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AGRICULTURAL ADAPTATION TO CLIMATE CHANGE IN THE SAHEL: EXPECTED IMPACTS ON PESTS AND DISEASES AFFLICTING SELECTED CROPS

AUGUST 2014

ARCC

African and Latin American
Resilience to Climate Change Project

This report was prepared by Alfonso del Rio[1] and Brent M. Simpson[2] through a subcontract to Tetra Tech ARD.

[1]University of Wisconsin, Department of Horticulture

[2] Michigan State University, Department of Agriculture, Food and Resource Economics

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Tetra Tech ARD Contacts:

Patricia Caffrey
Chief of Party
African and Latin American Resilience to Climate Change (ARCC)
Burlington, Vermont
Tel.: 802.658.3890
Patricia.Caffrey@tetratech.com

Anna Farmer
Project Manager
Burlington, Vermont
Tel.: 802.658.3890
Anna.Farmer@tetratech.com

CLIMATE CHANGE IN MALI: EXPECTED IMPACTS ON PESTS AND DISEASES AFFLICTING SELECTED CROPS

AFRICAN AND LATIN AMERICAN RESILIENCE TO CLIMATE CHANGE (ARCC)

AUGUST 2014

TABLE OF CONTENTS

ABOUT THIS SERIES

ABOUT THE STUDIES ON CLIMATE CHANGE VULNERABILITY AND ADAPTATION IN WEST AFRICA

This document is part of a series of studies that the African and Latin American Resilience to Climate Change (ARCC) project produced to address adaptation to climate change in West Africa. Within the ARCC West Africa studies, this document falls in the subseries on Agricultural Adaptation to Climate Change in the Sahel. ARCC also has produced a subseries on Climate Change and Water Resources in West Africa, Climate Change and Conflict in West Africa, and Climate Change in Mali.

THE SUBSERIES ON AGRICULTURAL ADAPTATION TO CLIMATE CHANGE IN THE SAHEL

At the request of the United States Agency for International Development (USAID), ARCC undertook the Sahel series of studies to increase understanding of the potential impacts of climatic change on agricultural productivity in the Sahel, and to identify means to support adaptation to these impacts. Other documents in the Agricultural Adaptation to Climate Change in the Sahel series include: An Approach to Conducting Phenological Screening, An Approach to Evaluating the Performance of Agricultural Practices, Profiles of Agricultural Management Practices, A Review of 15 crops Cultivated in the Sahel, and Expected Impacts on Pests and Diseases Afflicting Livestock.

INTRODUCTION TO THE TABLES

The tables present an analysis of the potential impact of a changed climate on the most common pests and diseases afflicting 16 important crops of the Sahel. Information used to develop these tables was drawn from peer-reviewed scholarly journals found in 56 databases related to agriculture and botany. It does not include information from theses, technical reports, newspapers, mainstream magazines, or proceedings of conferences.

For each pest or disease identified, the current prevalence of the problem under current weather conditions was assessed. Assessments of prevalence took into account the biology and environmental requirements of each pest or disease, the endemic zone, relative frequency of outbreaks within endemic zones, and infection rates. These served as the baseline for an assessment of the likely change in risk of infection under future climate scenarios.

The fact that projections of climate change in the Sahel are currently uncertain informed the analysis. There is agreement among climate models that temperatures will increase, although the models vary on the extent and rate of that change. Precipitation in this region of the world is particularly difficult to model, and existing projections based on these models differ regarding the long-term evolution of annual rainfall amounts. Different models produce divergent outcomes for the region; a limited number project increased annual rainfall. The models also provide little insight regarding potential in geographic distribution. Most models project a slight increase in annual rainfall in the central Sahel and a decrease in the western Sahel.

Some models project that the onset of the rainy season may be delayed and extreme events may increase. Such intra-annual patterns play a critical role in the severity of pest and disease impact. Changes in the frequency of floods and drought, for example, may significantly impact prevalence. Unfortunately, on the whole, model projections do not address intra-seasonal weather patterns with the necessary accuracy, and such potential changes were not considered in the analysis.

This uncertainty and lack of specificity in projections argues for an analysis based upon simplified climate scenarios. Because projections are considered reliable with regard to temperature yet inconclusive with regard to annual rainfall amounts, the analysis considered two scenarios. One assumes warmer climate with increased rainfall. The second also assumes a warmer climate, but with lower rainfall.

Because the climate scenarios used were basic, the potential impacts identified are also straightforward; they consist of risk values of change in infestation or outbreak levels. A number of unknowns prevent greater precision. These include uncertainty regarding the impact of new climatic conditions on disease and pest biology; the health of crops themselves; and interactions between diseases and pests. Other factors less dependent on climate will also change. Farmers will adopt new techniques for managing pests and diseases and likely adopt varieties and crops with a different resistance to various pests and diseases. Farmers may also move to new types of land that pose a lesser (or greater) risk of infection.

Further, available research to explore these issues is limited, especially regarding minor pests, diseases, and crops considered less important. For all, little information exists on the sensitivity of specific pests and diseases to temperature, moisture, and humidity, making it difficult to gauge the severity of response to changes in climate.

The predictions that follow are based on expert opinion regarding probable trends. They are not the result of modeling or experimentation. They are intended to highlight potential areas of concern as well as possible trends. For greater precision, dedicated research targeting the specific geographic zones, crops, pests, and diseases under consideration will be necessary.

PRESENTATION OF THE TABLES

The report contains two tables: a summary table, followed by a more detailed table. The summary table is organized by crop and the current prevalence and impact of the pest or disease afflicting it; the effects are characterized as "very high," "high," "moderate," and "low." It presents, for each pest or disease, an estimate of the potential risk of outbreak or infestation under the two climate scenarios. Impacts are classified as "very high," "high," "moderate," "low," or "none."

The second table is also organized by crop, but grouped in this order: cereals, fiber crops, fruit crops, grasses, legumes, oilseed crops, and root crops. For each crop, the table presents the following information, listing pests first, then diseases: a description of the damage caused the individual plant (by phenological stage where possible); a description of the mode of transmission; and a description of the overall impact of the pest or disease. Due to gaps in the available literature, impact is described through a wide variety of measures and descriptors. In separate boxes for each crop, the table also presents the environmental conditions that affect the spread of the disease or pest. In most cases, these conditions consist of climatic factors, though may include other factors, such as soil moisture, shade, wind, or other important vectors. Whenever the research reviewed indicated that intra-annual events, such as drought, may influence a pest or disease, it is noted here.

VERY HIGH *Pests and diseases currently of serious prevalence and impact*		
AFFECTED SPECIES	***PEST OR DISEASE***	***CLIMATE IMPACT***
FONIO	Leaf Spot Disease	Hot/Wet – Very high risk of outbreak of Leaf Spot Disease Hot/Dry – No risk of outbreak of Leaf Spot Disease
	Stem Rust	Hot/Wet – Very high risk of outbreak of Stem Rust Hot/Dry – No risk of outbreak of Stem Rust
MAIZE	Maize Stalk Borer	Hot/Wet – Low risk of infestation of Maize Stalk Borer Hot/Dry – High risk of infestation of Maize Stalk Borer
	Pink Stem Borer	Hot/Wet – Low risk of infestation of Pink Stem Borer Hot/Dry – High risk of infestation of Pink Stem Borer
	Gray Leaf Spot (GLS), Cercospora Leaf Spot	Hot/Wet – Very high risk of outbreak of Gray Leaf Spot Hot/Dry – No risk of outbreak of Gray Leaf Spot.
	Maize Streak Virus	Hot/Wet – Low risk of severe infestation of MSV vector leaf grasshoppers Hot/Dry – Moderate risk of severe infestation of MSV vector leaf grasshopers
PEARL MILLET	Witchweed	Hot/Wet – Low risk of severe parasitism of Witchweed Hot/Dry – Moderate risk of severe parasitism of Witchweed
	Downy Mildew	Hot/Wet – Very high risk of outbreak of Downy Mildew Hot/Dry – No risk of outbreak of Downy Mildew.
RICE	African Rice Gall Midge	Hot/Wet – High risk of infestation of African Rice Gall Midge. Hot/Dry – Low risk of infestation of African Rice Gall Midge.
	African Striped Rice Borer	Hot/Wet – Low risk of infestation of African Striped Rice Borer Hot/Dry – Low risk of infestation of African Striped Rice Borer
	African White Borer	Hot/Wet – Low risk of infestation of African White Borer Hot/Dry – Low risk of infestation of African White Borer
	Rice Weevil	Hot/Wet – Moderate risk of infestation of Rice Weevil Hot/Dry – Low risk of infestation of Rice Weevil

	Whitefly	Hot/Wet – Low risk of severe infestation of Whitefly Hot/Dry – High risk of severe infestation of Whitefly
	Bacterial Leaf Blight	Hot/Wet – High risk of infection of Bacterial Leaf Blight Hot/Dry – No risk of infection of Bacterial Leaf Blight
	Rice Yellow Mottle Virus (RYMV)	Hot/Wet – Low risk of infection of Rice Yellow Mottle Virus Hot/Dry – Moderate risk of infection of Rice Yellow Mottle Virus
SORGHUM	Khapra Beetle	Hot/Wet – Low risk of infestation of Khapra Beetle Hot/Dry – High risk of infestation of Khapra Beetle
	Sorghum Midge	Hot/Wet – Moderate risk of infestation of Sorghum Midge Hot/Dry – Low risk of infestation of Sorghum Midge
	Striga Purple Witchweed	Hot/Wet – Low risk of parasitism of Striga Purple Witchweed Hot/Dry – High risk of parasitism of Striga Purple Witchweed
	Anthracnose	Hot/Wet – High risk of significant infection of Anthracnose Hot/Dry – No risk of significant infection of Anthracnose
	Sorghum Downy Mildew	Hot/Wet – High risk of infection of Sorghum Downy Mildew Hot/Dry – No risk of infection of Sorghum Downy Mildew
	Zonate Leaf Spot	Hot/Wet – High risk of infection of Zonate Leaf Spot. Hot/Dry – No risk of infection of Zonate Leaf Spot.
COTTON	Cotton Aphid	Hot/Wet – Low risk of infestation of Cotton Aphid Hot/Dry – High risk of infestation of Cotton Aphid
	Cotton Bollworm	Hot/Wet – Low risk of infestation of Cotton Bollworm Hot/Dry – High risk of infestation of Cotton
	Pink Bollworm	Hot/Wet – Low risk of infestation of Pink Bollworm Hot/Dry – High risk of infestation of Pink Bollworm
	Red Bollworm	Hot/Wet – Low risk of infestation of Red Bollworm Hot/Dry – High risk of infestation of Red Bollworm
	Angular Leaf Spot, Bacterial Blight of Cotton	Hot/Wet – Very high risk of infection of Angular Leaf Spot Hot/Dry – No risk of infection of Angular Leaf Spot
CASHEW	Cashew Weevil , Stem	Hot/Wet – Low risk of infestation of Cashew Weevil

	Borers	Hot/Dry – Moderate risk of infestation of Cashew Weevil
	Helopeltis Bugs , Mosquito Bug, Mirid Bugs	Hot/Wet – High risk of infestation of Helopeltis Bugs Hot/Dry – Low risk of infestation of Helopeltis Bugs
	Powdery Mildew	Hot/Wet – Very high risk of infection of Powdery Mildew Hot/Dry – No risk of infection of Powdery Mildew
MANGO	Mango Fruit Fly	Hot/Wet – Moderate risk of infection of Mango Fruit Fly Hot/Dry – Low risk of infection of Mango Fruit Fly
	Mealy Bug	Hot/Wet – Low risk of infestation of Mealy Bugs Hot/Dry – Moderate risk of infestation of Mealy Bugs
	Anthracnose	Hot/Wet – Very high risk of infection of Anthracnose Hot/Dry – No risk of infection of Anthracnose
COWPEA	Cowpea aphid	Hot/Wet – Low risk of infestation of Cowpea Aphid Hot/Dry – High risk of infestation of Cowpea Aphid
	Cowpea Witchweed	Hot/Wet – Moderate risk of infestation of Cowpea Witchweed Hot/Dry – Low risk of infestation of Cowpea Witchweed
	Legume Pod Borer, Cowpea Caterpillar	Hot/Wet – High risk of infestation of Legume Pod Borer Hot/Dry – Low risk of infestation of Legume Pod Borer
	Witchweed, Purple Witchweed	Hot/Wet – Moderate risk of parasitism of Witchweed Hot/Dry – Low risk of parasitism of Witchweed
	Cowpea Aphid-Borne Mosaic Virus (CABMV)	Hot/Wet – Low risk of significant infestation of *Aphis craccivora* and low risk of transmission of CABMV Hot/Dry – High risk of significant infestation of *Aphis craccivora* and high risk of transmission of CABMV
GROUNDNUT	Aspergillus flavus	Hot/Wet – Moderate high risk of infection of *Aspergillus flavus* Hot/Dry – Very high risk of infection of *Aspergillus flavus*
	Groundnut Rosette Virus	Hot/Wet – Low risk of significant infestation of *Aphis cracivora* and low risk of GRV Hot/Dry – Moderate risk of significant infestation of *Aphis cracivora* and low risk of GRV
SESAME	Green Peach Aphid	Hot/Wet – Low risk of infestation of Green Peach Aphid Hot/Dry – Moderate risk of infestation of Green

		Peach Aphid
	Sesame Webworm	Hot/Wet – Low risk of infestation of Sesame Webworm Hot/Dry – Moderate risk of infestation of Sesame Webworm
	Alternaria Leaf Spot	Hot/Wet – Low risk of infection of Alternaria Leaf Spot Hot/Dry – Moderate risk of infection of Alternaria Leaf Spot
	Leaf Spot Disease	Hot/Wet – High risk of infection of Leaf Spot Disease Hot/Dry – No risk of infection of Leaf Spot Disease
	Leaf Curl Virus Disease	Hot/Wet – Low risk of infection of *B. tabaci* and low risk of infection of LCVD Hot/Dry – High risk of infection of *B. tabaci* and high risk of infection of LCVD
CASSAVA	Cassava Mealybug	Hot/Wet – Low risk of infestation of Cassava Mealybug Hot/Dry – High risk of infestation of Cassava Mealybug
	Cassava Bacterial Blight (CBB)	Hot/Wet – Very high risk of infection of Cassava Bacterial Disease Hot/Dry – No risk of infection of Cassava Bacterial Disease
SWEET POTATO	Sweet Potato Weevil	Hot/Wet – Low risk of infestation of Sweet Potato Weevil Hot/Dry – Low risk of infestation of Sweet Potato Weevil
	Bacterial Stem and Root Rot	Hot/Wet – Very high risk of infection of Bacterial Stem and Root Rot Hot/Dry – No risk of infection of Bacterial Stem and Root Rot

HIGH/SIGNFICANT *Pests and diseases currently of significant prevalence and impact*		
AFFECTED SPECIES	**PEST OR DISEASE**	**CLIMATE IMPACT**
FONIO	Striga Witchweed	Hot/Wet – High risk of infestation of *Striga senegalensis* Hot/Dry – Low risk of infestation of *Striga senegalensis*
MAIZE	Spotted Stem Borer	Hot/Wet – Low risk of infestation of Spotted Borer Hot/Dry – Low risk of infestation of Spotted Borer
PEARL MILLET	Millet Earhead Caterpillar, Millet Head Miner	Hot/Wet – Low risk of infestation of Millet Earhead Caterpillar Hot/Dry – Moderate risk of infestation of Millet Earhead Caterpillar
	Millet Grain Midge	Hot/Wet – Moderate risk of infestation of Millet Grain Midge Hot/Dry – Low risk of infestation of Millet Grain Midge
	Millet Stem Borers	Hot/Wet – No risk of infestation of Millet Stem Borer Hot/Dry – High risk of infestation of Millet Stem Borer
SORGHUM	Sorghum Aphid	Hot/Wet – Low risk of infestation of Sorghum Aphid Hot/Dry – High risk of infestation of Sorghum Aphid
	Sorghum Shoot Fly	Hot/Wet – Low risk of infestation of Sorghum Shoot Fly Hot/Dry – Low risk of infestation of Sorghum Shoot Fly
	Leaf Blight	Hot/Wet – High risk of infection of Leaf Blight Hot/Dry – No risk of infection of Leaf Blight
COTTON	Anthracnose, Pink Boll Rot, Seedling Blight	Hot/Wet – Very high risk of infection of Anthracnose Hot/Dry – No risk of infection of Anthracnose
CASHEW	Coreid Coconut Bugs	Hot/Wet – Low risk of infestation of Coreid Coconut Bug Hot/Dry – High risk of infestation of Coreid Coconut Bug
MANGO	Powdery Mildew	Hot/Wet – High risk of infection of Powdery Mildew Hot/Dry – No risk of infection of Powdery Mildew
COWPEA	Scab	Hot/Wet – High risk of infection of Scab Hot/Dry – No risk of infection of Scab
GROUNDNUT	Groundnut Bruchid, Groundnut Seed Beetle	Hot/Wet – Moderate risk of infestation of Groundnut Bruchid

		Hot/Dry – Low risk of infestation of Groundnut Bruchid
	Early Leaf Spot	Hot/Wet – Very high risk of infection of Early Leaf Spot Hot/Dry – No risk of infection of Early Leaf Spot
	Groundnut Rust	Hot/Wet – High risk of infection of Groundnut Rust Hot/Dry – No risk of infection of Groundnut Rust
	Late Leaf Spot	Hot/Wet – High risk of infection of Late Leaf Spot Hot/Dry – No risk of infection of Late Leaf Spot
SESAME	Legume Pod Borer	Hot/Wet – Low risk of infestation of Legume Pod Borer Hot/Dry – High risk of infestation of Legume Pod Borer
CASSAVA	Cassava Brown Streak Disease (CBSD)	Hot/Wet – Low risk of infection of *B. tabaci* and low risk of infection of CBSD Hot/Dry – High risk of infection of *B. tabaci* and high risk of infection of CBSD
SWEET POTATO	Sweet Potato Hawk Moth, Sweet Potato Hornworm, Sweet Potato Moth	Hot/Wet – Low risk of infestation of Sweet Potato Hawk Moth Hot/Dry – Moderate risk of infestation of Sweet Potato Hawk Moth

