Issue #5

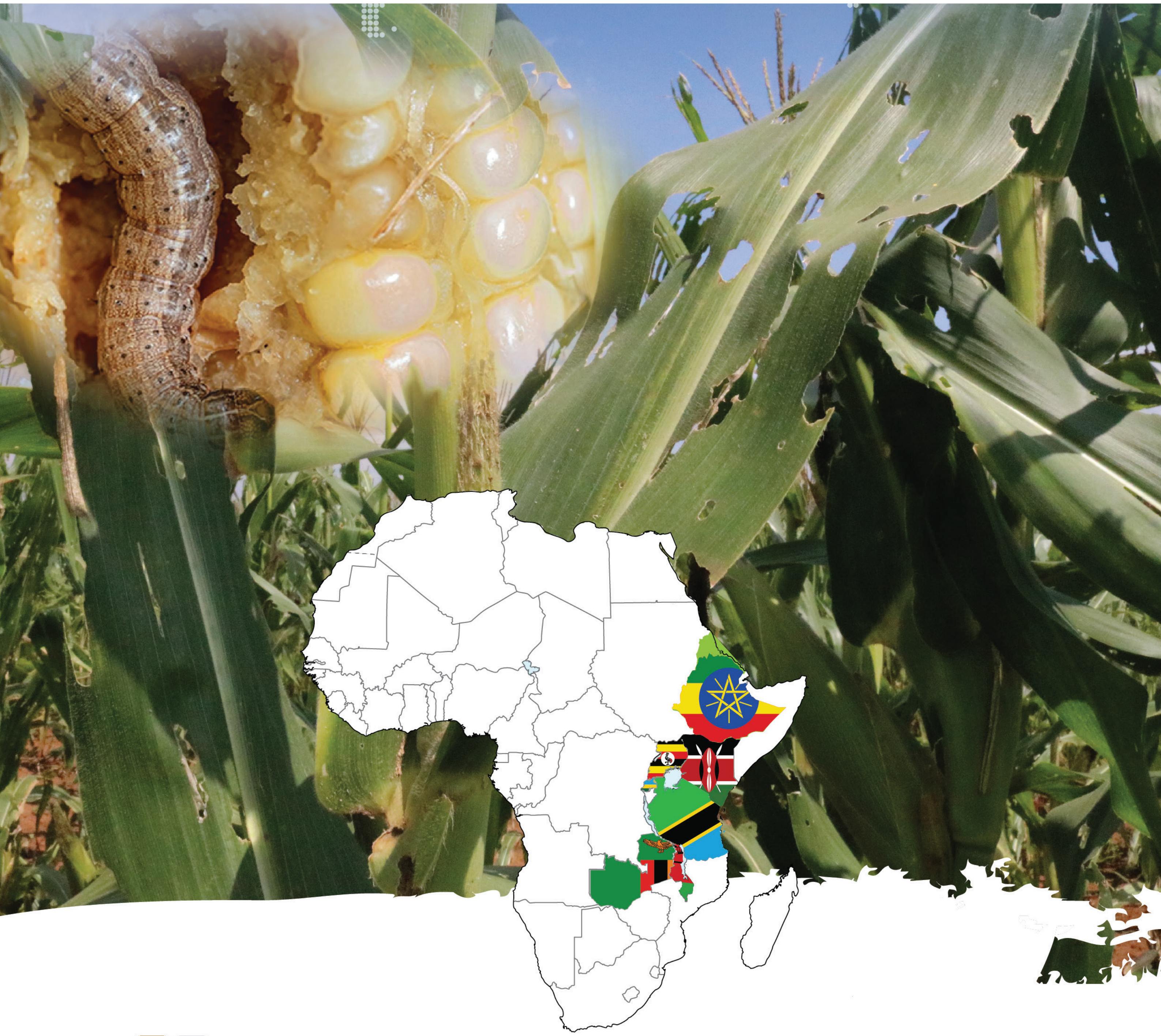
FALL ARMYWORM
Monitoring

Structure of the Countries Profile

January - June 2023 Issue

FAW INVASION RISK PREDICTION

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



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ABOUT THE NEWSLETTER AND THE CBFAMFEW II PROJECT

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 2023. This profile is the 5th issue produced within a series of other FAW spread and risk newsletters published since 2021 under the USAID-funded Community-Based Fall Armyworm Monitoring and Forecasting Early Warning System (CBFAMFEW II) project. These series provide preinvasion and near-real-time predicted density of FAW and the areas at risk of attack at the country level in different months (summed quarterly). The profiles also propose country-specific actionable solutions, and adaptation mechanisms to manage the FAW invasion for each period in which it is produced. The core objective that this series of newsletter is centered on stimulating community and citizen information sharing, inclusive policy drafting, engagement to design homegrown solutions, community-based monitoring for the FAW, and improving the regional data collection mechanisms for increased data quantity and quality.

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Fall armyworm is a transboundary pest that can fly up to 400 km/night. 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 tons in the maize farming sector in 12 African countries

Food and Agriculture Organization of the United Nations

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

Download from the Google play store:

https://play.google.com/store/apps/details?id=org.fao.famews&hl=ar&gl=US

TABLE OF CONTENTS

LIST OF ACRONYMS

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CABI	The Centre for Agriculture and Bioscience International
CBFAMFEW	Community-Based Fall Armyworm Monitoring, Forecasting, and Early Warning
CIMMYT	International Maize and Wheat Improvement Centre
DARS	Department of Agricultural Research Services
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization of the United Nations
FAMEWS	Fall armyworm Monitoring and Early Warning System
FH	Food for the Hungry
GAP	Good Agricultural Practices
icipe	International Centre of Insect Physiology and Ecology
IFRI	International Forestry Resource and Institutions/International Food Research Institute
IITA	International Institute of Tropical Agriculture
IPM	Integrated Pest Management
KATC	Kasisi Agricultural Training Centre
MoA	Ministry of Agriculture
PPT	Push-Pull Technology
RAB	Rwanda Agriculture and Animal Resources Development Board
SAC	Send A Cow
TLC	Total Land Care
USAID	United States Agency for International Development
ZARI	Zambia Agricultural Research Institute (ZARI)
ATI	Agricultural Transformation Institute

BACKGROUND

Fall armyworm (FAW), *Spodoptera frugiperda*, is a destructive pest of variety of crops. It is a native to tropical and subtropical regions of the Americas but has recently spread around the world owing to their speedy migration and reproduction [1]. It was reported in west Africa in January 2016 but by June 2017, it had spread to most countries of sub-Saharan Africa [2]. Its larval stages actively feed on crops and are causing significant damage and yield losses globally. The strain of FAW that is prevalent in Africa prefers maize but can also feed on more than 350 other crops, including wheat, sorghum, millet, sugarcane, vegetable crops, and cotton [2]. FAW is established in Africa and some studies are already suggesting it will soon be an endemic pest hence the need to continuously understand its natural spread in near-real-time to foster proactive mitigatory and monitoring plans [3]. The seasonal spread of FAW is highly dependent on crop availability, staggered planting, host plant stage, management practices, availability of natural enemies within the area, conducive weather, and flying conditions such as wind speed and direction. An adult FAW can fly up to a hundred kilometers in a single night.

