OPEN ACCESS Freely available online

Journal of Agricultural Science and Food Research

Research Article

Distribution of Sweet Potato Viruses and Vectors in Homabay County, and under Climate Change Scenarios in Kenya

Quinter Akinyi Oginga[1*], Chemeda Fininsa[2], Simon Onywere[3], Bramwel Wanjala[4], Gladys Mosomtai[5], Alok Kumar[2]

[1]*Department of Agriculture and Biodiversity, Haramaya University, Dire Dawa, Ethiopia;* [2]*Department of Agriculture and Environmental Sciences, Haramaya University, Dire Dawa, Ethiopia;* [3]*Department of Environmental Planning and Management, Kenyatta University, Nairobi, Kenya;* [4]*Department of Biotechnology, Biotechnology Research Institute, Nairobi, Kenya;* [5]*Department of Physiology and Ecology, International Centre of Insect Physiology and Ecology, Nairobi, Kenya*

ABSTRACT

Sustainable agricultural productivity and food security are critical concerns in the face of climate change. Sweet potato (*Ipomoea batatas*) is among climate smart crops that can strengthen farming resilience and enhance food and nutrition security in Sub-Saharan Africa. However, farmers have not been able to achieve optimum productivity partly due to diseases caused by sweet potato viruses. This study sought to identify experiences and practices of sweet potato growers; assess prevalence of sweet potato viruses (*i.e.* Sweet Potato Chlorotic Stunt Virus (SPCSV), Sweet Potato Feathery Mottle Virus (SPFMV) and vectors; and model their future distribution under climate change scenarios of RCPs 4.5 and 8.5. Survey was conducted and virus testing done using RT-PCR. A total of 294 presence data of sweet potato viruses (SPCSV, SPFMV and begomovirus) and 65 presence data of vectors (whitefly and aphid) collected from field surveys and the Kenya Agricultural and Livestock Research Organization (KALRO) database were used as dependent variables. Bioclimatic data retrieved from AfriClim and soil data from ISRIC database were used to model the spread of sweet potato vectors and viruses using the MaxEnt model. Occurrence of virus disease and vectors was 51% and 31.6% respectively and the models' most significant variables were moisture (moisture index moist quarter) and temperature (number of dry months and length of longest dry season). The results showed that on one hand, geographical extent of areas at risk of sweet potato virus disease will increase for Kenya under future climate change scenarios from a current 36,736.09 km^2 to about 63,179.76 km^2 by 2085 under RCP 8.5. On the other hand, virus disease risk incidence will decrease for Homabay County in future climate scenarios from a current 2,804.92 km^2 to 2,625.05 by 2085 under RCP 4.5. Increase in temperature and moisture variables will enhance niche suitability for sweet potato viruses and vectors. Therefore, the situation calls for climate smart practices such as better crop timing, better cultivar choice and management, integrated pest management and sustainable cropping systems to enhance sustainable production of sweet potato crop.

Keywords: Agricultural productivity; Sweet potato viruses; Moisture index; Production; Better cultivar

INTRODUCTION

Climate change manifested as increased temperature, erratic rainfall, frequent drought, and unpredictable weather conditions has increasingly posed challenges to food security and agricultural productivity in Sub-Saharan Africa (SSA) [1,2]. In absence of effective adaptive measures, areas suitable for production of major food crops such as maize and beans could decline by about 20%-40% while drought and flood-induced yield losses across Africa is estimated to be between 5%-17% for maize and wheat respectively by the year 2050. Crop pest and disease already affects about one-sixth of total global food

Correspondence to: Quinter Akinyi Oginga, Department of Agriculture and Biodiversity, Haramaya University, Dire Dawa, Ethiopia; E-mail: stephenj@gmail.com

Received: 19-Jul-2022, Manuscript No. JBFBP-22-18492; **Editor assigned:** 22-Jul-2022, PreQC No. JBFBP-22-18492 (PQ); **Reviewed:** 05-Aug-2022, QC No. JBFBP-22-18492; **Revised:** 11-Oct-2022, Manuscript No. JBFBP-22-18492 (R); **Published:** 17-Mar-2023, DOI: 10.35248/2593-9173.23.14.137

Citation: Oginga QA, Fininsa C, Onywere S, Wanjala B, Mosomtai G, Kumar A (2022) Distribution of Sweet Potato Viruses and Vectors in Homabay County, and under Climate Change Scenarios in Kenya. J Agri Sci Food Res. 14:137.

production and climate change is postulated to affect incidence of crop pests, diseases and pathogens [3].

Climate Smart Agriculture (CSA) is an integrated approach to reorient agricultural systems in a way that addresses interlinked challenges of food security under realities of a changing climate. It aims to sustainably increase agricultural productivity, build resilience to climate change, and reduce greenhouse emissions from agriculture where possible [4]. Crops adapted to a wide range of agro ecological conditions and yield response even under unfavorable and marginal growing conditions are considered climate smart. They include tubers such as cassava, roots such as sweet potato, pulses and millets. Sweet potato is considered a crop with significantly unrealized potential. Originally from Central America, the crop is now grown in over 100 countries, with 97% of world production concentrated in 15 developing countries. According to FAOSTAT, China is the largest (73.2 million tons) producer accounting for 74.7% of the total world production. The largest producers for the period 2008-2017 in Africa are: Malawi (4.1 million tons), Nigeria (3.2 million tons), Tanzania (3 million tons), Ethiopia (2.0 million tons), Uganda (1.9 million tons), Angola (1.3 million tons) and Kenya (0.84 million tons).

