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CLIMATE CHANGE IN MALI:

EXPECTED IMPACTS ON PESTS AND DISEASES AFFLICTING SELECTED CROPS

AUGUST 2014

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ARCC

African and Latin American Resilience to Climate Change Project

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AFRICAN AND LATIN AMERICAN RESILIENCE TO CLIMATE CHANGE (ARCC)

AUGUST 2014

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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 Climate Change in Mali. ARCC also has produced a subseries on Climate Change and Water Resources in West Africa, Climate Change and Conflict in West Africa, and Agricultural Adaptation to Climate Change in the Sahel.

THE SUBSERIES ON ADAPTATION TO CLIMATE CHANGE IN MALI

At the request of the United States Agency for International Development (USAID), ARCC undertook the Mali series of studies to increase understanding of the potential impacts of climatic change in rural Mali and identify means to support adaptation to these impacts. Other documents in the Climate Change in Mali series include: Expected Impacts on Pests and Diseases Afflicting Livestock, Impact Modeling of Selected Agricultural Adaptive Practices, Climate Vulnerability Mapping, Key Issues in Water Resources, Organizational Survey and Focus Groups of Adaptive Practices, and An Institutional Analysis of l'Agence de l'Environnement et du Développement Durable (AEDD) and l'Agence Nationale de la Météorologie (Mali-Météo).

INTRODUCTION TO THE TABLES

The tables present analyses of the potential impact of a changed climate on the most common pests and diseases afflicting 16 important crops in Mali. Information used in 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, the relative frequency of outbreaks within endemic zones, and infection rates.

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 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 of precipitation. Most models project a slight increase in annual rainfall in the central Sahel and a decrease in the western Sahel. Modeling efforts for Mali itself are not more precise.

Some models project that, in the Sahel as a whole, the onset of the rainy season may be delayed and the number of extreme events 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 to 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.
	Aflatoxin Fungus	Hot/Wet – High risk of infection of *Aspergillus flavus.* Hot/Dry – No risk of infection of *Aspergillus flavus.*
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
	Aflatoxin Fungus	Hot/Wet – Very high risk of infection of *Aspergillus flavus.* Hot/Dry – No risk of infection of *Aspergillus flavus.*
	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 grasshoppers
PEARL MILLET	Witchweed	Hot/Wet – Low risk of severe parasitism of Witchweed Hot/Dry – Moderate risk of severe parasitism of Witchweed
	Smut	Hot/Wet – High risk of outbreak of Smut. Hot/Dry – No risk of outbreak of Smut.
	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
	[Yellow Stem Borer]()	Hot/Wet – Low risk of severe infestation of Yellow Stem Borer. Hot/Dry – High risk of severe infestation of Yellow Stem Borer.
	[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
	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
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
	Spiny Bollworm	Hot/Wet – Low risk of infestation of Spiny Bollworm Hot/Dry – High risk of infestation of Spiny Bollworm
MANGO	Mango Fruit Fly	Hot/Wet – Moderate risk of infection of Mango Fruit Fly Hot/Dry – Low risk of infection of Mango Fruit Fly
	Mango Bacterial Canker	Hot/Wet – High risk of infection of Mango Bacterial Canker. Hot/Dry – No risk of infection of Mango Bacterial Canker.
	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 – Low risk of parasitism of Cowpea Witchweed Hot/Dry – moderate risk of parasitism 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	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/SIGNIFICANT

Pests and diseases currently of significant prevalence and impact

AFFECTED SPECIES	PEST OR DISEASE	CLIMATE IMPACT
MAIZE	Spotted Stem Borer	Hot/Wet – Low risk of infestation of Spotted Borer Hot/Dry – Low risk of infestation of Spotted Borer
	Maize Weevil	Hot/Wet – Low risk of infestation of Maize Weevil. Hot/Dry – Moderate risk of infestation of Maize Weevil.
	Maize Mosaic Virus (MMV)	Hot/Wet – Low risk of outbreak of Aphids, the vector causing infection of MMV. Hot/Dry – High risk of outbreak of Aphids, the vector causing infection of MMV.
	Peanut Clump Virus	Hot/Wet – High risk of infection of vector *P. graminis* and high risk of infection of PCV. Hot/Dry – Low risk of infection of vector *P. graminis* and high risk of infection of PCV.
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
	Grasshoppers	Hot/Wet – Low risk of serious infestation grasshoppers. Hot/Dry – Moderate risk of serious infestation grasshoppers.
	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 Shoot Fly	Hot/Wet – Low risk of infestation of Sorghum Shoot Fly Hot/Dry – Low risk of infestation of Sorghum Shoot Fly
	Sorghum Head Bug	Hot/Wet – Low risk of infestation of Sorghum Head Bug. Hot/Dry – High risk of infestation of Sorghum Head Bug.
	Striga Purple Witchweed	Hot/Wet – Low risk of parasitism of Striga Purple Witchweed. Hot/Dry – High risk of parasitism of Striga Purple Witchweed.
COTTON	Egyptian Cotton Leafworm	Hot/Wet – Low risk of infestation of Egyptian Cotton Leafworm. Hot/Dry – High risk of infestation of Egyptian Cotton Leafworm.
MANGO	Scab	Hot/Wet – Low risk of infection of Scab. Hot/Dry – No risk of infection of Scab.

COWPEA	Cowpea Witchweed	Hot/Wet – Low risk of parasitism of Cowpea Witchweed. Hot/Dry – Moderate risk of parasitism of Cowpea Witchweed.
	Flower Bud Thrips	Hot/Wet – Low risk of infestation of Flower Bud Thrips. Hot/Dry – Moderate risk of infestation of Flower Bud Thrips.
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

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 increase incidence of Flour Beetles Hot/Dry – Low risk of increase incidence of Flour Beetles
MAIZE	Striga Witchweed	Hot/Wet – Low risk of severe parasitism of Striga. Hot/Dry – Moderate risk of severe parasitism of Striga.
PEARL MILLET	Meloid and Scarabaeid Beetles	Hot/Wet – Low risk of infestation of Meloid and Scarabaeid Beetles. Hot/Dry – High risk of infestation of Meloid and Scarabaeid Beetles.
	Ergot	Hot/Wet – Very high risk of outbreak of Ergot. Hot/Dry – No risk of outbreak of Ergot.
RICE	Birds	Hot/Wet – High risk of infestation of birds Hot/Dry – Low risk of infestation of birds
	Stalk-Eyed Fly	Hot/Wet – Low risk of severe infestation of Stalk-Eyed Fly. Hot/Dry – High risk of severe infestation of Stalk-Eyed Fly.
	Rice Grasshoppers	Hot/Wet – Low risk of significant outbreak of rice grasshoppers Hot/Dry – High risk of significant outbreak of rice grasshoppers
SORGHUM	Lesser Grain Borer	Hot/Wet – Low risk of severe infestation of Lesser Grain Borer. Hot/Dry – Moderate risk of severe infestation of Lesser Grain Borer.
COTTON	Cotton Leaf Roller	Hot/Wet – Low risk of infestation of Cotton Leaf Roller Hot/Dry – Moderate risk of infestation of Cotton Leaf Roller
	Cotton Virescence Disease	Hot/Wet – High risk of infection of Cotton Virescence Disease. Hot/Dry – No risk of infection of Cotton Virescence Disease.
MANGO	Stem-End Rot	Hot/Wet – High risk of infection of Stem-End Rot. Hot/Dry – No risk of infection of Stem-End Rot.
GROUNDNUT	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