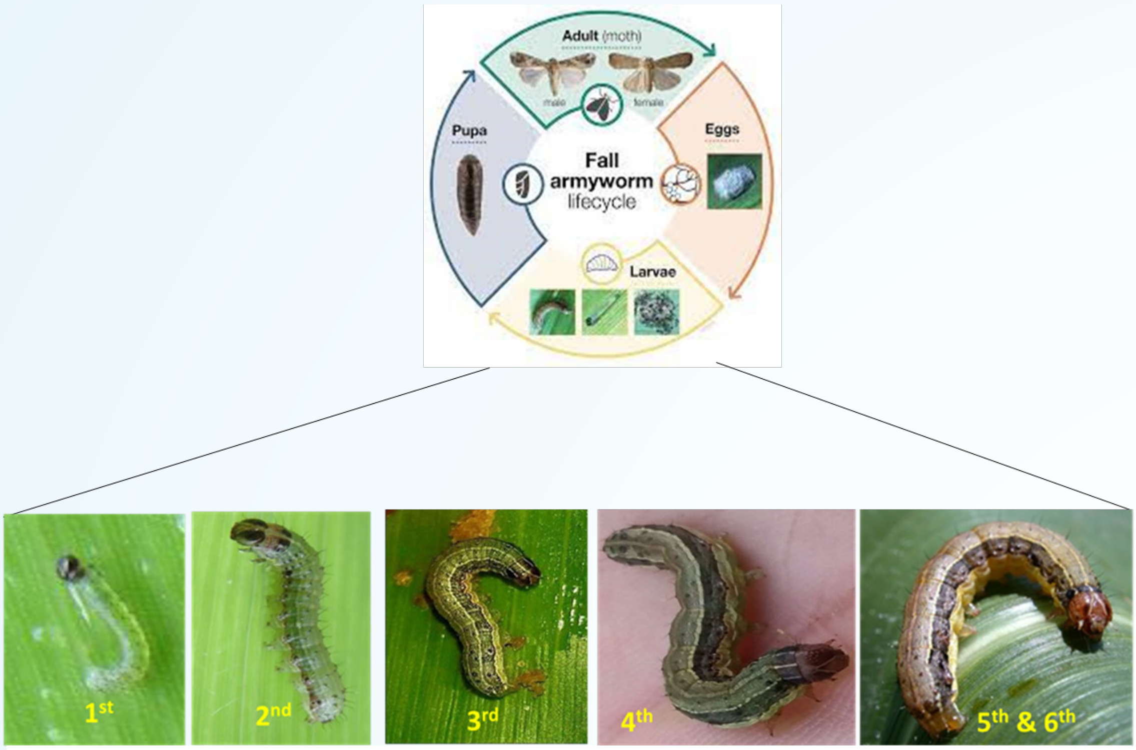
Over 17.7 million tons of maize are lost annually due to FAW in Africa. The most direct impact of these losses affects mainly tens of millions of smallholder maize farmers, the majority of whom rely on the crop to reduce hunger and poverty. Chemical pesticides are the most promoted control measures; however, they are associated with many health and environmental hazards. Their handling, use, and disposal always require special care. Advancement in research and development, natural enemies of FAW in Africa have been identified as *Cotesia icipe*, *Trichogramma mwanzae*, *Trichogramma chilonis*, *Telenomus remus* among others. These natural enemies are likely to exist in areas where FAW has been reported. Guimapi et al 2023 [4] concluded that the data on natural enemies of FAW occurrence would further strengthen the prediction capacity of the modeling initiatives such as the one presented in this series of newsletter and FAW country profiles. Therefore, knowledge, materials and information coupled with reciprocal regular updates to and from different stakeholders, including governments and the public are thus essential in increasing awareness and a systematic call for action. For this purpose, we adopted the use of random forest modeling, a machine learning (ML) approach to predict the FAW monthly occurrence in Africa.

Machine learning is an application of artificial intelligence that enables a system to learn from examples and experiences without explicit programming. Machine learning comprises a category of algorithms that allows software applications to become more accurate in predicting outcomes from systems of research interest [5]. The basic premise of ML is to build algorithms that can receive input data (in our case FAW occurrence data) and use statistical analysis to predict an output while updating outputs as new data become available. The advantages of ML include extracting more knowledge and identifying trends from big data sets. Given the increasing pressure from emerging pests such as the FAW, ML techniques play a critical role in forecasting pest occurrence and incidences which allows farmers, governments, NGOs, and private players to prepare control measures well in advance.

Factsheet:

FAW prefers hosts in the grass family i.e., maize, millets, rice, sorghum, wheat, 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.

FAW completes its life cycle in four stages (Figure 1). FAW is known for its ability to disperse within a crop locally and migrate long distances. Adult moths are good flyers and larvae of all ages can quickly crawl from one host plant to another. This means both adults and larvae can move quickly within crops and from one crop to another or nearby host plants after harvest. Fall armyworm can also be spread through the movement of people and commodities. Therefore, governments should closely regulate the importation of plant materials and strengthen their phytosanitary measures.



1st and 2nd bluish and green with black head, 3rd and 4th Dark green, 5th and 6th Brownish with reddish head

Figure. 1. Life cycle of Fall armyworm

To help identify symptoms of fall armyworm, examine plants for: (Figure 2)

• Leaf damage, including pinholes, windowing, and defoliation.

• Newly hatched larvae are more active at night and eat, causing pinholes and transparent windows in leaves.

• Injury to developing tassel, bored ear husks from side and feeding on developing kernels in cob (Figure 2A)

• In some cases, FAW larvae cut the seedlings from the base of the stem like cutworm damage

• Bigger larvae graze on leaves, stems, tassel, silk, and seed, leave sawdust-like frass (droppings) in the whorl, and

• FAW Larvae themselves in plant whorls, particularly in maize and sorghum (Figure 2B).

• Regularly monitoring the crop, surveying sections on the edges of the crop

Cluster of small, Round Window Panes (A), Elongated Window Panes (B), Whorl-feeding damage and elongated ragged holes (c)

FAW lavae and frass (D), plants with fresh feeding damage on the tassel (E), cobs/ears (G) and stem base (H)

Figure. 2. FAW Damage Symptoms

Why is FAW so difficult to manage in Africa? *Because of their short generation time (25 – 30 days), multiple generations of FAW may happen within a field in the same crop season (Figure 3)*

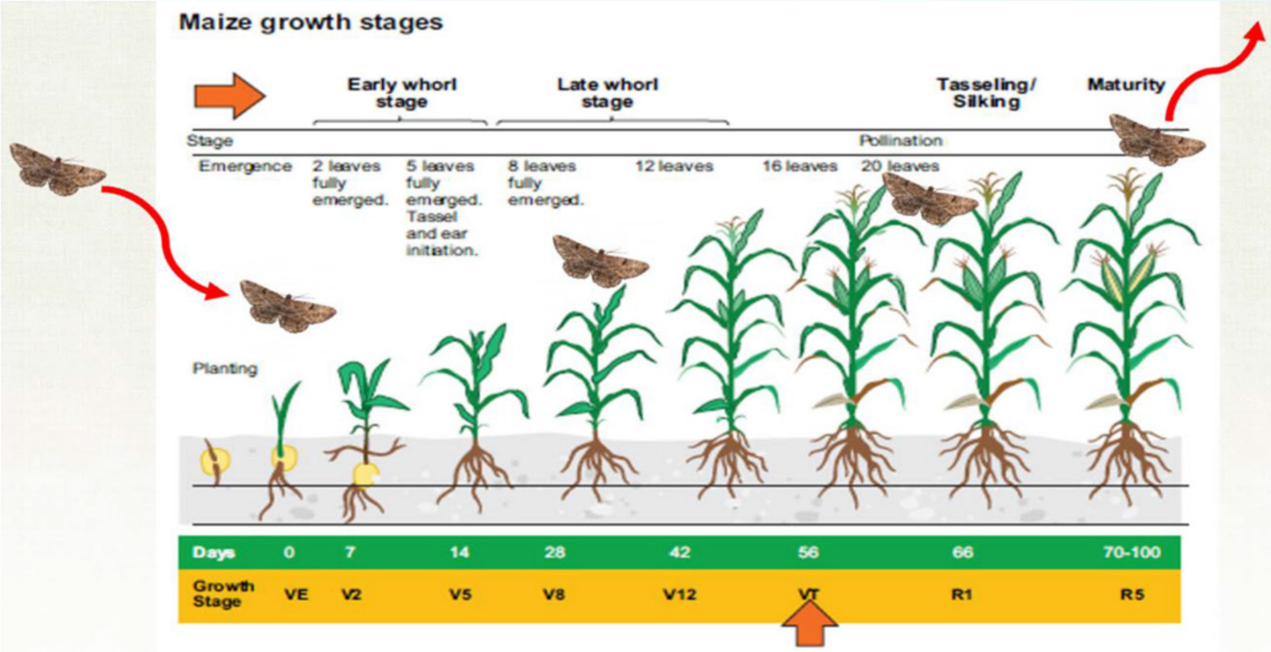


Figure. 3. Different FAW generation at different maize growth stages

CEREAL CROP CALENDARS IN EAST AND SOUTHERN AFRICA

Cereal calendars differ across countries/regions and sometimes within different 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 levels 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, Tanzania, Uganda, Rwanda, Zambia, and Malawi, for the period Jan to June 2023 can be/ and were sourced from FAO/GIEWS and FEWSNET.