Sweet potato has recently gained importance as a potential food security crop due to its ability to adapt to a wide range of agro-ecologies [6]. The crop has a growth cycle (3-7 months) and can survive and yield under water stress and low soil fertility conditions [7]. Orange and yellow fleshed varieties in particular have great potential to improve nutrition security in addressing vitamin A deficiency in developing countries [8,9]. Like other roots and tubers, it has greater ability to produce higher dietary energy per hectare compared to cereal staples like maize, wheat and rice, in adverse soil and climate conditions. For instance, in 2017, yield of cassava (12,301.7 kg/ha) and sweet potato (9,422.0 kg/ha) were higher compared to maize (1,522.6 kg/ha) and rice (2,717.5 kg/ha). In addition, sweet potato is a remedial crop for mixed crop-livestock farmers and can be utilized as raw material for other food and feed-based industries.

Agriculture is the mainstay of Kenya's economy but a large area of its food basket of maize production has lately been under attack from severe drought, maize lethal necrosis disease and an invasive fall armyworm (Spodoptera frugiperda) pest [10]. The government has sought to diversify into root crops such as potatoes which are more tolerant to harsh climatic conditions with a strategic target to increase area under sweet potato cultivation from 61,067 ha to 73,280 ha between 2016 and 2021 [11]. However, the risk to sustainable production has been attributed to challenges from biotic factors such as insect pests and diseases, including sweet potato virus [12]. Yield loss of between 14%-97% due to various sweet potato viruses has been reported in Kenya [13,14]. Major viruses reported include aphid-transmitted Sweet Potato Feathery Mottle Virus (SPFMV), whitefly-transmitted Sweet Potato Chlorotic Stunt Virus (SPCSV) and begomovirus. Optimum temperature for aphid survival and reproduction is 25°C while whitefly reproduces best at temperature between 15°C-32°C. Warmer temperature enhances growth, survival and spread of sweet potato virus vectors and it is assumed that with increasing temperature due to climate change, sweet potato virus disease will increase, further compromising productivity of sweet potato farmers.

Anticipating distribution of sweet potato viruses and their vectors under changing climate conditions is imperative to enhance decision making and strategies for sweet potato farming in Kenya. On this wise, Species Distribution Models (SDMs) have increasingly become useful tools for informing and assessing potential impact of environment conditions on species population dynamics. Correlative model types such as MaxEnt have been used in predicting effects of climate change on insect population dynamics as well as disease outbreaks. Several studies have employed MaxEnt and Geographic Information System (GIS) models for species distribution including eco-geographic distribution of whitefly as an important agricultural pest in Ecuador; Tunisia; Europe and India. At the time of this study, there was no documentation on species distribution modeling for sweet potato viruses and vectors done in Kenya. The current study sought to assess occurrence of sweet potato viruses and vectors in Kenya; and model their future distribution under climate change scenarios.

MATERIALS AND METHODS

MaxEnt model was used for this study and it requires presence-only and bioclimatic datasets to project future distribution of species. Consequently, a total of 294 presence data of sweet potato viruses (SPCSV, SPFMV and begomovirus) and 65 data points for vectors (whitefly and aphids) were used as dependent variables. The dataset was from drawn from two sources; leaf samples tested for viruses from a field survey and from KALRO database. Independent variables used were temperature, moisture and soil data (Table 1). Current and future climate datasets were retrieved from the AfriClim database at a spatial resolution of 30 arc seconds (~1km^2). Soil data (type and pH) was retrieved from ISRIC Data Hub at a spatial resolution of 1 M for the base year 1972-2003. Both jackknife and variance inflation factor were used to remove multi collinearity of environmental layers. Homabay County was extracted from the model for case study as one of the major sweet potato growing areas in Kenya.

Table 1: Bioclimatic variables to model distribution of sweet potato viruses and vectors in Kenya.

Temperature variables (tbio)			Moisture variables (mbio)		
Code	Description	Units	Code	Description	Units
Bio1	Mean annual temperature	°C	Bio12	Mean annual rainfall	mm
Bio2	Mean diurnal range in temp	°C	Bio13	Rainfall wettest month	mm
Bio3	Isothermally	°C	Bio14	Rainfall driest month	mm
Bio4	Temperature seasonality	°C	Bio15	Rainfall seasonality	mm
Bio5	Max. temp warmest month	°C	Bio16	Rainfall wettest quarter	mm
Bio6	Min. temp coolest month	°C	Bio17	Rainfall driest quarter	mm
Bio7	Annual temperature range	°C	MI	Annual moisture index	n/a
Bio10	Mean temp warmest quarter	°C	MIMQ	Moisture index moist quarter	n/a
Bio11	Mean temp coolest quarter	°C	MIAQ	Moisture index arid quarter	n/a
PET	Potential evapotranspiration	mm	DM	Number of dry months	month
			LLDS	Length of longest dry season	month

Source: AfriClim (2020).

Downscaled current climate data (1950-2000) and future climate data consisting of RCPs 4.5 and 8.5 were used for time periods 2055 (2041-2070) and 2085 (2071-2100) to project current and future scenarios. RCP 4.5 is stabilization scenario where radioactive forcing stabilizes at 4.5 W/m^2 before the year 2100 through employment of strategies and technologies to reduce greenhouse gas emissions.

On the other hand, RCP 8.5 is characterized by high emission over the years reaching radioactive forcing of 8.5 W/m^2, where there is minimum intervention to reduce greenhouse gas emission. MaxEnt relies on species data and environmental thereby requiring precise formatting of environmental and species data layers predictors. Spatial attributes of data were processed to be identical in extent, resolution and projection, converted in ArcGIS (version 10.5) to Environmental Systems Research Institute (ESRI) ascii grid format readable by MaxEnt (version 3.4.4). Default settings were used with little adjustments such as selection of logistic output to generate a continuous map with an estimated probability of presence, maximum number of iterations set to 5000 and maximum number of background points at 10000. Cross validation run type was selected and occurrence data randomly split into 75% as training and 25% as test data. Ten (10) percentile logistic threshold values for the minimum training presence were used to determine areas suitable and unsuitable for future sweet potato virus and vector distribution using ArcGIS. Figure 1 illustrates development process and methods used to determine suitable variables for modeling (Figure 1).

