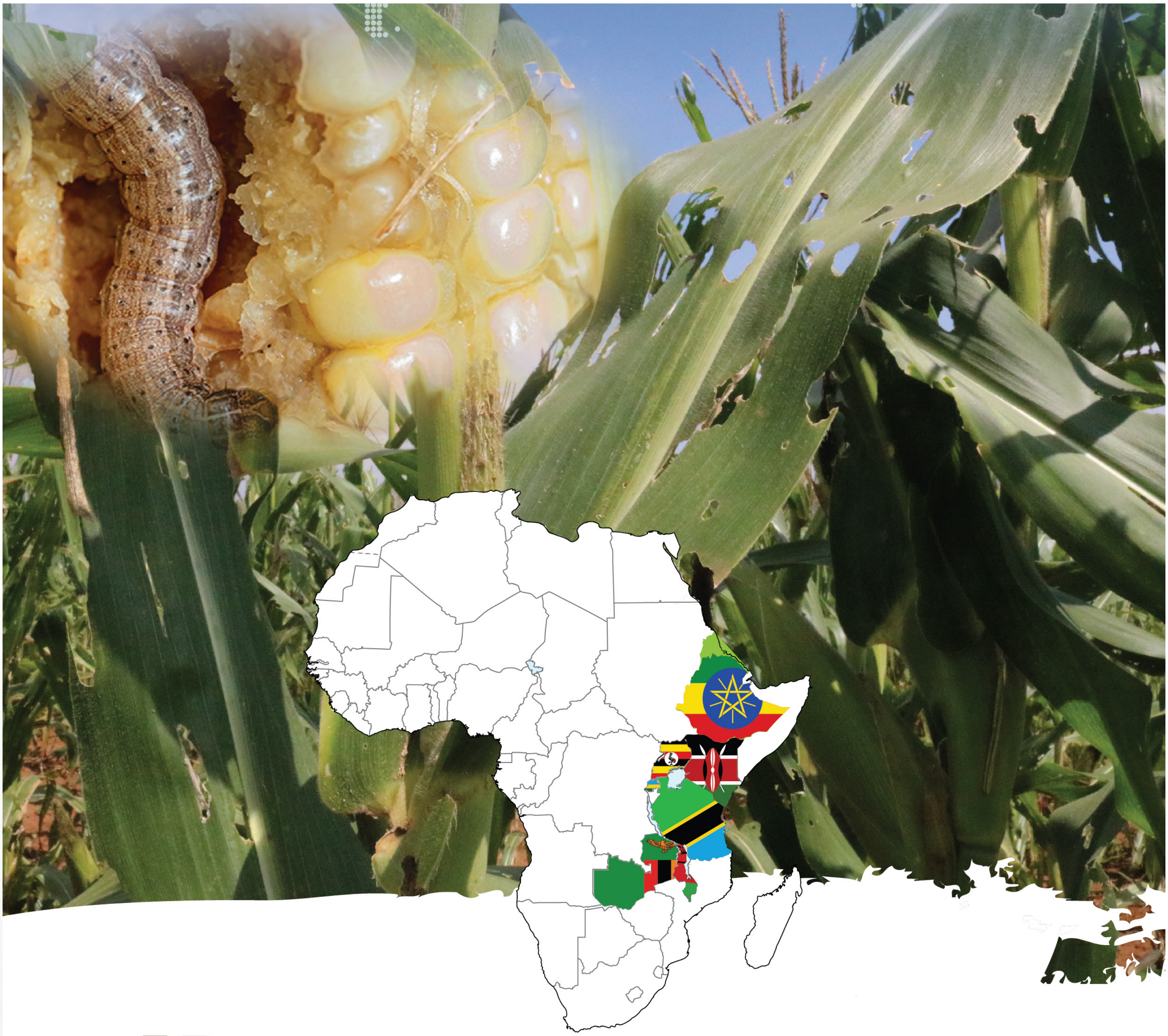
FALL ARMYWORM Monitoring

Structure of the Countries Profile

January - June 2022 Issue

FAW INVASION RISK PREDICTION

ETHIOPIA | KENYA | TANZANIA | UGANDA | RWANDA | MALAWI | ZAMBIA



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OVERVIEW

This profile provides the potential Fall armyworm (FAW) spread and risks within the maize cropping areas in Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda, and Zambia from January to June 2022. FAW poses a serious threat to many smallholder farmers. This profile has been scaled down to the country level. It depicts the FAW risks and proposes actionable solutions, mitigations, and adaptation mechanisms to manage the FAW invasion at the country level. The core objective of this profile is to stimulate information sharing, inclusive policy drafting, engagement to design homegrown solutions, community-based monitoring for the FAW, and improve the regional data collection mechanisms for increased data quantity and quality.

Fall armyworm is a transboundary pest that can fly up to 100 km/ day. The larval stages feed on crops. Currently, it has spread to over 109 countries globally. Recent reports show an annual loss of 17.7 million tonnes in the maize farming sector in 12 African countries.

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The FAW Monitoring and Early Warning System (FAMEWS) mobile app is free, works offline, and provides farmers with advice on the FAW management.

Download from the Google play store:
https://play.google.com/store/apps/det

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BACKGROUND

Fall armyworm (FAW), *Spodoptera frugiperda*, is a moth native to tropical and subtropical regions of the Americas that has now spread globally [1]. FAW can cause significant damage and yield losses. FAW prefers maize but can also feed on more than 80 other crops, including wheat, sorghum, millet, sugarcane, vegetable crops, and cotton. FAW is established in Africa with seasonal spread depending on the crop availability – an adult can fly up to a hundred kilometres in a single night. Since its appearance in West Africa at the beginning of 2016, FAW has reached most African countries. It has also spread further to the Near East, Asian countries, including China, India, and Japan. It has been reported in Australia, Mauritania, and Timor Leste. Southern parts of Europe could be next. Based on 2018 estimates from 12 African countries, up to 17.7 million tons of maize could be lost annually due to FAW on that continent – enough to feed tens of millions of people. The most direct impact of these losses affects mainly smallholder maize farmers, the majority of whom rely on the crop to reduce hunger and poverty. Chemical pesticides are the most promoted control measures; however, they are associated with many health and environmental hazards. Their handling, use, and disposal always require special care.

POTENTIAL FAW INFESTATION IN EAST AND SOUTHERN AFRICA

The FAW spread and risk within the seven countries from January to June 2022 have been characterized by low, moderate, and high infestation. Moderate to high infestation is expected between January to March, particularly in Southern Africa (Zambia and Malawi). An increase in infestation is expected in East Africa in the second quarter of the year between April to June 2022. January to June period coincides with the onset of the main cropping period for the rainfed maize in Southern Africa. However, the countries located in the North of the equator, i.e., Uganda and Ethiopia, will experience relatively low to moderate infestation within the first quarter of the year but steadily increase towards the second quarter in the same period compared to Southern Africa. The regional profile maps (Figure 1) demonstrate that the level of infestations across the region is sensitive to the monthly variations of climatic and environmental factors and the availability of the host plants/ crops, mainly maize. Moreover, the occurrence of FAW in each area depends on the suitable interaction of a wide range of other non-climatic factors whose mechanisms of interaction are vaguely understood. These factors vary from the farm size area and its geographical location to the cropping calendar of the FAW host plant over the year and the control mechanism that is implemented on the farm.

CEREAL CROP CALENDERS

Cereal calendars differ across countries/regions and sometimes within locations in a country. The variation is dictated by climatic conditions, especially rainfall patterns. Cereal calendars are particularly important because they determine the FAW and other cereal pests spread, risks and management options to be deployed. Studies have demonstrated that the level of infestations across the regions are sensitive to the monthly variations of climatic and environmental factors and the availability of the host plants/ crops, mainly maize. Type of major cereal crops and crop calendar in Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda, and Zambia for the period January to June 2022 can be sourced from FAO/GIEWS and FEWSNET.