POTENTIAL FAW INFESTATION IN EAST AND SOUTHERN AFRICA

The FAW spread and risk within the seven African countries from Jan to June 2023 have been characterized by a low, moderate, and high infestation. Generally, moderate to high infestation is likely to be detected in June. Low infestation is expected in Uganda, Tanzania, Rwanda, Malawi, and Zambia, in January to May, in southern Africa (Zambia and Malawi). The Jan to March period coincides with the sowing and vegetative period for the rainfed maize. The regional profile maps (Figure 4) demonstrated that the level of infestations across the region is determined by 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 staggered cropping calendar of the FAW host plant over the year, the control mechanism implemented on the farm and the availability of natural enemies. High infestation is signified by > 30 FAW moths, and the mild infestation is signified by 11 – 30 FAW moths in a maize field which is significant enough to cause yield losses between 20 – 80%.

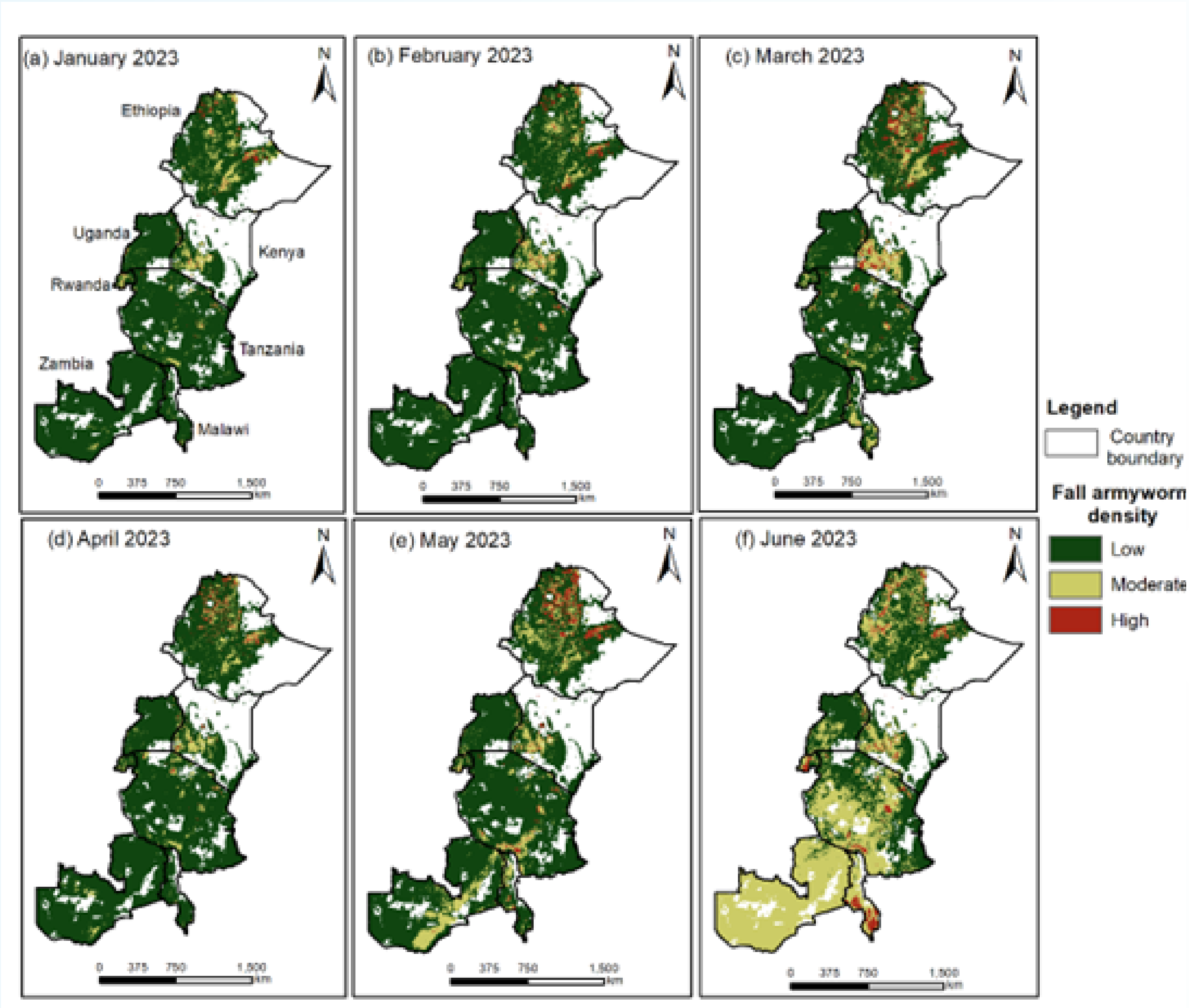


Figure. 4: Monthly probability of occurrence and predicted density of the fall armyworm (FAW) in Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda, and Zambia for the period January to June 2023. The maps were produced using the random forest model and data from the representative concentration pathway (RCP4.5) data provided by Envidat (https://www.envidat.ch/#/metadata/chelsa_cmip5_ts).

FAW RISK AND SPREAD PREDICTION IN ETHIOPIA

January to March 2023

Between January to March, most of the irrigated 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 happen in most cereal growing regions except Domo, Ferfer, Omi, and parts of Tirgol and Moyale. There will be high to moderate FAW occurrence in and areas bordering Gonder, Mekele, Dese, Dire Dewa, Axum, Bahir Dar, Hawasa, Welkite, areas bordering Addis Ababa, Harar, and Jijiga. Humera, Nazret (Adama), Jimma, Jijiga, and most regions in western and southern parts of Ethiopia will experience low FAW occurrence.

April to June 2023

Between April to June, most of the cereal growing areas shall experience FAW occurrence. The FAW occurrence will be more severe compared to the period of January to March. FAW occurrence is high in Mekele, Gonder, Bahir Dar, Dese, and Dire Dawa. Moderate to low FAW occurrence will be happened in Humera, Jimma, Welkite, Jijiga, Nazret (Adama), Hawassa, south of Harar, south of Hawassa, south of Jimma and south of Jijiga.

About 3,112 hectares of cereal farms are expected to experience high FAW infestation during the periods of January-March 2023. There will be a slight increase of acreage of farms (to 3,592 hectares) with high FAW infestation in April-June 2023. Also, acreage of land with moderate FAW infestation is likely to increase from 5,754 hectares in January-March to 8,420 hectares in April-June 2023. Farmers and extension officials need to be proactive and vigilant in the regions experiencing high and moderate infestations, considering that the period between April and June are growing seasons for the maize, sorghum, and millet.