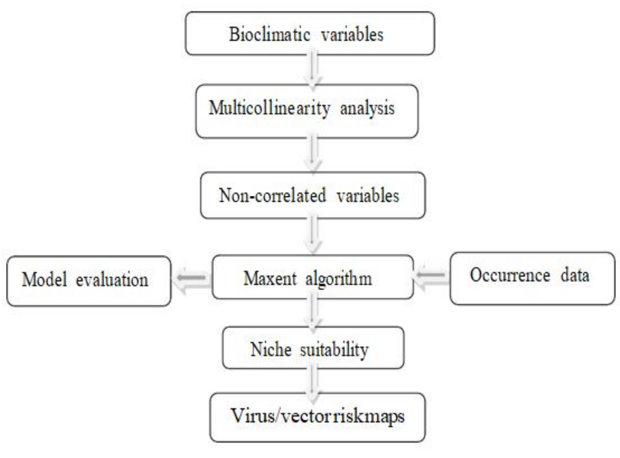

Figure 1: Flowchart of MaxEnt prediction.

Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) plot was used to appraise model performance with probability ranging from 0 to 1. The performance is categorized as failing (no fit) when the value is <0.5, poor (0.5-0.6), fair (0.6-0.7), good (0.7-0.8), very good

(0.8-0.9) and excellent for 0.9-1. Outputs from MaxEnt including jackknife, variable contribution table and response curves were used to analyze variable importance to projected occurrence of the species and area calculation done for niche suitability of sweet potato viruses and vectors in Kenya.

RESULTS AND DISCUSSION

From MaxEnt model, current and future Area Under the Curve (AUC) values for sweet potato viruses and their vectors in Kenya were >0.9 for testing and training datasets, indicating robust performance of the model. From 23 variables initially downloaded for use in the projection models, 9 variables were retained after multi collinearity test. For sweet potato virus, moisture variables contributed more (80%) to the model performance, with Moisture Index Moist Quarter (MIMQ) contributing 36.4%, number of Dry Months (DM) 26.5%, Length of Longest Dry Month (LLDS) 7.6%, rainfall seasonality (bio15) 6.3% and rainfall driest month (bio14) at 3.3%. Temperature variables; isothermally (bio3) and maximum temperature warmest month (bio5) contributed 14.4% while edaphic variables; soil type and pH contributed 5.6% (Table 2).

Table 2: Variable contribution from MaxEnt models to project sweet potato viruses and vectors in Kenya.

SP_virus			*A. gosypii*		*B. tabaci*	
Variable	%c	pi	%c	pi	%c	pi
Moisture Index Moist Quarter (MIMQ)	36.4	4.9	0	0	0	0
Number of Dry Months (DM)	26.5	51.4	30.7	1.4	18.4	73.1
Max. temp of warmest month (bio5)	7.7	10.2	6.2	1.4	3.9	6.8
Length of Longest Dry Season (LLDS)	7.6	13.5	4.1	90.1	1.4	15.7
Isothermality (bio3)	6.7	1.9	7.5	5.2	4.8	0.3
Rainfall seasonality (bio15)	6.3	4.6	0	0	0.1	0
Soil type (claf)	3.4	7.7	23.9	2	9.8	3.6
Rainfall driest month (bio14)	3.3	2.5	27.7	0	61.6	0.4
Soil pH (pH)	2.2	3.3	0	0	0	0

%c=percent contribution; pi=permutation importance

For vector *B. tabaci* model, moisture variables contributed 81.5%, edaphic variables at 9.8% and temperature variables at 8.7%. Rainfall driest month (bio14) was the most important variable contributing 61.6% to predicting niche suitability of whitefly.

Additionally, moisture variables contributed 62.5% toward performance of *A. gosypii* model while edaphic and temperature variables contributed 23.9 and 13.7 percent respectively (Table 2).

The most important variable for predicting habitat suitability of aphid was number of Dry Months (DM) at 30.7%. Moisture and temperature variables contributed most to the models since whitefly and aphids are temperature and moisture dependent species.

Jackknife output results showed that (A) Moisture Index Moist Quarter (MIMQ), number of Dry Months (DM) and maximum temperature of warmest month (bio5) were the top three influential factors for distribution of sweet potato viruses and their vectors.

Soil type and bio5 reduced regularized gain the most when removed from all the models, indicating that they have important information not present in the other variables (Figure 2).

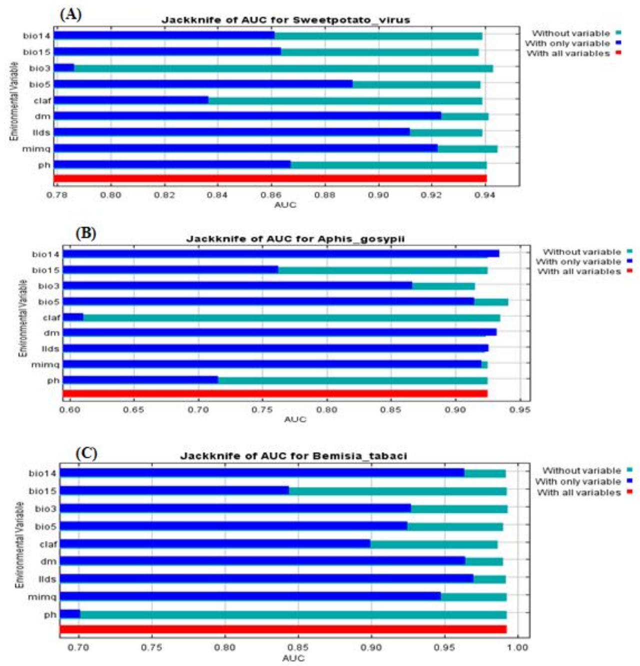

Figure 2: Jackknife of area under the curve gain for sweet potato virus and vectors in Kenya.