MODERATE *Pests and diseases currently of moderate prevalence and minor impact*		
AFFECTED SPECIES	***PEST OR DISEASE***	***CLIMATE IMPACT***
FONIO	Flour Beetles	Hot/Wet – High risk of increased incidence of Flour Beetles Hot/Dry – Low risk of increased incidence of Flour Beetles
MAIZE	Downy Mildew	Hot/Wet – Very high risk of outbreak of Downy Mildew Hot/Dry – No risk of outbreak of Downy Mildew
	Maydis Leaf Blight	Hot/Wet – Very high risk of outbreak of Maydis Leaf Blight Hot/Dry – Low high risk of outbreak of Maydis Leaf Blight
PEARL MILLET	Bacterial Leaf Streak	Hot/Wet – Very high risk of outbreak of Bacterial Leaf Streak Hot/Dry – No risk of outbreak of Bacterial Leaf Streak
RICE	Birds	Hot/Wet – High risk of infestation of birds Hot/Dry – Low risk of infestation of birds
	Spider Mites	Hot/Wet – Low risk of significant infestation of Spider Mites Hot/Dry – Moderate risk of significant infestation of Spider Mites
	Rice Grasshoppers	Hot/Wet – Low risk of significant outbreak of rice grasshoppers Hot/Dry – High risk of significant outbreak of rice grasshoppers
SORGHUM	Angoumois Grain Moth	Hot/Wet – Low risk of infestation of Angoumois Grain Moth Hot/Dry – High risk of infestation of Angoumois Grain Moth
CASHEW	Long-Tailed Mealy Bug	Hot/Wet – Low risk of infestation of Long-Tailed Mealy Bug Hot/Dry – Very high risk of infestation of Long-Tailed Mealy Bug
	Anthracnose	Hot/Wet – Very high risk of infection of Anthracnose Hot/Dry – No risk of infection of Anthracnose
MANGO	Mango Weevil	Hot/Wet – Moderate risk of infection of Mango Weevil Hot/Dry – Low risk of infection of Mango Weevil
	Mango Malformation Disease	Hot/Wet – High risk of infection of Mango Malformation Disease Hot/Dry – No risk of infection of Mango Malformation Disease
SHEA NUT	Nematodes	Hot/Wet – Moderate risk of infestation of Nematodes

		Hot/Dry – No risk of infestation of Nematodes
	Shea Defoliator	Hot/Wet – Low risk of infestation of Shea Defoliator Hot/Dry – High risk of infestation of Shea Defoliator
COWPEA	Root-Knot Nematode	Hot/Wet – Low risk of infestation of Root-Rot Nematode Hot/Dry – High risk of infestation of Root-Rot Nematode
	White Grubs	Hot/Wet – Moderate risk of infestation of White Grubs Hot/Dry – Low risk of infestation of White Grubs
GROUNDNUT	Leaf Scorch	Hot/Wet – High risk of infection of Leaf Scorch Hot/Dry – High risk of infection of Leaf Scorch
	Web Blotch	Hot/Wet – Moderate risk of infection of Web Blotch Hot/Dry – No risk of infection of Web Blotch
	Peanut Clump Virus (PCV)	Hot/Wet – High risk of significant infection of *P. graminis* and high risk of infection of PCV Hot/Dry – Low risk of significant infection of *P. graminis* and low risk of infection of PCV
SESAME	Green Stink Bug	Hot/Wet – Low risk of infestation of Green Stink Bug Hot/Dry – Moderate risk of infestation of Green Stink Bug
CASSAVA	Cassava mosaic virus disease (CMD)	Hot/Wet – Low risk of infection of *B. tabaci* and low risk of infection of CMD Hot/Dry – High risk of infection of *B. tabaci* and high risk of infection of CMD
	Cassava Green Mite (CGM)	Hot/Wet – Low risk of infestation of Cassava Green Mite Hot/Dry – High risk of infestation of Cassava Green Mite
SWEET POTATO	Nematodes	Hot/Wet – Moderate risk of infestation of Nematodes Hot/Dry – Low risk of infestation of Nematodes
	Charcoal Rot	Hot/Wet – Moderate risk of infection of Charcoal Rot Hot/Dry – Low risk of infection of Charcoal Rot
	Rhizophus Soft Rot	Hot/Wet – High risk of infection of Rhizophus Soft Rot Hot/Dry – Moderate risk of infection of Rhizophus Soft Rot

LOW/SPORADIC		
AFFECTED SPECIES	***PEST OR DISEASE***	***CLIMATE IMPACT***
MAIZE	African Sugarcane Borer	Hot/Wet – Low risk of infestation of African Sugarcane Borer Hot/Dry – Moderate risk of infestation of African Sugarcane Borer
	Rust	Hot/Wet – Low risk of outbreak of Rust Hot/Dry – No risk of outbreak of Rust
CASHEW	Thrips	Hot/Wet – No risk of infestation of Thrips Hot/Dry – High risk of infestation of Thrips
SHEA NUT	Bark Borer	Hot/Wet – Low risk of infestation of Bark Borer Hot/Dry – High risk of infestation of Bark Borer
	Fruit Fly	Hot/Wet – Low risk of infection of Fruit Fly Hot/Dry – Low risk of infection of Fruit Fly
	Mistletoe, Hemi-Parasitic Plant	Hot/Wet – Assessment not possible Hot/Dry – Assessment not possible
BOURGOU (ECHINOCHLOA STAGNINA)	Maize Streak Virus	Hot/Wet – Low risk of infestation of *Cicadulina* and low risk of transmission of MSV Hot/Dry – High risk of infestation of *Cicadulina* and high risk of transmission of MSV
AFRICAN LOCUST BEAN (NERE)	Mistletoe (Hemi-Parasitic Plants)	Hot/Wet – Assessment not possible Hot/Dry – Assessment not possible
	Brown Root Rot	Hot/Wet – Moderate risk of infection of Brown Root Rot Hot/Dry – Low risk of infection of Brown Root Rot
	Cercospora Leaf Spot	Hot/Wet – Very high risk of infection of Cercospora Leaf Spot Hot/Dry – No risk of infection of Cercospora Leaf Spot
	Hypoxylon Canker	Hot/Wet – Low risk of infection of Hypoxylon Canker Hot/Dry – Moderate risk of infection of Hypoxylon Canker
COWPEA	Cowpea weevil	Hot/Wet – Moderate risk of infestation of Cowpea Weevil Hot/Dry – Low risk of infestation of Cowpea Weevil
	Cercospora Leaf Spot	Hot/Wet – Very high risk of infection of Cercospora Leaf Spot Hot/Dry – No risk of infection of Cercospora Leaf Spot

SESAME	Common Blossom Thrip	Hot/Wet – Moderate risk of infestation of Common Blossom Thrip Hot/Dry – Low risk of infestation of Common Blossom Thrip
	Cowpea Pod-Sucking Bugs, Giant Coreid Bug or Tip Wilter	Hot/Wet – Moderate risk of infestation of Cowpea Pod-Sucking Bugs Hot/Dry – High risk of infestation of Cowpea Pod-Sucking Bugs
	Cluster Bug, Sorghum Bug	Hot/Wet – Moderate risk of infestation of Cluster Bug Hot/Dry – No risk of infestation of Cluster Bug
	Death's-Head Hawkmoth	Hot/Wet – Low risk of infestation of Death's Head Hawk Moth Hot/Dry – Moderate risk of infestation of Death's Head Hawk Moth
	Gall Fly or Simsim Gall Midge	Hot/Wet – Low risk of infestation of Gall Fly Hot/Dry – Moderate risk of infestation of Gall Fly
SWEET POTATO	Mole Cricket	Hot/Wet – Low risk of infestation of Mole Cricket Hot/Dry – Moderate risk of infestation of Mole Cricket
	Sweet Potato Tortoise Beetle	Hot/Wet – Low risk of infestation of Sweet Potato Tortoise Beetle. Hot/Dry – Low risk of infestation of Sweet Potato Tortoise Beetle.

CEREALS

FONIO

FONIO PESTS

FLOUR BEETLES[i,ii,iii]

Tribolium castaneum, T. confusum, and *Ephestia cautella*

- Damage: Causes serious damage in storage. *T. castaneum* is a major pest of cereal grains and their products in storage.
- Mode of Transmission: The infestation occurs when contaminated products are introduced into storage. This pest can be found under the bark of trees and in rotting logs. Insects may readily fly from heavy silo infestations when conditions are suitable.
- Impact: Pest status is considered to be secondary, requiring prior infestation by an internal feeder. It can readily infest grains damaged in the harvesting operation. Compared to pearl millet, fonio is the most resistant to *C. cephalonica* but can be heavily attacked by *T. confusum* and *E. cautella*. In dry Sahelian countries, proper crop storage is a matter of subsistence and survival.

Environmental Conditions	Climate Change Impacts	
Can complete development within a wide range of temperatures and relative humidity conditions. Adult development can be reached in as little as 20 days if the temperature is between 20-37.5 °C and the relative humidity (RH) is greater than 70 percent. *T. confusum* can develop in environments with RH as low as 10 percent, a level that is prohibitive for the development of most other stored product insect pests.	Hot/Wet	**High risk of increased incidence of Flour Beetles**
	Hot/Dry	**Low risk of increased incidence of Flour Beetles**

STRIGA WITCHWEED[iv,v]

Striga senegalensis

- Damage: This parasitic weed attacks all the plant stages and plant parts. It can impact flowering, podding, pre-emergence, seedling and vegetative phase, the leaves, stems, and whole plant.
- Mode of transmission: Striga is difficult to control, as it produces thousands of small and light seeds per plant that are easily and widely dispersed by wind, water, animals, and agricultural implements. They also can lie dormant but still potentially active for many years.
- Impact: In West Africa, it is estimated that about 40 million hectares in cereal production are severely infested by Striga, and farmers usually abandon those fields.

Environmental Conditions	Climate Change Impacts	
Tolerate a wide range of climatic and soil conditions. Develop in areas with an annual rainfall between 250 to 1500 mm. The optimum temperature for seed germination is between 30-40 °C, with no germination lower than 15 °C or higher than 45 °C.	Hot/Wet	**High risk of infestation of *Striga senegalensis***
	Hot/Dry	**Low risk of infestation of *Striga senegalensis***

FONIO FUNGAL DISEASES

LEAF SPOT DISEASE (LSD)[vi,vii]

Helminthosporium spp., *Phyllachora sphearosperma*

- Damage: Produces small spots or lesions of different colors (from reddish brown to purplish black). Lesions appear on the leaves from early spring to late fall. Lesions may increase rapidly in size and become round to oval, oblong, elongate, or irregular. Spots are commonly surrounded by brown to black borders.
- Mode of transmission: It survives in the decomposing flesh of infected plants. The fungus can live for several years in rotting foliage or stems. Most *Helminthosporium* species are favored by moderate to warm temperatures (18 °C to 32 °C) and particularly by humid conditions.
- Impact: Yield losses due to LSD are variable but are considered to be very significant. In farmer's fields, losses up to 20 percent have been reported; in several areas it is the major biotic constraint on fonio.

Environmental Conditions	Climate Change Impacts	
These diseases reduce vigor and can be very destructive during wet, humid weather, especially in late afternoon and early evening, in poorly drained areas, and where it is shady. The more often and longer the plant remains wet, the greater the chance of disease. Dry periods alternating with prolonged clouds, moisture, and moderate temperatures promote the disease.	Hot/Wet	**Very high risk of outbreak of Leaf Spot Disease**
	Hot/Dry	**No risk of outbreak of Leaf Spot Disease**

STEM RUST[viii,ix]

Puccinia graminis

- Damage: In cereals or grasses, the infection tends to take place on stems and leaf sheaths, but they occasionally can be also found on leaf blades and glumes. The first visual symptom is usually a small chlorotic fleck, which appears a few days after infection. Rust causes loss of photosynthetic area, chlorosis, and premature leaf senescence, which leads to incomplete grain filling and yield losses.
- Mode of transmission: Stem rust is highly mobile, spreading rapidly over large distances by wind or via accidental human transmission (e.g., infected clothing).
- Impact: It has the capacity to turn a healthy-looking crop, only weeks away from harvest, into nothing more than a tangle of black stems and shriveled grains at harvest. Under

suitable conditions, yield losses of 70 percent or more are possible.

Environmental Conditions	Climate Change Impacts	
Severe epidemics occur when higher than average temperatures and frequent rains favor infection. In general, it occurs where the growing season is characterized by mild temperatures, high relative humidity, and high moisture.	Hot/Wet	**Very high risk of outbreak of Stem Rust**
	Hot/Dry	**No risk of outbreak of Stem Rust**

MAIZE

MAIZE PESTS

AFRICAN SUGARCANE BORER[x,xi,xii]

Eldana saccharina

- Damage: Attacks maize during late vegetative stage. Prior to pupation, larvae make an exit hole in the stem, which often has a large amount of frass hanging from it.
- Mode of transmission: The African sugarcane borers may be present in older crops and in crop residues. Caterpillars and pupae can be found inside stems and infest new crops when finding proper conditions.
- Impact: Sugarcane is the main crop host of the African sugarcane borer but it also will attack maize (where it is a relatively minor pest), sorghum, and rice. It attacks maize plants late in their development when it can affect grain filling, which results in yield loss.

Environmental Conditions	Climate Change Impacts	
Plants under stress are more susceptible to be attacked by the borer; extreme conditions such as drought therefore can favor attacks. Generally borers reach higher levels of infestation during the second growing season.	Hot/Wet	**Low risk of infestation of African Sugarcane Borer**
	Hot/Dry	**Moderate risk of infestation of African Sugarcane Borer**

MAIZE STALK BORER (a.k.a. African Stalk Borer)[xiii,xiv,xv]

Busseola fusca

- Damage: Larval stages (caterpillars) cause damage to maize by feeding on young leaves, from where they can enter the stems. This action may kill the plant. In older plants, their feeding damage can reduce grain production.
- Mode of transmission: Maize Stalk Borer is an indigenous African moth that has larvae (caterpillars) that bore into grasses with thick stems. They can survive in crop residues. For instance, pupae are found in old stems and stubble, which can then establish in the following season's crops.
- Impact: In some places, Maize Stalk Borer is considered to reduce maize production between 10 and 70 percent. Damage to sorghum is usually less serious than damage to maize because sorghum easily tillers, which partly can compensate for the damage.

Environmental Conditions	Climate Change Impacts	
Temperature, rainfall, and humidity are factors responsible for the distributions of stem borers, with temperature being the most important. Borers thrive in a warmer climate and with reduced rain.	Hot/Wet	**Low risk of infestation of Maize Stalk Borer**
	Hot/Dry	**High risk of infestation of Maize Stalk Borer**

PINK STEM BORER[xvi,xvii,xviii]

Sesamia calamistis

- Damage*:* The larvae usually cause the damage; their feeding leads to the death of the growing points, early senescence, "dead heart" condition, reduced translocation, lodging, and indirect damage to the ears. Pre-tasseling is the most attractive stage at which the plant is susceptible to attack.
- Mode of transmission*:* The African Pink Stem Borer breeds throughout the year and has no period of suspended development. They can survive in maize residues as larvae and pupae stay within the stems, as well as volunteer crop plants and/or alternative hosts.
- Impact*:* Affects flowering stage and vegetative growing stage of maize. Occurs throughout Sub-Saharan Africa but is only a serious pest of cultivated cereals in West Africa.

Environmental Conditions	Climate Change Impacts	
Borer populations peak with low rainfall and high temperatures. High rainfall is an important mortality factor of stem borers in most agro-ecosystems. Heavy rains could reduce the incidence of stem borers by preventing contact of males and females for mating, increasing predation, and washing off eggs and newly hatched larvae.	Hot/Wet	**Low risk of infestation of Pink Stem Borer**
	Hot/Dry	**High risk of infestation of Pink Stem Borer**

SPOTTED STEM BORER[xix,xx,xxi]

Chilo partellus

- Damage: *Chilo partellus* lays its eggs on the lower surfaces of maize leaves near the midrib; upon hatching, early instars move into the whorl, where they begin feeding on leaves.
- Mode of transmission: Spotted Stem borers may infest older crops and crop residues, where they can move into the next season's crops.
- Impact: *Chilo partellus is* one of the important stem borers. This species causes maize losses estimated at about 13 percent. *B. fusca* and *C. partellus* attacked the crop from seedling stage until harvest.

Environmental Conditions	Climate Change Impacts	
It is found in warmer regions. Relative humidity and wind velocity had significant positive correlation with infestation. Larvae population negatively correlated with very high temperatures, but positively correlated with elevated relative humidity. Pupal population did not exhibit any consistent relationship with any abiotic factors.	Hot/Wet	**Low risk of infestation of Spotted Stem borer**
	Hot/Dry	**Low risk of infestation of Spotted Stem borer**

MAIZE FUNGAL DISEASES

DOWNY MILDEW[xxii,xxiii,xxiv,xxv]

Several species of the genera *Peronosclerospora, Sclerospora,* and *Sclerophthora*

- Damage: The expression of symptoms is affected by plant age, pathogen species, and environment. Usually there is chlorotic striping or partial symptoms in leaves and leaf sheaths, along with dwarfing. Downy mildew becomes conspicuous after development of a downy growth on or under leaf surfaces. Leaves may become narrow, thick, and abnormally erect.
- Mode of transmission: Primary inoculum comes from oospores over-seasoning in contaminated soil or plant debris or from mycelium in infected seed. Maize seed may be contaminated in two ways. The seed surface may carry plant debris containing viable oospores, and the seed may carry oospores or mycelium within the embryo.
- Impact: Causes severe infection on susceptible maize genotypes in areas of high rainfall, where the disease is common and can occur at 20 to 70 percent incidence. In some locations, disease incidence can be as high as 100 percent.

Environmental Conditions	Climate Change Impacts	
The disease is most likely to occur in warmer, humid regions. Moist soils favor oospore germination, and therefore damp soil from irrigation or reduced tillage techniques will encourage disease development.	Hot/Wet	**Very high risk of outbreak of Downy Mildew**
	Hot/Dry	**No risk of outbreak of Downy Mildew**

GRAY LEAF SPOT (GLS), CERCOSPORA LEAF SPOT[xxvi,xxvii,xxviii,xxix]

Cercospora zeae-maydis

- Damage: Can result in severe leaf senescence following flowering and in poor grain fill. Also causes loss of photosynthetic leaf area, which results in reduced yield (in excess of 70 percent).
- Mode of transmission: Maize is most vulnerable following full canopy development, which results in high relative humidity within the crop canopy.
- Impact: GLS has become increasingly important and is currently seen as one of the most serious yield-limiting diseases of maize. It is the most important maize foliar disease in sub-Saharan Africa.