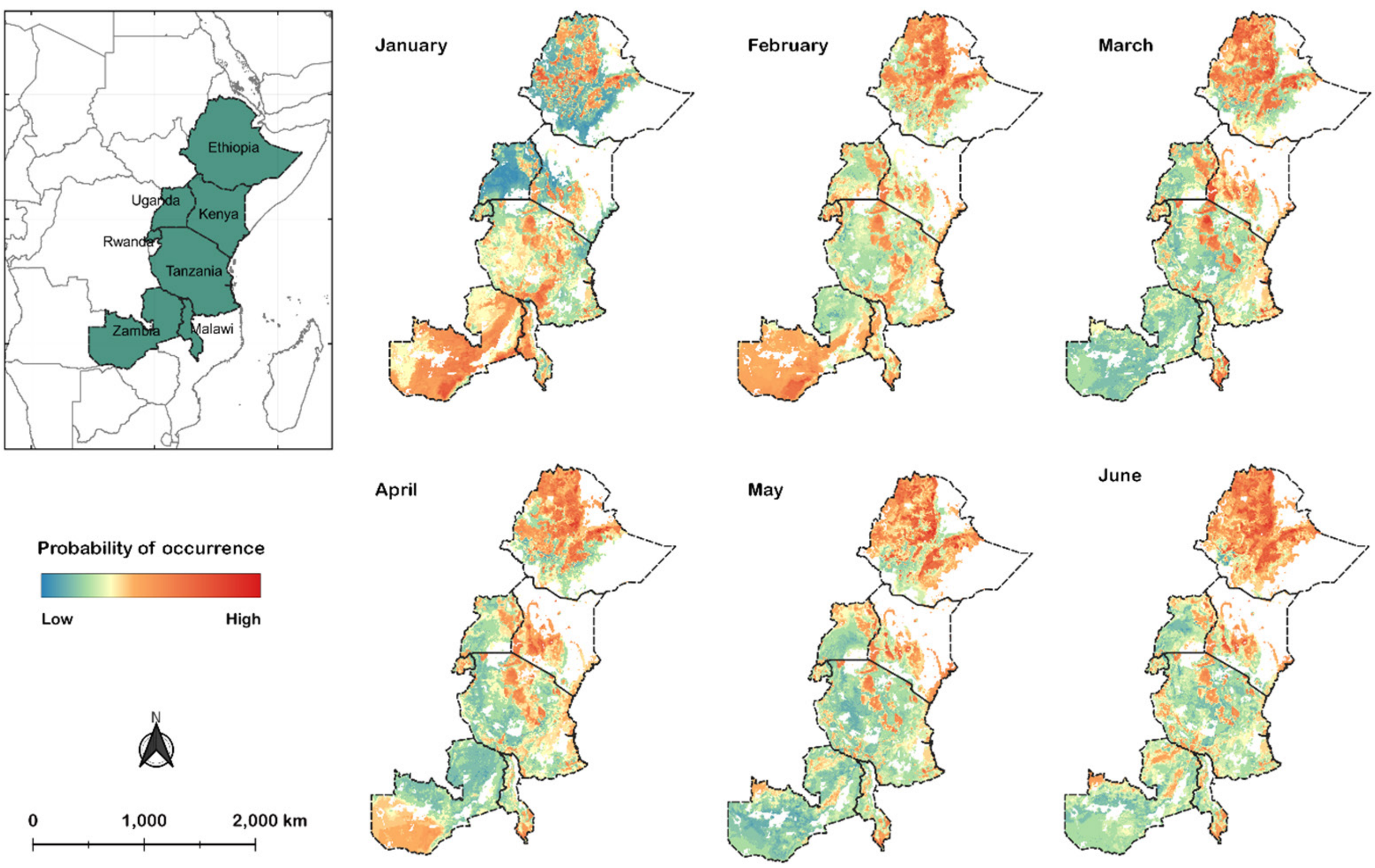

Figure 1: Monthly probability of occurrence and predicted density of the Fall armyworm (FAW) in Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda, and Zambia for the period January to June 2022. The maps were produced from the representative concentration pathway (RCP4.5) data provided by Envidat (https://www.envidat.ch/#/metadata/chelsa_cmip5_ts) and the random forest algorithm

FAW prefers hosts in the grass family i.e., maize, millets, rice, sorghum, sugarcane, but it also attacks banana, cotton, cowpeas, ginger, peanut, tobacco, some forage legumes, and vegetables, e.g., beans (including soybean), cabbage, capsicum, cauliflowers, cucumber, eggplant, potato, sweet potato, tomato, and some weeds and ornamentals.

Therefore, farmers need significant support to manage FAW sustainably in their cropping systems through Integrated Pest Management (IPM) activities. FAW cannot be eliminated; therefore, environmentally friendly control methods should be adopted and championed.
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FAW INFESTATION COVERAGE IN MAIZE GROWING AREAS

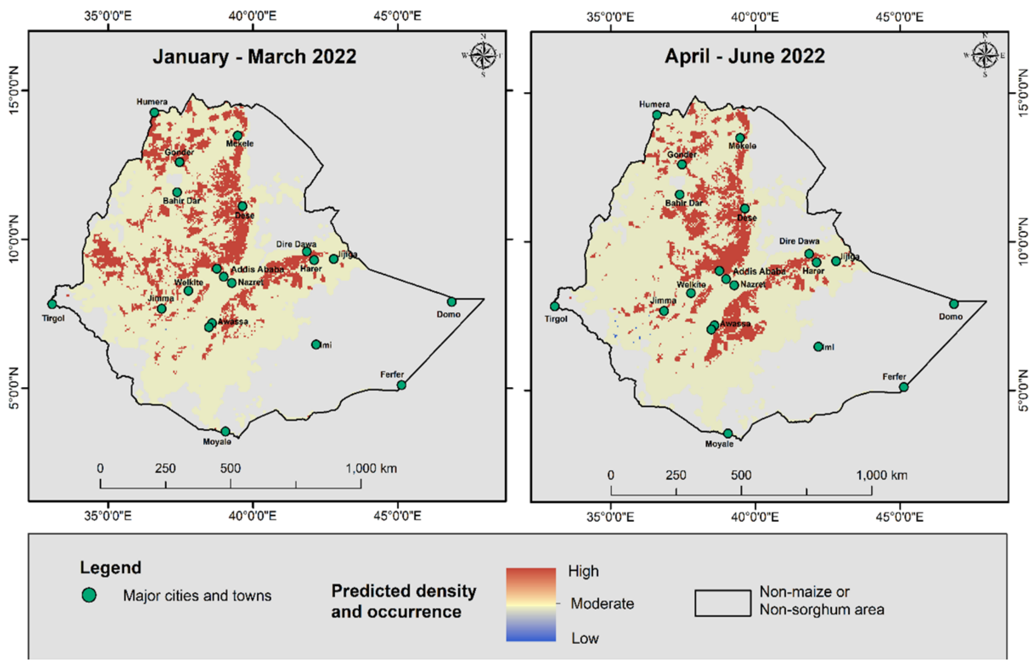
FAW RISK AND SPREAD PREDICTION MAPS IN ETHIOPIA

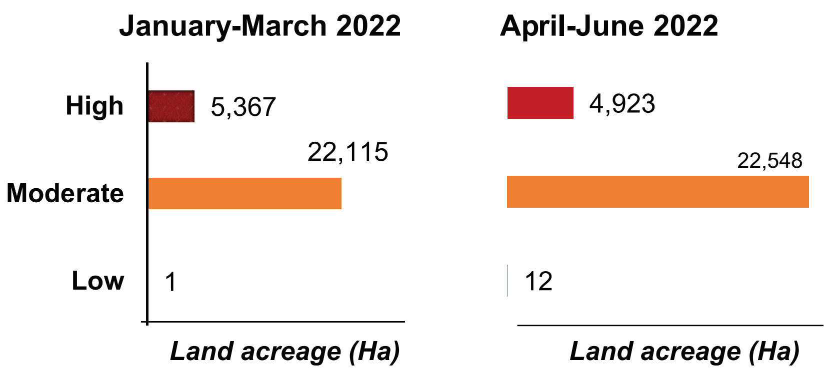
January to March 2022

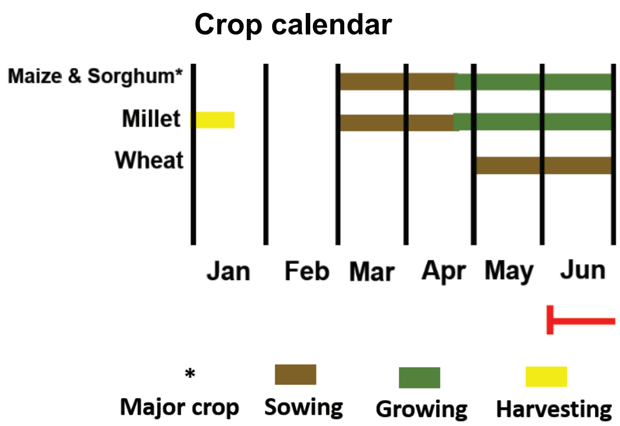
Between January to March, most of the crops are at seedling stage, or the land is under preparation for the cultivation of maize, sorghum, and millet in Ethiopia. It is predicted that FAW occurrence will be high to moderate in Humera, Gondar, Mekele town, Dese town, Dire Dewa, Axum, Bahir Dar, Jima, Awasa areas bordering Addis Ababa, Harar, Jijiga and some Western parts of Ethiopia. Most western parts of the country where maize and sorghum are cultivated will experience a moderate infestation of FAW. NB the high infestation predicts FAW moths > 30 while the mild infestation approximates between 11 – 30 FAW moths in a maize field which is significant enough to cause yield losses between 20 – 80%.