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
PEARL MILLET	Blister Beetles	Hot/Wet – Low risk of infestation of Blister Beetles. Hot/Dry – High risk of infestation of Blister Beetles.
	Dactuliophora Leaf Spot, Leaf Spot of Pearl Millet	Hot/Wet – Very high risk of outbreak of Dactuliophora Leaf Spot. Hot/Dry – No risk of outbreak of Dactuliophora Leaf Spot
CASHEW	Cashew Stem and Root Borer	Hot/Wet – Low risk of infestation of Cashew Stem and Root Borer. Hot/Dry – High risk of infestation of Cashew Stem and Root Borer.
	Fruit Fly	Hot/Wet – Low risk of infestation of Fruit Fly. Hot/Dry – Moderate risk of infestation of Fruit Fly.
SHEA NUT	Bark Borer	Hot/Wet – Low risk of infestation of Bark Borer Hot/Dry – High risk of infestation of Bark Borer
	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
COWPEA	Cowpea weevil	Hot/Wet – Moderate risk of infestation of Cowpea Weevil Hot/Dry – Low risk of infestation of Cowpea Weevil
	Cowpea Root-Knot Nematode	Hot/Wet – Moderate risk of infestation of Cowpea Root-Knot Nematode. Hot/Dry – Low risk of infestation of Cowpea Root-Knot Nematode.

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: This is considered to be a secondary pest, 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**

FONIO FUNGAL DISEASES

AFLATOXIN FUNGUS[iv,v]

Aspergillus flavus

- Damage: *A. flavus* contamination produces potent toxins known as aflatoxins which can be harmful for humans.
- Mode of Transmission: Infection and contamination of plant parts is influenced by stress or by insect damage (the more common). *A. flavus* can overwinter in the soil and will exist on decaying matter. It can infect crops before and after harvesting.
- Impact: Aflatoxins are potent carcinogens which are highly regulated in most countries. They can cause developmental and immune system suppression, cancer, and death. Aflatoxin contamination causes important economic loss for producers and processors of a wide variety of susceptible crops.

Environmental Conditions	Climate Change Impacts	
Aflatoxin contamination is prevalent both in warm humid climates and in irrigated hot deserts. Rain combined with warm, wet conditions favor contamination of the crop after maturation.	Hot/Wet	**High risk of infection of *Aspergillus flavus***
	Hot/Dry	**No risk of infection of *Aspergillus flavus***

LEAF SPOT DISEASE[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, elongated, 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 of up to 20 percent have been reported, and 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**

MAIZE

MAIZE PESTS

MAIZE WEEVIL[viii]

Sitophilus zeamais

- Damage: Maize Weevil produces tunneling of whole, previously unspoiled grains. In severe infestations, only the grain hull remains along with powdery white frass. It produces distinctive large holes with asymmetrical ends. Grains floating in water frequently indicate that larval damage has occurred.
- Mode of Transmission: Females gnaw into maize grains where they lay their eggs throughout most of their adult life. Both adults and larvae damage the grain by chewing. The infestation can start in the field, but most damage occurs in storage.
- Impact: *Sitophilus zeamais* is an important pest that causes deterioration of stored maize. It has serious economic impact.

Environmental Conditions	Climate Change Impacts	
Significant storage pest in warm climates around the world. Adults fly from the storage facility to fields, where infestation starts and may continue after crop harvest.	Hot/Wet	**Low risk of infestation of weevil**
	Hot/Dry	**Moderate risk of infestation of weevil**

STRIGA WITCHWEED[ix]

Striga hermonthica

- Damage: This parasitic weed can attack at all the plant stages and plant parts. It can affect flowering, podding, pre-emergence, seedling, and vegetative phases; and the leaves, stems and whole plant.
- Mode of transmission: The weed is difficult to control as it produces thousands of small and light seeds per plant that are easily and broadly dispersed by wind, water, animals, and agricultural tools. *Striga* seeds can be dormant but still potentially active for many years.
- Impact: In some locations and years, *Striga* infestation may lead to total crop failure. Severe infestation may make continued cultivation of cereals difficult, forcing farmers to change cropping strategy or abandon their fields.

Environmental Conditions	Climate Change Impacts	
Temperatures ranging from 30 to 35 °C are ideal for germination. The weed will not develop in temperatures below 20 °C.	Hot/Wet	**Low risk of severe parasitism of *Striga***
	Hot/Dry	**Moderate risk of severe parasitism of *Striga***

AFRICAN SUGARCANE BORER[x,xi,xii]

Eldana saccharina

- Damage: Attacks maize during the 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: 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 will also 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, and therefore extreme conditions, such as drought, 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 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, from which they can then attack the following season's crops.
- Impact: In some places, it can reduce maize production between 10 and 70 percent. Damage to sorghum is usually less serious than damage to maize, because sorghum easily tillers and this can partly 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 warmer climate and 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 death of the growing points, early senescence, "dead heart" condition, reduced translocation, lodging, and indirect damage to the ears. Pre-tasseling is the stage at which the plant is most attractive to stem borers and 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 in volunteer crop plants and/or alternative hosts.
- Impact: Affects flowering stage and vegetative growing stage of maize. *Sesamia calamistis* 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 be infesting older crops and in 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	
The spotted stem borer 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 positive 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 Borer**
	Hot/Dry	**Low risk of infestation of Spotted Borer**