Environmental Conditions	Climate Change Impacts	
May occur in subtropical and temperate, humid areas. GLS is favored by temperatures in the range of 22 to 30 °C. Overcast, cloudy days can increase severity of the disease. Optimal disease conditions in the early part of the season could increase severity as inoculum levels are able to increase. The crop is most vulnerable following full canopy development, which results in high relative humidity within the crop canopy. The disease tends to be more prevalent in regions where reduced tillage techniques have been adopted.	Hot/Wet	**Very high risk of outbreak of GLS**
	Hot/Dry	**No risk of outbreak of Gray Leaf Spot**

MAYDIS LEAF BLIGHT (MLB)[xxx,xxxi,xxxii]

Bipolaris maydis

- Damage: Causes loss of photosynthetic leaf area due to foliar lesions that later reduce production for grain filling. Further damage is caused by lodging, which occurs when plants divert sugars from the stalks for grain filling during severe disease pressure. Young lesions are small and diamond shaped. As they mature, they elongate.
- Mode of transmission: The pathogen is only able to overwinter in infected crop debris, so management of crop debris between growing seasons can help reduce the initial amount of inoculum.
- Impact: MLB is most serious in warm and wet temperate and tropical areas, where yield losses close to 70 percent have been reported due to the disease. Several races of *B. maydis* are pathogenic to maize. Symptoms and severity of *B. maydis* depend on the pathogen race and host germplasm.

Environmental Conditions	Climate Change Impacts	
The amount of rainfall, relative humidity, and temperature of the area is critical to the spread and survival of disease. This is because MLB prefers a warm, moist climate.	Hot/Wet	**Very high risk of outbreak of Maydis Leaf Blight**

Environments with warm temperatures (20 °C to 32 °C) and a high humidity level are particularly conducive to MLB. On the other hand, long and sunny growing seasons with dry conditions are highly adverse.	Hot/Dry	**Low high risk of outbreak of Maydis Leaf Blight**

RUST[xxxiii,xxxiv,xxxv,xxxvi]

Puccinia sorghi

- Damage: This disease causes leaf damage due to loss of photosynthetic area (due to chlorosis and premature leaf senescence), which leads to incomplete grain filling and yield losses. Common rust is most noticeable when plants are close to tasseling.
- Mode of transmission: Occurs where the growing season is characterized by mild temperatures, high relative humidity, and high moisture. Late planted maize is particularly vulnerable to common rust.
- Impact: The main effect of common rust is a reduction of grain yield. Only small losses are generally reported in the corn-growing areas of the world, but the disease has the potential to damage susceptible genotypes.

Environmental Conditions	Climate Change Impacts	
Occurs where the growing season is characterized by mild temperatures, high relative humidity, and high moisture. Unlike other fungi, rust favors cool temperatures (below 24 °C). Late planted maize is very vulnerable to common rust.	Hot/Wet	**Low risk of outbreak of Rust**
	Hot/Dry	**No risk of outbreak of Rust**

MAIZE VIRAL DISEASES

MAIZE STREAK VIRUS (MSV) [xxxvii,xxxviii,xxxix,xl]

- Damage: Yield loss is caused by plant stunting and the termination of ear formulation, development, and grain filling in infected plants. With severe infection, plants can die prematurely. Early disease symptoms begin within a week after infection and consist of very small, round, scattered spots in the youngest leaves.
- Mode of transmission: Like many other viruses, MSV depends on insect vectors for transmission between host plants. MSV is primarily transmitted by leafhopper species *Cicadulina mbila*, but other leafhopper species such as *C. storeyi*, *C. arachidis,* and *C. dabrowski* can also transmit the virus to the plants.
- Impact: It is an important economic disease occurring in most sub-Saharan African countries. Yield losses can range from a trace to virtually 100 percent.

Environmental Conditions	Climate Change Impacts	
Many cereal crops and wild grasses serve as reservoirs of the virus and the vectors. Outbreaks of maize streak have been associated with drought and irregular rain in west Africa. As maize streak is vector transmitted, disease outbreaks depend on favorable conditions for viruliferous leafhoppers of the genus *Cicadulina*.	Hot/Wet	**Low risk of severe infestation of MSV vector leaf grasshoppers**
	Hot/Dry	**Moderate risk of severe infestation of MSV vector leaf grasshopers**

PEARL MILLET

PEARL MILLET PESTS

MILLET EARHEAD CATERPILLAR, MILLET HEAD MINER[xli,xlii]

Rhaguva albipunctella, Heliocheilus albipunctella

- Damage: Larval instars eat florets and peduncles, thereby killing the developing grains and creating mines around the rachis. When mature, they drop to the ground, where they burrow into the soil to pupate, usually close to the host plant.
- Mode of transmission: Fly period of the adult moth coincides with the peak of millet panicle emergence and flowering. Caterpillars eat and finish the larval development inside panicles. During this period the seed head also grows and develops, passing from emergence through flowering to grain-filling and maturity.
- Impact: It was very destructive in the Sahelian regions of West Africa in the early 1970s. Now percentages of crop losses vary from 1 percent to 41 percent, with a mean of 20 percent.

Environmental Conditions	Climate Change Impacts	
Soil temperature and moisture are critical in determining the survival of diapausing pupae. Moths become active at 25-29 °C and between a 20-30 percent increase in air humidity.	Hot/Wet	**Low risk of infestation of Millet Earhead Caterpillar**
	Hot/Dry	**Moderate risk of infestation of Millet Earhead Caterpillar**

MILLET GRAIN MIDGE[xliii,xliv]

Geromyia penniseti

- Damage: Millet midges damage flower spikelets, leading to poor seed set.
- Mode of transmission: Diapause termination and subsequent emergence of adult midges occurs in response to warm, moist soil conditions. Environmental conditions can increase the size of the pest population and the severity of infestation.
- Impact: It is reported that they cause severe grain yield reduction of mid-season millets.

Environmental Conditions	Climate Change Impacts	
Soil temperature and moisture are critical in determining the survival of diapausing pupae. Moths become active at 25-29 °C and between a 20-30 percent increase in air humidity.	Hot/Wet	**Moderate risk of infestation of Millet Grain Midge**
	Hot/Dry	**Low risk of infestation of Millet Grain Midge**

MILLET STEM BORERS[xlv,xlvi]

Acigona ignefusalis, Sesamia calamistis

- Damage: The damage starts from the seedling stage and continues till maturity. Early-sown millet attacked by first-generation larvae damage young plants and cause dead-hearts. Seedlings of late-sown millet are exposed to larger populations of second or third-generation larvae, which produce extensive tunnels in the stems that may kill the plant. On older plants, stem tunneling may cause lodging and panicle damage due to disruption of the vascular system, which prevents grain formation.
- Mode of transmission: Larvae and pupae over wintering on the stubbles, which serves as a chief source of infestation in the succeeding seasons.
- Impact: *S. calamistis* is generally less important than *other* pests of cereal crops in Africa but may be locally significant and abundant.

Environmental Conditions	Climate Change Impacts	
Borer populations peak with low rainfall and high temperatures. However, larvae populations can be drastically reduced when temperatures exceed 40 °C.	Hot/Wet	**No risk of infestation of Millet Stem Borer**
	Hot/Dry	**High risk of infestation of Millet Stem Borer**

WITCHWEED[xlvii,xlviii,xlix]

Striga hermonthica, Striga asiatica

- Damage: Striga will parasitize millet plants and prevent root development and nutrient uptake. Severe attack produces leaf wilting and chlorosis. Infected plants may be stunted and die before seed set.
- Mode of transmission: This weed is naturally widespread in Africa. *Striga* is difficult to control, as it produces thousands of small and light seeds per plant that are easily and widely dispersed by wind, water, animals, and agricultural implements. They also can lie dormant but still potentially active for many years.
- Impact: They are an important problem in Senegal. Large areas of pearl millet in the Sahel have been devastated by *S. hermonthica.*

Environmental Conditions	Climate Change Impacts	
Striga seeds will germinate better under conditions of sufficient moisture and warm temperatures (i.e., available soil moisture adequate for seed imbibition at temperatures between 20 and 33 °C). The higher transpiration rate of *S. hermonthica* even under water stress and greater stomatal aperture may induce the maintenance of water and solutes transfer from the host to the parasite, leading to severe damage to the host under drought.	Hot/Wet	**Low risk of severe parasitism of Witchweed**
	Hot/Dry	**Moderate risk of severe parasitism of Witchweed**

PEARL MILLET BACTERIAL DISEASES

BACTERIAL LEAF STREAK[l]

Xanthomonas campestris pv. pennamericanum

- Damage: Symptoms are not clearly defined in the literature but are apparently similar to those of bacterial leaf stripe and streak of sorghum. So symptoms are seen as narrow, dark-greenish, water-soaked, inter-veinal streaks of various lengths on the leaf blades.
- Mode of transmission: *Xanthomonas* is both soil-borne and seed-borne. It is also transmitted by infected plant debris. Optimal growth occurs between 26 °C and 30 °C, and rain can help spread the inoculum among plants.
- Impact: BLS is reported from Nigeria and Senegal. It is reported to be a pest of moderate importance.

Environmental Conditions	Climate Change Impacts	
High temperature and high humidity favor disease development. Optimal growth occurs between 26 and 30 °C. Some reports indicate an optimal temperature at 28 °C. Rain and high humidity favor development of the disease.	Hot/Wet	**Very high risk of outbreak of Bacterial Leaf Streak**
	Hot/Dry	**No risk of outbreak of Bacterial Leaf Streak**

PEARL MILLET FUNGAL DISEASES

DOWNY MILDEW[li,lii]

Sclerospora graminicola

- Damage: Symptoms often vary as a result of systemic infection. Leaf symptoms begin as chlorosis at the base, and successively higher leaves show progressively greater chlorosis. Severely infected plants are stunted and do not produce panicles. Green ear symptoms result from transformation of floral parts into leafy structures.
- Mode of transmission: Evidence for transmission by seed is inconsistent and controversial. It has been suggested that this disease can be transmitted by oospores on the seed surface.
- Impact: It is the most important fungal disease in millets in Senegal.

Environmental Conditions	Climate Change Impacts	
Asexual sporangia are produced during the night with moderate temperatures and high humidity. Optimum sporangium production occurs at 20 °C. No sporulation takes place below 70 percent of relative humidity. In favorable conditions, disease cycles are rapid, leading to severe infection and spread of disease.	Hot/Wet	**Very high risk of outbreak of Downy Mildew**
	Hot/Dry	**No risk of outbreak of Downy Mildew**

RICE

RICE PESTS

AFRICAN RICE GALL MIDGE (AfRGM)[liii]

Orseolia oryzivora

- Damage: The larvae produce serious damage in the rice crop, in particular, throughout the vegetative periods (seedling to panicle initiation) by producing tube-like "silver shoot" or "onion leaf" galls that block panicle formation and restrict production.
- Mode of transmission: Volunteer rice plants, weeds (in particular, *Oryza longistaminata),* and ratoons (tillers that sprout from rice stubble) act as alternative hosts for premature population build-up in the wet season before rice crops are planted.
- Impact: Severe yield losses have been reported in countries where AfRGM is endemic (25 to 80 percent). This is a significant insect pest of rain-fed and irrigated lowland rice in Africa, especially in Burkina Faso, Nigeria, Mali, and Sierra Leone.

Environmental Conditions	Climate Change Impacts	
The insect is favored by a wet-season weather pattern. It is reported that cloudy, humid weather with frequent rain and mist promotes AfRGM development more than heavier, sporadic rainfall. Outbreaks tend to happen in years that are rainier than normal.	Hot/Wet	**High risk of infestation of African Rice Gall Midge**
	Hot/Dry	**Low risk of infestation of African Rice Gall Midge**

AFRICAN STRIPED RICE BORER[liv,lv,lvi]

Chilo zacconius

- Damage: Plant damage is similar to other stem borers. Feeding inside the stem during the vegetative stage prevents the central leaf whorl from opening; instead, it turns brown and withers. The apical reproductive portion of the tiller is destroyed, and the tiller fails to produce a panicle. Larval feeding at the panicle initiation stage or thereafter prevents the development of the panicle, resulting in a whitehead.
- Mode of transmission: It attacks both cultivated and wild gramineous plants, which serve as alternate hosts (larvae can survive during the off-season, when rice is not available).
- Impact: It is the predominant rice stem borer in West Africa. In the irrigated Sahel region, it is a major stem borer species.

Environmental Conditions	Climate Change Impacts	
Dry-season crops are almost free of borers, while the main-season crop is heavily attacked. Environmental conducive factors favoring the pest are indicated as cold dry weather with high humidity and low temperature and presence of stubble of previous crop. In general, mild, cool seasons are favorable for the development of the insect.	Hot/Wet	**Low risk of infestation of African Striped Rice Borer**
	Hot/Dry	**Low risk of infestation of African Striped Rice Borer**

AFRICAN WHITE BORER[lvii,lviii,lix]

Maliarpha separatella

- Damage: Larval damage within the stem results in reduced plant vigor, fewer tillers, and many unfilled grains. The larva does not cause *deadhearts* because the growing apical portion of the plant is not cut from the base. Thus, panicles can be initiated at the last node. An early infestation can result in white panicles; but if the panicle develops, the larvae affect neither maturation nor grain fertility but rather reduce grain weight.
- Mode of transmission: The white borer lays egg masses during the vegetative stages of the plant.
- Impact: It is the most common stem borer attacking rice in Africa. It is a specific pest of the *Oryza* genus. It is found only on cultivated and wild rice (*O. barthii, O. longistaminata,* and *O. punctata*).

Environmental Conditions	Climate Change Impacts	
Most abundant in rain-fed lowland and irrigated ecosystems. Moderate and cool environments favor development of the white borer.	Hot/Wet	**Low risk of infestation of African White Borer**
	Hot/Dry	**Low risk of infestation of African White Borer**

BIRDS[lx,lxi]

Red-billed Quelea (*Quelea quelea*). Other bird species causing damage to cereal crops in West Africa include the Spur-winged Goose (*Plectropterus gambensis*), Knob-billed Goose (*Sarkidiornis melanota*), Village Weaver (*Ploceus cucullatus*), Black-headed Weaver (*Ploceus melanocephalus*), Red-headed *Quelea* (*Quelea erythrops*), and Golden Sparrow (*Passer luteus)*

- Damage: Birds typically feed on wild annual grasses, but when this natural source becomes scarce during the dry season, cultivated cereals become their alternative food source.
- Impact: The Red-billed *Quelea* is one of the most notorious pest bird species in the world. It is considered the most abundant bird worldwide. It occurs in sub-Saharan Africa, where it gathers in vast flocks of several million and breeds in gregarious colonies that can cover more than 100 hectares.

Environmental Conditions	Climate Change Impacts	
Birds are a rather specific pest species on cereal crops in Africa due to the fact that they can migrate (seasonally) over long distances, occur in great numbers, and have a flexible diet of which agricultural crops may only be a part. Great variability exists in the occurrence and extent of the damage because there are many factors influencing bird damage, such as field size, composition of the surrounding vegetation, timing of cropping, climate, etc. Often, the breeding season begins with the onset of seasonal rains. If the dry season starts early, a breeding colony may be abandoned. Alternatively, if the rainy season is prolonged, then several more clutches of eggs are laid.	Hot/Wet	**High risk of infestation of birds**
	Hot/Dry	**Low risk of infestation of birds**

RICE GRASSHOPPERS[lxii,lxiii,lxiv]

Short-Horned Grasshoppers: *Atractomorpha* spp., *Chrotogonus* spp., *Hieroglyphus africanus, H. daganensi, Oxya hyla,* and *Zonocerus variegatus*

Long-Horned Grasshopers: *Conocephalus* spp.

- Damage: They produce holes in leaves, causing injuries similar to those caused by armyworms. Both nymphs and adults feed on leaf tissue, consuming large sections from the edges of leaf blades.
- Impact: They are most important on irrigated rice grown in dry zones of the Sahel, because

rice is a major form of green vegetation during the hot dry season, and insects congregate there. About 30 grasshopper species attack rice, but most are not of economic importance. They also feed on many other hosts including maize, millet, sugarcane, and many grasses in West Africa.

Environmental Conditions	Climate Change Impacts	
They can cause considerable damage to crops that are grown during the dry season months. Grasshoppers require warm, sunny conditions for optimal growth and reproduction.	Hot/Wet	**Low risk of significant outbreak of rice grasshoppers**
Drought stimulates grasshopper population increase, apparently because there is less rainfall and cloudy weather to interfere with grasshopper activity. A single season of such weather is not adequate to stimulate massive population increase; rather, two to three years of drought usually precede grasshopper outbreaks.	Hot/Dry	**High risk of significant outbreak of rice grasshoppers**

RICE WEEVIL (RW)[lxv,lxvi]

Lissorhoptrus oryzophilus

- Damage: The adults cause feeding scars on leaves, but major damage is created by larvae that feed on the roots. Reduced root volume negatively impacts plant growth, and heavy infestations can delay maturity and reduce yield.
- Mode of transmission: RW overwinters in grasses and leaf litter. They emerge from diapause and invade rice fields to feed on the leaves of seedlings. Eggs are deposited in foliage sheath at or below the water line.
- Impact: They cause damage in flooded fields that are adjacent to mangrove swamps. It has been suggested that this situation may have potential to cause serious damage to rice in West Africa.

Environmental Conditions	Climate Change Impacts	
When daytime temperatures climb above 21°C, rice weevil adults begin feeding on grasses to build up their wing muscles. On calm, warm evenings (sunset to midnight), they fly in search of plant hosts growing in water. They are attracted to flooded rice fields and begin feeding on emerged rice or grasses in water along the levee banks.	Hot/Wet	**Moderate risk of infestation of Rice Weevil**
	Hot/Dry	**Low risk of infestation of Rice Weevil**

SPIDER MITES[lxvii]

Oligonychus pratensis, O.senegalensis, *Tetranychus neocaledonicus*

- Damage: Suck sap from leaves and produce large masses of webbing. They often feed under the leaves, which become bleached with white patches and dry up starting from the leaf tip. Later, plants become stunted with deformed panicles and empty spikelets. Spider mites can generally feed on the rice crop at all growth stages

- Impact: Spider mites are more important constraints to rice production than are the whiteflies. They are extremely small arthropods that are important pests of rice in the Sahel area of West Africa.