Response curves from the models showed the most significant variables influencing distribution of sweet potato virus and vectors in Kenya. Niche suitability of sweet potato virus increased with an increase in Moisture Index Moist Quarter (MIMQ) up to 25% while it decreased with increase in number (DM) and Length of Dry Months (LLDS) beyond 2 months. Additionally, maximum temperature of warmest month (bio5) increased suitability exponentially then decreased beyond 30°Coptimum temperature (Figure 3). Sweet potato is a sun loving crop and it grows best at temperatures above 25°C but growth becomes retarded at temperatures below 12°C or above 35°C. Short sun days promote flowering and root development while long sun days promote top growth. Optimum temperature for top growth is >25°C. The crop is considered drought tolerant and yields better in sandy loam soil with moisture content of 25% compared to soils with moisture content of 40, 60 and 80 percent. It tolerates rainfall ranges between 500 mm-1300 mm with optimum rainfall levels at 900 mm-1330 mm. With temperature ranges (bio5) in future scenarios from a minimum of 10.6°C in RCP 2055_45 to 44.6°C in RCP 2085_85, the temperatures would be favorable for top growth of sweet potato crop thereby enhancing suitable condition for the virus host. These moisture and temperature conditions can be attributed to the increased niche for sweet potato virus in Kenya in future scenarios. Response curves for *A. gosypii* and *B. tabaci* indicated decrease in niche suitability with increase in number (dm) and length (llds) of dry months beyond 2 months for both vectors. Increase in rainfall amounts in the driest month (bio14), isothermally (bio3) and maximum temperature warmest month (bio5) exponentially enhanced niche suitability for A. gosypii beyond the optimum 48 mm, 87 units and 35°C respectively (Figure 3). Optimal temperature for aphid survival and reproduction is 25°C and the models show temperature threshold of up to 40°C. Maximum temperature warmest month (bio5) is expected to increase from the current 8.6°C-40.2°C to ranges of 10.6°C-44.6°C in future scenarios. The temperature ranges fall within optimum conditions for aphid survival, thereby supporting increase in niche suitability for aphids under future climate scenarios in Kenya (Table 3 and Figure 3).

Table 3: Variable values for modeled, current and future climate scenarios in Kenya.

Variable	Modeled	Current	2055_45	2055_85	2085_45	2085_85
mimq	25	16-37.7	17-40.9	18-40.5	18-42.4	19-45.8
bio5 (°C)	30-35	8.6-40.2	10.6-42.3	11.3-42.9	11.1-42.8	12.8-44.6
bio14 (mm)	46-48	0-90	0-90	0-93	0-90	0-96
bio3 (°C)	87	63.5-89.8	61.4-89.1	60.8-89.2	60.8-88.9	59.3-88.5

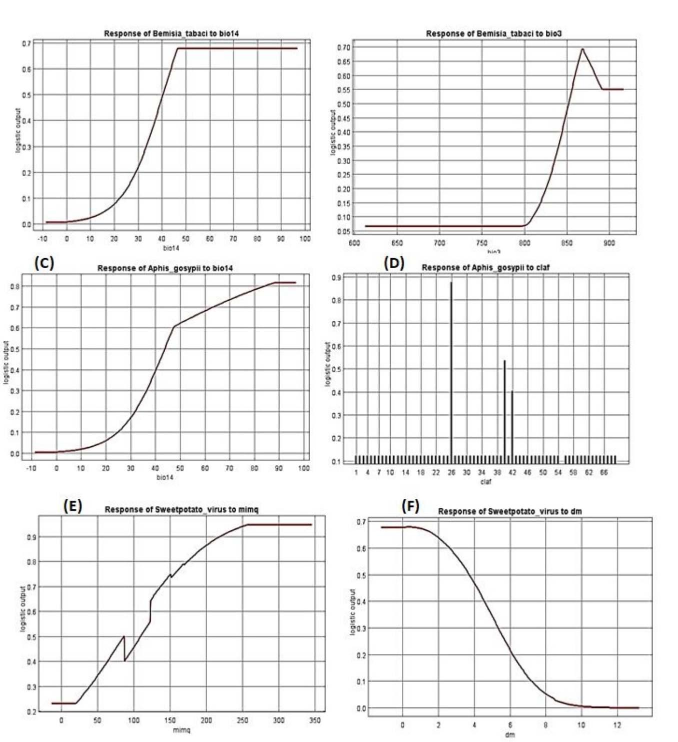

Figure 3: Response curves of sweet potato virus and vectors to predictor variables. Response of *B. tabaci* to (A) bio14 and (B) bio3; and *A. gosypii* to (C) bio14 and (D) soil type; sweet potato virus to (E) mimq, (F) dm.

An increase in bio5 and bio3 beyond an optimum of 30°C and 80 units respectively increased niche suitability for *B. tabaci*. Suitability increased for bio3 up to 87 units after which it declined and leveled off after 89 units. An increase in bio14 enhanced niche suitability up to an optimum of 46 mm beyond which it leveled off (Figure 3). Whitefly completes its development from egg to adult at temperature between 15°C-32°C, but not at 35°C or 10°C-12°C and eggs hatch after a period of 5-10 days with 2 to 4 weeks to mature into an adult depending on temperature. Whitefly population can increase by 2.5 generations at 23.3°C mean temperature, 1.9 generations at 18.9°C mean temperature and 2.0 generations at 16.8°C mean temperature, 2.2 generations at 19.7°C. According to Henneberry, et al. the higher the temperature and humidity, the more the increase in whitefly population as it is more common in dry seasons. Future moisture and temperature ranges (Table 3) fall within required levels for survival and reproduction of whitefly thereby enhancing niche suitability for the vector in Kenya.