MAIZE FUNGAL DISEASES		
AFLATOXIN FUNGUS[xxii] *Aspergillus flavus* • Damage: *A. flavus* contamination produces potent mycotoxins known as aflatoxins, which can be harmful for humans. • Mode of Transmission: Infection and contamination of plant parts predisposed by stress or insect damage is most common. *A. flavus* overwinters in the soil and will appear on decaying matter, it can infect crops before and after harvesting. • Impact: Aflatoxin is a potent carcinogen that is highly regulated in most countries. They can cause developmental and immune system suppression, cancer, and death. Aflatoxin contamination causes important economic loss for producers and processors of a wide variety of susceptible crops.		
Environmental Conditions	**Climate Change Impacts**	
Aflatoxin contamination is prevalent both in warm humid climates and in irrigated hot deserts. Rain combined with warm, wet conditions favor contamination.	Hot/Wet	**Very high risk of infection of *Aspergillus flavus***
	Hot/Dry	**No risk of infection of *Aspergillus flavus***
MAIZE VIRAL DISEASES		
MAIZE MOSAIC VIRUS (MMV)[xxiii] • Damage: Infected plants show irregular chlorosis in the leaves, mottle, striping and a tendency to develop ring-like spots. Susceptible varieties may show extreme distortion and stunted growth. • Mode of transmission: Aphids transmit MMV during feeding. The aphid immediately acquires the virus (latent period not required for transmission to new host plants). MMV overwinters in alternate hosts and is sap-transmissible. Seed transmission has also been reported. The virus occurs where aphid vectors are prevalent and where alternate hosts are cultivated. • Impact: Damage is most significant when plants are infected early, which can cause cessation of ear growth and production of infertile ears. Damage is also critical when large populations of aphid vectors are present, susceptible hybrids are cultivated, and infected plants are widespread in the vicinity. Yield losses of 40 percent have been attributed to MMV.		
Environmental Conditions	**Climate Change Impacts**	
Rain limits aphids from dispersing, and knocks them off plants. In most cases, this situation kills aphids. Many species of aphids cause the greatest damage when temperatures are warm.	Hot/Wet	**Low risk of outbreak of aphids, the vector causing infection of Rice Yellow Mottle Virus**
	Hot/Dry	**High risk of outbreak**

		of aphids, the vector causing infection of Rice Yellow Mottle Virus

PEANUT CLUMP VIRUS[xxiv]

- Damage: Infected plants are severely stunted, often showing chlorotic lesions on younger leaves, and older leaves are dark green. Root system is also stunted, limiting plants of nutrient and water uptake.
- 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 can suffer very important yield loss; up to 60 percent. PCV has been described as infecting maize in Malian fields.

Environmental Conditions	Climate Change Impacts	
Magnitude and distribution of rainfall influence incidence PCV and *P. graminis*. High rainfall causes high incidences of both virus and *P. graminis*. Temperatures ranging from 23 to 30°C are reported to be conducive to virus transmission.	Hot/Wet	**High risk of infection of vector *P. graminis* and high risk of infection of PVC**
	Hot/Dry	**Low risk of infection of vector *P. graminis* and high risk of infection of PVC**

MAIZE STREAK VIRUS (MSV) [xxv,xxvi,xxvii,xxviii]

- 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*, are also able to 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 are dependent 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**

		grasshoppers

PEARL MILLET

PEARL MILLET PESTS

BLISTER BEETLES[xxix]

Psalydolytta fusca

- Damage: Beetles feed on pollen and stigma or whole flowers**.** They can also eat the grains of pearl millet at milky stages (tips are often cut and the fluid consumed).
- Mode of transmission: The mode of infestation is not clear, but alternative hosts such as local weeds and trees appear to contribute to the survival and prevalence of the insect.
- Impact: Grain yield is directly affected as flowers do not form seed. However, there are no reports of the magnitude of yield losses. Blister beetles used to be minor pests, but in recent years serious outbreaks have occurred in northwest Mali and southern Senegal.

Environmental Conditions	Climate Change Impacts	
They have a worldwide distribution and thrive mainly in warm, dry areas on flowers and foliage.	Hot/Wet	**Low risk of infestation of Blister Beetles**
	Hot/Dry	**High risk of infestation of Blister Beetles**

GRASSHOPPERS[xxx]

Kraussaria angulifera, Oedaleus senegalensis, Hieroglyphus daganensis, Cataloipus cymbiferus, and *Kraussella amabile.*

- Damage: They puncture 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.
- Mode of transmission: Periods of drought appear to enhance population growth and chances of grasshopper outbreaks.
- Impact: These five grasshopper species occur in the Sahel zone. Some species are also responsible for transmitting viruses.

Environmental Conditions	Climate Change Impacts	
Populations increase in size when warm and dry weather occur in late spring. This offers good conditions for feeding. Hot summer with adequate rainfall provides good food supply and low incidence of disease in the populations.	Hot/Wet	**Low risk of serious infestation grasshoppers**
	Hot/Dry	**Moderate risk of serious infestation grasshoppers**

MELOID AND SCARABAEID BEETLES[xxxi,xxxii]

- Damage: The feeding of adult beetles may cause serious defoliation and damage or destroy flowers or buds, in both cases the impact on yield and quality of the harvested crop can be negative.
- Mode of transmission: Most species of these beetles have one generation per year. Adults lay eggs in the soil and larvae undergo several transformations before overwintering as pseudo-pupae. The adults eventually emerge from soil throughout the growing season.
- Impact: Although the meloid beetles is typically not considered to be a serious pest, heavy infestations may cause considerable damage because of the gregarious nature of adult beetles.

Environmental Conditions	Climate Change Impacts	
In response to high temperature, meloid beetles larvae will pupate faster from grub phases. They are often found in regions of warmer and drier climate.	Hot/Wet	**Low risk of infestation of Meloid and Scarabaeid Beetles**
	Hot/Dry	**High risk of infestation of Meloid and Scarabaeid Beetles**

MILLET EARHEAD CATERPILLAR, MILLET HEAD MINER[xxxiii,xxxiv]

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: These caterpillars were very destructive in the Sahelian regions of West Africa in the early 1970s. Now percentages of crop losses vary from 1 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 with 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 STEM BORERS[xxxv,xxxvi]

Acigona ignefusalis, Sesamia calamistis

- Damage: The damage starts from the seedling stage and continues till maturity. Early-sown millet is attacked by first-generation larvae, which 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 overwintering on the stubbles, which serves as 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.	Hot/Wet	**No risk of infestation of Millet Stem Borer**
However, larvae populations can be drastically reduced when temperatures exceed 40 °C.	Hot/Dry	**High risk of infestation of Millet Stem Borer**

WITCHWEED[xxxvii,xxxviii,xxxix]

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. The seeds also can lie dormant, but still potentially active, for many years.
- Impact: 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).	Hot/Wet	**Low risk of severe parasitism of Witchweed**
The higher transpiration rate of *S. hermonthica,* even under water stress and greater stomatal aperture, may induce the retention of water; solutes transfer from the host to the parasite, leading to severe damage to the host under drought.	Hot/Dry	**Moderate risk of severe parasitism of Witchweed**

PEARL MILLET FUNGAL DISEASES

DACTULIOPHORA LEAF SPOT, LEAF SPOT OF PEARL MILLET[xl]

Dactuliophora elongate

- Damage: The fungus affects foliage and has the most severe damage on lower leaves. The damage is observed as individual, brown, necrotic lesions surrounded by circular to irregular purple water-soaked margins. The lesions tend to expand in irregular concentric rings, with zones of necrosis often separated by clean zones. Entire leaves can be blighted by coalescing lesions.
- Mode of transmission: The disease is spread through airborne conidia, which survive and develop in contaminated plant debris.
- Impact: Leaf spot of pearl millet caused by *D. elongata* is reported only in Nigeria, but recent observations confirm that the pathogen also is present on pearl millet of Niger and Mali.