April to June 2022

Between April to June, most of the areas shall experience more severe infestation compared to a period of January to March. FAW infestation is moderate to high in Dese, Awasa, north regions bordering Addis Ababa, Dire Dawa, Dese and Bahir Dar, moderate in Harori, Jima, Gondar, Humera and Mekeleand Jijiga.
A relatively large farmland area is expected to experience moderate infestation during periods of January to March and April to June. Farmers and extension officials need to be proactive and vigilant in regions experiencing high and moderate infestations, considering that the period between April and June is growing seasons of maize, sorghum, and millet


January - March 2022
April - June 2022
Humera
Mekele
Gonder
Bahir Dar
Dese
Dire Dawa
Jijiga
Addis Ababa
Harer
Nazret
Welkite
Jimma
Tirgol
Awassa
Domo
Imi
Ferfer
Moyale
0 250 500 1,000 km
35°0'0"E
40°0'0"E
45°0'0"E
15°0'0"N
10°0'0"N
5°0'0"N
Legend
Major cities and towns
Predicted density and occurrence
High
Moderate
Low
Non-maize or Non-sorghum area


January-March 2022
April-June 2022
High
Moderate
Low
5,367
22,115
1
4,923
22,548
12
Land acreage (Ha)
Land acreage (Ha)


Crop calendar
Maize & Sorghum*
Millet
Wheat
Jan
Feb
Mar
Apr
May
Jun
* Major crop
Sowing
Growing
Harvesting

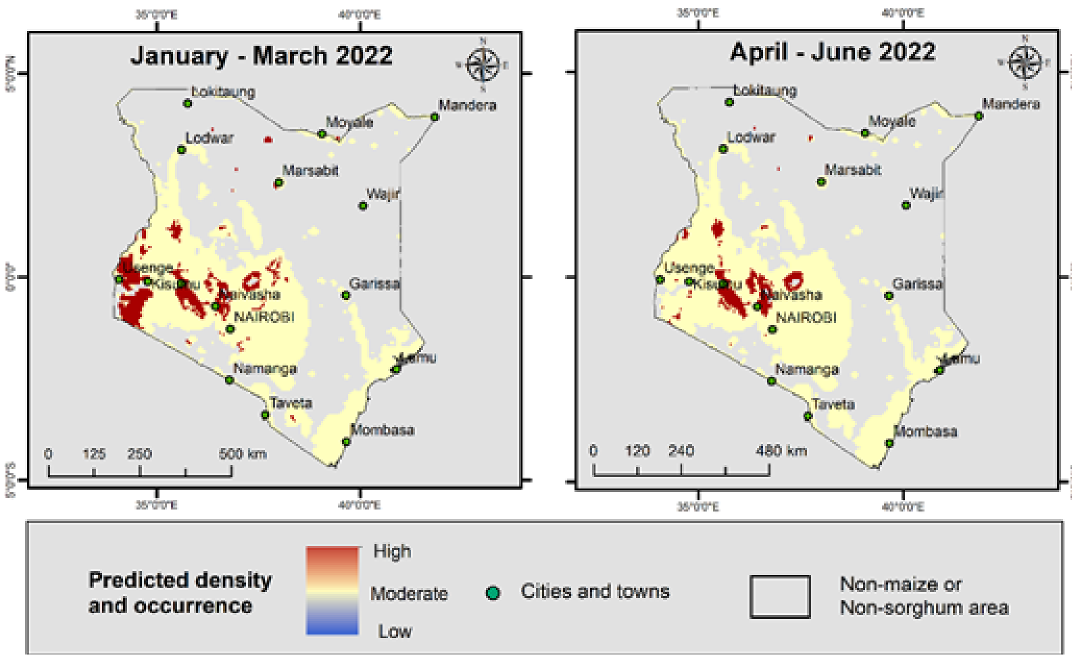
FAW RISK AND SPREAD PREDICTION MAPS IN KENYA

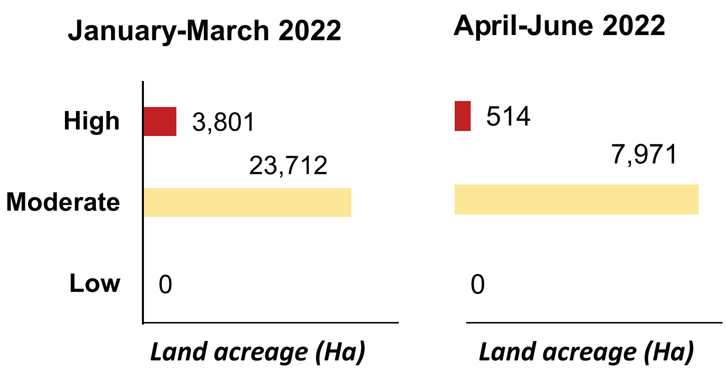
January to March 2022

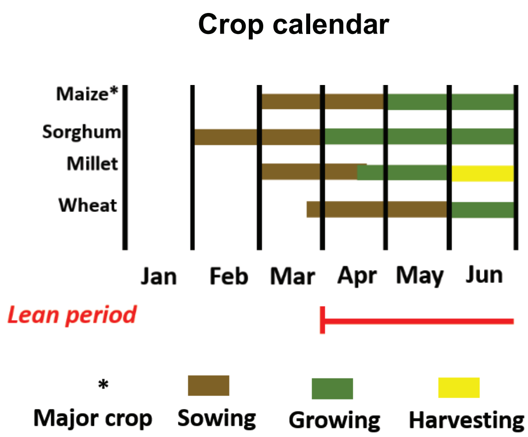
Between January and March, FAW occurrence is expected to be high in western parts of Kenya, especially in areas bordering Usenge, Kisumu, Migori and Nakuru, while being moderate in Naivasha and all the surrounding areas. However, January-March 2022 constitutes farrowing and sowing season; thus, mostly irrigated and early planted crops will be most susceptible to the attacks. The farmers and extension officers can potentially establish alternative host plants for FAW during this period and prioritize areas predicted to have the highest probability of attack (FAW moths >30).

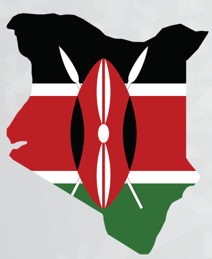
April to June 2022

Between April and June, areas around Nakuru and Naivasha will likely experience moderate to high infestation, while FAW infestation will potentially be low in Usenge, Kisumu, and Migori. This period matches the season where maize, sorghum and millet are in their early vegetative stages and at their most vulnerable. However, the acreage with the potential for high and moderate FAW incidences is likely to decrease substantially during April to June 2022 compared to the January to March 2022 period.

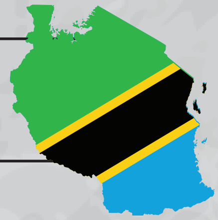

January - March 2022
April - June 2022
Lokitaung
Lodwar
Moyale
Mandera
Marsabit
Wajir
Usenge
Kisumu
Naivasha
NAIROBI
Garissa
Namanga
Taveta
Mombasa
0 125 250 500 km
0 120 240 480 km
Predicted density and occurrence
High
Moderate
Low
Cities and towns
Non-maize or Non-sorghum area


January-March 2022
High
3,801
Moderate
23,712
Low
0
Land acreage (Ha)
April-June 2022
514
7,971
0
Land acreage (Ha)


Crop calendar
Maize*
Sorghum
Millet
Wheat
Jan
Feb
Mar
Apr
May
Jun
Lean period
* Major crop
Sowing
Growing
Harvesting