Environmental Conditions	Climate Change Impacts	
Spider mite development is favored by hot, dry conditions. In Senegal, it has been reported that at temperatures of 27 °C and 50 percent humidity, *T. neocaledonicus* can complete a life cycle in only 2 weeks	Hot/Wet	**Low risk of significant infestation of Spider Mites**
	Hot/Dry	**Moderate risk of significant infestation of Spider Mites**

WHITEFLY[lxviii,lxix,lxx]

Aleurocybotus indicus

- Damage: It damages plants by sucking sap from leaves. Honeydew excreted on the leaves has high sugar content, and a black sooty mold fungus grows on it. Extensive feeding and high amounts of sooty mold lead to wilting and death of the plants. Whitefly occurs on the plant from seedling to maturity stages.
- Mode of transmission: Whiteflies are driven by environmental fluctuations and will migrate to areas of favorable conditions, infesting the rice plants inhabiting those areas.
- Impact: Considered a major pest in Senegal, where yield losses have been reported to reach up to 80 percent.

Environmental Conditions	Climate Change Impacts	
The whitefly is a dry-season insect. High temperatures and low humidity favor its buildup.	Hot/Wet	**Low risk of severe infestation of Whitefly**
During the 1982–1983 dry season at Fanaye, Senegal, whitefly was present on the rice crops planted from September to February and was most severe on the crop planted in September.	Hot/Dry	**High risk of severe infestation of Whitefly**

RICE BACTERIAL DISEASES

BACTERIAL LEAF BLIGHT (BLB)[lxxi,lxxii,lxxiii]

Xanthomonas oryzae

- Damage: BLB can be observed on both seedlings and older plants. On seedlings, leaves turn grayish green and roll up; later they wilt, causing whole seedlings to dry up and die. On older plants, lesions are water-soaked to yellow-orange stripes on leaf blades. On young lesions, bacterial ooze resembles a milky dew drop. The ooze later dries up and becomes small yellowish beads underneath the leaf. The old lesions turn yellow to grayish white, with black dots due to the growth of various saprophytic fungi.
- Mode of transmission: Plants can become infected through rice seed, stem, and roots left behind at harvest. BLB can be transmitted by alternative weed hosts. *X. oryzae* survives on dead plants and seeds; it probably travels plant-to-plant via water from irrigation or rains.

- Impact: BLB is one of the most serious of all diseases that affect rice worldwide. Yield loss corresponds to the growth stages at which the plants were infected. The earlier the disease occurs, the higher the yield loss. Infection at booting stages does not affect yield but results in poor quality and a high proportion of broken kernels.

Environmental Conditions	Climate Change Impacts	
The disease occurs in both tropical and temperate environments, particularly in irrigated and rain-fed lowland areas. It is commonly observed when strong winds and continuous heavy rains occur.	Hot/Wet	**High risk of infection of Bacterial Leaf Blight**
Warm temperatures (25-30 °C), high humidity, rain, and deep water favor the disease. Wetland areas also encourage the presence of the disease. Severe winds, which cause wounds, are additional factors enhancing chances for the development of the disease.	Hot/Dry	**No risk of infection of Bacterial Leaf Blight**

RICE VIRAL DISEASES

RICE YELLOW MOTTLE VIRUS (RYMV)[lxxiv,lxxv,lxxvi,lxxvii]

Geminivirus

- Damage: RYMV is characterized by pale yellow mottle leaves, stunting, reduced tillering, non-synchronous flowering, and yellowish streaking of rice leaves. Malformation and incomplete emergence of panicles and sterility are observed on infected rice plants
- Mode of transmission: It gains entry into rice plants through injuries, which may be inflicted by insects (which also act as vectors) or mechanically during the course of crop cultivation; for example, damage to plants during hoe-weeding.
- Impact: RYMV is one of the most economically damaging diseases affecting rice in Africa.

Environmental Conditions	Climate Change Impacts	
About 12 insect species are known to transmit RYMV between rice plants, and from rice plants to alternative (weed) hosts. These include beetles and grasshoppers, which bite the plants, as well as leaf-sucking bugs.	Hot/Wet	**Low risk of infection of Rice Yellow Mottle Virus**
Thus, climate conditions that favor vectors correlate with RYNV outbreaks. For instance, drought stimulates grasshopper population increase, while warm, dry weather favors beetles.	Hot/Dry	**Moderate risk of infection of Rice Yellow Mottle Virus**

SORGHUM

SORGHUM PESTS

ANGOUMOIS GRAIN MOTH[lxxviii,lxxix]

Sitotroga cerealella

- Damage: The larva bores into the grain and remains there until it emerges as an adult from round emergence holes. The infested grain is completely hallowed out and filled with larval excreta.
- Mode of transmission: Infestation can begin in the fields where the insect bores inside grains. In storage, the infestation expands and is often confined to the upper layer of the grains.
- Impact: Important stored sorghum pest. It can cause losses of up to 50 percent during storage.

Environmental Conditions	Climate Change Impacts	
High temperature and poor storage hygiene are major factors resulting in insect infestation. Mild winter weather, hot dry summer weather, damp grain, and early harvest are conditions reported to take place in times of severe outbreaks.	Hot/Wet	**Low risk of infestation of Angoumois Grain Moth**
	Hot/Dry	**High risk of infestation of Angoumois Grain Moth**

KHAPRA BEETLE (KB)[lxxx,lxxxi,lxxxii]

Trogoderma granarium

- Damage: KB will feed on most any dried plant, but they prefer grain and cereal products.
- Mode of transmission: This pest hides in cracks and crevices and can survive for several years without food, making detection, control, or eradication very difficult. Finding larvae and cast skins could indicate beetle infestation.
- Impact: KB is considered to be one of the world's most destructive pests of grain products and seeds. If the beetle is left undisturbed in stored grain, it can cause significant weight loss and lead to significant reduction in seed viability. The presence of this pest creates trade restriction implications.

Environmental Conditions	Climate Change Impacts	
Complete development from egg to adult can vary significantly, from 26 to 220 days depending upon temperature. Optimum temperature for development is 35 °C.	Hot/Wet	**Low risk of infestation of Khapra Beetle**
Trogoderma granarium is a serious pest of stored products under hot dry conditions. Research under controlled conditions show that the beetle's breeding is slow at 25 °C and very slow at 22.5 °C; populations decline at 20 °C and below. The results indicated that cooling to 25 °C would be sufficient to prevent *T. granarium* populations from reaching levels of	Hot/Dry	**High risk of infestation of Khapra Beetle**

economic importance.		

SORGHUM APHID[lxxxiii,lxxxiv]

Melanaphis sacchari

- Damage: Attacked plants are sometimes stunted, leaves dry up, and yield is reduced. Young plants suffering from drought stress may be killed. The aphid also transmits the maize dwarf mosaic virus to sorghum. Aphids often suck on the underside of leaves. They produce large quantities of honeydew, which enable black sooty molds to grow.
- Mode of transmission: Under warm and dry conditions, the populations of sorghum aphid can reach large sizes at the time of flowering, which triggers significant infestation.
- Impact: High infestations can cause substantial yield loss. It is emerging as a serious pest of sorghum during periods of prolonged drought or low humidity.

Environmental Conditions	Climate Change Impacts	
Damage to sorghum is heavier in sandy soils, especially during dry periods. Well-developed seedlings tend to be more resistant than less-developed seedlings. Most damage is caused when the temperature is very high and humidity is very low, and natural enemies are still low in number.	Hot/Wet	**Low risk of infestation of Sorghum Aphid**
	Hot/Dry	**High risk of infestation of Sorghum Aphid**

SORGHUM MIDGE[lxxxv,lxxxvi,lxxxvii]

Stenodiplosis sorghicola

- Damage: Larvae of the sorghum midge feed on the ovary, thereby preventing normal seed development. Infested heads appear blighted or blasted and produce small, malformed grain.
- Mode of transmission: It is one of the most destructive pests to grain sorghum, and it is difficult to detect in the field. Infestations tend to be more common in areas where sorghum has been grown for several years and other host grasses are present. Larvae overwinter inside cocoons spun within the spikelets of sorghum, grasses, or other host-plant residues.
- Impact: It is one of the most important pests of sorghum in African countries. Sorghum midge is the most serious pest of sorghum worldwide. It annually destroys about 10-15 percent of the sorghum crop.

Environmental Conditions	Climate Change Impacts	
Emergence of adult midges occurs in response to warm, moist soil conditions. Temperatures between 20 and 30 °C are optimal for insect emergence. At 26 °C and humid conditions, more generations of the midge per year are possible.	Hot/Wet	**Moderate risk of infestation of Sorghum Midge**
	Hot/Dry	**Low risk of infestation of Sorghum Midge**

SORGHUM SHOOT FLY[lxxxviii,lxxxix]

Atherigona soccata

- Damage: Females lay eggs on the under-surface of leaves, near the midribs. After eggs hatch, larvae crawl to the plant whorl and move downward until they reach the growing point. When they feed, they cut the growing tip, which results in dying of the central leaf (deadheart).
- Mode of transmission: Fly infestation occurs when sorghum sowings are staggered due to erratic rainfall distribution.
- Impact: Damage may occur to the extent that plant population density is severely reduced. If plants survive, they often tiller excessively and produce less grain. Shoot fly is considered one of the major seedling insect pests of sorghum in West Africa.

Environmental Conditions	Climate Change Impacts	
Weather factors influence fly abundance. Rainfall appears to affect fly activity: the more rainfall, the more abundant are the flies. These relationships were negative during 1980 for Bambey and Louga because of drought. Shoot fly numbers are positively related to high humidity and cool temperature, as high temperatures did not favor fly abundance.	Hot/Wet	**Low risk of infestation of Sorghum Shoot Fly**
	Hot/Dry	**Low risk of infestation of Sorghum Shoot Fly**

STRIGA PURPLE WITCHWEED[xc,xci,xcii]

Striga hermonthica

- Damage: *S. hermonthica* causes characteristic yellowish blotches in the foliage. In later stages whole leaves may wilt, become chlorotic and dying. Stems are shortened, though leaf number may not be reduced. Inflorescence development is delayed or prevented. At least in early stages, root tissue can be penetrated by haustoria, which restricts nutrient uptake of the plant.
- Mode of transmission: *Striga* produces thousands of small and light seeds per plant that are easily and widely dispersed by wind, water, animals, and agricultural implements. They also can lie dormant, but still potentially active, for many years.
- Impact: *S. hermonthica* is responsible for more crop loss in Africa than any other individual weed species. One plant of *S. hermonthica* per host plant is estimated to cause approximately 5 percent loss of yield, and high infestations can cause total crop failure.

Environmental Conditions	Climate Change Impacts	
Optimum day/night temperatures for germination and attachment of *S. hermonthica* are reported at 30/20 °C and 35/25 °C, respectively. Deviations from the optimum significantly reduce germination and attachment to host.	Hot/Wet	**Low risk of parasitism of Striga Purple Witchweed**
	Hot/Dry	**High risk of parasitism of Striga**

S. hermonthica is very adaptive to adverse climatic conditions of increased osmotic potential and extreme temperature.		**Purple Witchweed**

SORGHUM FUNGAL DISEASES

ANTHRACNOSE[xciii,xciv]

Colletotrichum graminicola

- Damage: Anthracnose damages foliage and stems of grain sorghum. On susceptible plants, the peduncle becomes infected, and a brown sunken area with distinct margins develops. Fungus penetrates the soft pith tissue and causes discolorations. Peduncle infection inhibits the flow of water and nutrients to the grain, causing poor grain development. The extent of damage is related to the degree of host susceptibility, the environment, the aggressiveness of the strains, and the physiological status of the crop.
- Mode of transmission: Seasonal persistence is on infected crop residues and weed hosts; sporulation has been observed on sorghum stalks and stubble after overwintering in the field. Frequent rainfall during the development of the crop is especially beneficial to the development of the pathogen. There are reports that anthracnose can be seed-transmitted.
- Impact: Sorghum anthracnose is one of the most important diseases of sorghum, limiting grain production in most of the regions where sorghum is grown. Anthracnose can cause severe foliage damage, resulting in up to 46 percent yield loss in some countries of West Africa.

Environmental Conditions	Climate Change Impacts	
Anthracnose most often develops during the warm, humid conditions. Under humid conditions, grey/cream/salmon-colored spore masses are produced. In many instances leaves can be entirely blighted, and when it attacks the stem it is known as “stalk rot.”	Hot/Wet	**High risk of significant infection of Anthracnose**
	Hot/Dry	**No risk of significant infection of Anthracnose**

LEAF BLIGHT[xcv,xcvi,xcvii]

Helminthosporium turcicum

- Damage: Small reddish-purple or yellowish-brown spots usually develop on the leaves of infected seedlings. The spots can kill large parts of the leaves, which then dry to the extent that severely affected plants look as if they were burned.
- Mode of transmission: The causal fungus is carried on the seed and also lives in the soil on dead or decaying plant material. Seedlings readily can become infected and either die or develop into stunted plants. Spores are spread by wind or rain and infect other leaves and plants.
- Impact: If this disease becomes established on susceptible cultivars before panicle emergence, yield losses can approach 50 percent or higher.

Environmental Conditions	Climate Change Impacts	
Causes seed rot and seedling blight, especially in cool and excessively moist soil. Under warm, humid conditions, the disease may cause serious damage by killing all leaves before plants have matured.	Hot/Wet	**High risk of infection of Leaf Blight**
	Hot/Dry	**No risk of infection of Leaf Blight**

SORGHUM DOWNY MILDEW[xcviii,xcix,c]

Peronosclerospora sorghi

- Damage: Symptoms appear as chlorotic foliage. The first infected leaf shows chlorosis on the lower part of the lamina, which further grows to cover a large part of the leaves. The other infected leaves on the plant subsequently show more chlorosis.
- Mode of transmission: SDM can be spread by oospores on seeds or with plant debris, by wind, or in soil from infested areas. It can also be disseminated by conidia from infected plants and mycelium in seed and in living hosts.
- Impact: This is one of the most destructive diseases of sorghum worldwide. The disease is highly destructive due to the systemic nature of the infection, resulting in death of the plants or lack of grain formation in the panicles.

Environmental Conditions	Climate Change Impacts	
P. sorghi requires warm temperatures and high humidity to succeed. Moisture in soils ensures suitable germination of oospores. Conidia are also generated if the environment is proper, specifically when there has been rain, because moisture is a key factor. Rain or high humidity causes leaf wetness, which is the optimal environment for the pathogen to produce the conidia. A normal temperature range for production is 13-24 °C. If these conditions are met, wind will disperse numerous conidia. The conidia is a source of secondary inoculum.	Hot/Wet	**High risk of infection of Sorghum Downy Mildew**
	Hot/Dry	**No risk of infection of Sorghum Downy Mildew**

ZONATE LEAF SPOT[ci]

Gloeocercospora sorghi

- Damage: Foliar lesions appear as water-soaked spots that develop tan centers and dark brown borders. Lesions enlarge with time and become rather circular in shape and cover half or more of the leaf width. Concentric and irregular dark brown rings are often apparent, but may be absent in narrow-leafed varieties.
- Mode of transmission: Contaminated seed or soil-borne sclerotia initiate epidemics during warm, wet weather. Spores (conidia) produced in lesions can be disseminated within and between fields by wind and splashing water. The pathogen can survive in the soil for several years in the absence of a host.
- Impact: Zonate leaf spot can considerably reduce forage and seed yield. Crop rotation and deep tillage of residues are the primary management methods.

Environmental Conditions	Climate Change Impacts	
Conditions considered ideal for disease spread and development are unclear; however, it is reported that moderate to high temperatures with periods of high relative humidity and wet weather promote outbreaks. The impact of leaf wetness is not conclusive, but it is clear that wind and rain disperse the conidia.	Hot/Wet	**High risk of infection of Zonate Leaf Spot**
	Hot/Dry	**No risk of infection of Zonate Leaf Spot**

FIBER CROPS

COTTON

COTTON PESTS

COTTON APHID[cii,ciii,civ]

Aphis gossypii

- Damage: Initially leaves will yellow, and with an increasing number of aphids, the leaves will begin to curl. Continuing infestation can cause stems to become stunted and twisted. Leaves can be damaged to such an extent that they wilt and fall off. The effects of chlorosis and heavy sap loss through sucking severely reduce plant growth and health. The honeydew forms a sticky film on the leaves and supports sooty mold growth. This action impairs photosynthesis, weakening the plant even further. It may render fruits unmarketable.
- Mode of transmission: Infestation depends on environmental conditions that favor population development and migration to favorable places.
- Impact: Like most aphids, *A. gossypii* is an important virus vector; it can transfer about 70 different types, some of which may cause more damage than the aphid itself.

Environmental Conditions	Climate Change Impacts	
In temperate regions, *A. gossypii* is partly holocyclic; but in warmer areas, it will always reproduce asexually. Significant damage appears more likely when environmental conditions such as dry weather are already stressing cotton growth. It is unusually resistant to summer heat for an aphid. The generation time can be reduced under favorable conditions, so that it can produce up to 60 generations per year.	Hot/Wet	**Low risk of infestation of Cotton Aphid**
	Hot/Dry	**High risk of infestation of Cotton Aphid**

COTTON BOLLWORM[cv,cvi,cvii]

Helicoverpa armigera

- Damage: Newly hatched larvae initially feed on terminals, but larger larvae tend to move downward into the plant canopy to feed on blooms, large squares, and bolls. A single larva is capable of destroying several squares and bolls before pupating. Larvae attack all stages of plant growth. Larval feeding can result in seedlings being tipped out; chewing damage to squares and small bolls causes them to shed.
- Mode of transmission: *H. armigera* can move very easily due to natural migration and reach and contaminate cotton fields along their migration path.
- Impact: Chewed holes in maturing bolls prevent normal development and encourage boll rot. Chewing damage is mostly confined to fruit and may lead to yield loss.

Environmental Conditions	Climate Change Impacts	
Moths lay a large number of eggs, and the life cycle may be completed in a short time under warm conditions. However, under prolonged exposure to temperatures above 35 °C, survival is reduced as well as fertility and fecundity.	Hot/Wet	**Low risk of infestation of Cotton Bollworm**
	Hot/Dry	**High risk of infestation of Cotton Bollworm**

PINK BOLLWORM (PB)[cviii,cix]

Pectinophora gossypiella

- Damage: When the pest attacks developing fruits, it bores directly into the developing seeds. Due to this action, the weight of the bolls is drastically reduced, and the ginning percentage is reduced. Damaged seeds do not germinate, and many of them contain the overwintering pupae.
- Mode of transmission: PB infests wild cotton and other host plants; moth dispersal over hundreds of miles has been reported. At the time of flowering, each female moth lays several hundred eggs, in small groups on young cotton bolls, flower buds, or in the space between these and the bracts.
- Impact: It causes failure of buds to open, failure of fruit to shed, lint damage, and seed loss. PB is found in nearly all cotton-growing countries. In some of them, losses of about a quarter of the crop are quite common, and sometimes they are much higher.