Environmental Conditions	Climate Change Impacts	
Optimum temperature is indicated in the range of 25-28 °C. Wet conditions favor fungus growth and infection.	Hot/Wet	**Very high risk of outbreak of Dactuliophora Leaf Spot**
	Hot/Dry	**No risk of outbreak of Dactuliophora Leaf Spot**

ERGOT[xli]

Claviceps fusiformis

- Damage: On panicles, droplets of a mucilaginous fluid are observed as they secrete from the infected florets. This "honeydew" contains numerous conidia and, when abundant, honeydew drops fall onto the foliage and the ground. The droplets on the panicle become darker and coalesce to form compact patches. Infected florets do not produce grains because the ovaries are replaced by compact, dark, hard fungal masses.
- Mode of transmission: Conidia are spread from plant to plant by wind, rain-splash, and insects. Wild species of *Pennisetum* and related grasses are hosts that may serve as reservoirs of inoculum.

Environmental Conditions	Climate Change Impacts	
Cloudy skies, drizzling rain (with 80 percent or more of relative humidity), temperatures between 20 and 25 °C), and air movement during crop flowering favor the development and spread of ergot.	Hot/Wet	**Very high risk of infection of Ergot**
	Hot/Dry	**No high risk of infection of Ergot**

SMUT[xlii]

Moesziomyces penicillariae

- Damage: Immature green sori which often are larger than the seed develop on panicles during grain fill. Most times, a single sorus develops per floret and as grain matures, sori change in color from green to dark brown.
- Mode of transmission: Infection occurs when sporidia suspended in rain or dew infiltrate into the boot. Seed may be infested with teliospore balls, but infection does not take place through seedlings. Sori are filled with dark teliospores.
- Impact: Smut is considered one of the major pathogens of pearl millet in Sub-Sahelian areas of Africa.

Environmental Conditions	Climate Change Impacts	
Large populations of sporidia are observed when minimum and maximum temperatures range between 21 and 31°C and, the maximum relative humidity is greater than 80 percent.	Hot/Wet	**High risk of infection of Smut**
	Hot/Dry	**No risk of infection of Smut**

DOWNY MILDEW[xliii,xliv]

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 millet in Senegal.

Environmental Conditions	Climate Change Impacts	
Asexual sporangia are produced during nights 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

STALK-EYED FLY[xlv]

Diopsis longicornis, D. apicalis, D. collaris

- Damage: The larvae feed inside the tillers, causing "dead-hearts." Damage is apparent as early as 14 days after transplanting and continues to appear up to the early vegetative stage.

The damage, however, begins to decline as the plant approaches maturity.

- Mode of transmission: The flies are found in areas with water and occur in swarms in shady areas close to streams and canals, and infest weeds during dry periods.
- Impact: The fly attacks rice plants at very early stages of crop growth. Depending on the severity of the infestation, the crop can be prevented from reaching its full yield potential.

Environmental Conditions	Climate Change Impacts	
Diopsis infestation occurs later in the season, in particular when the dry season starts. At that stage the population of *Diopsis* increases rapidly.	Hot/Wet	**Low risk of severe infestation of Stalk-Eyed Fly**
	Hot/Dry	**High risk of severe infestation of Stalk-Eyed Fly**

YELLOW STEM BORER[xlvi]

Scirpophaga subumbrosa

- Damage: YSB causes “dead-hearts” or dead tiller (which can be effortlessly pulled from the base at vegetative stages). The so-called “whiteheads” can be seen during reproductive stages where the emerging panicles are white and empty. In addition, plants can present small holes on stems and tillers and, also frass inside the damaged stems.
- Mode of transmission: YSB is a pest of flooded rice. It is found in environments where there is constant flooding. The larvae enfold themselves in body leaf wrappings and detach themselves from the leaf to fall onto the water surface. They attach themselves to the tiller and bore into the stem.
- Impact: Stem borers can eat the crop during the vegetative and reproductive stages. Heavy infestations causing extreme boring through the sheath can destroy the crop. Damage can cause reduction in the number of reproductive tillers.

Environmental Conditions	Climate Change Impacts	
High incidence of YSB is reported to occur between 26 °C and 30 °C. Years in which stem borer outbreaks occur are associated with low rainfall.	Hot/Wet	Low risk of severe infestation of Yellow Stem Borer
	Hot/Dry	High risk of severe infestation of Yellow Stem Borer

AFRICAN RICE GALL MIDGE (AFRGM)[xlvii]

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[xlviii,xlix,l]

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. 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: 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[li,lii,liii]

Maliarpha separatella

- Damage: Larval damage within the stem results in reduced plant vigor, fewer tillers and many unfilled grains. The larva does not cause "dead heart" 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 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[liv,lv]

Red-billed Quelea (*Quelea quelea*). Other bird species causing damage to cereal crops in West Africa include: 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 appears in sub-Saharan Africa where gathers in vast flocks of several million and breeds in gregarious colonies which can cover more than 100 hectares.

Environmental Conditions	Climate Change Impacts	
Birds are 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[lvi,lvii,lviii]

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

Long-Horned Grasshopers: *Conocephalus* spp.

- Damage: 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: 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. Also feed on many other hosts including maize, millet, sugarcane, and many grasses in West Africa.

Environmental Conditions	Climate Change Impacts	
Grasshoppers can cause considerable damage to crops that are grown during the dry season months. Grasshoppers require warm, sunny conditions for optimal growth and reproduction. 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/Wet	**Low risk of significant outbreak of rice grasshoppers**
	Hot/Dry	**High risk of significant outbreak of rice grasshoppers**

RICE BACTERIAL DISEASES

BACTERIAL LEAF BLIGHT[lix,lx,lxi]

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, yellow-orange stripes on leaf blades. On young lesions, bacterial ooze resembles a milky dew drop. The ooze later on 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 seeds, stems, and roots that are left behind at harvest. BLB can also be transmitted by alternative weed hosts. *X. oryzae* survives on dead plants and seeds and probably travels plant-to-plant through water from irrigation or rains.
- Impact: BLB is one of the most serious of all diseases which 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. 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 increasing chances for the development of the disease.	Hot/Wet	**High risk of infection of Bacterial Leaf Blight**
	Hot/Dry	**No risk of infection of Bacterial Leaf Blight**