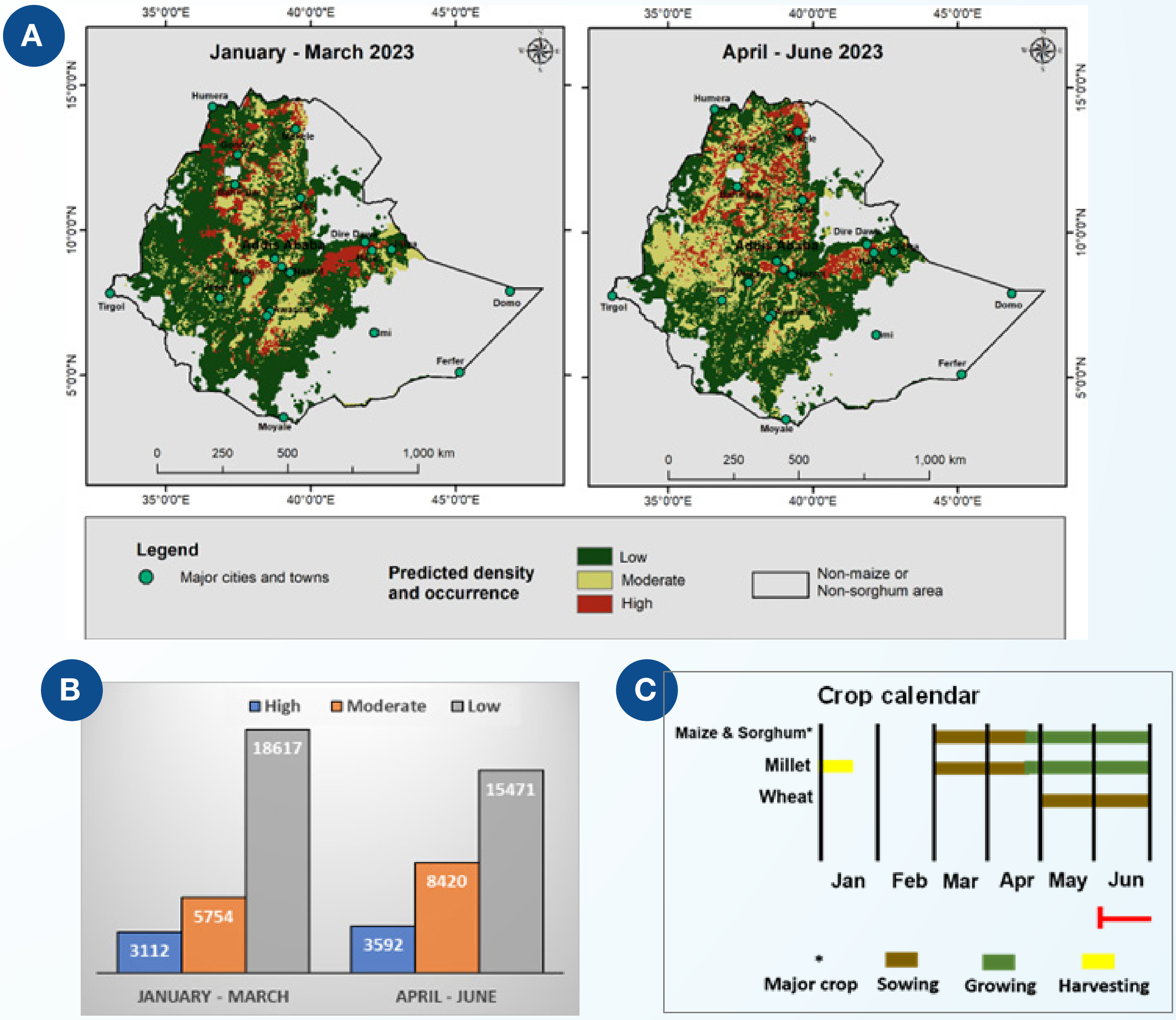
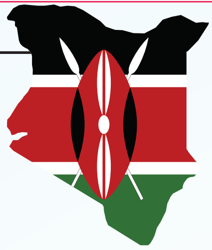


Figure 5. A) Fall armyworm spread prediction map (top), area of land under infestation in km2 (bottom left) and cereal crop calendar (bottom right) between January to June 2023 in Ethiopia, B) Infestation level area coverage and C) the cropping calendar.

FAW RISK AND SPREAD PREDICTION IN KENYA



January to March 2023

Between January and March, FAW occurrence is expected to be high to moderate in western parts of Kenya (Bungoma, Kakamega, and Busia), Nyanza regions (Kisumu, Migori and Siaya) and Trans Nzoia and Nakuru counties and areas bordering Nairobi. Regions such as Lodwar, Garissa, Lamu, Mombasa, Taveta and Namanga and parts of Moyale will experience low FAW occurrence. However, January-March 2022 constitutes farrowing and sowing season; thus, mostly irrigated and early planted crops are the most susceptible to attacks.

April to June 2023

Between April and June, the FAW occurrence will remain moderate to high in most of cereal growing regions. However, the high FAW occurrence in the western regions will reduce to moderate occurrence. Although, this period matches the season where maize, sorghum and millet are in their early vegetative stages and at their most vulnerable.

Relatively higher acreage of cereal farms (about 1,362 hectares) will experience high FAW incidences in January to March than April to June 2023 whereby 629 hectares will be affected. In April to June, most regions receive high rainfall and therefore, there will be low FAW occurrence. However, about 2,566-2,798 hectares of cereal farms will be under moderate FAW infestation during half part of the year 2023.

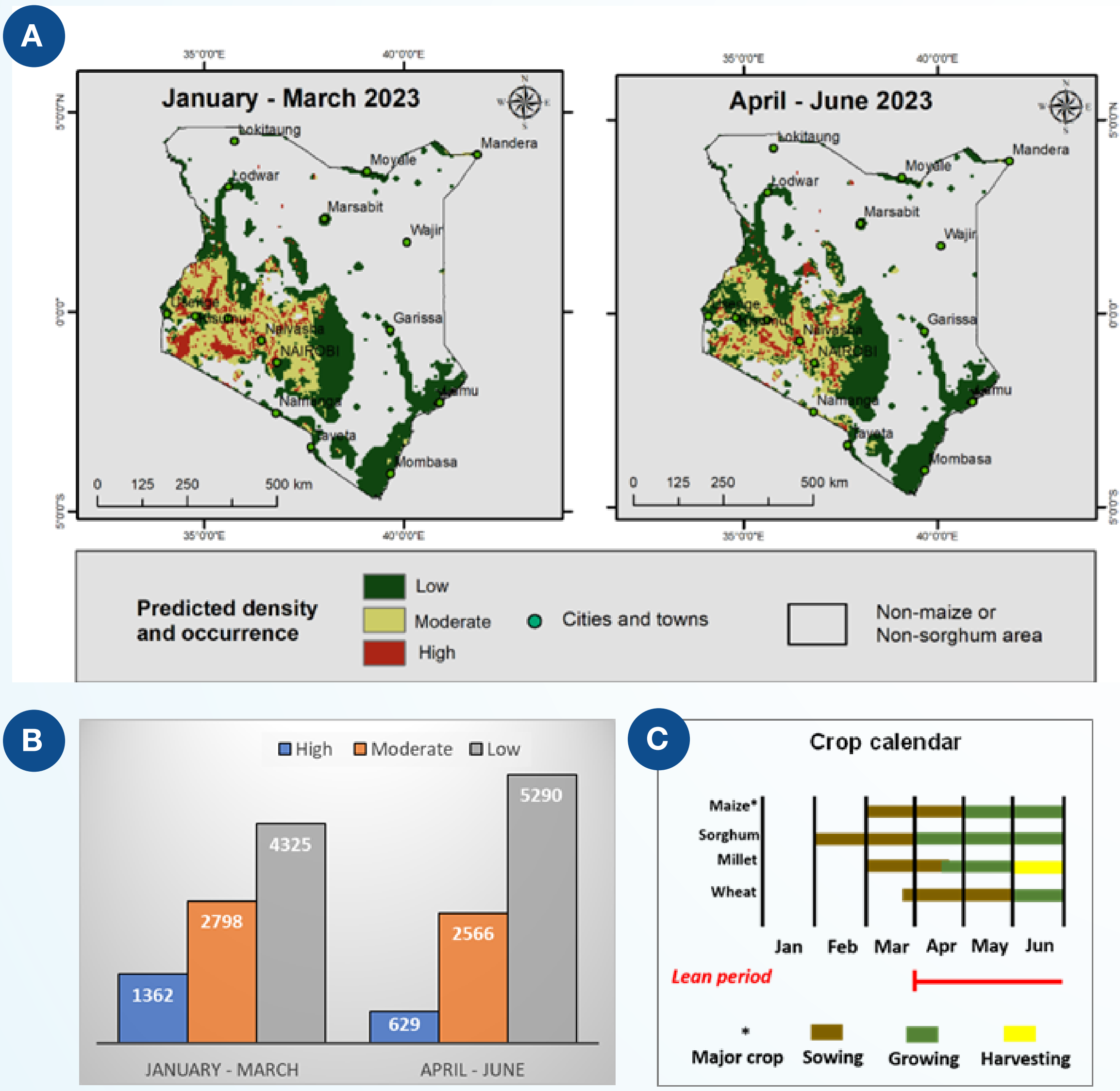


Figure 6. A) Fall armyworm spread prediction map (top), area of land under infestation in squared km2 (bottom left) and cereal crop calendar (bottom right) between Jan to June 2023 in Kenya, B) Infestation level area coverage and C) the cropping calendar.