Soil type was the third most important variable for modeling aphid ecological niche (23.9%) after bio14 (27.7%) and dm (30.7%). Similarly, it was the third most contributing variable for whitefly species distribution modeling (9.8%) after dm (18.4%) and bio14 (61.6), although it was not among the top influencing variables for sweet potato virus model. Limiting soil types for B. tabaci were lithic leptosols, eutric fluvisols, eutric planosols, calcaric regosols, calcic solonchaks, cambic arenosols and luvic calcicols while the most limiting soil types for aphid species were calcic solonchaks, cambic arenosols and luvic calcicols (Table 4). The soils are characteristically sandy soils with weak soil development and high salinity. Structural soil properties are more limiting for sweet potato crop compared to chemical soil properties. The crop prefers slightly acidic to neutral soils with an optimum pH between 5.5 and 6.8. Areas with weak developed soils limit suitability of sweet potato crop (host), thereby limiting occurrence of vectors on the host plant, which in turn limit incidence of sweet potato virus.

Table 4: Soil types influencing occurrence of sweet potato virus and vectors in Kenya.

Soil code	Type key	Soil type	Soil characteristics
26	SC	Calcic solonchaks	Strongly saline
34	PL	Eutric planosols	Soils with bleached and temporarily water-saturated top soil or slowly permeable sub-soil
40	AR	Cambic arenosols	Sandy soils with no or very weak soil development
42	CL	Luvic calcicols	Soils with secondary calcium carbonates accumulation
48	FL	Eutric fluvisols	Alluvial deposits of young soils
52	RG	Calcaric regosols	Soils with highly limited soil development
57	LP	Lithic leptosols	Very shallow soils on hard rock or unconsolidated and very gravelly material

Visualization of potential ecological niche for sweet potato virus and vectors

The MaxEnt models projected varied habitat suitability for sweet potato viruses and vectors. The logistic threshold value for the 10 percentile training presence used to produce suitability maps was 0.2, 0.239 and 0.217 for whitefly, aphid and sweet potato virus respectively. Niche suitability for sweet potato virus and vectors was higher for RCP 8.5 than RCP 4.5 each of the time periods. Current niche suitability is highest for whitefly (36,756.84 km^2), followed by sweet potato virus (36,736.09 km^2) with aphids having the least distribution (16,636.45 km^2). Niche suitability for *A. gosypii* is generally restricted in the Western region with Homabay, Migori and Kericho being the most suitable (Figure 4). Geographic suitability for the vector is to increase in future scenarios to cover more Counties such as Kakamega, Nandi, Kisii, Busia, Siaya and Kisumu.

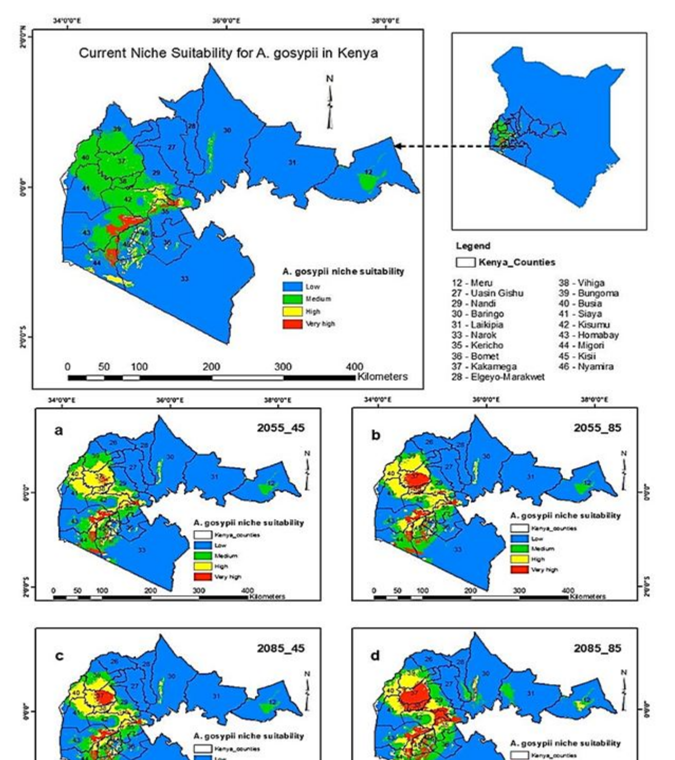

Figure 4: Niche suitability for *A. gosypii* under climate change scenarios in Kenya.

On the other hand, current and future whitefly vector distribution mainly in Western region covering Elgeyo-Marakwet, Kakamega, Busia, Vihiga, Siaya, Kisumu, Homabay and Migori and at the Coastal region covering Kwale and Kilifi Counties (Figure 5). These areas are characterized by high humidity and temperature conditions, thereby providing conducive environment for survival of sweet potato vectors.

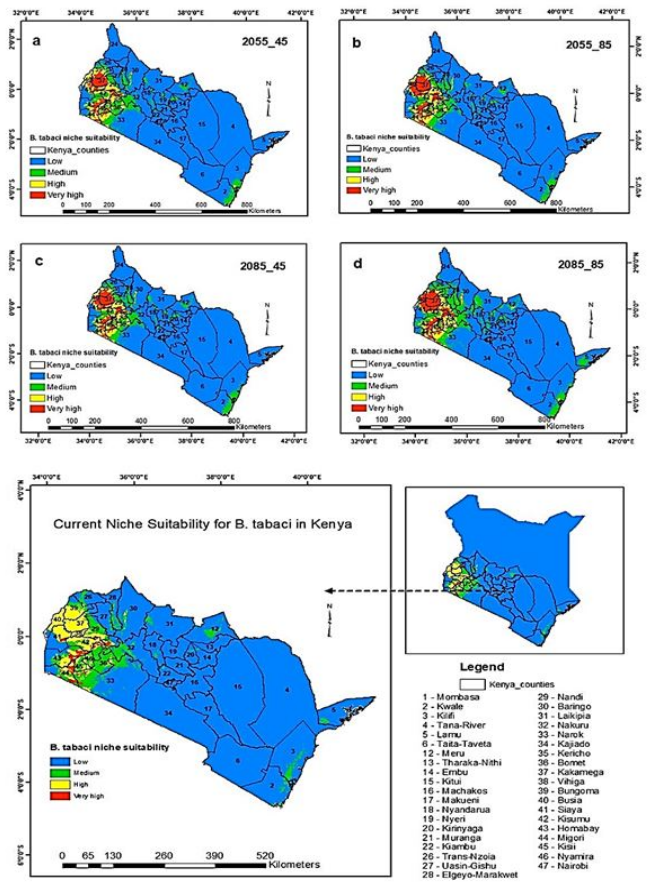

Figure 5: Niche suitability for *B. tabaci* under climate change scenarios in Kenya.