FAW RISK AND SPREAD PREDICTION MAPS IN TANZANIA

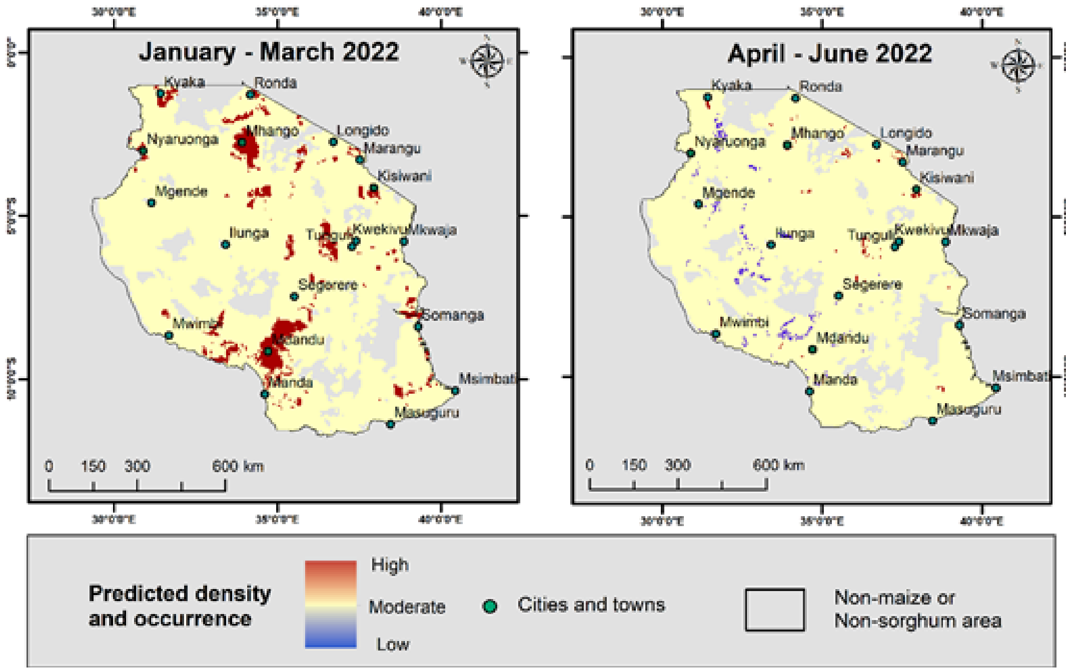


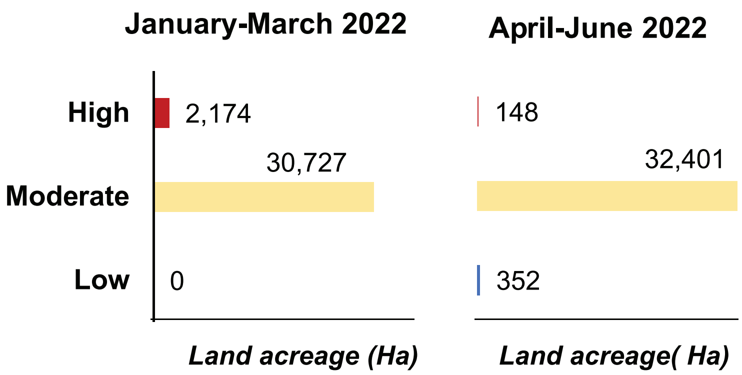
January to March 2022

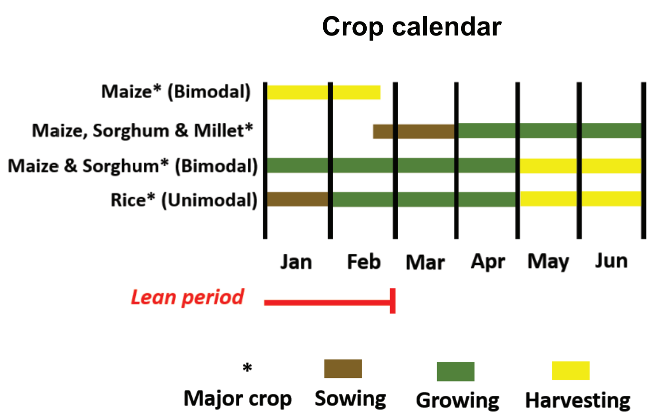
Prediction map of FAW occurrence between January and March 2022 indicates a potentially high infestation in areas around Mhango, Mdandu, Kyaka, Marangu, Kisiwani, Tunguli, Segerere, Somanga and Manda, while infestation will likely be moderate in most parts of the country. The period between January and March constitutes the early vegetative stages of maize grown under bimodal rainfall in Tanzania.

April to June 2022

Between April and June 2022, most cereal growing areas will experience a moderate infestation. Low infestation will be partially distributed mainly in Mhango, Marangu, Kisiwani, Teguli and Segerere. While the high infestation is likely to decrease from April to June 2022, the acreage of land to be covered with a moderate infestation is expected to increase. However, caution must be taken since the high infestation predicts FAW moths > 30 while the moderate infestation approximates between 11 – 30 FAW moths in a maize field which are both significant enough to cause yield losses between 20 – 80%.


January - March 2022
April - June 2022
Kyaka
Ronda
Nyaruonga
Mhango
Longido
Marangu
Kisiwani
Mgende
Ilunga
Tungui
Kwekivu
Mkwaja
Segerere
Somanga
Mwimbi
Mdandu
Manda
Msimbati
Masuguru
0 150 300 600 km
Predicted density and occurrence
High
Moderate
Low
Cities and towns
Non-maize or Non-sorghum area


January-March 2022
April-June 2022
High
Moderate
Low
2,174
30,727
0
148
32,401
352
Land acreage (Ha)
Land acreage(Ha)


Crop calendar
Maize* (Bimodal)
Maize, Sorghum & Millet*
Maize & Sorghum* (Bimodal)
Rice* (Unimodal)
Jan
Feb
Mar
Apr
May
Jun
Lean period
*
Major crop
Sowing
Growing
Harvesting

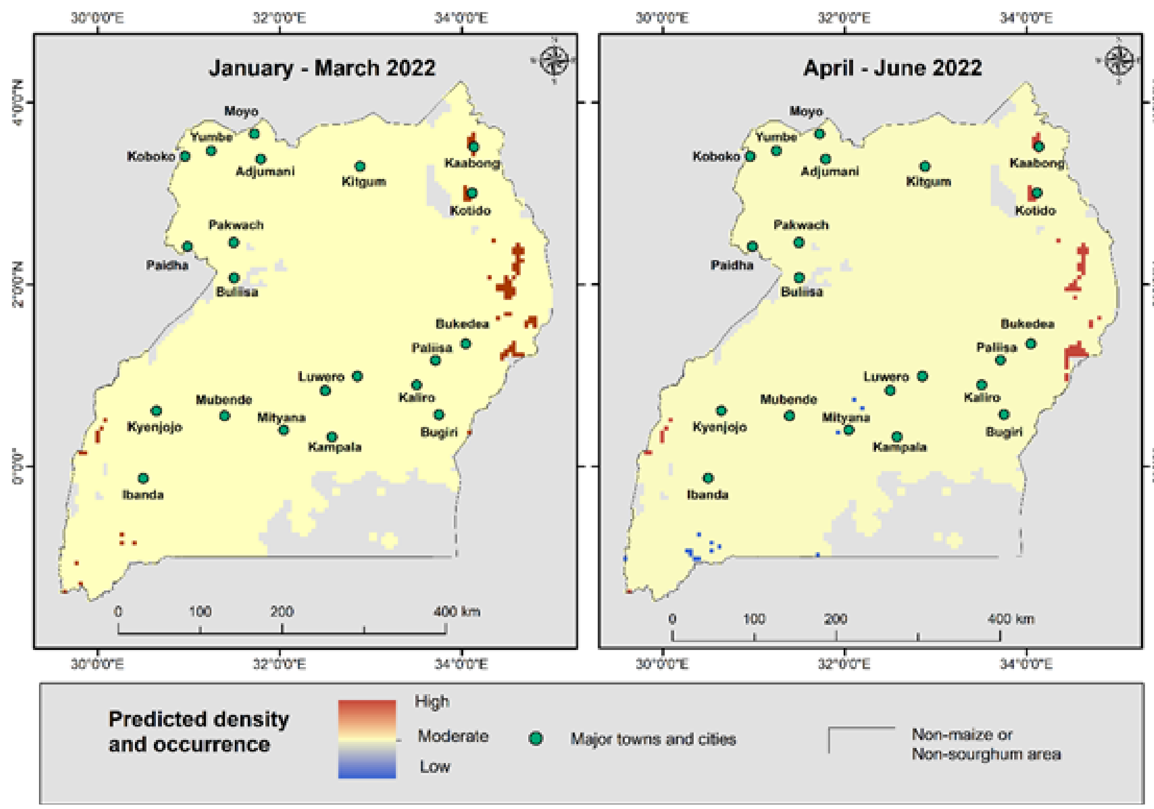
FAW RISK AND SPREAD PREDICTION MAPS IN UGANDA

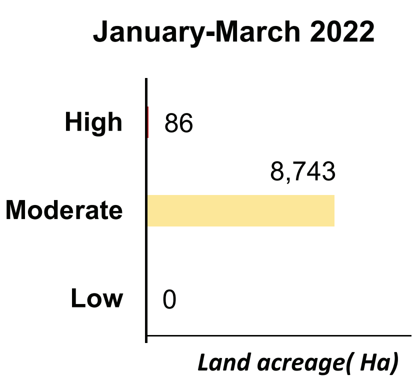
January to March 2022

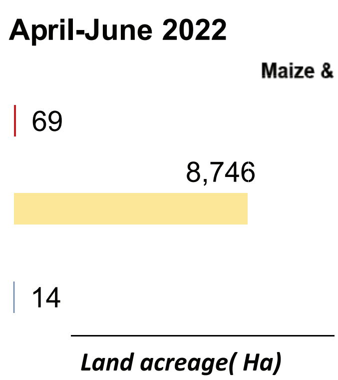
January to March in Uganda coincides with the maize harvesting season and sowing season of maize and millet. FAW infestation is anticipated to be moderate in most parts of the country, particularly the central and most parts of the southern region of Uganda. High FAW infestations are expected in the eastern (Bukedea, Kapchorwa, Nakapiripit).