FAW RISK AND SPREAD PREDICTION IN TANZANIA

January to March 2023

Prediction map of FAW occurrence between January and March 2023 indicates that most cereal growing areas will experience low FAW occurrence. However, moderate to high FAW occurrence will be observed in areas around Mhango, Kisiwani, Segerere, Mdandu, Marangu, and Tunguli. The period between January and March constitutes the early vegetative stages of maize grown under bimodal rainfall in Tanzania.

April to June 2023

Between April and June 2023, most cereal growing areas will experience a moderate FAW occurrence compared to the January to March period. Some areas such as will partly experience low FAW occurrence and they include Mhango, Kisiwani, Nyaruonga, Mkwaja, Teguli, Somanga, Msimbati, Masuguru, and Segerere. However, high FAW occurrence will be observed in Kisiwani, Tunguli and Mdandu.

The high infestation is likely to increase slightly in April to June 2023 period with 840 hectares of cereal farms being affected. The acreage of land under with moderate infestation is also expected to increase from 2,596 hectares in the January-March period to 15,850 hectares in the April-June period. This indicates that the best time to curb the spread of FAW and reduce its population is January-March.

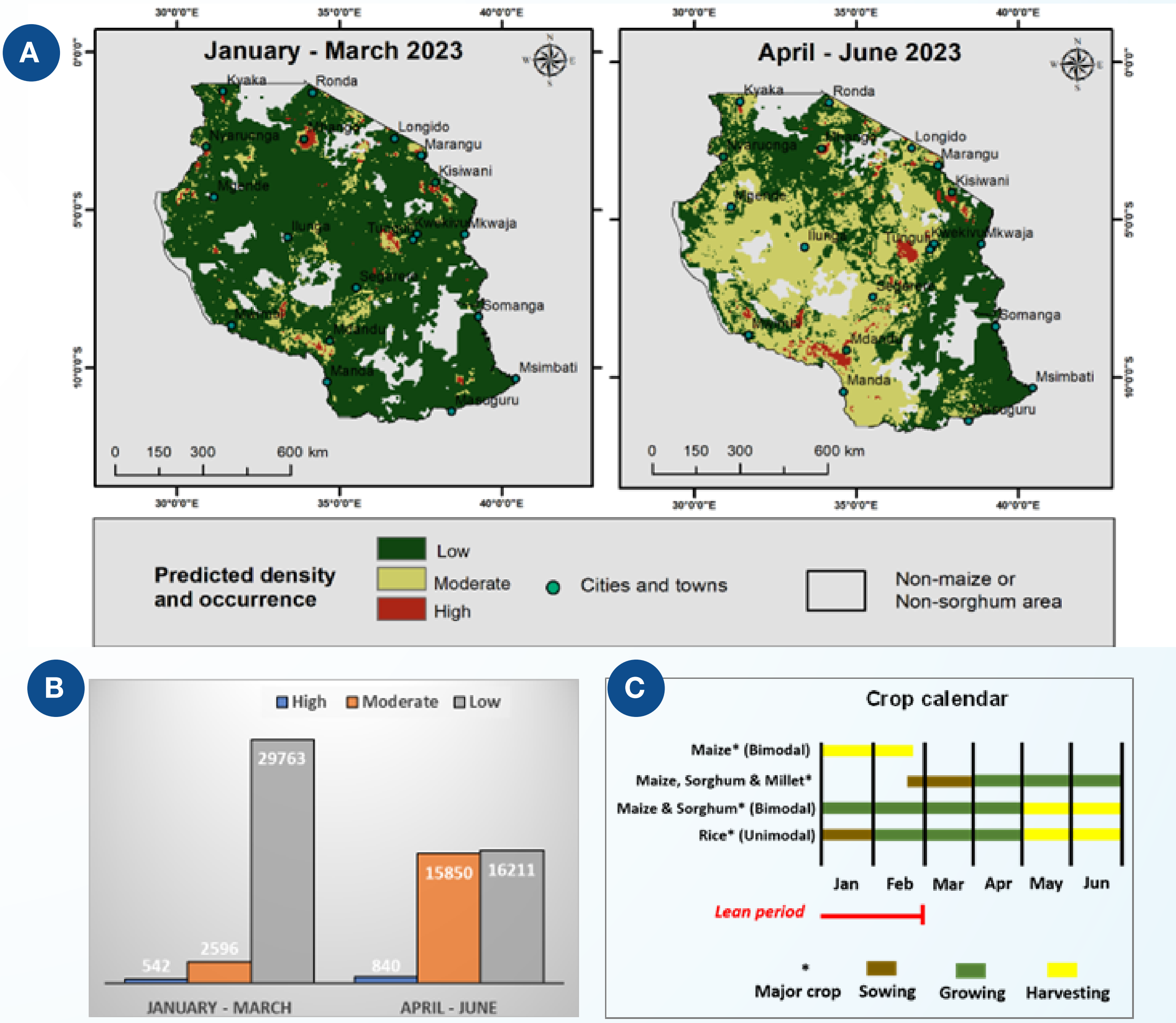
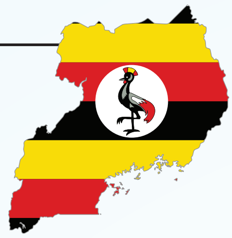


Figure 7. Fall armyworm spread prediction map (top), area of land under infestation in km2 (bottom left) and cereal crop calendar (bottom right) between Jan to June 2023 in Republic of Tanzania, B) Infestation level area coverage and C) the cropping calendar

FAW RISK AND SPREAD PREDICTION IN UGANDA



January to March 2023

January to March in Uganda coincides with the maize harvesting season and sowing season of maize and millet. FAW occurrence is anticipated to be low in most cereal growing regions except for a few areas such as Kyenjojo Ibanda, Mubende, and Paidha that will experience moderate FAW occurrence. High FAW occurrences are expected in the eastern areas (Kaabong, Bukedea, Kapchorwa, Nakapiripit) and west parts of Kyenjojo.

April to June 2023

During this period, the FAW occurrence will increase compared to the January to March period. The period of April to June also coincides with the period of vegetative stage of maize. Most areas will experience a moderate FAW occurrence. Moderate FAW occurrence will be observed in Koboko, Luwero, Mubende, Mityana, Kyenjojo, Bukedea, and Kapchorwa. High FAW occurrence is expected in some parts of eastern Uganda, including eastern (Bukedea, Kapchorwa, Nakapiripit).

While less than 109 hectares of cereal farms will have high FAW infestation, more land (1,727 hectares) will experience moderate FAW infestation in April-June 2023 compared to January-March 2023, where 442 hectares will have moderate FAW infestation.