Current distribution of sweet potato virus (Figure 6) shows Western and Coastal regions having higher likelihood for sweet potato virus suitability and medium to low probability for Central and Eastern regions. Specifically, Kakamega, Vihiga, Bungoma, Busia and Siaya Counties have the highest risk of geographic suitability for sweet potato viruses while Homabay, Migori, Kisii, Kwale and Kilifi Counties indicate varied probability. Areas with high sweet potato virus suitability will increase in future scenarios from a current 36,736 km2 to 63,179 km2 for the time period 2085 for RCP 8.5 scenario. However, the risk of virus spread in Homabay County decreases over time under climate change scenarios (Tables 5 and 6) (Figures 6 and 7).

.

Table 5: Area calculation for sweet potato virus and vectors niche suitability in Kenya

	Projection period	Area (Km^2)	Variance (Km^2)	Variance (%)
Aphid Kenya				
	Current	16,636.45	-	-

	2055_4.5	20,696.33	4,059.88	24.4
	2055_8.5	22,363.65	5,727.20	34.4
	2085_4.5	21,431.46	4,795.01	28.8
	2085_8.5	27,021.64	10,385.19	62.4
Whitefly Kenya				
	Current	36,756.84	-	-
	2055_4.5	41,840.45	5,083.61	13.8
	2055_8.5	42,064.03	5,307.19	14.4
	2085_4.5	42,822.12	6,065.16	16.5
	2085_8.5	56,342.93	19,586.09	5.3
Sweet potato virus Kenya				
	Current	36,736.09	-	-
	2055_4.5	47,954.60	11,218.51	30.5
	2055_8.5	49,351.44	12,615.35	34.3
	2085_4.5	49,029.28	12,293.19	33.5
	2085_8.5	63,179.76	26,443.67	72

Table 6: Area calculation for sweet potato virus and vectors niche suitability in Homabay County, Kenya.

	Projection period	Area (Km^2)	Variance (Km^2)	Variance (%)
Aphid Homabay				
	Current	2,149.07	-	-
	2055_4.5	1,992.99	-156.08	7.3
	2055_8.5	1,861.61	-287.46	13.4
	2085_4.5	1,972.66	-176.41	8.2
	2085_8.5	1,957.96	-191.11	8.9
Whitefly Homabay				
	Current	2,859.45	-	-
	2055_4.5	2,958.60	99.15	3.5
	2055_8.5	2,898.17	38.72	1.4
	2085_4.5	3,097.38	237.93	8.3

	2085_8.5	3,544.81	685.36	24
Sweet potato virus Homabay				
	Current	2,804.92	-	-
	2055_4.5	2,667.85	-137.07	4.9
	2055_8.5	2,589.87	-215.05	7.7
	2085_4.5	2,625.05	-179.87	6.4
	2085_8.5	2,802.46	-2.46	0.1

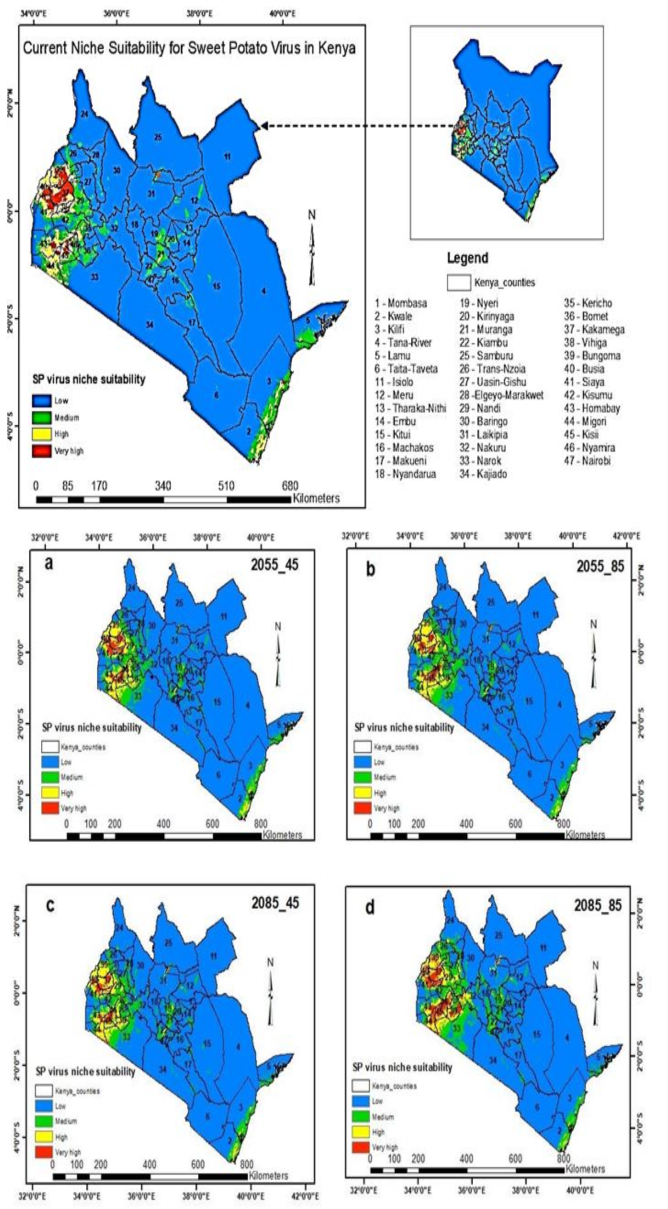

Figure 6: Niche suitability for sweet potato virus under climate change scenarios in Homabay.