RICE VIRAL DISEASES

RICE YELLOW MOTTLE VIRUS (RYMV)[lxii,lxiii,lxiv,lxv]

Geminivirus

- Damage: RYMV is characterized by pale yellow mottled 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, (e.g., 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, and leaf-sucking bugs. Thus, climate conditions that favor vectors correlate with RYNV outbreaks. For instance, drought stimulates grasshopper population increase, while warm, dry weather favors beetles.	Hot/Wet	**Low risk of infection of Rice Yellow Mottle Virus**
	Hot/Dry	**Moderate risk of infection of Rice Yellow Mottle Virus**

SORGHUM

SORGHUM PESTS

LESSER GRAIN BORER[lxvi]

Rhyzopertha dominica

- Damage: The adults and larvae bore into unharmed kernels, turning them into hollow husks. The borer is also capable of surviving and developing in the accumulated "flour" produced as the seeds are chewed up.
- Mode of transmission: Adult females lay eggs singly or in groups of up to 30. The eggs are laid on the outside of the grain or in the fine powdered grain associated with infestations of this beetle. Development from egg to adult depends on temperature. In hot summer conditions it may take as few as 30 days. Pupation takes place inside the hollow shell of the seed or in the "flour" that accumulates with infested grain.
- Impact: Although losses reported in some Malian villages were not significant, LGB was identified as the major pest infesting more than 25 villages surveyed.

Environmental Conditions	Climate Change Impacts	
The development from egg to adult depends on temperature. In hot summer conditions it may take as few as 30 days, but the average is about 58 days. Specifically, larval development usually takes 27-31 days at 28 °C and 46 days at 25 °C.	Hot/Wet	**Low risk of severe infestation of Lesser Grain Borer**
	Hot/Dry	**Moderate risk of severe infestation of Lesser Grain Borer**

SORGHUM HEAD BUG[lxvii]

Eurystylus oldi

- Damage**:** Damage usually starts at the time panicle emerges from the boot leaf. The damaged grain shows distinct red-brown feeding punctures. High levels of bug damage lead to tanning and shriveling of the grain.
- Mode of transmission: Insects can survive in other plant hosts. Maximum head bug abundance is often observed during the dough stage.
- Impact: SHB reduces grain yield, quality and makes grains inadequate for human consumption. The affected grains also have reduced seed germination. Sometimes, farmers are fully unaware of this insect and its damage potential because it remains hidden inside the panicle. *E oldi* causes severe yield losses due to its feeding and oviposition in Asia and Africa, particularly in Western Africa.

Environmental Conditions	Climate Change Impacts	
Hot, dry weather favors buildup of head bug populations. When the population has large numbers of bugs, they may migrate from wild grasses or small grains, such as wheat, to attack grain sorghum.	Hot/Wet	**Low risk of infestation of Sorghum Head Bug**
	Hot/Dry	**High risk of infestation of Sorghum Head Bug**

KHAPRA BEETLE (KB) [lxviii,lxix,lxx]

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. *Trogoderma granarium* is a serious pest of stored products under hot dry conditions. Research under controlled conditions show that beetle's breeding is slow at 25 °C, very slow at 22.5 °C and 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 economic importance.	Hot/Wet	**Low risk of infestation of Khapra Beetle**
	Hot/Dry	**High risk of infestation of Khapra Beetle**

SORGHUM SHOOT FLY[lxxi,lxxii]

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 ("dead heart").
- Mode of transmission: Fly infestation occurs when sorghum sowings are staggered due to erratic rainfall distribution.
- Impact: Damage may be so severe 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[lxxiii,lxxiv]

Striga hermonthica

- Damage: This parasitic weed attacks all 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, which are easily and widely dispersed by wind, water, animals, and agricultural implements. In addition, *Striga* seeds can remain dormant, but still potentially active, for many years.
- Impact: In some locations and years, *Striga* infestation may lead to total crop failure. Severe infestation may make continued cultivation of cereals difficult, forcing farmers to change cropping strategy or abandon their fields.

Environmental Conditions	Climate Change Impacts	
For *Striga hermonthica* and other *Striga species* the most favorable temperatures for germination range from 30 °C to 35 °C. Germination does not occur when temperatures fall below 20 °C.	Hot/Wet	**Low risk of parasitism of Striga Purple Witchweed**
	Hot/Dry	**High risk of parasitism of Striga Purple Witchweed**

SORGHUM FUNGAL DISEASES

ANTHRACNOSE[lxxv,lxxvi]

Colletotrichum graminicola

- Damage: 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 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. When anthracnose 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**

FIBER CROPS

COTTON

COTTON PESTS

COTTON LEAF ROLLER[lxxvii]

Sylepta Derogata

- Damage**:** Young caterpillars feed originally on the underside of leaves, but when older, the caterpillars spin or roll leaves together and eat the leaf margins, causing the leaves to curl and droop.
- Mode of transmission: Moths lay eggs on the underside of leaves. They pupate in the leaf roll or in debris on the ground
- Impact: Although the cotton leaf-roller has long been a pest in cotton, it was not considered a major pest in many areas until recent years. More recently, however, yield losses of up to 50 percent have been reported.

Environmental Conditions	Climate Change Impacts	
Warm and dry climate impacts life cycle allowing more overlapping generations to develop in a season. Durations of egg-laying, larval, pupal, and adult stages of *S. derogata* are extended at 32-35 °C. Plants growing under shade on the margins of a field usually carry a higher infestation and may be completely defoliated.	Hot/Wet	**Low risk of infestation of Cotton Leaf Roller**
	Hot/Dry	**Moderate risk of infestation of Cotton Leaf Roller**

EGYPTIAN COTTON LEAFWORM[lxxviii]

Spodoptera littoralis

- Damage: Although caterpillars feed primarily on leaves, they occasionally can cut plants and attack fruits. Young caterpillars feed on leaves and later on stems. Mature caterpillars are responsible for the most damage.
- Mode of transmission: They can be found in the soil up to a depth of about 5 cm around the plant host. The nature and structure of the soil has a large influence on the rate of infestation. Leafworms tend to be more frequent in soil with high amounts of decaying organic material.
- Impact: Heavy infestations of ECL are capable of consuming or destroying the entire plant.

Environmental Conditions	Climate Change Impacts	
Distribution is limited by temperature. In Africa this	Hot/Wet	**Low risk of**

cutworm is absent in the inner Sahel, where the climate is too harsh, but warm and dry weather favors outbreaks.		**infestation of Egyptian Cotton Leafworm**
	Hot/Dry	**High risk of infestation of Egyptian Cotton Leafworm**

SPINY BOLLWORM[lxxix]

Earias spp.

