 0%) was far less than the total suitable area (suitable > 90%). The analysis based on projecting the final model into the future climate scenarios (2050) revealed no predicted increase of unsuitable areas for groundnut phytopathogens under low carbon concentration (Figure 2).

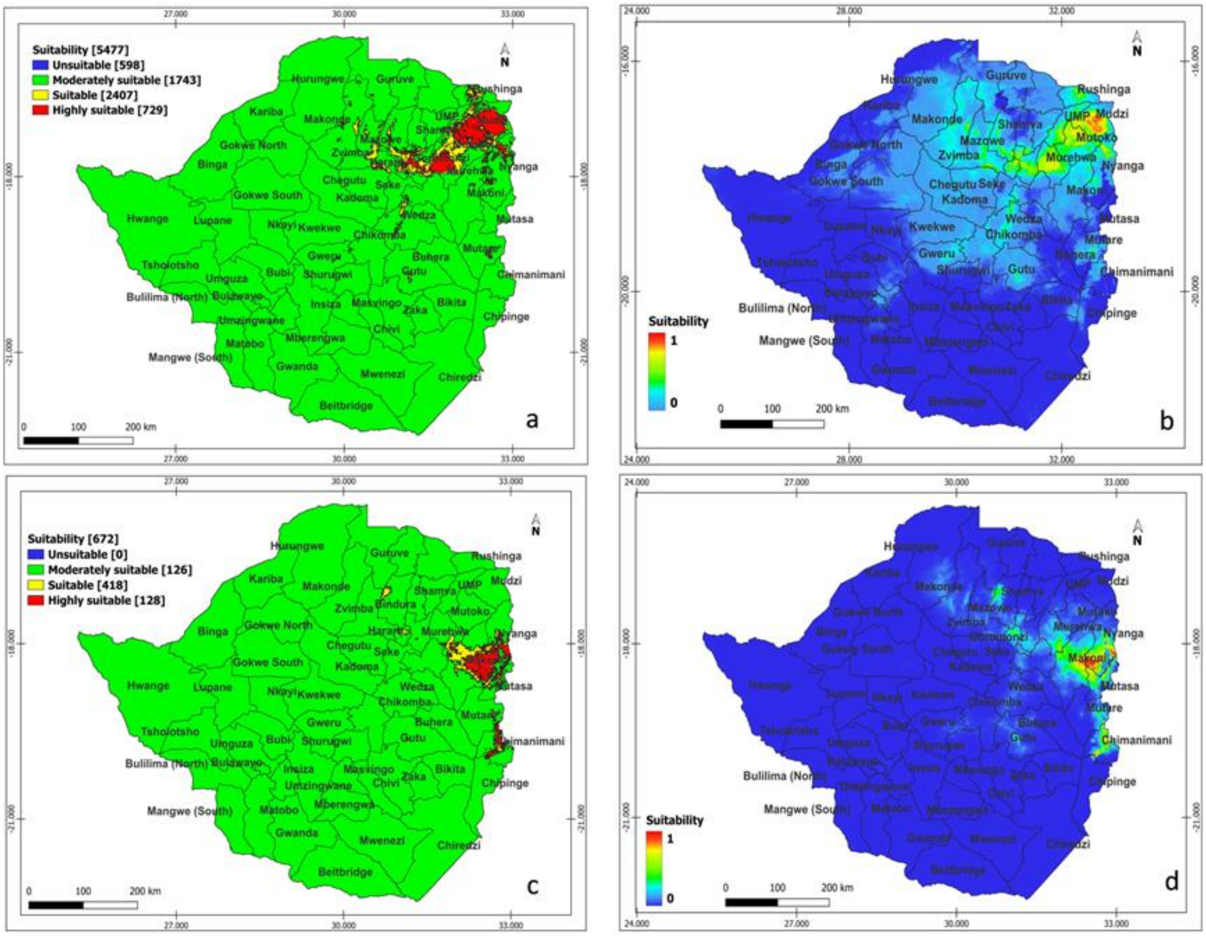

Figure 2. Suitable areas for groundnut phytopathogens in Zimbabwe under current climate and future scenario (SSP1-2.6)

DISCUSSION

The current and future distribution of groundnut phytopathogens in Zimbabwe could be attributed to several factors including: (i) host distribution and susceptibility, (ii) pathogen evolution, (iii) vector distribution and life cycle, (iv) management and farming systems, and (v) government policy.

Host distribution and susceptibility

The distribution of groundnut phytopathogens under current and future climates is likely to be influenced by the distribution of the hosts and their susceptibility. The study concurred with the findings reported in Kenya by Mabele, Were (13) that, legumes including groundnut and non-legume crops were susceptible to GRV.