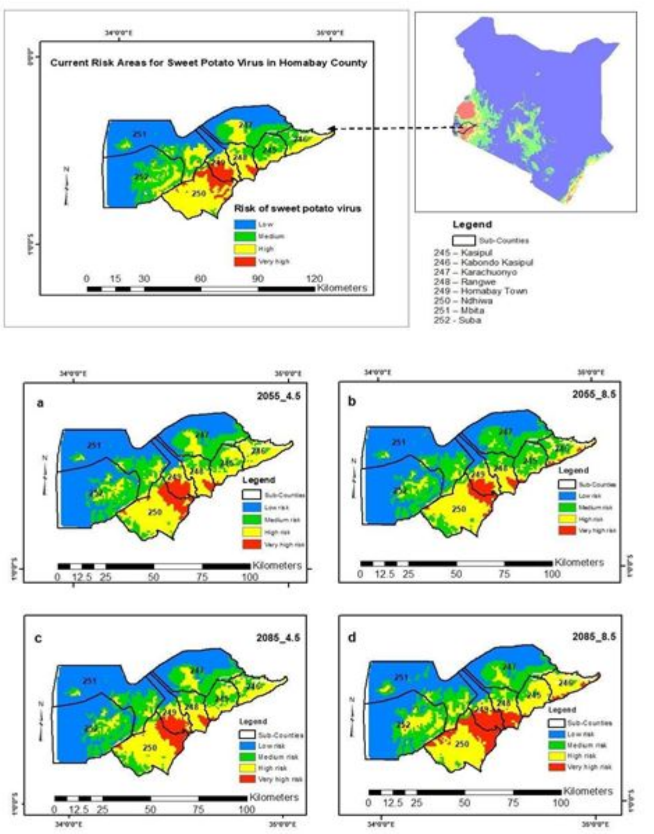

Figure 7: Niche suitability for sweet potato virus under climate change scenarios in Kenya.

Understanding factors influencing geographic spread of sweet potato viruses and vectors under a changing climate, and the risk level they pose is very important in climate smart farming. Improved predictability of virus/vector distribution will provide useful information for sweet potato virus and vector control. From ecological niche models of this study, the pattern of spread shows increasing sweet potato virus and vector niche suitability under future climate change scenarios in Kenya. Under current conditions, areas most favorable for the virus and vectors are the Western, Central and Coastal regions, which are basically the most favorable sweet potato growing zones in Kenya. Areas along Lake Victoria and Coastal region are considered high risk and studies by Prabhulinga, et al.; Luquet, et al. and Wokorach, et al. show that proximity to areas characterized by high humidity and temperature such as the Lake Victoria and Coast regions enhance vector suitability. An increasing risk of virus and vector incidence poses a threat to sweet potato production in Kenya.

Moisture and temperature are the most significant variables influencing geographical suitability of sweet potato virus and vectors. Previous studies by Durak, et al. CIP and Luquet, et al. showed that moisture and temperature greatly influenced suitability for sweet potato crop and abundance of aphid and whitefly vectors. Sweet potato is cultivated as a perennial crop majorly in tropical and subtropical regions but it can adapt to temperate climates provided that average temperature does not go below 20°C. Temperatures between 15°C-33°C are recommended for the vegetative cycle with 20°C-25°C as the most ideal. Highest yields are realized when day temperature is high (25°C-30°C) and night temperature is low (15°C-20°C). This is because high temperature during the day favors vegetative development while low temperature during the night favors formation of tubers.

The crop requires at least 500 mm of rainfall during the growing period and can tolerate periods of drought although yield is reduced when water shortage occurs between 10-30 days after planting. High rainfall conditions produce extensive vine growth but with poor tuber yield. Increasing niche suitability is expected as temperature and moisture conditions in future scenarios fall well within the ranges required for optimum growth of the crop. However, dry months and length of the longest dry season beyond 45 days will reduce niche suitability for virus and vector survival as they cannot tolerate dry periods beyond 30 days.

Increasing moisture levels (mimq) and temperature (bio5) increased niche suitability for sweet potato virus vectors since moist and warm weather conditions favor rapid population increase in temperature dependent insects such as aphids and whitefly. Studies have shown that temperature exceeding optimum temperature will limit survival and reproduction of whitefly at 32°C and 25°C for aphids respectively. Niche suitability for whitefly vector was higher compared to aphids since the whitefly is more tolerant to higher temperatures. Projected temperature ranges between 10.6°C-44.6°C will provide a conducive environment for reproduction and survival of the vectors, provided it does not exceed the threshold of 30°C-35°C. On this premise, future models show reducing risk for sweet potato virus and aphid vectors in Homabay County and can be attributed to persistent high temperatures. The situation could enhance suitability of Homabay County as a major sweet potato crop growing zone in Kenya.

Soil type in Kenya varies due to topography, rainfall and parent material. Soils in the humid Western region are basically red clay of cambisols, acrisols and their mixtures. Northern and Eastern parts of Kenya under current and future climate scenarios have low probability of sweet potato virus and vector occurrence. The situation could be attributed to existing soil types which do not well support sweet potato crop. The areas have fluvisols, solonchaks, arenosols, regosols and leptosols which are characteristically sandy soils with weak soil development and high salinity. Sweet potato can do well in a wide range of soil type provided it has a depth of more than 25 cm and good drainage. It grows best in sandy loam and well-drained soil and yields better in soils with 25 percent moisture content compared to soils with 40, 60 or 80 percent moisture content. Chemical soil properties are less limiting for sweet potato crop compared to structural properties and it prefers slightly acidic to neutral soils with an optimum pH between 5.5 and 6.8. Excessive alkaline or acidic soils encourage bacterial infection that negatively influences crop growth.