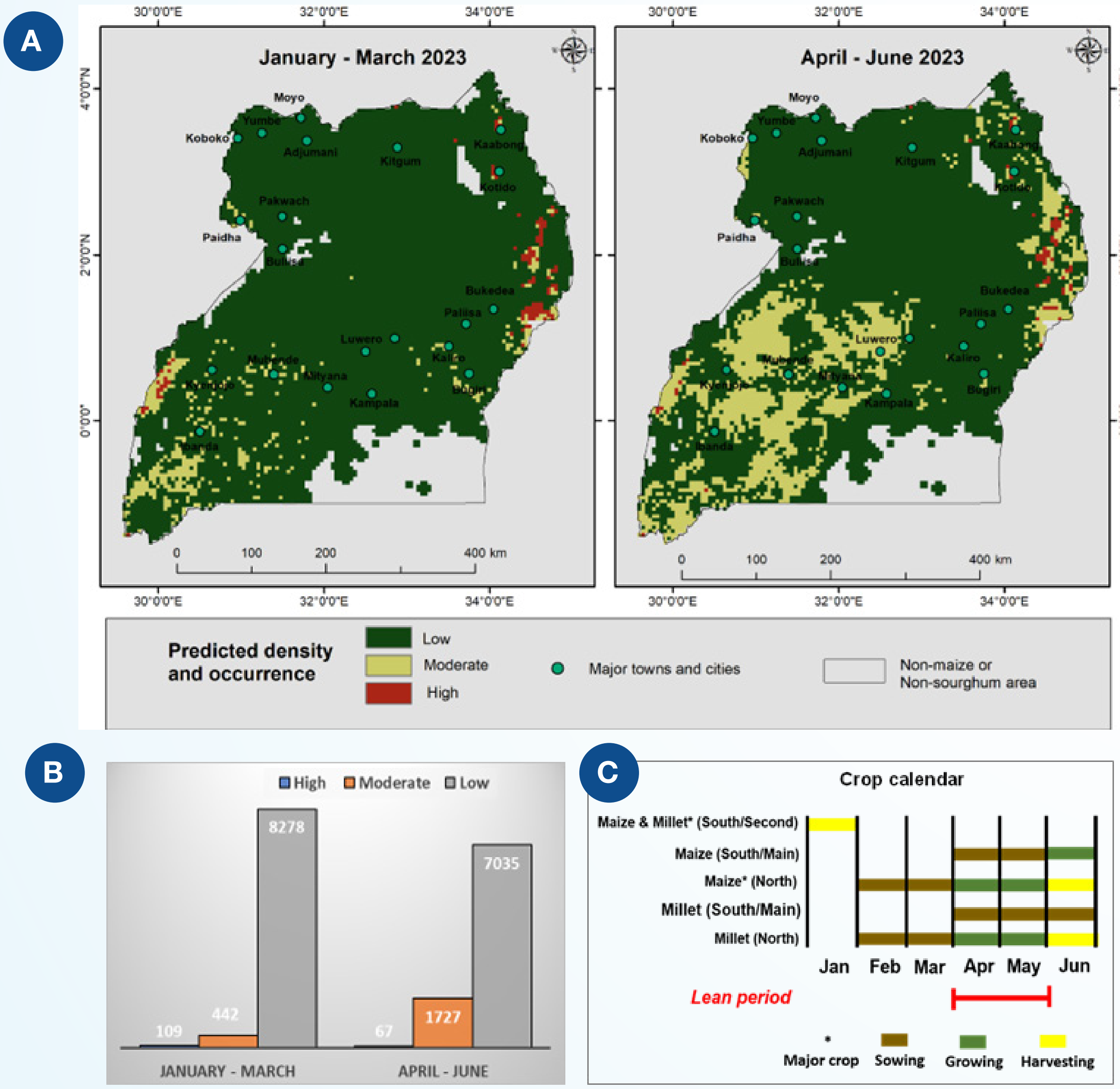


Figure 8. Fall armyworm spread prediction map (top), area of land under infestation in km2 (bottom left) and cereal crop calendar (bottom right) between January to June 2023 in Uganda, B) Infestation level area coverage and C) the cropping calendar.

FAW RISK AND SPREAD PREDICTION IN RWANDA

January to March 2023

January to March constitute the harvesting period of maize and sorghum during the season A and the sowing period of maize and sorghum during the season B. FAW occurrence is moderate, particularly in the northwestern (Rubavu and Musanze), Central (Ville de Kigali, Rurango, Gicumbi and Muhanga), southwestern (Nyamagabe, Nyanza and Huye) and eastern (Rwamagana) regions. Low FAW occurrence is expected in northeastern regions (Nyagatare), eastern (Rwamagana, and Ngoma) and western regions (Karongi, Rusizi and parts of Rubavu). Low FAW occurrence is due to the lack or low presence of maize and sorghum plants during this period.

April to June 2023

From April to June 2023, the occurrence of FAW will increase compared to January to March period. Nearly all maize growing areas will have moderate to high occurrence of FAW with Musanze, Gicumbi, Muhanga, Ruhango, Nyanza, Nyamagabe and Huye having potentially high occurrence of FAW.

The acreage of land under high FAW infestation will increase from 46 hectares in January-March to 222 hectares in April-June. Likewise, the acreage of land under medium FAW infestation will increase from 419 hectares in January-March to 558 hectares in April-June. Management interventions should be deployed as early as January to curb the spread and increase in the population of FAW.

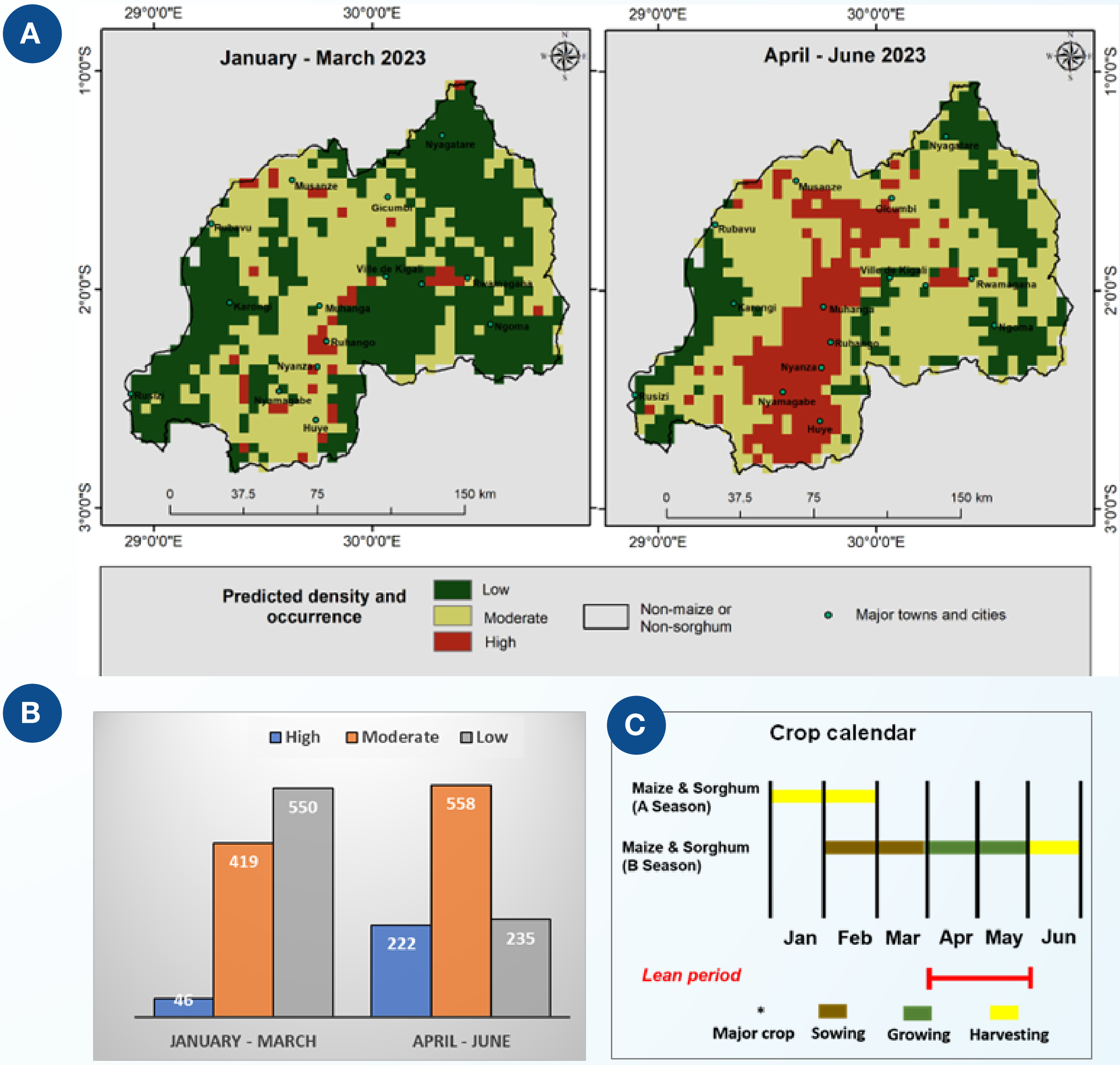


Figure 9. A) Fall armyworm spread prediction map (top), area of land under infestation in km2 (bottom left) and cereal crop calendar (bottom right) between January to June 2023 in Rwanda, B) Infestation level area coverage and C) the cropping calendar.

FAW RISK AND SPREAD PREDICTION IN MALAWI

January to March 2023

January to March period is when cereal crops (maize, sorghum, and rice) are in their early vegetative stages. FAW occurrence will be observed in most cereal growing regions. High to moderate FAW occurrence is expected in the western regions (Mchinji), central regions (Lilongwe), southern regions (Blantyre), and parts of western regions (Liwonde NP) and areas around Limbe, Thyolo, Zomba, Mzimba, and Chikwawa.