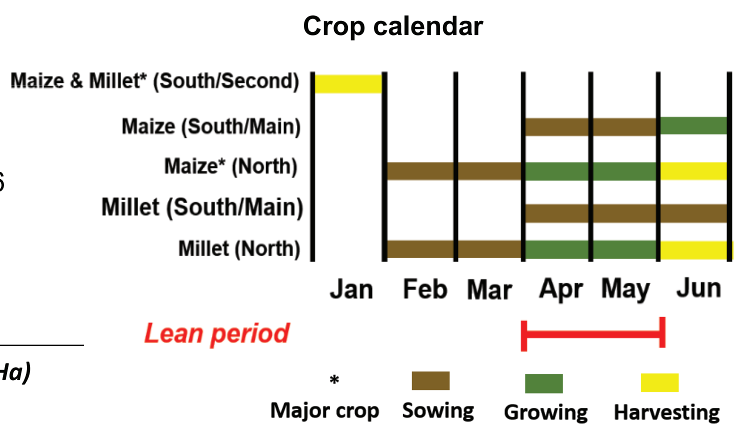
April to June 2022

During this period, most areas will continue to experience a moderate infestation. Similar to the January to March 2022 period, high infestation rates are expected in some parts of eastern Uganda, including eastern (Bukedea, Kapchorwa, Nakapiripit). Hot spots that may provide suitable FAW management options must be established during non-rainfed cropping systems to counter the potentially high infestation.
There is hardly any change in the acreage of lands under high and moderate infestation of FAW during periods of January to March compared to the April to June 2022 period.


January - March 2022
April - June 2022
Moyo
Yumbe
Koboko
Adjumani
Kitgum
Kaabong
Kotido
Pakwach
Paidha
Buliisa
Bukedea
Pallisa
Luwero
Kaliro
Mubende
Kyenjojo
Mityana
Kampala
Bugiri
Ibanda
0 100 200 400 km
30°0'0"E
32°0'0"E
34°0'0"E
4°0'0"N
2°0'0"N
0°0'0"
Predicted density and occurrence
High
Moderate
Low
Major towns and cities
Non-maize or Non-sourghum area


January-March 2022
High
Moderate
Low
86
8,743
0
Land acreage(Ha)


April-June 2022
69
8,746
14
Land acreage(Ha)


Crop calendar
Maize & Millet* (South/Second)
Maize (South/Main)
Maize* (North)
Millet (South/Main)
Millet (North)
Jan
Feb
Mar
Apr
May
Jun
Lean period
*
Major crop
Sowing
Growing
Harvesting

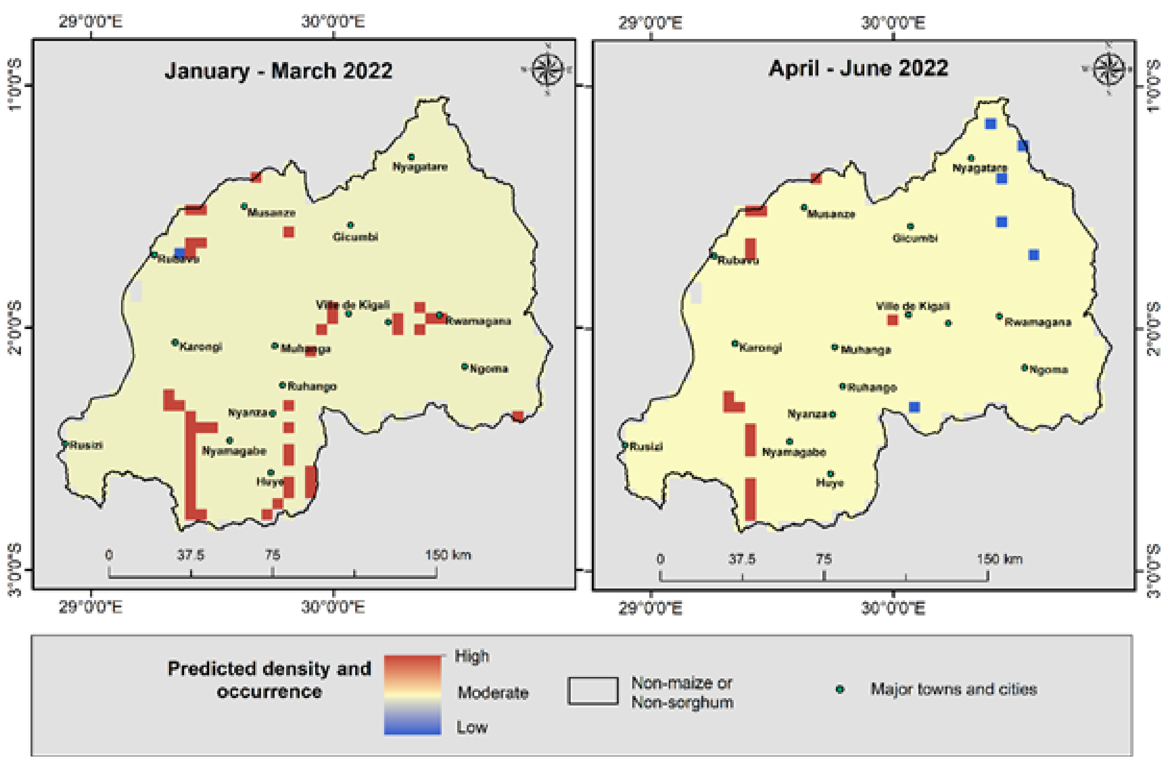
FAW RISK AND SPREAD PREDICTION MAPS IN RWANDA

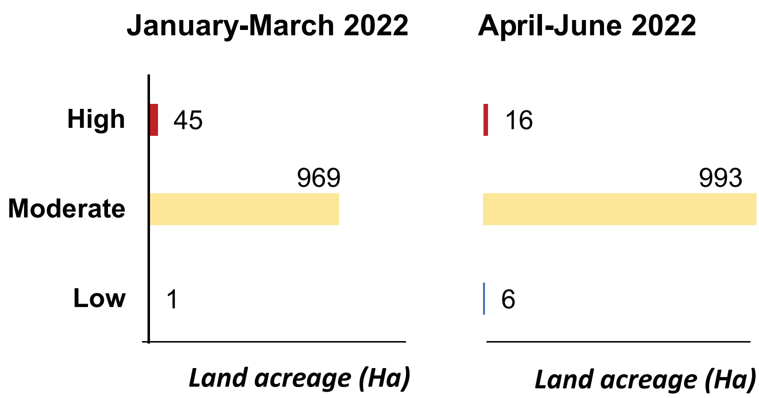
January to March 2022

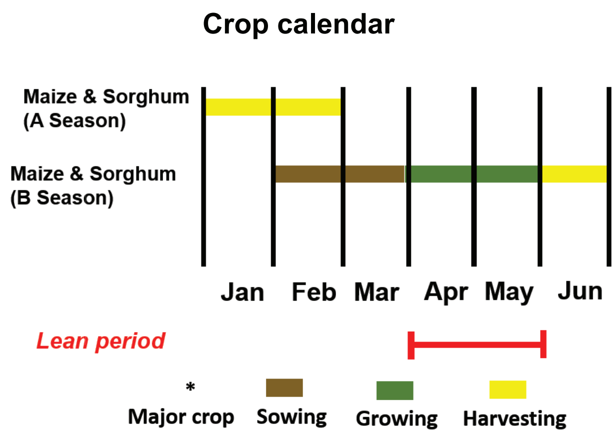
January to March constitute the harvesting period of maize and sorghum during the A season and the sowing period of maize and sorghum during the B season. This period also marks the beginning of maize and sorghum sowing for season B. FAW infestation is moderate, particularly in the northwestern (Rubavu and Musanze), Central (Ville de Kigali and Muhanga), southwestern (Nyamagabe, Nyanza and Huye) and eastern (Rwamagana) regions. FAW infestation is low in Rubavu.