Difference in total suitable areas between current and future scenarios are higher under RCP 8.5 scenario compared to RCP 4.5. This could be attributed to projected conditions under each scenario whereby adaptation and mitigation activities will be applied under 4.5 pathway whereas little mitigation effort (business as usual) worst case scenario exist under 8.5 pathway. Based on extrapolation of current driving forces (social, economic and technological trends) which drive major emitters (energy and land use), the 4.5 pathway considers B1 emission scenario story line with more focus on social, economic and environmental sustainability at global level, reduction in material intensity, more use of clean energy technologies, rising population (9 billion by 2050) with rapid changes towards service and information economy; whereas 8.5 pathways considers A2 story line with more economic focus at regional level, high emissions and continuously increasing population (over 10 billion by 2050) in a very fragmented environment. Following either of the future scenarios and time periods calls for adaptation measures to ensure sustainable sweet potato production in Kenya.

CONCLUSION

Climate change and variability manifested as increased temperature, flooding, drought and unpredictable rainfall patterns increasingly pose a challenge to food security and agricultural productivity in Sub-Saharan Africa, Kenya included. Sweet potato is a potential climate smart crop that can enhance adaptive capacity of farmers to the changing climate. However, sweet potato virus disease is a major constrain to optimizing sweet potato productivity. Future climate scenarios with increasing temperature and moisture conditions favoring ecological requirements of whitefly and aphids will increase niche suitability for sweet potato virus and vectors. This will in turn enhance risk of sweet potato virus disease, further compromising productivity of the crop. The probable situation calls for climate smart practices such as better crop timing, better cultivar choice and management, integrated pest management and sustainable cropping systems. Even as adaptation measures are important, mitigation measures are also required to minimize impact of climate change on future pest and disease distribution since niche suitability will be higher under RCP 8.5 than gathering quantitative information on the extent and direction of risks is important to better inform management practices and policies in the agriculture sector. In the century of climate change, a better way to ensure food security and sustainable livelihoods is through adoption of climate smart crops such as sweet potato.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

AUTHOR CONTRIBUTIONS

QAO: Conceptualization, methodology, investigation, writing-original draft

CF: Supervision, validation, writing-review and editing

SO: Supervision, validation, writing- review and editing

GM: Software, data curation, visualization

BW: Data curation, review

AK: Conceptualization, review 324

FUNDING

This work was supported by Africa center of excellence for climate smart agriculture and biodiversity conservation hosted at Haramaya University, Ethiopia.

ACKNOWLEDGMENTS

The authors acknowledge contribution of agriculture officers and sweet potato farmers in Homabay. County, colleagues at Haramaya University and Kenya Agricultural and Livestock Research Organization (KALRO), biotechnology research institute, in data collection and preparing this article.

REFERENCES

1. Makini F, Mose L, Kamau G, Salasya B, Mulinge W, Ongala J. Innovation opportunities in sweet potato production in kenya. Forum for Agricultural Research in Africa (FARA), Accra, Ghana, 2018.
2. Bendjebbar P, Bricas N, Giordano T. Food systems at risk. A scientific handout for the high-level event of the global network against food crises: Food and agriculture in times of crisis, brussels. 2019;2-3.
3. Dinesh D, Bett B, Boone R, Grace D, Kinyangi J, Lindahl J, et al. Impact of climate change on African agriculture: Focus on pests and diseases. CGIAR-CCAFS, Copenhagen, Denmark, 2015.
4. Momanyi VN, Amata R, Atuncha H. A baseline survey on enhancing sweet potato production through development and promotion of appropriate weed management and spacing technologies in Kenya. Int J Sci Res. 2016;6(1):656-663.
5. Nedunchezhiyan M, Byju G, Jata SK. Sweet potato agronomy. Fruit Veg Cereal Sci Biotech. 2012;6(1):1-10.
6. Sugri I, Maalekuu BK, Gaveh E, Kusi F. Sweet potato value chain analysis reveals opportunities for increased income and food security in Northern Ghana. Advances in Agriculture. 2017:1-14.
7. Kiome RM, Bamanya B, Wamwere-Njoroge G, Rao J, Audi P, Parker M. The accelerated value chain development program national conference report, 26–27 April 2018: Developing value chains to farming as business with technology and Innovations in Kenya, International Livestock Research Institute, Nairobi, Kenya, 2019.
8. Gibson RW, Kreuze JF. Degeneration in sweet potato due to viruses, virus cleaned planting material and reversion: A review. Plant Pathol. 2015;64(1):1-15.
9. Onyango RA, Thagana WM, Karanja L, Onyango-Gweyi J. Assessment of sweet potato propagules for re-infection by various viruses in East Kamagak Location Homabay County-Kenya. Am J Exp Agric. 2016;11(1):1-9.
10. Durak R, Węgrzyn E, Leniowski K. Do all aphids benefit from climate warming? An effect of temperature increase on a native species of temperate climatic zone Cinara juniper. Ethol Ecol Evol. 2015;2(2):188-201.
11. Gilioli G, Pasquali S, Parisi S, Winter S. Modelling the potential distribution of Bemisiatabaci in Europe in light of the climate change scenario. Pest Manag Sci. 2014;70(10):1611-1623.
12. Luquet M, Hulle M, Simon JC, Parisey N, Buchard C, Jaloux B. Relative importance of long-term changes in climate and land-use on the phenology and abundance of legume crop specialist and generalist aphids. Insect Science. 2019;26(5):881-896.
13. Makori DM, Fombong AT, Abdel-Rahman EM, Nkoba K, Ongus J, Irungu J, et al. Predicting spatial distribution of key honeybee pests in Kenya using remotely sensed and bioclimatic variables: Key honeybee pests distribution models. Int J Geogr. 2017;6(3):66.
14. Mwakapeje ER, Ndimuligo SA, Mosomtai G, Ayebare S, Nyakarahuka L, Nonga HE, et al. Ecological niche modeling as a tool for prediction of the potential geographic distribution of *Bacillus anthracis* spores in Tanzania. Int J Infect Dis. 2019;79:142-151.