Environmental Conditions	Climate Change Impacts	
Warmer temperatures and low humidity favor the development of the pest. Infestations may be reduced by the heating of cotton seeds at about 55 °C.	Hot/Wet	**Low risk of infestation of Pink Bollworm**
	Hot/Dry	**High risk of infestation of Pink Bollworm**

RED BOLLWORM (a.k.a Cotton Boll caterpilar)[cx,cxi]

Diparopsis watersi

- Damage: Cotton plants are the sole hosts for the larvae; it will attack at all development stages of the boll, which is normally completely destroyed.
- Mode of transmission: The moths lay eggs at the time of emergence. They take five days to hatch; after that period, larvae start feeding the plant.
- Impact: Poor control of this pest at the end of the season (e.g., failure to eliminate contaminated plant and debris) will generally lead to heavier attacks in the following season.

Environmental Conditions	Climate Change Impacts	
Warmer temperatures can increase the occurrence of these pests.	Hot/Wet	**Low risk of infestation of Red Bollworm**
	Hot/Dry	**High risk of infestation of Red Bollworm**

COTTON BACTERIAL DISEASES

ANGULAR LEAF SPOT, BACTERIAL BLIGHT OF COTTON[cxii,cxiii,cxiv]

Xanthomonas citri subsp. malvacearum

- Damage: This disease starts as angular leaf spot followed by black canker on stems and boll rot that produces discolored lint. It affects all growth stages, infecting stems, leaves, bracts, and bolls. It causes seedling blight, leaf spot, blackarm (on stem and petioles), and boll rot. Cotyledons can be distorted if infection is intense. On susceptible cultivars, it can cause chlorosis, necrosis and distortion, and eventually defoliation.
- Mode of transmission: Infested seeds are the main source of pathogen transmission.
- Impact: This is one of the most devastating bacterial diseases. The extent to which bacterial blight will impact cotton yield in infested fields will depend on environmental conditions.

Environmental Conditions	Climate Change Impacts	
It may cause severe defoliation during periods of warm weather and high humidity. The optimum temperature for infection falls between 20 and 30 °C. This pathogen is seed-borne.	Hot/Wet	**Very high risk of infection of Angular Leaf Spot**
	Hot/Dry	**No risk of infection of Angular Leaf Spot**

COTTON FUNGAL DISEASES

ANTHRACNOSE, PINK BOLL ROT, SEEDLING BLIGHT[cxv,cxvi]

Glomerella gossypii

- Damage: The disease is most serious on seedlings and bolls, but lesions also occur on the stems and leaves of plants, sometimes producing a scald-like effect. Seedlings from infected seeds wilt and die.
- Mode of transmission: *G. gossypii* is transmitted through seed and may also overwinter in infected cotton plant debris. Perithecia usually develop in old, dead tissues, and release ascospores that are the primary inoculum source. Natural spore dispersal will only move the fungus locally.
- Impact: Seriously infected bolls become mummified (darkened and hardened) and never open. In partially affected bolls, the fungus grows through and infects the seed. Lint from affected bolls is often colored pink and of inferior quality.

Environmental Conditions	Climate Change Impacts	
The disease survives on old rotten bolls, crop refuse in the field, and on the seeds. It is spread on diseased seeds. Infection is favored by moderate temperatures and high moisture. For symptoms to develop, a relative humidity close to 100 percent and temperatures of about 25 °C are needed.	Hot/Wet	**Very high risk of infection of Anthracnose**
	Hot/Dry	**No risk of infection of Anthracnose**

FRUIT CROPS

CASHEW

CASHEW PESTS

CASHEW WEEVIL, STEM BORERS[cxvii,cxviii]

Mecocorynus loripes

- Damage: They lay eggs in small holes made by females in the bark of the trunk and large branches of a tree. Larvae tunnel down under the bark, eating the sapwood. It causes substantial economic damage to the crop. Heavily infested trees die in a short period of time. Both larvae and pupa damage the crop
- Mode of transmission: The attack generally is limited to a few trees at a time. When the tree is completely dead, the insect migrates to the next tree.
- Impact: Reported as one of the most important insect pests in cashew.

Environmental Conditions	Climate Change Impacts	
They cause the most damage when they attack trees during dry weather.	Hot/Wet	**Low risk of infestation of Cashew Weevil**
	Hot/Dry	**Moderate risk of infestation of Cashew Weevil**

COREID COCONUT BUGS[cxix,cxx]

Pseudotheraptus wayi

- Damage: Larvae and adults suck developing shoots and nuts. After they attack, young nuts shrivel, dry, and blacken before they fall off. Feeding points become hollow spots, and mature kernels will show black and sunken spots.
- Mode of transmission: It is reported that more work is needed to determine the biology of *P. wayi* as a vector as well as how the insects overcome the dry period in order to resurface during the next growing season.
- Impact: The damage is most noticeable in younger trees, but the tips of older plants are also attacked. Infected products present lower market value or are not accepted.

Environmental Conditions	Climate Change Impacts	
Insects require warmer, drier environments to develop. Temperature has a substantial effect on development and activity of *P. wayi*. For example, at 20-22 °C it would take 66-78 days to develop to adulthood; at warmer temperatures (26-27 °C) it would take only 34-38 days. The insects are more active outside the nest at temperatures of 24-30 °C, and thus the amount of activity during different parts of the day and night can vary at different times of the year.	Hot/Wet	**Low risk of infestation of Coreid Coconut Bug**
	Hot/Dry	**High risk of infestation of Coreid Coconut Bug**

HELOPELTIS BUGS, MOSQUITO BUG, MIRID BUGS[cxxi,cxxii,cxxiii]

Helopeltis spp.

- Damage: Typical feeding damage on stems appears as necrotic area or lesion; similar lesions also occur on fruits and developing nuts. Leaf damage can take the form of black lesions on petioles, or black angular spots on the leaf surface. When *Helopeltis* feeding pressure is intense, the whole shoot dies; this damage is typically called "Dieback." In very serious cases, the entire tree looks burned.
- Mode of transmission: The insects lay eggs into the soft tissue near the tips of flowering or vegetative shoots.
- Impact: They are the most important pests of cashew. Heavy infestations by *Helopeltis* species can result in pod malformations and premature drop, thus providing a venue for secondary infection by microorganisms and serving to attract other pests.

Environmental Conditions	Climate Change Impacts	
The attack occurs very suddenly, particularly during the rainy season or when water is available, leading to flushing (production of young shoots) when *Helopeltis* populations normally build up.	Hot/Wet	**High risk of infestation of Helopeltis Bugs**
	Hot/Dry	**Low risk of infestation of Helopeltis Bugs**

LONG-TAILED MEALY BUG[cxxiv,cxxv]

Pseudococcus longispinus

- Damage: They attack leaves, flowers, or fruits, sucking sap, often injecting toxic saliva, and sometimes spreading viral diseases. Trees infested during the flowering stage fail to produce fruits. Adults are usually slow-moving insects and are called mealy bugs because most species secrete a thin cover of white mealy wax over the surface of the body.
- Mode of transmission: Females are wingless but freely mobile, though sluggish, and occur exposed on the foliage or twigs of the host. Females seek out a protected place to lay eggs. All life stages of the female feed, as do the male nymphs. Pupating and adult males do not feed.

- Impact: Cashew trees infested at the nut swelling stage produce discolored nuts, which result in lower-grade products for the market.

Environmental Conditions	Climate Change Impacts	
Temperature is the driving force for mealybug development. Warm temperatures favor insect development, although high summer temperatures in excess of 40 °C may slow the growth of the population and increase mortality.	Hot/Wet	**Low risk of infestation of Long-Tailed Mealy Bug**
	Hot/Dry	**Very high risk of infestation of Long-Tailed Mealy Bug**

THRIPS[cxxvi,cxxvii]

Selenothrips rubrocinctus

- Damage: The vast majority of thrips species derive their nutriment by penetrating the living tissues of plants with their piercing mouthparts and imbibing the sap. Loss of sap can result in yield loss, and some thrips species can transmit viral diseases. As a result of such feeding, mainly on the more mature cashew leaves, they turn a bronze color and eventually drop off.
- Mode of transmission: Thrips attack older leaves, flowers, and shoots.
- Impact: Attacked leaves drop off, leaving bare shoots with few young leaves at the tip. Infestation of flowers causes poor fruit formation. Locally limited infestations may cause considerable damage.

Environmental Conditions	Climate Change Impacts	
The severity of attack by thrips usually varies from year to year and place to place. Normally they are only dry season pests; as soon as the heavy rains start, they disappear.	Hot/Wet	**No risk of infestation of Thrips**
	Hot/Dry	**High risk of infestation of Thrips**

CASHEW FUNGAL DISEASES

ANTHRACNOSE[cxxviii,cxxix,cxxx,cxxxi]

Colletotrichum gloeosporioides

- Damage: The disease produces cankers on stems. The infected fruits have small, water-soaked, circular spots that increase in size. The symptoms are most visible on leaves and ripe fruits. At first, anthracnose appears on leaves as small and irregular spots. The spots can expand and merge to cover the whole affected area.
- Mode of transmission: Anthracnose is primarily transmitted through seed, but also through infected plant parts. Rain splash will also disperse spores within the crop canopy. The pathogen persists on and in seed, crop residues, and weed hosts.
- Impact: The disease attacks young plant tissues and can cause severe crop loss when it infects flowers.

Environmental Conditions	Climate Change Impacts	
The anthracnose pathogen reaches its most serious infection at high moisture and warm temperatures. The optimum temperature range is 25-29 °C, but it can survive at temperatures as low as 4 °C. Spore germination, dispersal, and infection require relative humidity near 100 percent. However, their incidence is minor in a drier climate more suited to most cashew production.	Hot/Wet	**Very high risk of infection of Anthracnose**
	Hot/Dry	**No risk of infection of Anthracnose**

POWDERY MILDEW (PM)[cxxxii,cxxxiii,cxxxiv]

*Oidium sp***.**

- Damage: The fungus primarily attacks young shoots, leaves, and inflorescences. As a result, fruit setting is reduced, and those that reach maturity are small, crunched, and cracked. Commonly observed on the upper sides of the leaves, PM also affects the lower sides of leaves, young stems, and young fruits.
- Mode of transmission: PM growth consists of many fungal spores that are spread by wind. The disease can spread very rapidly and be more prevalent when humidity is high and nights are cool. The fungus survives from season to season in dormant buds. The flowering is the most critical stage for infection.
- Impact: Yield losses may reach 80 percent in infected trees.

Environmental Conditions	Climate Change Impacts	
Powdery mildews are severe in warm, humid climates. The fungus does not need the presence of water on the leaf surface for infection to occur. But the relative humidity of the air needs to be high for spore germination. Disease development appears to be enhanced by low light, high humidity, moderate to high temperatures (18 to 32 °C), and moderate rainfall. Disease is common in high density plantings where air circulation is poor, and in damp, shaded areas. Incidence of infection increases as relative humidity rises to 90 percent. Young, succulent growth usually is more susceptible than older plant tissues.	Hot/Wet	**Very high risk of infection of Powdery Mildew**
	Hot/Dry	**No risk of infection of Powdery Mildew**

MANGO

MANGO PESTS

MANGO FRUIT FLY[cxxxv,cxxxvi]

Ceratitis cosyra, C. Capitata, Bactrocera invadens

- Damage: The symptoms tend to vary from fruit to fruit. Attacked fruit usually shows punctures (made by females while laying eggs). At those places, necrosis may occur. Small holes on the fruits are observed when the maggot exits the fruits. The affected part of the fruit becomes soft and gets color earlier than normal.
- Mode of transmission: Fruit flies survive and breed in falling fruits and in overripe or damaged fruits in trees.
- Impact: The fly is a serious pest in smallholder and commercial mango across sub-Saharan Africa.

Environmental Conditions	Climate Change Impacts	
Development of this fruit fly principally depends on temperature. The optimum is around 32 °C, which enables completion of a generation within two weeks. Population increases with onset of higher temperatures and moisture level. Larvae develop on the pulp of fruits; about 15 days at a mean temperature of 25 °C are necessary to complete their development.	Hot/Wet	**Moderate risk of infection of Mango Fruit Fly**
	Hot/Dry	**Low risk of infection of Mango Fruit Fly**

MANGO WEEVIL[cxxxvii,cxxxviii,cxxxix]

Sternochetus mangiferae

- Damage: Infected fruits are difficult to detect since no damage is externally visible. Most often, fruits are not harmfully affected by infestation. However, in rare cases fruit is significantly damaged when larvae feed and pupate within the pulp or upon their emergence from seeds. Internally these infected fruits rot from the outer surface of the stones. Damaged seeds fail to germinate.
- Mode of transmission: Infestation is very difficult to detect since there are no external signs of infestation, except for an inconspicuous egg-laying scar; consequent feeding activity in the seed remains undetected.
- Impact: Mango seed weevil is a quarantine pest. Its greatest significance as a pest is that it interferes with the export of the fruit.

Environmental Conditions	Climate Change Impacts	
High temperatures speed up the reproductive phases of the insect. Temperatures between 19 and 30 °C are optimal.	Hot/Wet	**Moderate risk of infection of Mango Weevil**

Adults are capable of surviving long periods in unfavorable conditions. In studies under controlled conditions, an average temperature of 28 °C and relative humidity of 73 percent have been found favorable for a longer life cycle, whereas 26 °C with 75 percent relative humidity has been observed to shorten it.	Hot/Dry	**Low risk of infection of Mango Weevil**

MEALY BUG[cxl,cxli]

Rastrococcus invadens

- Damage: Damage is caused by sucking sap from roots, tender leaves, petioles and fruit. They excrete honeydew, upon which sooty mold develops. Severely infested leaves turn yellow and gradually dry. Severe attack can result in shedding of leaves and inflorescences, reduced fruit setting and shedding of young fruit. The foliage and fruit may become covered with sticky honeydew, which serves as a medium for the growth of sooty molds.
- Mode of transmission: Mealybug infestations of above-the ground plant parts start with the presence of crawlers (the first-instar nymphs) on the underside of the leaves on terminal shoots, stems, and other plant parts.
- Impact: Damage to fruits can lead to 40 to 80 percent losses. *It is* a serious pest of fruit crops in West Africa.

Environmental Conditions	Climate Change Impacts	
Abiotic factors that appear to affect populations of pest are mainly rainfall and temperature variations, and, to a lesser extent, humidity. Rainfall and strong winds dislodge the insect from the point of attachment, thereby preventing feeding from taking place. High rainfall decreases survival of the larvae. Optimum development can be expected around 28°C, while the maximum temperature threshold can go up as high as 32°C.	Hot/Wet	**Low risk of infestation of Mealy Bugs**
	Hot/Dry	**Moderate risk of infestation of Mealy Bugs**

MANGO FUNGAL DISEASES

ANTHRACNOSE[cxlii,cxliii,cxliv,cxlv]

Colletotrichum gloeosporioides

- Damage: Initially appears as small black spots. On leaves, spots can expand to form an irregular patch. On young fruit, pin-sized, brown or black, hollow spots develop.
- Mode of transmission: Anthracnose can be transmitted through infected plant parts. Rain splash will also disperse spores within a crop canopy. The pathogen persists on and in crop residues and weed hosts.
- Impact: This is the most serious and widespread fungus in mango. It is an important problem after harvesting the fruit, especially during transport and storage, where fruit can develop round, blackish sunken spots of anthracnose.

Environmental Conditions	Climate Change Impacts	
Environmental conditions favoring the pathogen are high temperatures, 28 °C being optimal, and high humidity. Spores must have free water to germinate; germination is negligible below 97 percent relative humidity. Spores are only released when there is an abundance of moisture. Splashing from rain is a common means of spreading the disease. Severity of disease is related to weather, and the fungus is relatively inactive in dry weather. Sunlight, low humidity, and temperature extremes (below 18 °C or greater than 35 °C) rapidly inactivate spores. The fungus survives from season to season on dead leaves and twigs. Rainy weather during blooming and early fruit set will favor its development.	Hot/Wet	**Very high risk of infection of Anthracnose**
	Hot/Dry	**No risk of infection of Anthracnose**

MANGO MALFORMATION DISEASE (MMD)[cxlvi,cxlvii]

Fusarium tupiense

- Damage: Produces compounds that have hormonal effects on the plant. Symptoms cause affected flowers to develop a similarity to cauliflower heads: the axes of the panicles are shorter and thicker than normal, and branch more often; a profusion of enlarged flowers is produced. Although affected panicles retain their green color, they are sterile and produce no fruits.
- Mode of transmission: It spreads by grafting and through infected trees.
- Impact: This is the first confirmed record in Senegal of MMD caused by *F. tupiense*.

Environmental Conditions	Climate Change Impacts	
Flowers, seedlings, branches, and leaves in older trees show symptoms of infection by MMD. The fungus produces spores (a primary source of infection)	Hot/Wet	**High risk of infection of Mango Malformation**

especially during the rainy season.		**Disease**
Spores are spread by mango mites or by the wind to infect other trees and orchards.	Hot/Dry	**No risk of infection of Mango Malformation Disease**

POWDERY MILDEW[cxlviii,cxlix]

Oidium mangiferae

- Damage: Attacks flowers and young fruits. It can dramatically affect the harvest. It appears as a white, powdery growth on leaves, flowers, and young fruit. Infected leaves curl, and flowers fail to open and fall from the tree without forming a fruit.
- Mode of transmission: The fungus survives from season to season in dormant buds. The flowering stage is the most critical stage for infection.
- Impact: Mango powdery mildew is a sporadic but very severe disease of mango leaves, panicles, and young fruits; up to 90 percent crop loss can occur due to its effect on fruit set and development.

Environmental Conditions	Climate Change Impacts	
This fungus grows during warm weather with high humidity, especially in rainy weather or frequent fog. Cool nights favor development of the fungus. Temperature is the most important factor for the start and the development of an outbreak. Optimum temperature is reported at 26 °C and relative humidity of 95 percent of higher. Rainfall is not as important during the development of the disease, but it is important in providing good levels of soil/plant moisture. The range of temperatures for fungus growth is 17-32 °C. The disease is spread by wind and can spread very rapidly.	Hot/Wet	**High risk of infection of Powdery Mildew**
	Hot/Dry	**No risk of infection of Powdery Mildew**

SHEA NUT

SHEA NUT PESTS

BARK BORER[cl]

Xyloctonus scolytoides

- Damage: This borer tunnels through the bark of twigs, impeding growth of leaves and flower bud. It destroys the bark.
- Mode of transmission: Stems of living trees in the area provide food and shelter for this insect. After that, trees at different stages can be attacked.
- Impact: Young trees can be killed.