- Damage: The caterpillars bore into tender shoots, flower buds and fruits. As a result, the shoots dry and, the flower buds and fruits drop prematurely. The fruits remaining on the plants get deformed and often show exit holes of the larvae.
- Mode of transmission: The larvae can attach to dry leaves on the plant or to plant debris on the ground. There is no true diapause. In some areas, the insects move between crops with different growing seasons (e.g., okra and cotton), and so there is no interruption to their food supply, and populations can build up over a long period.
- Impact: Can make cultivation nearly impossible; one of the most important pests of cotton.

Environmental Conditions	Climate Change Impacts	
The length of the developmental stages depends largely on temperature. Warm temperatures favor the pest. However, aestivation is induced in some populations when exposed to temperatures of 35°C or higher. Rain (or overhead irrigation) can drown larvae or wash off eggs; wind can result in eggs being brushed off leaves.	Hot/Wet	**Low risk of infestation of Spiny Bollworm**
	Hot/Dry	**High risk of infestation of Spiny Bollworm**

COTTON APHID[lxxx,lxxxi,lxxxii]

Aphis gossypii

- Damage: Initially, leaves will yellow, and with an increasing number of aphids, 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 impairs photosynthesis, weakening plant even further, and may render fruits unmarketable.
- Mode of transmission: Infestation depends of 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.	Hot/Wet	**Low risk of infestation of Cotton Aphid**

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, allowing it to produce up to 60 generations per year.		
	Hot/Dry	**High risk of infestation of Cotton Aphid**

COTTON BOLLWORM[lxxxiii][lxxxiv][lxxxv]

Helicoverpa armigera

- Damage: Newly hatched larvae initially feed on terminals; however, 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 and chewing damage to squares; small bolls cause 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[lxxxvi,lxxxvii]

Pectinophora gossypiella

- Damage: When the pest attacks developing fruits, it bores directly into the developing seeds. This causes the weight of the bolls to be drastically reduced and the ginning percentage to be 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: PB causes failure of buds to open, fruit to shed, lint damage and seed loss. It 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 even 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)[lxxxviii,lxxxix]

Diparopsis watersi

- Damage: Cotton plants are the sole hosts for the larvae and 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 5 days to hatch and 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

COTTON VIRESCENCE DISEASE[xc]

Phytoplasma

- Damage: The main symptoms are virescence, yellowing and reddening of the leaves, and general stunting of the plant. In all cases, infected plants are infertile.
- Mode of transmission: The leafhopper *Orosius cellulosus* has been recognized as the vector of the CVP and two weeds the genus *Sida*, also reported to act as phytoplasma reservoirs.
- Impact: The economic importance of the disease is variable, but in several regions up to 30 percent of damage has been reported.

Environmental Conditions	Climate Change Impacts	
Rates of phytoplasma multiplication are reported to be faster under warmer and moist conditions. Temperature between 22 and 26°C and CO_2 concentration of 800 ppm are favorable.	Hot/Wet	**High risk of infection of Cotton Virescence Disease**
	Hot/Dry	**No risk of infection of Cotton Virescence Disease**

CASHEW

CASHEW PESTS

CASHEW STEM AND ROOT BORER[xci]

Unknown species

- Damage: During the grub stages, the pest feeds inside the tree trunks or branches, carving tunnels which cause the tree to wilt. The leaves turn yellow, twigs dry up, and the tree can die in one to three years depending on the extent of pest infestation.
- Mode of transmission: The adult beetle always lays eggs in the loose bark of the trunk up to 1m from the ground or in exposed roots.
- Impact: Trees over 15 years old are often infested with this pest. The level of infestation ranges from 4-10 percent in affected crops.

Environmental Conditions	Climate Change Impacts	
It appears infestation is linked to warm and dry weather. However, a short period of wet conditions early in the season enhances infestation.	Hot/Wet	**Low risk of infestation of Cashew Stem and Root Borer**
	Hot/Dry	**High risk of infestation of Cashew Stem and Root Borer**

FRUIT FLY[xcii]

Bactrocera invadens

- Damage: Attacked nuts usually exhibit punctures and, necrosis may occur at those infection places. Small holes on the fruits are observed when the maggot exits the fruits. The affected part of the fruit becomes soft and acquires its color earlier than normal.
- Mode of transmission: Adults can fly but there is no data specifying their flying capacity. Trade of infested fruit can spread the pest. The literature does not present any assumption on the pathway of introduction of *B. invadens* from Asia to Africa.
- Impact: Since its first detection in Kenya in 2003, *B. invadens* has spread to at least 27 countries in Africa and is known to attack at least 46 host plants, including many commercially grown crops and species indigenous to Africa.

Environmental Conditions	Climate Change Impacts	
The optimal temperature for survival is found to be around 25°C. On the other hand, temperatures of 35°C and higher are reported as very damaging for reproduction and survival of the fly.	Hot/Wet	**Low risk of infestation of Fruit Fly**
	Hot/Dry	**Moderate risk of infestation of Fruit Fly**

MANGO

MANGO PESTS

MANGO FRUIT FLY[xciii,xciv]

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 gains 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 is principally dependent 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**

MEALY BUG[xcv,xcvi]

Rastrococcus invadens

- Damage: Damage is caused by sucking sap from roots, tender leaves, petioles and fruit. They excrete honeydew on 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 losses of 40 to 80 percent. *It is* a serious pest of fruit crops in West Africa.

Environmental Conditions	Climate Change Impacts	
Abiotic factors that appear to affect populations of the 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 the survival of the larvae. The optimum development can be expected around 28 °C, while the maximum temperature threshold can extend 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

SCAB[xcvii]

Elsinoe mangiferae

- Damage**:** Damage of mango scab is very diverse and depends on factors like the part of the plant being affected, cultivar, age of tissue at the time of infection, inoculum amounts, water levels, and volume and allocation of water. Only young tissue is susceptible to infection. Fruit is no longer susceptible after it reaches about half size.
- Mode of transmission**:** The pathogen only infects young tissue, especially newly set fruit. The spores are predominantly spread by rain, over short distances. But heavy rains and irrigation, as well as moisture inductive microclimate promote generation of conidia and spread them over larger areas.
- Impact**:** If controlled, mango scab should cause little economic damage. Without chemical control, losses as high as 90 percent have been observed.

Environmental Conditions	Climate Change Impacts	
Spores are primarily spread by rain dispersal, over short distances. Heavy rains and irrigation, as well as moisture, promote conidiation and spread over larger areas.	Hot/Wet	**Low risk of infection of Scab**
	Hot/Dry	**No risk of infection of Scab**

STEM-END ROT[xcviii,xcix]

Lasiodiplodia sp.