April to June 2023

Between April and June, the entire of Malawi will experience a moderate infestation rate and spatial coverage of FAW. High FAW occurrence is expected in Lilongwe, Zomba, Limbe and Blantyre. 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 increase significantly from 39 hectares in January-March to 1,148 hectares in April-June 2023. Likewise, the area of land under moderate FAW infestation is likely to increase from 1,283 hectares in January-March to 2,702 hectares in April-June 2023. The farmers and extension officers should be proactive in managing FAW in the period of January-March before the situation worsens.

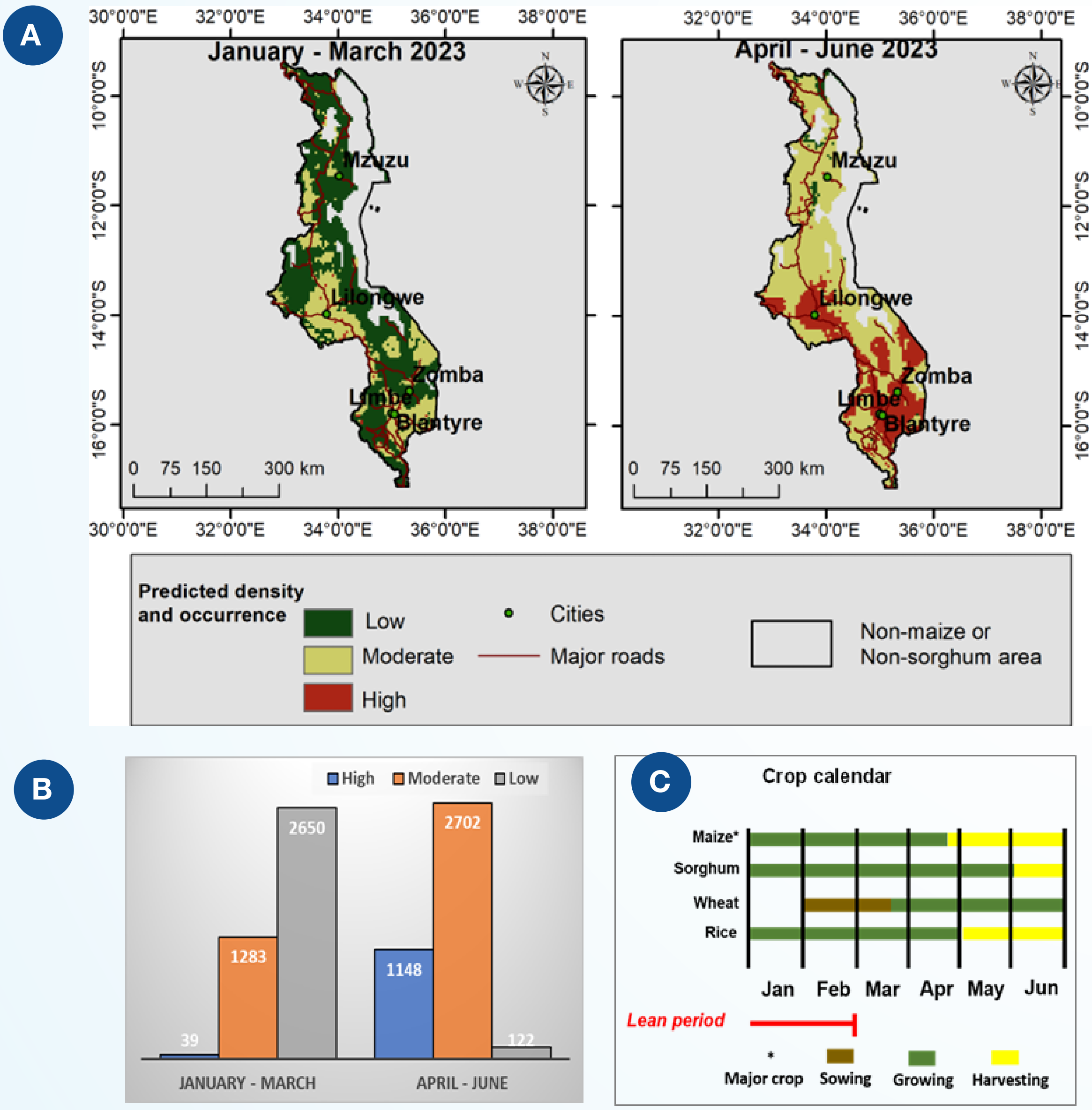
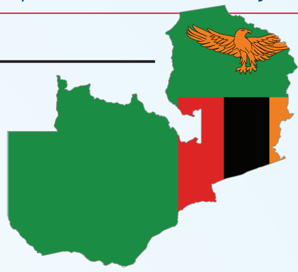


Figure 10.) Fall armyworm spread prediction map (top), area of land under infestation in km2 (bottom left) and cereal crop calendar (bottom right) between January to June 2023 in Malawi, B) Infestation level area coverage and C) the cropping calendar.



FAW RISK AND SPREAD PREDICTION IN ZAMBIA

January to March 2023

Between January and March 2023, FAW occurrence is likely to be low in most cereal growing areas. A moderate FAW occurrence will be observed in some areas such as Mpika, and parts of Lusaka. The January to March 2023 period coincides with the peak maize growing season in southern Africa, similar to Malawi.

April to June 2023

From April to June, Zambia is expected to have moderate to high occurrence of FAW in all cereal growing areas. This period coincides with the late stages of cereals.

There will be few traces of high FAW infestation in 33 hectares of land in April-June 2023. However, the acreage of land under moderate infestation is expected to increase to 26,984 hectares in April-June from 744 hectares in January to March. Therefore, interventions should be put in place to curb FAW populations in January, since this is the period with lowest occurrence of FAW.