April to June 2022

From April to June 2022, a moderate infestation is in the parts of northwestern (Rubavu and Musanze), central (Ville de Kigali) and southwestern (Nyamagabe). Low infestation is in parts of northeastern (Nyagatare) and Nganda. Low infestation is due to the lack or low presence of maize and sorghum plants during this period. However, the entire country will likely receive moderate infestation levels during the period April to June 2022. There will be less change in the acreage of land under high and medium infestation by FAW. In Rwanda, rice is the most likely crop to be affected by FAW throughout this period. Hence more caution is necessary for the rice farmers in the entire country.


January - March 2022
April - June 2022
29°0'0"E
30°0'0"E
1°0'0"S
2°0'0"S
3°0'0"S
Nyagatare
Musanze
Gicumbi
Rubavu
Ville de Kigali
Rwamagana
Karongi
Muhanga
Ngoma
Ruhango
Nyanza
Rusizi
Nyamagabe
Huye
0
37.5
75
150 km
Predicted density and occurrence
High
Moderate
Low
Non-maize or Non-sorghum
Major towns and cities


January-March 2022
April-June 2022
High
Moderate
Low
45
969
1
16
993
6
Land acreage (Ha)
Land acreage (Ha)


Crop calendar
Maize & Sorghum (A Season)
Maize & Sorghum (B Season)
Jan
Feb
Mar
Apr
May
Jun
Lean period
*
Major crop
Sowing
Growing
Harvesting

FAW RISK AND SPREAD PREDICTION MAPS IN MALAWI

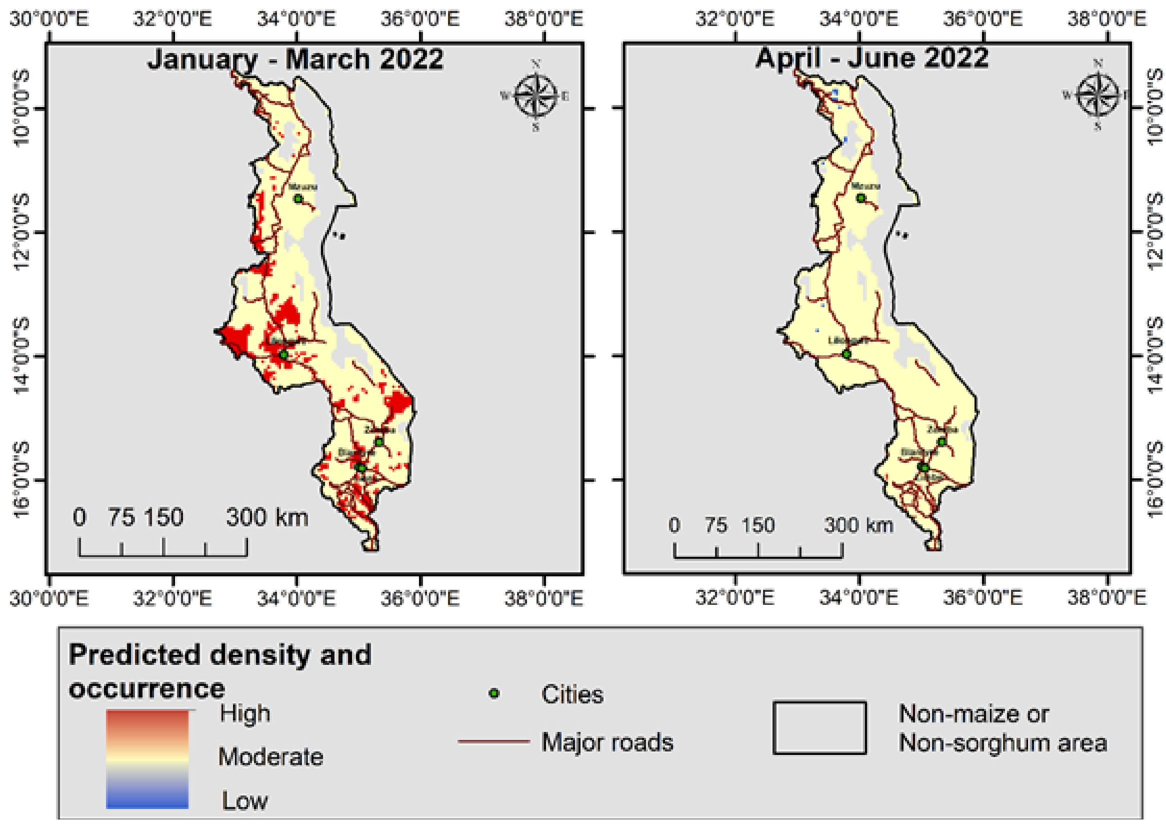
January to March 2022

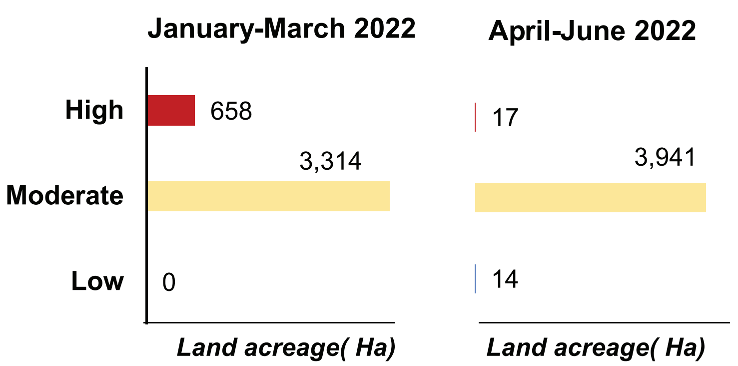
In general, in Southern African regions such as Malawi and Zambia, the January to March period is when cereal crops (maize, sorghum, and rice) are in their early vegetative stages. The prediction map of Malawi between January to March 2022 indicates a high to a moderate infestation in the western regions (Mchinji), central (Lilongwe), southern (Blantyre) regions, and parts of western (Liwonde NP) regions and areas around Limbe, Thyolo, Zomba, Mzimba, and Chikwawa. Most cereal growing areas are expected to experience moderate infestation levels.

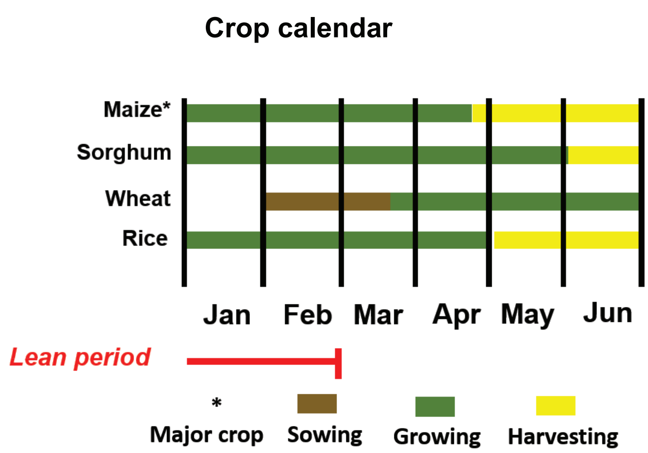
April to June 2022

Between April and June, the entire of Malawi will experience a moderate infestation rate and spatial coverage of FAW. This period coincides with the late vegetative stages of cereals, where they are approaching the harvesting period.

The area of land under high FAW infestation is expected to reduce significantly, while the area of land under moderate FAW infestation is likely to increase during the period of April to June 2022.


January - March 2022
April - June 2022
30°0'0"E
32°0'0"E
34°0'0"E
36°0'0"E
38°0'0"E
10°0'0"S
12°0'0"S
14°0'0"S
16°0'0"S
0 75 150 300 km
Predicted density and occurrence
High
Moderate
Low
Cities
Major roads
Non-maize or Non-sorghum area


January-March 2022
April-June 2022
High
Moderate
Low
658
3,314
0
17
3,941
14
Land acreage(Ha)
Land acreage(Ha)


Crop calendar
Maize*
Sorghum
Wheat
Rice
Jan
Feb
Mar
Apr
May
Jun
Lean period
*
Major crop
Sowing
Growing
Harvesting