Management and farming systems

Other elements which are likely to propel the distribution of groundnut phytopathogens in Zimbabwe are management and farming systems currently used by farmers. Commonest farming systems such as crop rotations, intercropping and mulching may be inappropriate in the future as they can serve as vehicles for spreading disease inoculum [17].

CONCLUSION

The Maxent algorithm successfully predicted the current and future distribution of groundnut phytopathogens under the current and future climates in Zimbabwe. Among those environmental factors, isothermality, precipitation and temperature seasonality emerged as the top factors associated with groundnut phytopathogens distribution. Therefore, current and future climatic conditions helped to determine the potential range of the phytopathogens and hotspot areas where proactive measures may be necessary to prevent severe yield losses

REFERENCES

1. Kumar V, Thirumalaisamy P. Diseases of groundnut. New Delhi: Indian Phytopathological Society, Today, Tomorrow's Printers Publishers; 2016. 459-87 p.
2. Prabhu R, Manivannan N, Mothilal A, Ibrahim SM. Artificial screening for foliar fungal diseases in groundnut (Arachis hypogaea L.). Adv Life Sci. 2016;5(14):5634-8.
3. Appiah AS, Offei SK, Tegg RS, Wilson CR. Varietal response to groundnut rosette disease and the first report of Groundnut ringspot virus in Ghana. Plant Dis. 2016;100(5):946-52.
4. Sudini H, Upadhyaya HD, Reddy SV, Naga Mangala U, Rathore A, Vijay Krishna Kumar K. Resistance to late leaf spot and rust diseases in ICRISAT's mini core collection of peanut (Arachis hypogaea L.). Australas Plant Pathol. 2015;44:557-66.
5. Kumar N, Ajay BC, Jadon KS, Gangadhara K, Kona P, Rathanakumar AL, et al. Genetic variability for Alternaria leaf blight resistance in groundnut genotypes. 2020.
6. Amoah RA, Akromah R, Asibuo JY, Oppong A, Nyadanu D, Agyeman A, et al. Genetic control of resistance to rosette virus disease in groundnut (Arachis hypogaea L.). Journal of Plant Breeding and Crop Science. 2016;8(6):87-93.
7. Gaikpa DS, Akromah R, Asibuo JY, Appiah-Kubi Z, Nyadanu D. Evaluation of yield and yield components of groundnut genotypes under Cercospora leaf spots disease pressure. International Journal of Agronomy and Agricultural Research. 2015;7(3):66-75.
8. Nutsugah SK, Oti-Boateng C, Tsigbey FK, Brandenburg RL. Assessment of yield losses due to early and late leaf spots of groundnut (Arachis hypogaea L.). Ghana Journal of Agricultural Science. 2007;40(1):21-7.
9. Mau YS, Ndiwa ASS. Field evaluation of late leaf spot and leaf rust resistance and the associated yield losses in Indonesian groundnut genotypes. Asian J Plant Sci. 2018;17(3):134-41.
10. Katema T, Hanyani-Mlambo EMBT, Gomera MR, Chamboko T. An Analysis of the Profitability of Groundnut Production by Small-holder Farmers in Chegutu District, Zimbabwe. J Econ Sustain Dev. 2017;8:167-75.
11. Allahyari MS, Sadeghzadeh M. Agricultural extension systems toward SDGs 2030: zero hunger. Zero hunger. 2020:41-52.
12. Mollier L, Seyler F, Chotte J-L, Ringler C. End hunger, achieve food security and improved nutrition and promote sustainable agriculture: SDG 2. A Guide to SDG Interactions: From Science to Implementation Paris, France: ICSU; 2017. p. 34-80.
13. Mabele AS, Were HK, Ndong'a MF, Mukoye B. Distribution, molecular detection and host range of groundnut rosette assistor virus in western Kenya. Journal of Plant Sciences. 2019;7(5):100-5.
14. van Niekerk J, Wynberg R. Traditional seed and exchange systems cement social relations and provide a safety net: A case study from KwaZulu-Natal, South Africa. Agroecol Sustain Food Syst. 2017;41(9-10):1099-123.

15. Kearney MR, Wintle BA, Porter WP. Correlative and mechanistic models of species distribution provide congruent forecasts under climate change. Conservation letters. 2010;3(3):203-13.
16. Phillips SJ, Dudík M. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography. 2008;31(2):161-75.
17. Juroszek P, Von Tiedemann A. Potential strategies and future requirements for plant disease management under a changing climate. Plant Pathol. 2011;60(1):100-12.