- Damage: This fungus has been reported as a mango pathogen associated with several plant disease symptoms that include decline, canker, and dieback.
- Mode of transmission: These species are recognized as successful opportunistic pathogens that sometimes cause massive disease symptoms when their plant hosts are exposed to adverse conditions. Among those factors are mechanical injuries, mineral deficiencies, and environmental conditions.
- Impact: Serious post-harvest losses (more serious when fruit storage is prolonged).

Environmental Conditions	Climate Change Impacts	
Conidia germinate with optimum temperature between 20 and 25 °C. Four to eight hours of wetness at optimum temperature are needed for mycelium to grow.	Hot/Wet	**High risk of infection of Stem-End Rot**
Relative humidity affects mode of conidial germination. The optimum is indicated to be at 90 percent and higher.	Hot/Dry	**No risk of infection of Stem-End Rot**

ANTHRACNOSE[c,ci,cii,ciii]

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: It can be transmitted through infected plant parts. Rain splash also disperses spores within a crop canopy. It 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.	Hot/Wet	**Very high risk of infection of Anthracnose**
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/Dry	**No risk of infection of Anthracnose**

MANGO BACTERIAL DISEASES

MANGO BACTERIAL CANKER[civ]

Xanthomonas citri pv. mangiferaeindicae

- Damage**:** *X. citri* pv. *mangiferaeindicae* causes serious infection in a broad range of mango cultivars and induces raised, sharp, black leaf lesions, which sometimes appear as a chlorotic halo. Severe leaf infection may result in abscission. Fruit symptoms appear as small, water-soaked spots on the lenticels that later become star shaped, and exude an infectious gum. Often, a "tear stain" infection pattern is observed on the fruit. Severe fruit infections cause premature drop.
- Mode of transmission: Twig cankers are potential sources of inoculum and weaken branch resistance to winds. High levels of humidity enhance infection.
- Impact: Yield loss up to 85 percent has been reported for susceptible cultivars.

Environmental Conditions	Climate Change Impacts	
This disease is favored by high relative humidity (>90 percent) and temperatures of 25-30 °C. Frequent rainfall is not essential for the build-up of inoculums; in fact, some reports indicate that one rainy day is enough. However, additional early rains play an important role in disease expansion.	Hot/Wet	**High risk of infection of Mango Bacterial Canker**
	Hot/Dry	**No risk of infection of Mango Bacterial Canker**

SHEA NUT

SHEA NUT PESTS

BARK BORER[cv]

Xyloctonus scolytoides

- Damage: This borer tunnels through the bark of twigs, impeding growth of leaves and flower bud, and destroys the bark.
- Mode of transmission: Stems of living trees in the area provide food and shelter for this insect. Then, 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**

MISTLETOE, HEMI-PARASITIC PLANT[cvi,cvii]

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 on the significance of the impact on the host plant.	Hot/Wet	**Assessment not possible**
	Hot/Dry	**Assessment not possible**

GRASSES

BOURGOU (ECHINOCHLOA STAGNINA)

BOURGOU PESTS

MAIZE STREAK VIRUS[cviii]

- *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, maize streak virus depends on insect vectors for transmission between host plants. Maize streak virus 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 and 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)[cix,cx]

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 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 on significance of impact on host plant.	Hot/Wet	**Assessment not possible**
	Hot/Dry	**Assessment not possible**

COWPEA

COWPEA PESTS

FLOWER BUD THRIPS [cxi]

Megalurothrips sjostedti

- Damage**:** Attacks cowpea at early stages of floral development. Feeding damage results in necrosis and/or abscission of flower buds and flowers. Feeding also causes distortion and discoloration of the floral parts of cowpea, leading to reduced pollen production.
- Mode of transmission: Some studies indicate that *M. sjostedti* survives the dry season on a wide range of alternative hosts all belonging to the Leguminosae, where this species can feed and reproduce. The thrips move to cowpea plants when floral stages start.
- Impact: Estimated yield losses are in the range of 20 to 70 percent. Without chemical protection, thrips can reduce cowpea yield substantially, sometimes leading to complete crop failure.

Environmental Conditions	Climate Change Impacts	
FBT life cycle is dependent of temperature. Better insect development occurs at warmer temperatures and dry conditions.	Hot/Wet	**Low risk of infestation of Flower Bud Thrips**
Early season drought can cause thrip populations, which would normally not be detrimental, to become serious problems.	Hot/Dry	**Moderate risk of infestation of Flower Bud Thrips**

COWPEA ROOT-KNOT NEMATODE[cxii]

Scutellonema clathricaudatum

- <u>Damage</u>: The nematode causes relatively small galls to develop on roots of affected plants. However, can also affect flowering, podding, seedling, and other vegetative growing stages. At the roots, galls cause abnormal development and function of the root system and, obstruction of the vascular system. The stem above the ground can display irregular, stunted growth; discoloration and the leaf can present chlorosis and wilting.
- <u>Mode of transmission</u>: Nematodes can survive in the soils for several years and keep constantly infecting plants.
- <u>Impact</u>: Nematodes can reduce yields by 20 to 30 percent. The whole plant shows reduced yield in quantity and quality as well as premature death.

Environmental Conditions	Climate Change Impacts	
This species is adapted to the climatic conditions of both semi-arid and rainy tropics of West Africa. It is capable to reproduce at medium to high soil temperature (30-36 °C).	Hot/Wet	**Moderate risk of infestation of Cowpea Root-Knot Nematode**
Soil moisture does not seem to have a significant effect on reproduction rate.	Hot/Dry	**Low risk of infestation of Cowpea Root-Knot Nematode**

COWPEA APHID[cxiii, cxiv]

Aphis craccivora

- <u>Damage</u>: 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.
- <u>Mode of transmission</u>: 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.
- <u>Impact</u>: Cowpea aphids can cause damage as a vector of serious virus diseases.

Environmental Conditions	Climate Change Impacts	
Cowpea aphids cause the most damage when they attack seedlings during dry weather.	Hot/Wet	**Low risk of infestation of**

Colony development is dependent on temperature; it is retarded by low temperatures in the winter and by hot summer temperatures.		**Cowpea Aphid**
	Hot/Dry	**High risk of infestation of Cowpea Aphid**

COWPEA WEEVIL[cxv,cxvi]

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: 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: This is the most common and widespread insect pest affecting crops 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 to 90 percent).	Hot/Wet	**Moderate risk of infestation of Cowpea Weevil**
	Hot/Dry	**Low risk of infestation of Cowpea Weevil**

COWPEA WITCHWEED[cxvii]

Striga gesnerioides

- Damage: The symptoms are difficult to distinguish from those caused by drought, (i.e., wilting and curling of leaves at an early stage). The infected plant may also show stunting and a pronounced burning of the leaf borders.
- Mode of transmission: Infection in cowpea is more devastating in areas with sandy soils, low fertility, and low rainfall. The weed produces large numbers of seeds and up to 75 percent of the crop damage can occur before they even emerge from the ground.
- Impact: *Striga* weeds are difficult to control once they are established on the plants. Because they get their nutrients from cowpea, they contribute to very low production in most countries in Africa.