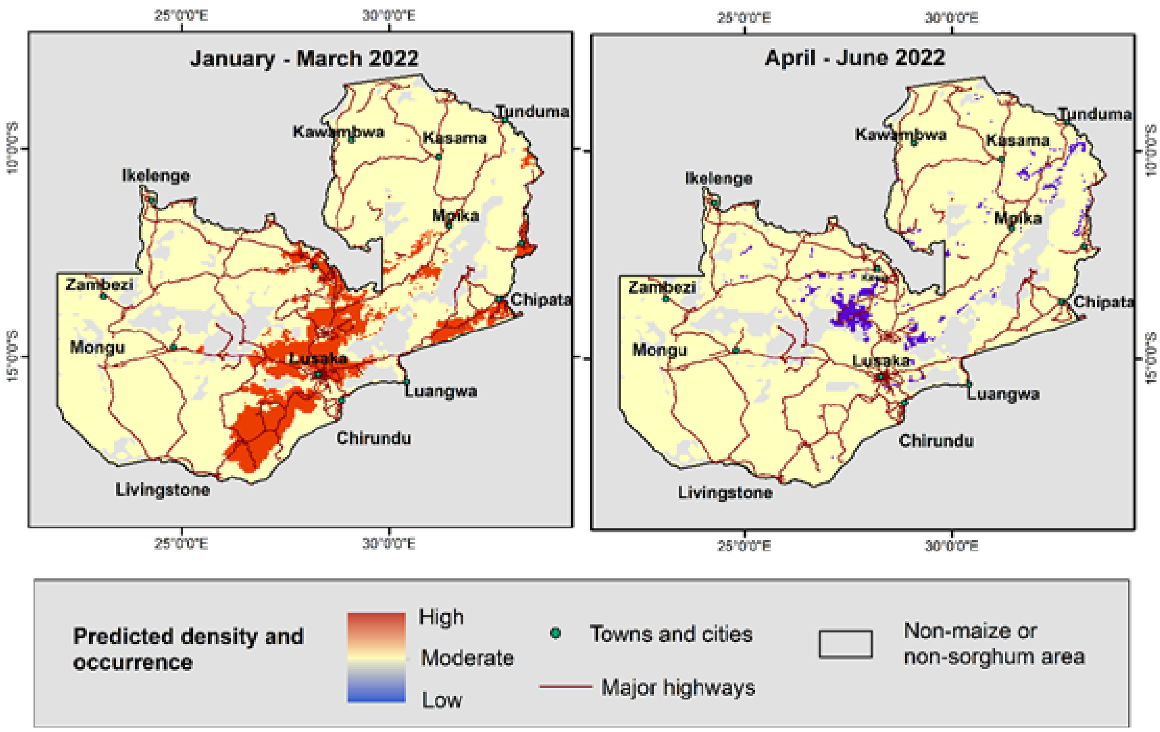
FAW RISK AND SPREAD PREDICTION MAPS IN ZAMBIA

January to March 2022

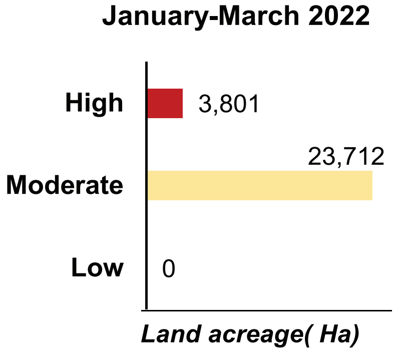
Between January and March 2022, FAW infestation is likely to be high in the central region, especially in Solwezi, Chingola, Kitwe, Luanshya, Kabwe, Lusaka, Kafue, Mazabuka, Monze, Chipata, Choma, Isoka and Serenje. These are areas known for high maize productivity and will likely to be under intense stress from the FAW. However, moderate infestation is expected in most other cereal growing areas. The January to March 2022 period coincides with the peak maize growing season in southern Africa, similar to Malawi.

April to June 2022

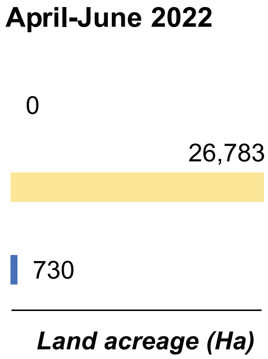
From April to June, Zambia is expected to have a high infestation rate in most cereal growing areas and a low FAW infestation, particularly in Kitwe, Luanshya, parts of Lusaka, Kabwe, Isoka, Kasama and Mpika. This period coincides with the harvesting season of most southern African countries, including Zambia, hence the low to moderate infestation. Thus, the high infestation observed in the January to March prediction period is likely to reduce to moderate during the April to June 2022. Therefore, the acreage of land under moderate infestation is expected to increase between April-June 2022.



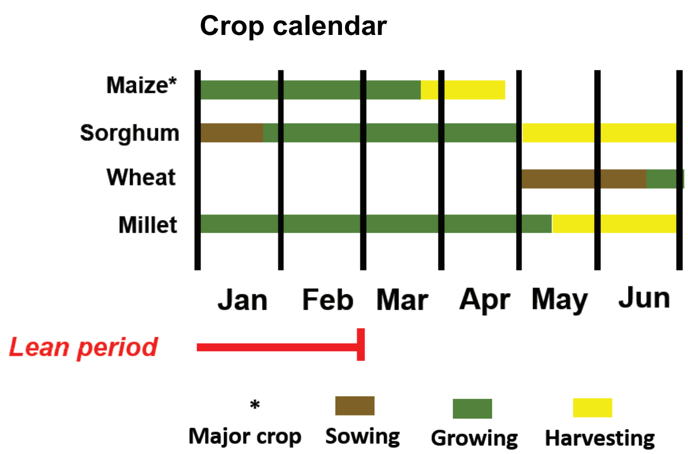
January - March 2022
April - June 2022
25°0'0"E
30°0'0"E
10°0'0"S
15°0'0"S
Tunduma
Kawambwa
Kasama
Ikelenge
Mpika
Zambezi
Chipata
Mongu
Lusaka
Luangwa
Chirundu
Livingstone
Predicted density and occurrence
High
Moderate
Low
Towns and cities
Major highways
Non-maize or non-sorghum area



January-March 2022
High
3,801
23,712
Moderate
Low
0
Land acreage(Ha)



April-June 2022
0
26,783
730
Land acreage (Ha)



Crop calendar
Maize*
Sorghum
Wheat
Millet
Jan
Feb
Mar
Apr
May
Jun
Lean period
* Major crop
Sowing
Growing
Harvesting

RECOMMENDED PRACTICAL ACTIONS (TECHNOLOGIES)

	GAP and Cultural	Push-Pull	Agroecological management options (legume intercropping)	Biopesticides and Biorationals	Natural enemies
Ethiopia	Introduce incentives to promote adoption of GAP among small. Support training and extension activities to strengthen the adoption of GAP	Support seed certification for the locally produced Desmodium and Brachiaria seeds	Sensitize policymakers on the effectiveness of intercropping and support the development of policies to facilitate access to seeds.	Support certification, commercialization, and distribution of biopesticides	Support licensing of mass rearing and distribution of natural enemies in the country
Kenya	Promote national programs to sensitize and train farmers on GAP	Integrate Push-Pull into the National Extension system. Officially roll out a scaling strategy technology for adoption	Sensitize policymakers on the effectiveness of intercropping and support the development of policies to facilitate access to seeds.	Promote national biopesticide programmes to promote the uptake and utilization of Biopesticides and biorationals Provide subsidy for local manufacture of biopesticides	Support licensing of mass rearing and distribution of natural enemies in the country
Tanzania	Introduce incentives to promote the adoption of GAP among small scale farmers	Integrate into the national Extension system Promote local seed Production	Sensitize policymakers on the effectiveness of intercropping and support the development of policies to facilitate access to seeds.	Provide subsidy for local manufacture of biopesticides	Promote national programs on research and farmer sensitization on the use of natural enemies alongside other techniques in the management of FAW
Uganda	Introduce incentives to promote the adoption of GAP among small scale farmers	Integrate into the national Extension system Promote local seed Production	Sensitize policymakers on the effectiveness of intercropping and support the development of policies to facilitate access to seeds.	Promote national biopesticide programmes to promote the uptake and utilization of Biopesticides and biorationals.	Support licensing of mass rearing and distribution of natural enemies in the country. Promote national programs on research and farmer sensitization on the use of natural enemies alongside other techniques in the management of FAW

	GAP and Cultural	Push-Pull	Agroecological management options (legume intercropping)	Biopesticides and Biorationals	Natural enemies
Rwanda	Support certification and accreditation for established GAP in the country. Establish National programs to promote the adoption of GAP	Integrate Push-Pull into the National Extension system. Officially roll out a scaling strategy technology for adoption	Sensitize policymakers on the effectiveness of intercropping and support the development of policies to facilitate access to seeds.	Implement Agri -policies on chemical pest reduction. Provide subsidies on biopesticides	Promote national programs on research and farmer sensitization on the use of natural enemies alongside other techniques in the management of FAW
Malawi	Establish National programs to promote the adoption of GAP. Establish National programs to strengthen technical know-how in the application of GAP	Integrate into the national Extension system. Support local seed production	Sensitize policymakers on the effectiveness of intercropping and support the development of policies to facilitate access to seeds.	Provide subsidy for local manufacture of biopesticides Implement national programs on farmer sensitization and training on biopesticides and biorationals as safe alternative to chemical pesticides	Support licensing of mass rearing and distribution of natural enemies in the country
Zambia	Promote national programs to sensitize and train farmers	Integrate the technology in national Agriculture programs and extension system	Sensitize policymakers on the effectiveness of intercropping and support the development of policies to facilitate access to seeds.	Support registration, commercialization and distribution of biopesticides	Support licensing of mass rearing and distribution of natural enemies in the country. Promote national programs on research and farmer sensitization on the use of natural enemies alongside other techniques in the management of FAW