Environmental Conditions	Climate Change Impacts	
At warmer locations (such as lower elevations), the season of attack is usually longer, and beetles have more generations per year in comparison with cooler locations. Adults can emerge at any time of year if the temperatures are high.	Hot/Wet	**Low risk of infestation of Bark Borer**
	Hot/Dry	**High risk of infestation of Bark Borer**

FRUIT FLY[cli]

Ceratitis silvestrii

- Damage: The larva feed on the pulp of mature fruits.
- Mode of transmission: Adult flight and the transport of infested fruit are the major means of movement and dispersal to previously uninfested areas. *Ceratitis* species occurred during the dry season and infestation is greater when populations are larger. Temperature, relative humidity, and rainfall are the major climatic factors influencing size of fly populations.
- Impact: Damage is usually not significant for the health of the tree.

Environmental Conditions	Climate Change Impacts	
This species appears during the dry season and often reaches a peak at the end of the dry season. Population increases with the onset of higher temperatures and moisture level.	Hot/Wet	**Low risk of infection of Fruit Fly**
	Hot/Dry	**Low risk of infection of Fruit Fly**

MISTLETOE, HEMI-PARASITIC PLANT[clii,cliii]

Tapinanthus globiferus

- Damage: Mistletoes are often described as hemiparasitic because they are partial parasites on various hosts. *T.globiferus* is a woody, spreading shrub with blackish, smooth stems made rough by the presence of lenticels.
- Mode of transmission: This plant parasite inhabits forest and bush savanna in drier locations, and it is widely dispersed north of the Equator across Africa.
- Impact: Though they are parasitic plants, the association is almost symbiotic, so limited damage takes place.

Environmental Conditions	Climate Change Impacts	
Stem parasitic mistletoes exceed their hosts' transpiration rates. Thus, mistletoes are most abundant in areas where access to sunlight is not limited, such as savannahs and at the top of forest canopies. No reports are available on how climate influences parasitism or how significant the impact is on the host plant.	Hot/Wet	**Assessment not possible**
	Hot/Dry	**Assessment not possible**

NEMATODES[cliv]

Aphasmatylenchus straturatus

- Damage: This nematode infects roots and is capable of damaging them if conditions are adequate.
- Mode of transmission: It is found infecting agricultural soils, in particular soil around roots of peanuts. Nematodes can then parasitize crops in close vicinity or planted in contaminated areas. The time at which symptoms appear is a function of the original level of soil infestation.
- Impact: They can be a serious pest of shea trees but are susceptible to dry environments (lack of anhydrobiotic stage). This nematode species is reported to be found in the Sahelian zones of West Africa.

Environmental Conditions	Climate Change Impacts	
It is reported that some levels of moisture are required in the soil. Dry soils during the dry season do not allow them to reproduce. Soil temperature and soil moisture affect the multiplication rate of *Aphasmatylenchus straturatus*. This nematode is unable to enter anhydrobiosis and to survive in dry soil during the dry season.	Hot/Wet	**Moderate risk of infestation of Nematodes**
	Hot/Dry	**No risk of infestation of Nematodes**

SHEA DEFOLIATOR[clv,clvi]

Cirina forda

- Damage: This larva feeds on the leaves of Shea trees. All larval stages can be destructive.
- Mode of transmission: The insect survives in weed hosts and can move to infect trees.
- Impact: It may cause serious and heavy defoliation.

Environmental Conditions	Climate Change Impacts	
They require warm temperatures for the adults to emerge, have time to mate, lay eggs, and also for the eggs to develop prior to the onset of cooler temperatures.	Hot/Wet	**Low risk of infestation of Shea Defoliator**
	Hot/Dry	**High risk of infestation of Shea Defoliator**

GRASSES

BOURGOU (ECHINOCHLOA STAGNINA)

BOURGOU PESTS

MAIZE STREAK VIRUS (MSV)[clvii]

- *E. stagnina* is reported as a host of MSV, but no additional information is available about symptoms or damage. In some regions, bourgou is considered a weed.

Environmental Conditions	Climate Change Impacts	
Like many other viruses, MSV depends on insect vectors for transmission between host plants. MSV cannot be transmitted through seeds or any other method. *Cicadulina* species are the only insects known to transmit maize streak virus from one maize plant to another; climate effects are related to the insect vector.	Hot/Wet	**Low risk of infestation of *Cicadulina* and low risk of transmission of MSV**
	Hot/Dry	**High risk of infestation of *Cicadulina* and high risk of transmission of MSV**

LEGUMES

AFRICAN LOCUST BEAN (NERE)

AFRICAN LOCUST BEAN PESTS

MISTLETOE (HEMI-PARASITIC PLANTS)[clviii,clix]

Tapinanthus globiferus, T. dodonifolius

- Damage: *T. globiferus* is a mistletoe of the family Loranthaceae. It is a woody, spreading shrub with blackish, smooth stems made rough by the presence of lenticels. These plants attach to and penetrate the branches of a tree by a structure called the haustorium, through which they absorb water and nutrients from the host plant.
- Mode of transmission: Mistletoes grow naturally and are often described as hemiparasites because they are partial parasites on various hosts.
- Impact: There are no reports on the intensity of damage or on the levels of parasitism.

Environmental Conditions	Climate Change Impacts	
Stem parasitic mistletoes exceed their hosts' transpiration rates. Thus, mistletoes are most abundant in areas where access to sunlight is not limited, such as savannahs and at the top of forest canopies. There are no reports on how climate influences parasitism or how significant the impact is on the host plant.	Hot/Wet	**Assessment not possible**
	Hot/Dry	**Assessment not possible**

AFRICAN LOCUST BEAN FUNGAL DISEASES

BROWN ROOT ROT[clx,clxi]

Phellinus sp.

- Damage: Attacks tree roots, causing decay; this action cuts off water and nutrient supply to the crown, resulting in tree death.
- Mode of transmission: It is a natural fungal species that is a regular component of rainforests. Tropical forests to be cleared for planting must be carefully surveyed for signs or symptoms of brown root rot. Planting in or near infected areas can infect new plantings.
- Impact: Tree death is often rapid in young trees, with wilting often the first obvious symptom. In older trees decline is more gradual; the leaves turn chlorotic, followed by thinning of the crown and eventual tree death. These symptoms and rates of development can vary, with tree death potentially taking years to occur.

Environmental Conditions	Climate Change Impacts	
It is present in warmer climates. The fungus prefers acidic, hot, and humid conditions. The mycelium of this tropical plant pathogen grows best at 25 to 30 °C; it does not grow at temperatures above 40 °C.	Hot/Wet	**Moderate risk of infection of Brown Root Rot**
	Hot/Dry	**Low risk of infection of Brown Root Rot**

CERCOSPORA LEAF SPOT[clxii,clxiii]

Cercospora sp.

- Damage: Symptoms are reported to affect leaves of the tree. Usually the observed symptoms are circular to broadly irregular spots. The spots coalesce to form round lesions that are brown and necrotic.
- Mode of transmission: Most likely, spores survive on and are produced by natural hosts. The trees are infected when climatic conditions favor the movement of spores.
- Impact: Not reported in the literature.

Environmental Conditions	Climate Change Impacts	
The disease is widespread in warmer subtropical and tropical regions. It is favored by warmer and humid weather.	Hot/Wet	**Very high risk of infection of Cercospora Leaf Spot**
	Hot/Dry	**No risk of infection of Cercospora Leaf Spot**

HYPOXYLON CANKER[clxiv,clxv]

Hypoxylon rubiginosum and *Phyllachora leonensis*

- Damage: Fungi in the genus *Hypoxylon* generally cause a white rot of hardwood slash. However, some species are known to cause severe cankering of stressed hardwoods.
- Mode of transmission: Like most fungi, hypoxylon canker is spread from one tree to the next by wind, rain, tools, and insects. Research shows that the fungus enters the tree through wounds; it grows through the wounds and sapwood, causing decay.
- Impact: Cankering caused by this fungus contributes to the premature death of trees stressed by drought, physical damage, or other problems.

Environmental Conditions	Climate Change Impacts	
Hypoxylon canker infection is exacerbated when trees are weakened by high temperatures and environmental stressors such as drought. Fungus takes advantage of rain and moisture to infect trees. Warmer weather and humidity favor presence of the fungi.	Hot/Wet	**Low risk of infection of Hypoxylon Canker**
	Hot/Dry	**Moderate risk of infection of Hypoxylon Canker**

COWPEA

COWPEA PESTS

COWPEA APHID[clxvi, clxvii]

Aphis craccivora

- Damage: Cowpea aphids inject toxins into the plant while feeding; they most likely reduce vigor and yields. Aphids feed on the phloem and are particularly damaging to young growing points, causing plants to be stunted.
- Mode of transmission: Cowpea aphids reside in neighbor crops and weeds. Under optimal conditions, populations can reach high numbers and infest the crop at different times during the growing season.
- Impact: Cowpea aphid can cause damage as a vector of serious virus diseases.

Environmental Conditions	Climate Change Impacts	
Cowpea aphid cause most damage when they attack seedlings during dry weather. Colony development is dependent on temperature; it is retarded by low temperatures in the winter and by hot summer temperatures.	Hot/Wet	**Low risk of infestation of Cowpea Aphid**
	Hot/Dry	**High risk of infestation of Cowpea Aphid**

COWPEA WEEVIL[clxviii,clxix]

Callosobruchus maculatus

- Damage: The insect attacks the fruiting stage, seeds, and all stored grains and products. In seeds, the weevil produces round holes.
- Mode of transmission: They prefer dried cowpeas but will attack other beans and peas in storage. Adults move about readily and can infest seeds in the field, but can also breed continuously in stored dry cowpeas.
- Impact: These are the most common and widespread insect pests in storage.

Environmental Conditions	Climate Change Impacts	
The cowpea weevil requires high temperatures and moderate relative humidity to develop. The optimal conditions for the weevil to multiply and become a pest are temperatures between 17 °C and 37 °C and a relative humidity of 90 percent. Larval and pupal development takes place inside the bean. At 44 percent humidity, a high rate of survival is noted in both stages. Adults can live much longer at higher humidity levels (81 percent to 90 percent).	Hot/Wet	**Moderate risk of infestation of Cowpea Weevil**
	Hot/Dry	**Low risk of infestation of Cowpea Weevil**

COWPEA WITCHWEED[clxx,clxxi]

Striga gesnerioides

- Damage: The flowering, fruiting and vegetative growth, leaves, and whole plant of cowpea is affected by this parasite. Symptoms are often not obvious at the start of infestation, but later the leaves suffer chlorosis of the veins. Witchweed causes poor pod development.
- Mode of transmission: *S. gesnerioides* is an obligate parasite with minute seeds. Incapable of establishing itself without the assistance of a host plant, *S. gesnerioides* develops infective hyphae on cowpea. Under conditions of dry weather and low relative humidity, witchweed seeds can move by wind, animals, and tools into agricultural areas and expand parasitism.
- Impact: *S. gesnerioides* is a severe pest of cowpea in Senegal, Mali, Togo, Benin, Burkina Faso, Ghana, Nigeria, Niger, Cameroon, and Chad, causing significant loss of yield.

Environmental Conditions	Climate Change Impacts	
Temperatures ranging from 30 to 35 °C in a moist environment are ideal for germination. Witchweed will not develop in temperatures below 20 °C. Cowpea witchweed is adapted to adverse climatic conditions of increased osmotic potential and extreme high temperatures.	Hot/Wet	**Moderate risk of infestation of Cowpea Witchweed**
	Hot/Dry	**Low risk of infestation of Cowpea Witchweed**

LEGUME POD BORER, COWPEA CATERPILLAR[clxxii,clxxiii]

Maruca vitrata

- Damage: Most serious damage is caused by the larvae. They attack flower buds and flowers and cause large damage to the green pods of cowpeas. Early generations can infest peduncles and tender parts of the stem.
- Mode of transmission: The moths prefer to oviposit at the flower bud stage. Then larvae move from one flower to another, and each may consume four to six flowers before the larval stage is completed.
- Impact: This is the most important pod borer pest, causing severe damage to cowpeas. Losses over 80 percent have been reported on indigenous varieties and even on high-yielding varieties.

Environmental Conditions	Climate Change Impacts	
The emergence of the moth is favored by rainfall or high moisture content in the soil. Adults are most active during the rainy season. They have a life span of five to seven days.	Hot/Wet	**High risk of infestation of Legume Pod Borer**
	Hot/Dry	**Low risk of infestation of Legume Pod Borer**

ROOT-KNOT NEMATODE[clxxiv,clxxv]

Meloidogyne javanica

- Damage: Nematode causes relatively small galls to develop on roots of affected plants. It can also affect flowering, podding, seedling, and other vegetative growing stages. In the roots, galls generate abnormal formation and function of the root system as well as obstruction of the vascular system. The stem above the ground can display patchy, stunted growth and discoloration; the leaf can present chlorosis and wilting.
- Mode of transmission: Nematodes can survive in the soils for several years and continue to constantly infect plants.
- Impact: Nematodes can reduce yields by 20-30 percent. The whole plant shows reduced yield in quantity and quality as well as premature death.

Environmental Conditions	Climate Change Impacts	
Nematodes are distributed in subtropical and tropical regions of the world. An increase in temperature influences infection.	Hot/Wet	**Low risk of infestation of Root-Rot Nematode**
In West Africa, *M. javanica* is predominant and is found in warmer and drier soils.	Hot/Dry	**High risk of infestation of Root-Rot Nematode**

WHITE GRUBS (WG)[clxxvi,clxxvii]

Coleoptera: Scarabaeidae

- Damage: White grubs attack plants at all stages of growth. WG on seedlings will cause stunting or wilting. They feed mainly on the tap roots and/or peripheral roots and reduce water absorption capacity, leading to stunting or death.
- Mode of transmission: Overwintering adult white grubs attack the roots of many cultivated crops. Eggs deposited by females a few inches below the surface hatch in two to three weeks, and then tiny first-instar grubs feed on fine roots and organic matter.
- Impact: Depressions cut by white grubs in the crown region of tap roots are often invaded by rot-causing fungi such as *Aspergillus niger, Fusarium* spp., and *Rhizoctonia solani.*

Environmental Conditions	Climate Change Impacts	
White grub damage appears more severe with relatively higher annual rainfall.	Hot/Wet	**Moderate risk of infestation of White Grubs**
	Hot/Dry	**Low risk of infestation of White Grubs**

WITCHWEED, PURPLE WITCHWEED[clxxviii,clxxix,clxxx]

Striga hermonthica

- Damage: Attacks all the plant stages and plant parts, flowering, podding, pre-emergence, seedling and vegetative phase, the leaves, stems, and whole plant. Symptoms observed are leaves with yellow blotches, abnormal patterns, wilt, and reduction in number. Inflorescences can be delayed and/or floral development is delayed. Stems are shortened and show abnormal growth. The roots can show wilting.
- Mode of transmission: This weed is naturally widespread in Africa. *Striga* can expand its growing areas and parasite crops.
- Impact: Parasitizing important economic plants, witchweed is one of the most destructive pathogens in Africa.

Environmental Conditions	Climate Change Impacts	
Germination and growth are generally favored by high temperatures around 30 to 35 °C, low soil nitrogen, low soil moisture, and dry conditions in the air.	Hot/Wet	**Moderate risk of parasitism by Witchweed**
	Hot/Dry	**Low risk of parasitism by Witchweed**

COWPEA FUNGAL DISEASES

CERCOSPORA LEAF SPOT (CLS)[clxxxi,clxxxii,clxxxiii]

Pseudocercospora cruenta, Cercospora apii

- Damage: Symptoms are more significant on the leaves where there are observed circular to broadly irregular spots with pale tan to grey centers. The spots coalesce to form round lesions that are brown and necrotic. Damaged pods dry up. Stems can display lesions. Fungus has been isolated from symptomless infected seeds.
- Mode of transmission: These fungi survive adverse conditions in leaves, in the canopy, and in fallen leaves. The spores they produce are blown by the wind or carried in splashing water to infect new leaves.
- Impact: CLS is considered a significant constraint in cowpea production worldwide.

Environmental Conditions	Climate Change Impacts	
The disease is widespread in warmer subtropical and tropical regions. CLS is favored by warmer and humid weather. *C. apii* have a higher maximum temperature tolerance (33 °C) than other Cercospora species. Most conidia are formed at optimal temperature of 28 °C. At 24 °C and 32 °C, however, conidia formation is reduced.	Hot/Wet	**Very high risk of infection of Cercospora Leaf Spot**
	Hot/Dry	**No risk of infection of Cercospora Leaf Spot**

SCAB[clxxxiv,clxxxv,clxxxvi]

Sphaceloma sp.

- Damage: *Sphaceloma* scab is characterized by the development of silvery grey, circular to oval lesions on stems, leaves and their petioles, peduncles, and pods. In severe infections, such lesions coalesce, causing distortion and flower bud abortion.
- Mode of transmission: Can survive in plant debris from previous harvest and contaminate new crop. *Sphaceloma* also occurs in major weed species growing in cowpea areas.
- Impact: Can cause yield losses of up to 60 percent in experimental and farmers' fields.

Environmental Conditions	Climate Change Impacts	
Wet weather, high temperature, and high humidity favor disease development. Conditions such as successive days of wet weather are ideal for scab development. Secondary spread of conidia takes place by rain splash, runoff, and wind-blown moisture.	Hot/Wet	**High risk of infection of Scab**
	Hot/Dry	**No risk of infection of Scab**

COWPEA VIRAL DISEASES

COWPEA APHID-BORNE MOSAIC VIRUS (CABMV)[clxxxvii,clxxxviii,clxxxix,cxc]

Potyvirus

- Damage: Causes distortion and mottling of leaves and can stunt plants. All plant stages and parts can be affected, including flowering, fruit development, seedling, and vegetative stages, in addition to the pods, growing points, inflorescence, leaves, seeds, stems, and whole plant.
- Mode of transmission: It is transmitted by cowpea aphids. Symptoms vary according to the cowpea cultivar and the existing CABMV race. It has been reported that CABMV symptoms observed on cowpea under field conditions can be exceptionally variable.
- Impact: The virus has worldwide distribution and it is considered to be a major and widespread disease of cowpea in sub-Saharan Africa.