Environmental Conditions	Climate Change Impacts	
Temperatures ranging from 30-35 °C are ideal for high rates of seed germination.	Hot/Wet	**Low risk of parasitism of Cowpea Witchweed**

Soil and air temperature, photoperiod, soil type, and soil nutrient and moisture levels do not significantly affect the expansion of CW.	Hot/Dry	**Moderate risk of parasitism of Cowpea Witchweed**

LEGUME POD BORER, COWPEA CATERPILLAR[cxviii,cxix]

Maruca vitrata

- Damage: Most serious damage is caused by the larvae. They attack flower buds and flowers, and also cause large damage to 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; each may consume 4-6 flowers before 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**

WITCHWEED, PURPLE WITCHWEED[cxx,cxxi,cxxii]

Striga hermonthica

- Damage: Attacks all the plant stages and plant parts, flowering, podding , pre-emergence, seedling, and vegetative phase, and 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 with 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 30-35 °C, low soil nitrogen, low soil moisture, and dry conditions of the air.	Hot/Wet	**Moderate risk of parasitism by Witchweed**
	Hot/Dry	**Low risk of parasitism by Witchweed**

COWPEA VIRAL DISEASES

COWPEA APHID-BORNE MOSAIC VIRUS (CABMV)[cxxiii,cxxiv,cxxv,cxxvi]

Potyvirus

- Damage: Causes distortion and mottling of the leaves and can stunt the plants. All the 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 the whole plant.
- Mode of transmission: 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 (through 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* 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

GROUNDNUT PESTS

GROUNDNUT BRUCHID, GROUNDNUT SEED BEETLE[cxxvii,cxxviii,cxxix,cxxx]

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 too severely damaged for human consumption or oil expulsion.
- Mode of transmission: The eggs are found attached to the pod wall. After hatching, larvae burrow through the egg shell and the pod wall, and start 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 to 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[cxxxi,cxxxii,cxxxiii]

- Damage: Affected seeds are shriveled and dried, covered by yellow or greenish spores. Cotyledons show necrotic lesions. Seedlings are highly stunted, and the leaf size 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 25 and 42 °C, and will still grow at temperatures from 12-48 °C. Two major environmental factors that affect aflatoxin contamination of the peanut fruit during growth and development are drought stress and insect damage.	Hot/Wet	**Moderately high risk of infection of *Aspergillus flavus***
	Hot/Dry	**Very high risk of infection of *Aspergillus flavus***

EARLY LEAF SPOT[cxxxiv,cxxxv]

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 plants via 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	
Under conditions of prolonged warm temperature and high (>95 percent) relative humidity can result in significant defoliation and yield loss. Temperatures in a range of 25 to 30 °C favor disease development.	Hot/Wet	**Very high risk of infection of Early Leaf Spot**
	Hot/Dry	**No risk of infection of Early Leaf Spot**

GROUNDNUT RUST[cxxxvi,cxxxvii]

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 the fungus can survive in volunteer groundnut plants from the field and contaminate new plants. Rust develops better in conditions of 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 20-22 °C, 85 percent or higher relative humidity, and about three rainy days in a week. Potential of severe outbreak increases if this trend last 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**

GROUNDNUT VIRAL DISEASES

GROUNDNUT ROSETTE VIRUS[cxxxviii,cxxxix,cxl,cxli]

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 favors 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)[cxlii,cxliii]

- Damage: Infected peanut plants are stunted, with 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 W Africa such as Burkina Faso, Gambia, 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

GREEN STINK BUG[cxliv,cxlv]

Acrosternum hilare

- Damage: The earlier that feeding occurs in the development of the fruit, the more severe the damage will be to the plant. 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; this liquefies the contents, which they then feed upon. 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**

SESAME WEBWORM (A.K.A. SESAME POD BORER)[cxlvi,cxlvii,cxlviii]

Antigastra catalaunalis

- Damage: The larvae feed 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 which 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[cxlix,cl,cli]

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[clii,cliii]

Cercospora sesami

- Damage: Disease affects leaves of plants as early as four weeks after planting. Starts as small pinhead-sized spots that extend in size over time. 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 and 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[cliv,clv]

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 become thickened 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 are dependent on the spread or colonization of the vector, whitefly *B. tabaci*. 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/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**

ROOT CROPS

CASSAVA

CASSAVA PESTS

CASSAVA GREEN MITE (CGM)[clvi,clvii,clviii]

Mononychellus tanajoa

- Damage: Active stages feed on the lower parts of leaves by sucking fluids from cells. This causes chlorosis, which can increase from a few spots to complete loss of chlorophyll. Most CGM are generally found on the upper third or 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 than in the wet. Heavy rainfall can reduce CGM populations. Populations increase with increasing temperature, leading at times to 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 [clix,clx]

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. Dry season favors outbreak. Rainfall is a key determinant in 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)[clxi,clxii]

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: Considered to be the most important bacterial disease of the crop. If no management strategies are in place, losses can be as high as over 90 percent.

Environmental Conditions	Climate Change Impacts	
Establishment of the bacteria requires above 90 percent of relative humidity with an optimum temperature of 22-26 °C. Dry weather substantially reduces the development of 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 MOSAIC VIRUS DISEASE (CMD)[clxiii,clxiv,clxv]

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 and 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 produce 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 15–24 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

NEMATODES[clxvi,clxvii,clxviii]

Meloidogyne incognita and *Radopholus similis*

- Damage: Above-ground symptoms include poor shoot growth, leaf chlorosis, and stunting. 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, in fibrous roots, or 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, taxa present, susceptibility of the crop, and environmental conditions, such as fertility, moisture, and presence of other pathogenic organisms, which may interact with nematodes.

Environmental Conditions	Climate Change Impacts	
Increases in temperature influence infection, but some levels of soil moisture are required. Development occurs between 13 °C and 34 °C, with optimal development at about 29 °C.	Hot/Wet	**Moderate risk of infestation of Nematodes**
Penetration, rate of development, and total population of *Meloidogyne incognita* in roots of susceptible and resistant sweet potatoes increase with temperatures 24-32 °C.	Hot/Dry	**Low risk of infestation of Nematodes**

SWEET POTATO WEEVIL[clxix,clxx,clxxi]

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. Adults feeding on foliage is seldom of consequence.
- Mode of transmission: Discarded and unharvested roots can support large populations, and be responsible of 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[clxxii,clxxiii, clxxiv]

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 evidence outside
- 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 economically significant crops.

Environmental Conditions	Climate Change Impacts	
The most significant factor in disease development is environmental conditions of high humidity and temperatures of 22 °C to 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**

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