ACTIONABLE GUIDES TO POLICYMAKERS IN EACH COUNTRY

	GAP and Cultural	Push-Pull	Agroecological management options (legume intercropping)	Biopesticides and Biorationals	Natural enemies
Description	Timely land preparation, planting and weeding, timely application of fertilizer or manure in the proper doses, use of certified and recommended seed varieties.	Push-Pull involves intercropping of Maize with Desmodium legume and Brachiaria grass.	Involves intercropping of maize with other legumes, i.e., Beans, Green grams, Mucuna etc.	These are fungal based and plant-derived pesticides.	Beneficial parasitoids of FAW eggs and larvae: *Trichogramma Chilonis, Telenomus remus, Cotesia icipe*)
Application Rate	Continuous Recommended in most low infestation regions (Green)	Applied once Legume intercropping and Push-Pull	Applied every season Need to facilitate introduction in Ethiopia	Applied every season Mass release recommended in highly infested regions	3-4 releases per season
Cost	A routine does not come with a cost	120 USD/acre or 30USD if seeds are locally produced	38 USD/acre	20- 40 USD/liter	Rearing costs
Where to get the service/ Technology	Own practice	Seeds: *Link* Training: Ministry, DARS, TLC in Malawi RAB, FH, SAC -Rwanda ZARI, KATC, SAC - Zambia, MOA-Kenya, MOA, ATA – Ethiopia	Seeds: Training: Ministry, DARS, TLC in Malawi RAB, FH, SAC-Rwanda. ZARI, KATC, SAC- Zambia, MOA-Kenya, MOA, ATA – Ethiopia	Training: Ministry, DARS, TLC in Malawi RAB, FH, SAC-Rwanda ZARI, KATC, SAC- Zambia, MOA-Kenya, MOA, ATA – Ethiopia	Training: Ministry, DARS, TLC in Malawi RAB, FH, SAC- Rwanda ZARI, KATC, SAC- Zambia, MOA- Kenya, MOA, ATA – Ethiopia

ITEMIZED ACTIONS BY THE STAKEHOLDERS

	GAP and Cultural	Push-Pull	Agroecological management options (legume intercropping)	Biopesticides and Biorationals	Natural enemies
Research / Academia	Establish standards and guidelines for GAP in various Agro-ecological zones in the country. Research on the challenges to the adoption of GAP and advise policymakers.	Conduct trials on suitable areas for the production of Desmodium and Bbrachiaria seeds in Tanzania, the West parts of Ethiopia and Southern regions of Rwanda. Provide evidence on the quality of local seeds to facilitate seed certification in Ethiopia and Kenya. Research on alternative crops for Push-Pull intensification in Malawi, Rwanda, Tanzania, Uganda and Zambia Conduct PPT validation in the Southern region of Zambia	Conduct research on the best edible legumes for intercropping and the most varieties considering agroecological context and cultural practices.	Validate the proven biopesticides for commercialization and release. Conduct efficacy trials to facilitate local registration	Conduct validation trials Facilitate mass rearing of Parasitoids. Provide training and protocols on mass rearing of parasitoids to interested farmers
Private Sector	Facilitate timely access to farm Inputs.	Commercialize production of Desmodium and Brachiaria seeds and Fast track certification of locally produced seeds in Ethiopia. Strengthen seed availability through local production and imports in the seven countries. Promote packaging of seed in smaller quantities affordable to smallholder farmers. Strengthen collaboration with local agro-dealers to improve the accessibility of seeds in Rwanda, Kenya, Tanzania, Ethiopia and Zambia	Facilitate access and availability of seeds at affordable prices.	Collaborate with researchers in the validation trials Fast track local registration of the proven biopesticides Commercialize and avail the products in the market	Establish and strengthen mass rearing of parasitoids

	GAP and Cultural	Push-Pull	Agroecological management options (legume intercropping)	Biopesticides and Biorationals	Natural enemies
Extension officers / NGOs	Strengthen farmer training to understand and apply GAP. Promote GAP alongside other FAW IPM techniques.	Create awareness and Introduce Push-Pull in areas where it is not practised Strengthen farmer training for correct application through demos	Promote legume intercropping in areas where it is uncommon. Establish demonstration sites showing various maize -edible legume intercropping options.	Support field validation. Strengthen farmer training and conduct demonstrations on correct application. Conduct field days to demonstrate results and benefits of the technology	Create awareness on the use and benefits of natural enemies Identify sites and promote field release of parasitoids
General Public / Media	Create massive awareness on the multiple benefits of applying GAP in increasing productivity, food safety and FAW management.	Create extensive scale awareness about the technology and its benefits in addressing multiple productions constraints Sensitize the policymakers on the benefits and the need to support the adoption of the technology.	Create awareness among farmers and the general public on the benefits of intercropping with edible legumes on FAW management and the additional benefits in household food security.	Create large-scale awareness of the availability of biopesticides and biorationals and its benefits Link farmers to service providers Create awareness on the effects of using chemical pesticides	Create massive awareness of the benefits of applying GAP in increasing productivity and food safety Host experts to address farmer questions and challenges to the adoption of the technology
Smallholder Farmers	Sensitize other farmers on the benefits of GAP through farmer-to-farmer extension and being good models	Train fellow farmers on the establishment and management of Pull plots Attend training and adopt the technology Host field days to demonstrate the results and benefits of the technology to other farmers and policymakers	Sensitize farmers on the effectiveness of intercropping with edible legumes on FAW management and the additional benefits in household food security.	Sensitize other farmers on the benefits of using biopesticides through field days and farmer field schools	Take part in field validation process Sensitize other farmers on the benefits of using natural enemies Attend training and adopt the technology

METHODOLOGY

Data

The reference FAW locational and density data were obtained from the Food and Agriculture Organization (FAO). These data are continuously collected using the FAW Monitoring and Early Warning System (FAMEWS: http://www.fao.org/fall-armyworm/monitoring-tools/famews-mobile-app/en/) that is facilitated by a global-wide network of data collectors across continents using smartphones. This database was then subjected to rigorous automated elimination criteria of the observations through spatial data validation and duplicate removal criterion to standardize and ensure data consistency. All the climatic data used in this study were obtained in raster format from the high-resolution monthly precipitation and temperature time-series for the period 2006-2100 provided by Envidat at 5km spatial resolution (https://www.envidat.ch/#/metadata/chelsa_cmip5_ts) global gridded database [2]. The data are provided on a monthly timestep at a spatial resolution of 5 km x 5 km pixel size. The period January 2018 – December 2020 was used in this analysis and was selected because it matched with the time the trap data was collected across the African continent. The monthly grid layers that were used are precipitation (pr), maximum temperature (Tmax), and minimum temperature (Tmin). These climate data were then extracted from the raster images using the locational data (longitude and latitude) of the FAW traps. They were matched with their corresponding month of data collection for each row of the FAMEWS data. The elevation was obtained from the 30m resolution Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version-2 (GDEM-V2; [3]). The physical areas covered by either maize or sorghum crops were derived from the International Food Policy Research Institute (IFPRI) under the harvest choice database (https://www.ifpri.org/project/harvestchoice). The physical area of both sorghum and maize we also extracted using the trap locational data and added as explanatory variables to the occurrence and density of the FAW.

MODEL CALIBRATION AND PREDICTION

Model fitting and prediction were made using the random forest (RF) algorithm [4] in the ‘ranger’ package [5] as implemented in the R environment for statistical computing [6]. RF running in the ‘ranger’ is fast and efficient at handling large datasets at regional and continental scales. The developed continent-wide database of the dependent variable (FAW density) and the respective explanatory variables matched to each month of data collection were used to develop the RF regression model and used to predict the occurrence and density of the FAW on a monthly timestep. In addition to the climate data, the specific month data as obtained from the month of trap data collection were added to the training data as explanatory categorical variables. The value 1 was assigned to observations in a specific month, while the rest were assigned value 0 to depict no data collection for that particular month. The model was then used to predict the monthly occurrence and quarterly average of the FAW in the seven African countries, i.e., Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda, and Zambia. The output maps were developed in a geographic information system (GIS), and three levels of infestation were used to describe the intensity of the potential density per target quarterly period, i.e., low (0-10), moderate (11-30), and high (>30). These three infestation levels were informed by the quantile classification analysis of the input density data obtained from the FAMEWS [7].

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