Environmental Conditions	Climate Change Impacts	
The virus is transmitted mechanically (sap), and vector transmitted by several aphid species. *Aphis craccivora* is identified as the most efficient vector. Climate conditions are then related to favorable conditions for the vector. Mosaic symptoms are best expressed at moderate temperatures (20-25 °C).	Hot/Wet	**Low risk of significant infestation of *Aphis craccivora;* low risk of transmission of CABMV**
	Hot/Dry	**High risk of significant infestation of *Aphis craccivora;* high risk of transmission of CABMV**

GROUNDNUT

GROUNDNUT PESTS

GROUNDNUT BRUCHID, GROUNDNUT SEED BEETLE[cxci,cxcii,cxciii,cxciv]

Caryedon serratus

- Damage: First sign of attack is the appearance of "windows" cut into the pod wall by the larva to allow the adult to leave the pod after emerging. Sometimes, fully grown larva come out through the exit holes made by the previous generations. By this stage, the groundnut seeds are severely damaged for human consumption or oil expulsion.
- Mode of transmission: The eggs are found attached to the pod wall. After hatching, larva burrows through the egg shell and the pod wall, and starts eating the seed. They often live in the storage sacks and pupate in large numbers at the bottom of the pile of sacks.
- Impact: It is a serious pest of stored products, particularly when these are still in their shells.

Environmental Conditions	Climate Change Impacts	
The optimum conditions for development are 30-33 °C and 70-90 percent relative humidity, under which the developmental period is reduced. Breeding is favored at temperatures between 23 °C and 35 °C.	Hot/Wet	**Moderate risk of infestation of Groundnut Bruchid**
	Hot/Dry	**Low risk of infestation of Groundnut Bruchid**

GROUNDNUT FUNGAL DISEASES

ASPERGILLUS FLAVUS[cxcv,cxcvi,cxcvii]

- Damage: Affected seeds are shriveled and dried, covered by yellow or greenish spores. Cotyledons show necrotic lesions. Seedlings are highly stunted, and leaf size is greatly reduced with pale to light green color. The growth of the fungus often leads to contamination with aflatoxin, a toxic compound. Unlike most fungi, *Aspergillus flavus* is favored by hot dry conditions. The optimum temperature for growth is 37 °C.
- Mode of transmission: Pre-harvest infection by *A. flavus* is more important in the semi-arid tropics, especially when drought occurs just before harvest. Drought-stressed plants lose moisture from pods and seeds; physiological activity is greatly reduced. Both factors increase susceptibility to fungal invasion.
- Impact: A*flatoxin* contamination poses a risk to human health and has been identified as a major constraint to trade in *Africa*.

Environmental Conditions	Climate Change Impacts	
Unlike most fungi, *Aspergillus flavus* is favored by hot dry conditions. The optimum temperature for growth is 37 °C, but the fungus readily grows between the temperatures of 25 and 42 °C, and will still grow at temperatures from 12 to 48 °C.	Hot/Wet	**Moderate high risk of infection of *Aspergillus flavus***
Drought stress and insect damage are two major environmental factors that affect aflatoxin contamination of the peanut fruit during growth and development.	Hot/Dry	**Very high risk of infection of *Aspergillus flavus***

EARLY LEAF SPOT (ELS)[cxcviii,cxcix]

Cercospora arachidicola

- Damage: Chlorotic spots appear on the upper surface of leaflets; these enlarge and change to brown or black color, with sub circular shapes. On the lower surface of the leaves, light brown coloration is seen; lesions also appear on petioles, stems, and stipules. In severe cases, several lesions coalesce and result in premature senescence.
- Mode of transmission: The fungi reproduce and infect by conidia. ELS is capable of producing very large numbers of spores on infected plant parts. Spore production is favored by high humidity. Primary inoculum that causes the initial leaf spot infections during the growing season are spores produced on infested peanut residue in the soil.
- Impact: Groundnut leaf spot is one of the important factors limiting groundnut productivity in Africa. Defoliation and reduced yield at harvest can result if this disease is not controlled.

Environmental Conditions	Climate Change Impacts	
Conditions of prolonged warm temperature and high relative humidity (>95 percent) can result in significant defoliation and yield loss.	Hot/Wet	**Very high risk of infection of Early Leaf Spot**
Temperatures between 25 and 30 °C favor disease development.	Hot/Dry	**No risk of infection of Early Leaf Spot**

GROUNDNUT RUST (GR)[cc,cci]

Puccinia arachidis

- Damage: Pustules of rust appear first on the lower surface. In highly susceptible cultivars, the initial pustules may be bordered by groups of secondary pustules. Pustules may also develop on the upper surface of the leaflet. They may be produced on all aerial plant parts apart from flowers and pegs. Severely infected leaves can turn necrotic and desiccate, though they can still be attached to the plant.
- Mode of transmission: Inoculum of GR can survive in volunteer groundnut plants from the field and contaminate new plants. Rust develops better in high humidity and cloudy weather.
- Impact: GR is one of the major foliar diseases of groundnuts. It is reported to cause yield losses of up to 50 percent in groundnut growing areas.

Environmental Conditions	Climate Change Impacts	
Rust outbreaks are favored by average temperatures around 20 to 22 °C, 85 percent or higher relative humidity, and about three rainy days in a week. Potential of severe outbreak increases if this trend lasts two weeks or more. Rain assists dispersal of spores.	Hot/Wet	**High risk of infection of Groundnut Rust**
	Hot/Dry	**No risk of infection of Groundnut Rust**

LATE LEAF SPOT[ccii,cciii]

Cercosporidium personatum

- Damage: Black and more or less circular spots appear on the lower surface of the leaflets. The lesions are rough in appearance. In extreme cases many lesions coalesce, resulting in premature senescence and shedding of the leaflets.
- Mode of transmission: Similar to Early Leaf Spot. The fungi infects by conidia, and spore production is favored by high humidity. Depending on the variety, infection can begin around two months after sowing.
- Impact: Small-scale farmers in semi-arid tropics who rarely can afford chemical control of this disease could have serious yield losses, in some cases up to 50 percent.

Environmental Conditions	Climate Change Impacts	
Temperatures in the 25 to 30 °C range and high relative humidity (greater than 93 percent) favor infection and disease development. Rain helps dispersal of the inoculum from plant to plant.	Hot/Wet	**High risk of infection of Late Leaf Spot**
	Hot/Dry	**No risk of infection of Late Leaf Spot**

LEAF SCORCH[cciv,ccv,ccvi]

Leptosphaerulina crassiasca

- Damage: Scorch symptom generally appears as a wedge-shaped, brown lesion. These lesions extend from the tip of a leaf to a point on the mid-vein. Leaf scorch progresses most commonly during the later part of the growing season.
- Mode of transmission: It is thought that leaves previously damaged by leafhoppers or one of the leaf spot fungi may be more prone to develop leaf scorch symptoms.
- Impact: Under certain conditions, this disease can cause serious damage in a peanut field.

Environmental Conditions	Climate Change Impacts	
During wet weather, spores are released, which may splash or be windblown onto newly emerging tender leaves. Peak periods of spore dispersal and germination occur at the end of the dew period and at the onset of rainfall.	Hot/Wet	**High risk of infection of Leaf Scorch**
	Hot/Dry	**High risk of infection of Leaf Scorch**

WEB BLOTCH[ccvii,ccviii,ccix]

Phoma arachidicola

- Damage: Symptoms appear first on the upper surface of the leaf. They are roughly circular, tan to dark brown blotches or net-like spots with irregular and light brown margins. The net-like webbing, often visible, is the growth of fungal strands just underneath the leaf. The yellow halo encircling early leaf spot lesions is absent in web blotch.
- Mode of transmission: Fungi can survive in debris from previous years. Movement of spores is facilitated by winds and high humidity; they could spread the disease over the new plants and infect them.
- Impact: Affected leaflets dry, become brittle, and fall from the plant. Complete defoliation and up to 50 percent yield loss may occur.

Environmental Conditions	Climate Change Impacts	
The disease cycle of web blotch is not well known. Fungus survives between peanut crops on infested crop residue in the soil. Web blotch is favored by cool (16 °C to 22 °C), wet weather, and at times when harvest is delayed by rainy weather. Disease requires extended periods of leaf wetness and can infect peanuts at lower temperatures than the fungus, causing early leaf spot.	Hot/Wet	**Moderate risk of infection of Web Blotch**
	Hot/Dry	**No risk of infection of Web Blotch**

GROUNDNUT VIRAL DISEASES

GROUNDNUT ROSETTE VIRUS[ccx,ccxi,ccxii,ccxiii]

Groundnut rosette virus (GRV) genus *Umbravirus* and its satellite RNA, and *Groundnut rosette assistor virus* (GRAV) genus *Luteovirus*

- Damage: Plants affected by either green or chlorotic rosette are severely stunted and of bushy appearance due to shortened internodes and reduced leaf size. Leaves of chlorotic rosette-affected plants are curled and puckered and show a bright chlorosis, usually with a few green spots.
- Mode of transmission: *Aphis craccivora* (groundnut aphid) is an important vector of plant viral disease, transmitting over 30 plant viruses, including groundnut rosette. The virus is transferred to the plant when this insect feeds on the plant. Contaminated groundkeepers and volunteer plants are also primary sources of infection.
- Impact: Groundnut rosette disease is important only in sub-Saharan Africa, where it is by far the most destructive of all groundnut diseases. The disease is not prevalent every year, and its unpredictability is one of its most harmful aspects.

Environmental Conditions	Climate Change Impacts	
Aphids (*Aphis cracivora*) are vectors of the disease, so climate conditions favorable to the aphid favor the spread of GRV. The aphids prefer cool temperatures; dry environments; and light, airy conditions to infest plants.	Hot/Wet	**Low risk of significant infestation of *Aphis cracivora* and low risk of GRV**
	Hot/Dry	**Moderate risk of significant infestation of *Aphis cracivora* and low risk of GRV**

PEANUT CLUMP VIRUS (PCV)[ccxiv,ccxv]

- Damage: Infected peanut plants are stunted and have small, dark green leaves. Number and size of pods are greatly reduced.
- Mode of transmission: PCV is transmitted by the soil-borne protist root endoparasite *Polymyxo graminis*. The virus is also transmitted through seed. The disease reappears in the same place in succeeding crops.
- Impact: in the case of early infections, the crop loss is very important; up to 60 percent. PCV was first described in Senegal but also occurs in other countries of West Africa such as Burkina Faso, Gambia, the Ivory Coast, and Senegal.

Environmental Conditions	Climate Change Impacts	
A fungus *Polymyxa graminis* is thought to be the natural vector of PVC. *P. graminis* is adapted to tropical conditions; the optimum temperature requirement for their development is high, at around 30 °C.	Hot/Wet	**High risk of significant infection of *P. graminis* and high risk of infection of PVC**
	Hot/Dry	**Low risk of significant infection of *P. graminis* and low risk of infection of PVC**

OILSEED CROPS

SESAME

SESAME PESTS

COMMON BLOSSOM THRIP[ccxvi,ccxvii]

Frankliniella schultzei

- Damage: *Frankliniella schultzei* can cause both direct and indirect damages to crops. Both adults and nymphs feed on pollen and floral tissue, leading to flower abortion. Severe infestations can cause discoloration and stunted growth of the plant
- Mode of transmission: Thrips stay in neighboring crops and weeds. At optimal conditions, they can infest the crop at different times during the growing season.
- Impact: It is a minor pest of sesame.

Environmental Conditions	Climate Change Impacts	
Hot temperatures and high humidity are important factors supporting huge populations of thrips.	Hot/Wet	**Moderate risk of infestation of Common Blossom Thrip**
	Hot/Dry	**Low risk of infestation of Common Blossom Thrip**

COWPEA POD-SUCKING BUGS, GIANT COREID BUG OR TIP WILTER[ccxviii,ccxix,ccxx]

Anoplocnemis curvipes

- Damage: Bugs have modified mouthparts in the shape of a tube or rostrum. Within this tube is a sharp needle-like structure with which the insect pierces plant tissue. Feeding by adults causes severe distortion of fruits/pods with considerable loss of yield. Insects inject saliva that assists in tissue breakdown, thereby making this tissue easier to assimilate. Saliva is an irritant and causes cells surrounding the point of feeding to grow disproportionately or, if feeding is severe, to shrivel completely.
- Mode of transmission: The pod-sucking bugs have been reported to migrate into sesame from a wide range of leguminous shrubs and trees that serve as maintenance hosts.
- Impact: These bugs are difficult to control since they usually feed on a wide range of crops and are very mobile. However damage caused by *A. curvipes* is minor.

Environmental Conditions	Climate Change Impacts	
Direct feeding damage is most harmful in dry climate and warm conditions.	Hot/Wet	**Moderate risk of infestation of Cowpea Pod-Sucking Bugs**
	Hot/Dry	**High risk of infestation of Cowpea Pod-Sucking Bugs**

CLUSTER BUG, SORGHUM BUG[ccxxi]

Agonoscelis pubescens

- Damage: Adult and immature bugs feed on the heads of sesame plants. Feeding results in pod damage and discoloration.
- Mode of transmission: These insects are usually found feeding in groups and expand infestation by migrating to places of favorable conditions.
- Impact: It is a minor pest.

Environmental Conditions	Climate Change Impacts	
No reports on impact of climate found. In general, these bugs are more active during the African rainy season and they rest during the dry season.	Hot/Wet	**Moderate risk of infestation of Cluster Bug**
	Hot/Dry	**No risk of infestation of Cluster Bug**

DEATH'S-HEAD HAWKMOTH[ccxxii,ccxxiii,ccxxiv]

Acherontia atropos

- Damage: When young, the caterpillar rests along a vein under a leaf and nibbles small holes in the leaf surface. Later, they get too heavy to continue feeding and rest along a leaf stalk or small branches.
- Mode of transmission: Moths deposit eggs in leaves; eggs are often laid singly under old leaves. The resulting caterpillars feed on the leaves but are not very active. They move only to find a new leaf after they finish the one they are on.
- Impact: Their large size occasionally makes them a minor pest because they can damage small sesame plants.

Environmental Conditions	Climate Change Impacts	
Cold temperatures can have negative effects on the life cycle of the moth. Warmer temperatures favor development.	Hot/Wet	**Low risk of infestation of Death's Head Hawk Moth**
	Hot/Dry	**Moderate risk of infestation of Death's**

		Head Hawk Moth

GALL FLY OR SIMSIM GALL MIDGE[ccxxv,ccxxvi]

Asphondylia sesami

- Damage: Maggots feed inside the floral bud, leading to formation of a gall-like structure, which does not develop into flower/capsules. The affected buds wither and drop.
- Mode of transmission: Female midges lay eggs along the veins of terminal leaves. Maggots pupate inside the galls. The larvae are typical maggots.
- Impact: The simsim gall midge is usually a minor pest; but occasionally high infestations occur, resulting in considerable crop losses. Generally, plants with green capsules appear to be more susceptible to attack than are plants with black capsules.

Environmental Conditions	Climate Change Impacts	
It was reported that warmer temperatures favor pest reproduction and infestation.	Hot/Wet	**Low risk of infestation of Gall Fly**
	Hot/Dry	**Moderate risk of infestation of Gall Fly**

GREEN PEACH APHID[ccxxvii,ccxxviii]

Myzus persicae

- Damage: Green peach aphids can attain very high densities on young plant tissue, causing water stress, wilting, and reduced growth rate of the plant.
- Mode of transmission: *M. persicae* survives on, and can emerge from, infested volunteer plants that could serve as reservoirs of infection for the following year's crop.
- Impact: Prolonged aphid infestation can cause appreciable reduction in yield of root crops and foliage crops. *M. persicae* is the most important aphid virus vector. It has been shown to transmit well over 100 plant virus diseases.

Environmental Conditions	Climate Change Impacts	
At the population level, migration favors survival of the aphids by avoiding abiotic hazards such as temperature extremes. This species migrates away when temperatures rise above 36 °C. The effects of dew and rain on insect flight activities have not been well studied. However, it is suggested that aphids might be heavily bathed when dew is present, and they are unable to fly until the leaf surface is dry.	Hot/Wet	**Low risk of infestation of Green Peach Aphid**
	Hot/Dry	**Moderate risk of infestation of Green Peach Aphid**

GREEN STINK BUG (GSB)[ccxxix,ccxxx]

Acrosternum hilare

- Damage: The earlier feeding occurs in the development of the fruit, the more severe the damage. Plant injuries are usually caused by adults, as the nymphs are not mobile enough to move to early-producing fruit trees. Feeding wounds also provide an opportunity for pathogens to gain entry.
- Mode of transmission: GSB overwinters as an adult and hides in the bark of trees, leaf litter, or other locations to obtain protection from the weather. As spring temperatures begin to warm, bugs move out of the winter cover and begin feeding and oviposition.
- Impact: While feeding, GSB inject digestive enzymes into food that liquefies the contents upon which they then feed. This action reduces the quality of the fruit or seed. The feeding wound also provides an opportunity for other pathogens to gain entry.

Environmental Conditions	Climate Change Impacts	
If weather stays warm, an adult stinkbug can survive about eight weeks. In cold weather, young stink bugs will hibernate in leaf litter or under tree bark until the onset of warmer temperatures.	Hot/Wet	**Low risk of infestation of Green Stink Bug**
	Hot/Dry	**Moderate risk of infestation of Green Stink Bug**

LEGUME POD BORER[ccxxxi,ccxxxii,ccxxxiii]

Maruca testulalis

- Damage: Feeds on plants flower-buds, flowers, and young pods (in some cases early instars feed on flower peduncles and young stems).
- Mode of transmission: Adults are not active during the day but are active at night. They are usually found at rest under the lower leaves of the host plant until conditions are proper to infest. They live for an average of six to 10 days; each female can lay up to 200 eggs.
- Impact: Plants are not killed, but a large proportion of the pods may be damaged and unmarketable.

Environmental Conditions	Climate Change Impacts	
The pupal diapause can be sustained for 120 to 180 days at a constant warm temperature of 25 °C. Other reports indicate that borer can be very active at 30 °C. Duration of different life stages is variable and depends on host plant and climatic conditions.	Hot/Wet	**Low risk of infestation of Legume Pod Borer**
	Hot/Dry	**High risk of infestation of Legume Pod Borer**

SESAME WEBWORM (a.k.a Sesame Pod Borer)[ccxxxiv,ccxxxv,ccxxxvi]

Antigastra catalaunalis

- Damage: The larva feeds on leaves and young shoots. At a later stage, the larvae infest the sesame fruit capsule, making an entrance hole on the lateral side and feeding on the seeds inside the capsule.
- Mode of transmission: This pest is endemic to tropical and subtropical areas, but is also found infesting other crops and areas due to its migratory nature.
- Impact: It is reported to attack the crop in all growth stages, after about two weeks of emergence. They leave excreta on the seeds, ruining them. The highest incidence of the sesame webworm is recorded in fields with a sesame and finger millet mixture.

Environmental Conditions	Climate Change Impacts	
The maximum temperature for pest development is reported between 31 °C and 36 °C and the mean optimal is 27 °C and low rainfall (below 55mm). These conditions increase the larval population. Plants grown in the shade are less infested than those that receive full sunlight.	Hot/Wet	**Low risk of infestation of Sesame Webworm**
	Hot/Dry	**Moderate risk of infestation of Sesame Webworm**

SESAME FUNGAL DISEASES

ALTERNARIA LEAF SPOT[ccxxxvii,ccxxxviii,ccxxxix]

Alternaria sesami

- Damage: Lesions are brown to black in color, round to irregular, and often localized. In severe attacks, the leaves dry out and fall off.
- Mode of transmission: *Alternaria sesami* is both externally and internally seed-borne, so infection is caused by contaminated seed used in the planting.
- Impact: Although considered an important fungal disease of sesame, there is little information about actual economic impact. Plants can be killed due to severe defoliation and stem infections.

Environmental Conditions	Climate Change Impacts	
Warmer climate could influence outbreaks. Yield losses are greatest in dry years, as plants under moisture stress are more susceptible.	Hot/Wet	**Low risk of infection of Alternaria Leaf Spot**
	Hot/Dry	**Moderate risk of infection of Alternaria Leaf Spot**

LEAF SPOT DISEASE[ccxl,ccxli]

Cercospora sesami

- Damage: Disease affects leaves of plants as early as four weeks after planting. The effect starts as small pinhead-sized spots that with time extend in size. Extensive infection of foliage and capsule leads to defoliation and damage of sesame capsules.
- Mode of transmission: The fungus is found in plant debris from previous growing seasons. Under favorable conditions, the disease spreads to leaf petiole, stem, and capsules.
- Impact: Extensive infection of foliage and capsule leads to defoliation and damage of sesame capsules; yield losses may range from 22 to 53 percent.

Environmental Conditions	Climate Change Impacts	
As with many other fungal diseases, warmer temperatures and high humidity could favor outbreaks.	Hot/Wet	**High risk of infection of Leaf Spot Disease**
	Hot/Dry	**No risk of infection of Leaf Spot Disease**

SESAME VIRAL DISEASES

LEAF CURL VIRUS DISEASE (LCVD)[ccxlii,ccxliii]

Caused by Potyvirus

- Damage: Severe curling, crinkling, and distortion of the leaves accompanied by vein clearing and reduction of leaf lamina. The leaf margins are rolled downward and inward in the form of an inverted cap. The veins thicken and turn dark green. The leaves become leathery and brittle, and petioles are twisted. Affected plants bear only a few flowers and fruits.
- Mode of transmission: Epidemics are often associated with the presence of whiteflies.
- Impact: In advanced stages defoliation takes place, and growth of the tree is stunted.

Environmental Conditions	Climate Change Impacts	
Outbreaks depend on the spread or colonization of the vector, whitefly *B. tabaci*.	Hot/Wet	**Low risk of infection of *B. tabaci* and low risk of infection of LCVD**
Warmer temperatures and altered rainfall patterns can affect the occurrence and dynamics of whitefly. The insects thrive in dry weather, so drought can boost infestation.	Hot/Dry	**High risk of infection of *B. tabaci* and high risk of infection of LCVD**

ROOT CROPS

CASSAVA

CASSAVA PESTS

CASSAVA GREEN MITE (CGM)[ccxliv,ccxlv,ccxlvi]

Mononychellus tanajoa

- Damage: Active stages feed on the lower parts of leaves by sucking fluids from cells. This action causes chlorosis, which can increase from a few spots to complete loss of chlorophyll. Most CGM are generally found on the upper third of the cassava plant. Leaves damaged by CGM may also show mottled symptoms. Severely damaged leaves dry out and fall off, which can cause a characteristic candlestick appearance.
- Mode of transmission: The mite spreads quickly, carried away by wind and movement of infested planting materials.
- Impact: CGM is a pest responsible for cassava yield losses of 30 to 50 percent in Africa.

Environmental Conditions	Climate Change Impacts	
Peak CGM densities occur during the first half of the dry season, with a smaller peak occurring within about a month of the start of the long rainy season. Severity is greater during the dry season as opposed to the wet season. Heavy rainfall can reduce CGM populations. Populations increase with increasing temperature, leading at times to a very rapid increase in populations and damage.	Hot/Wet	**Low risk of infestation of Cassava Green Mite**
	Hot/Dry	**High risk of infestation of Cassava Green Mite**

CASSAVA MEALYBUG [ccxlvii,ccxlviii]

Phenacoccus manihoti

- Damage: When it feeds on cassava, *P. manihoti* causes severe deformation of terminal shoots, yellowing and curling of leaves, reduced internodes, stunting, and weakening of stems used for crop propagation.
- Mode of transmission: The dispersal stage of mealybugs is the first-instar crawler stage; these are often dispersed passively in the wind. Crawlers may also be carried passively by passing animals and people that brush past the host plant.
- Impact: In the absence of control actions, damage can reduce yields by more than 80 percent. The insect became the major cassava pest and spread rapidly through most of the African cassava belt.

Environmental Conditions	Climate Change Impacts	
Optimal temperature is around 27 °C, but significant mortality occurs below 15 °C and above 33 °C. The dry season favors outbreak. Rainfall is a key determinant of abundance and population dynamics. Rainfall can suppress *P. manihoti* mainly by causing mechanical mortality.	Hot/Wet	**Low risk of infestation of Cassava Mealybug**
	Hot/Dry	**High risk of infestation of Cassava Mealybug**

CASSAVA BACTERIAL DISEASES

CASSAVA BACTERIAL BLIGHT (CBB)[ccxlix,ccl]

Xanthomonas axonopodis pv. Manihotis

- Damage: CBB causes leaf spotting, wilt, shoot die-back, gumming, and vascular necrosis.
- Mode of transmission: This disease is primarily spread by infected cuttings. It can also be mechanically transmitted by raindrops; use of contaminated farm tools (e.g., knives); chewing insects (e.g., grasshoppers); and movement of man and animals through plantations, especially during or after rain.
- Impact: It is considered to be the most important bacterial disease of the crop. If no management strategies are in place, losses can exceed 90 percent.

Environmental Conditions	Climate Change Impacts	
Establishment of the bacteria requires greater than 90 percent relative humidity, with an optimum temperature of 22-26 °C. Dry weather substantially reduces development of the disease.	Hot/Wet	**Very high risk of infection of Cassava Bacterial Disease**
	Hot/Dry	**No risk of infection of Cassava Bacterial Disease**

CASSAVA VIRAL DISEASES

CASSAVA BROWN STREAK DISEASE (CBSD)[ccli,cclii,ccliii]

Caused by Cassava Brown Streak Virus (CBSV)

- Damage: CBSD symptoms show in leaves, stems, fruits, and roots. Leaf symptoms are most pronounced in mature leaves and comprise a blotchy yellow chlorosis, in some varieties clearly associated with minor veins. The combination of symptoms varies between varieties, although there is an association between the range and severity of aboveground symptoms and the severity of symptoms in roots.
- Mode of transmission: It is reported that the whitefly *Bemisia tabaci* is the most likely vector of the virus. The virus is transmitted when this whitefly feeds on the plant.
- Impact: Reported new outbreaks and the increased spread of CBSD warn that the rapidly proliferating plant virus could cause a 50 percent drop in production.

Environmental Conditions	Climate Change Impacts	
Adult whiteflies *(B. tabacii)* are responsible for transmission. Warmer temperatures and altered rainfall patterns can affect the occurrence and dynamics of whitefly. Drought can increase infestation. Rising temperatures now pose a threat to cassava because they appear to trigger an explosion of whiteflies.	Hot/Wet	**Low risk of infection of *B. tabaci* and low risk of infection of CBSD**
	Hot/Dry	**High risk of infection of *B. tabaci* and high risk of infection of CBSD**

CASSAVA MOSAIC VIRUS DISEASE (CMD)[ccliv,cclv,cclvi]

Caused by cassava mosaic geminiviruses

- Damage: CMD causes characteristic leaf symptoms that can usually be recognized without difficulty. Plants affected by "green mosaic type" have leaves with contrasting sectors of dark and light green tissue. Plants affected by "yellow mosaic type" are much more obvious, as they have leaves with contrasting normal green and yellow tissue. Chlorotic areas may expand less than other parts of the leaf lamina, which can lead to distortion of leaflets and rupture of tissues. Severe chlorosis is often associated with premature leaf abscission, a characteristic S-shaped curvature of petioles as well as a decrease in vegetative growth and yield of roots.
- Mode of transmission: The whitefly vector *Bemisia tabaci* is responsible for the spread of CMD. The virus is transmitted when whitefly feeds on the plant and produces wounds. Warmer temperatures and altered rainfall patterns can affect the occurrence and dynamics of whitefly in cassava agro-ecosystems.
- Impact: The most severely affected plants are so stunted that they produce virtually no yield of roots or stems for further propagation. Africa-wide losses caused by CMD are in the range of 15 to 24 percent.

Environmental Conditions	Climate Change Impacts	
The whitefly vector *Bemisia tabaci* is responsible for the spread of CMD. Warmer temperatures and altered rainfall patterns can affect the occurrence and dynamics of whitefly in cassava agro-ecosystems. They thrive in dry weather, so drought can boost infestation.	Hot/Wet	**Low risk of infection of *B. tabaci* and low risk of infection of CMD**
	Hot/Dry	**High risk of infection of *B. tabaci* and high risk of infection of CMD**

SWEET POTATO

SWEET POTATO PESTS

MOLE CRICKET[cclvii,cclviii,cclix]

Gryllotalpa africana

- Damage: Damage caused by mole crickets to plants occurs mainly through feeding, but also in part by tunneling. Feeding occurs underground on roots, at any time of day or night. At night, in warm, wet weather, mole crickets also will feed at the ground-surface level on stems and leaves of plants; they do not climb above the ground level.
- Mode of transmission: *G. africana* prefers and thrives in moist, loose soil, so damage usually occurs in crop fields near moist locations. Outbreaks are reported when a period of drought preceded.
- Impact: It is considered a minor pest but can cause significant damage if conditions are suitable.

Environmental Conditions	Climate Change Impacts	
Mole crickets are cold-blooded. They cannot move at freezing temperatures and so must remain dormant underground. The temperature must be even higher before they can fly.	Hot/Wet	**Low risk of infestation of Mole Cricket**
	Hot/Dry	**Moderate risk of infestation of Mole Cricket**

NEMATODES[cclx,cclxi,cclxii]

Meloidogyne incognita and *Radopholus similis*

- Damage: Above-ground symptoms include poor shoot growth, leaf chlorosis, and stunting. Additional symptoms include galling of rootlets and severe cracking of storage roots on some varieties, or formation of small bumps or blisters on other varieties. There may also be brown to black spots in the outer layers of flesh, which are not evident unless the storage root is peeled. Presence can be diagnosed by the pearl-like swollen female nematodes in the flesh of storage roots or in fibrous roots, within the galls or dark spots.

- Mode of transmission: Nematodes can prevail in infected soils for a very long time, so transmission occurs when crops are planted in those fields.

- Impact: The degree of damage depends upon the population density of the nematode; present taxa; susceptibility of the crop; and environmental conditions such as fertility, moisture, and presence of other pathogenic organisms that may interact with nematodes.

Environmental Conditions	Climate Change Impacts	
An increase in temperature influences infection, but some levels of soil moisture are required. Development occurs between 13 °C and 34 °C, with optimal development at about 29 °C. Penetration, rate of development, and total population of *Meloidogyne incognita* in roots of susceptible and resistant sweet potatoes increase with temperatures	Hot/Wet	**Moderate risk of infestation of Nematodes**
	Hot/Dry	**Low risk of infestation of**

between 24 and 32 °C.		**Nematodes**

SWEET POTATO HAWK MOTH, SWEET POTATO HORNWORM, SWEET POTATO MOTH[cclxiii,cclxiv,cclxv]

Agrius convolvuli

- Damage: These pests cause complete defoliation of the crop if not controlled. *A. convolvuli* larvae can defoliate sweet potato vines and, even when damage is less severe, harvest is delayed. This situation increases the likelihood of major attack by the sweet potato weevil, *Cylas formicarius*.
- Mode of transmission: Under dry conditions, the female lays eggs singly on either surface of the leaves. Later, caterpillars feed on leaves, causing irregular holes. They may eat the entire leaf, leaving only the petiole.
- Impact: Defoliation results in partial or complete crop failure.

Environmental Conditions	Climate Change Impacts	
Drought or lower than normal rainfall can impact activity. They are more active in the dry season. Consumption of sweet potato leaves was greatest at 30 °C. The pupal diapause can be sustained for 120 to 180 days at a constant warm temperature of 25 °C.	Hot/Wet	**Low risk of infestation of Sweet Potato Hawk Moth**
	Hot/Dry	**Moderate risk of infestation of Sweet Potato Hawk Moth**

SWEET POTATO TORTOISE BEETLE[cclxvi,cclxvii]

*Aspidimorpha spp***.**

- Damage: Both adults and larvae eat large round holes in the leaves. Attacks are sometimes sufficiently severe to completely skeletonize the leaves and peel the stems.
- Mode of transmission: The pest survives in alternative host plants; it attacks when crops are planted in close vicinity and when conditions are favorable.
- Impact: Although their damage is quite conspicuous, they seldom if ever cause yield losses.

Environmental Conditions	Climate Change Impacts	
At 20 °C and 25 °C, the percent survival from first instar to adult is 75 and 73 percent, respectively. A constant temperature of 30 °C has a detrimental effect on the larvae.	Hot/Wet	**Low risk of infestation of Sweet Potato Tortoise Beetle**
	Hot/Dry	**Low risk of infestation of Sweet Potato Tortoise Beetle**

SWEET POTATO WEEVIL[cclxviii,cclxix,cclxx]

Cylas formicarius

- Damage: Damage is caused by mining of the tubers by larvae. The infested tuber is often riddled with cavities, spongy in appearance, and dark in color. Tunneling larvae also cause damage indirectly by facilitating entry of soil-borne pathogens. Larvae also mine the vine of the plant, causing it to darken, crack, or collapse. Adults may feed on the tubers, creating numerous small holes. Adult feeding on the foliage seldom is of consequence.
- Mode of transmission: Discarded and un-harvested roots can support large populations, and can be responsible for infestation in new plantings. Alternate hosts such as *Ipomoea* weeds also offer survival niches for *Cylas*.
- Impact: This is the most serious pest of sweet potato around the world, with up to 97 percent losses in some cases. It causes damage in the field and in storage, and has quarantine significance.

Environmental Conditions	Climate Change Impacts	
Reduced rainfall and lower temperatures can contribute to weevil development. It is reported that more damage takes place during the dry season. Adults survive better at cool temperatures.	Hot/Wet	**Low risk of infestation of Sweet Potato Weevil**
	Hot/Dry	**Low risk of infestation of Sweet Potato Weevil**

SWEET POTATO BACTERIAL DISEASES

BACTERIAL STEM AND ROOT ROT[cclxxi,cclxxii, cclxxiii]

Erwinia chrysanthemi

- Damage: Aerial symptoms are water-soaked brown to black lesions on stems and petioles. One or two branches may wilt, and eventually the entire plant collapses. Localized lesions on fibrous roots may also be present. On fleshy roots, localized lesions with black margins can be observed on the surface, but more frequently the rotting is internal with no outside evidence.
- Mode of transmission: It is spread through water, with the splashing of water from infected plants, insects, and cultural practices such as using contaminated tools or improper storage with infected products. Insects are significant vectors for movement of bacteria.
- Impact: It is a major pathogen for sweet potatoes and for many other economic crops.

Environmental Conditions	Climate Change Impacts	
The most significant factor to disease development is environmental conditions consisting of high humidity and temperatures between 22 °C and 34 °C.	Hot/Wet	**Very high risk of infection of Bacterial Stem and Root Rot**
	Hot/Dry	**No risk of infection of Bacterial Stem and Root Rot**

SWEET POTATO FUNGAL DISEASES

CHARCOAL ROT[cclxxiv,cclxxv,cclxxvi]

Macrophomina phaseolina

- Damage: In the field, brown to black, water-soaked lesions are noted on stems and petioles. Eventually, the stem may become watery and collapse, causing the ends of vines to wilt. Usually one or two vines will collapse, but occasionally the entire plant dies.
- Mode of transmission: *M. phaseolina* survives as microsclerotia in the soil and on infected plant debris. The microsclerotia serve as the primary source of inoculum and have been found to persist within the soil up to three years. The rate of infection increases with higher soil temperatures, and low soil moisture will further enhance disease severity.
- Impact: Charcoal rot, caused by the fungus, can cause losses of sweet potatoes in storage; serious losses seldom occur.

Environmental Conditions	Climate Change Impacts	
This is an important pathogen particularly where high temperatures and water stress occurs during the growing season.	Hot/Wet	**Moderate risk of infection of Charcoal Rot**
M. phaseolina is favored with higher temperatures of 30 to 35 °C and low soil moisture.	Hot/Dry	**Low risk of infection of Charcoal Rot**

RHIZOPHUS SOFT ROT[cclxxvii,cclxxviii,cclxxix]

Rhizopus stolonifer

- Damage: Infection and decay commonly occur at one or both ends of the root, although infection occasionally begins elsewhere. The color of the root is not significantly altered, but an odor is produced that attracts fruit flies to the area. If humidity is high, the sweet potatoes become heavily "whiskered" with a grayish black fungal growth. This feature distinguishes *Rhizopus* soft rot from other pathogens.
- Mode of transmission: *Rhizopus* survives on plant debris, grows rapidly, and sporulates readily. Spores are disseminated in wind and water and by insects. The incidence usually increases during rainy weather.
- Impact: It is reported as one of the most costly postharvest diseases of sweet potatoes.

Environmental Conditions	Climate Change Impacts	
Climate has a strong influence on outbreaks. Rotting may be inhibited under dry conditions; but humid conditions affect sweet potatoes by making them soft and watery, and the entire root rots within a few days. Infection can also occur when relative humidity is between 75 and 85 percent during storage or transport. Chilling and heat damage also predispose sweet potatoes to infection.	Hot/Wet	**High risk of infection of Rhizophus Soft Rot**
	Hot/Dry	**Moderate risk of infection of Rhizophus Soft Rot**

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