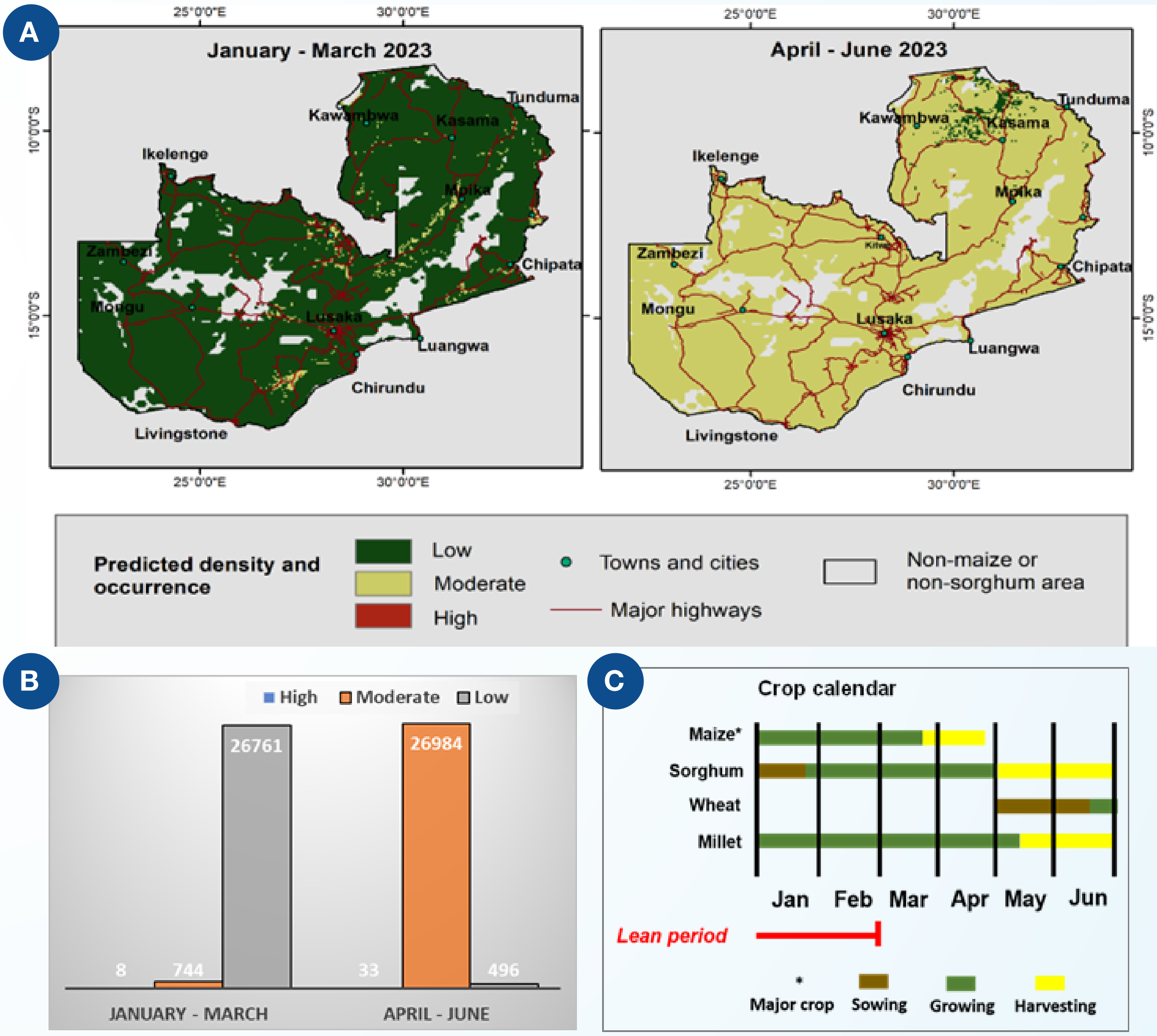


Figure 11. A) Fall armyworm spread prediction map (top), area of land under infestation in km2 (bottom left) and cereal crop calendar (bottom right) between January to June 2023 in Zambia, B) Infestation level area coverage and C) the cropping calendar.

MODELLING 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/) which 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 [6]. The data are provided on a monthly timestep at a spatial resolution of 5 km x 5 km pixel size. The period January 2018 – June 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). 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 in the ‘ranger’ package as implemented in the R environment for statistical computing. 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 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 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/km2), moderate (11-30/km2), and high (>30/km2). These three infestation levels were informed by the quantile classification analysis of the input density data obtained from the FAMEWS

RECOMMENDED PRACTICAL ACTIONS (TECHNOLOGIES) PER COUNTRY

Solution	Recommended actions
GAP and Cultural	• Introduce incentives to promote adoption of GAP among smallholder farmers in Ethiopia, Uganda, and Tanzania. • Promote national programs, support training and extension activities to strengthen the adoption of GAP in Ethiopia, Kenya, and Zambia • Establish national programs to promote the adoption of GAP in Rwanda and Malawi
Push-Pull	• Promote local seed production and support seed certification for the locally produced Desmodium and Brachiaria seeds in all countries • Officially roll out a scaling strategy technology for adoption in in all countries • Integrate into the national extension system in all countries
Agroecological management options (legume intercropping)	• Sensitize policymakers on the effectiveness of intercropping and support the development of policies to facilitate access to seeds in all countries
Biopesticides and Biorationals	• Support certification, commercialization, and distribution of biopesticides in all countries • Promote national biopesticide programmes to promote the uptake and utilization of Biopesticides and biorationals in all countries • Provide subsidy for local manufacture of biopesticides in Kenya and Tanzania • Implement Agri -policies on chemical pest reduction in all countries
Natural enemies	• 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
Indigenous management practices	• Develop a protocol for use of Rabbit urine and fish soup especially in Kenya, Uganda, Tanzania, and Malawi.

ACTIONABLE GUIDES TO POLICYMAKERS IN EACH COUNTRY

	GAP and Cultural Practices	Agroecological management options (legume intercropping)	Push-Pull Technology	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.	Involves intercropping of maize with other legumes, i.e., Beans, Green grams, Mucuna, etc.	Push-Pull involves intercropping of Maize with Desmodium legume and Brachiaria grass.	These are fungal based and plant-derived pesticides.	Beneficial parasitoids and fungus of FAW eggs and larvae. Parasitoids: Trichogramma chilonis, Telenomus remus, & Cotesia icipe) Entomopathogenic fungus (EPF): Metarizium & Buveria
Application Rate	To be applied continuously Recommended in most low infestation regions (Green)	Applied every season Need to facilitate introduction in Ethiopia	Applied once	Applied every season Mass release recommended in highly infested regions	3-4 releases per season
Cost	A routine does not come with a cost	38 USD/acre	120 USD/acre or 30USD if seeds are locally produced	20- 40 USD/liter	Rearing/Production costs
Where to get the service/ Technology	Own practice	Seeds: East African Seed Co. Ltd, Simlaw Seed Company Training: Ministries of agriculture and National Research Institutions such as DARS, TLC in Malawi, RAB, FH, SAC in Rwanda, ZARI, KATC, SAC in Zambia, MoA in Kenya EIAR, MoA, ATI in Ethiopia	Seeds: East African Seed Co. Ltd, Simlaw Seed Company, Mukushi Seed Company Training: NGOs (ICIPE), Ministries of agriculture and National Research Institutions such as DARS, TLC in Malawi, RAB, FH, SAC in Rwanda, ZARI, KATC, SAC in Zambia, MoA in Kenya, EIAR, MoA, ATI in Ethiopia	Source: RealIPM Ltd, Kenya Biologics Ltd,Dudutech, Ethio Agri-CEFT. Training: Ministries of agriculture and National Research Institutions such as DARS, TLC in Malawi, RAB, FH, SAC in Rwanda, ZARI, KATC, SAC in Zambia, MoA-Kenya, TARI in Tanzania, EIAR, MoA, ATI –in Ethiopia	Training: Ministries of agriculture and National Research Institutions such as DARS, TLC in Malawi, RAB, FH, SAC in Rwanda, ZARI, KATC, SAC in Zambia, MoA- Kenya, EIAR, MoA, ATI in Ethiopia, TARI in Tanzania,

ITEMIZED ACTIONS BY THE STAKEHOLDERS

	GAP and Cultural Practices	Agroecological management options (legume intercropping)	Push-Pull Technology	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 research on the best edible legumes for intercropping and the most varieties considering agroecological context and cultural practices.	• Conduct trials on suitable areas to produce Desmodium and Brachiaria seeds in Tanzania, the West parts of Ethiopia and the 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	• Validate the proven biopesticides for commercialization and release. • Conduct efficacy trials to facilitate local registration	• Conduct validation trials. • Facilitate mass rearing of Parasitoids. • Facilitate mass production of EPF • Provide training and protocols on mass rearing/production of parasitoids and EPF to interested farmers
Private Sector	• Facilitate timely access to farm inputs.	• Facilitate access and availability of seeds at affordable prices.	• 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 seeds 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	• 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/production of parasitoids/EPF

	GAP and Cultural Practices	Agroecological management options (legume intercropping)	Push-Pull Technology	Biopesticides and Biorationals	Natural enemies
Extension officers / NGOs	• Strengthen farmer training to understand and apply GAP. • Promote GAP alongside other FAW IPM techniques.	• Promote legume intercropping in areas where it is uncommon. • Establish demonstration sites showing various maize -edible legume intercropping options.	• Create awareness and Introduce Push-Pull in areas where it is not practiced. • Strengthen farmer training for correct application through demos.	• Support field validation. • Strengthen farmer training and conduct demonstrations on correct application. • Conduct field days to demonstrate the results and benefits of the technology.	• Create awareness on the use and benefits of natural enemies. • Identify sites and promote field release of parasitoids and EPF.
General Public / Media	• Create massive awareness of the multiple benefits of applying GAP in increasing productivity, food safety and FAW management.	• Create awareness among farmers and the public on the benefits of intercropping with edible legumes on FAW management and the additional benefits in household food security.	• Create extensive scale awareness about the technology and its benefits in addressing multiple production constraints. • Sensitize the policymakers on the benefits and the need to support the adoption of the technology.	• Create awareness of the availability of biopesticides and biorationals and its benefits. • Link farmers to service providers. • Create awareness of 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.	• Sensitize farmers on the effectiveness of • intercropping with edible legumes on FAW management and the additional benefits in household food security.	• 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. • Conduct technology evaluation with farmers in Malawi to solicit farmers' perceptions on the demonstrated technologies	• 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.

OTHER INSTITUTIONS WORKING ON FAW CONTROL AND MONITORING

A. NON-GOVERNMENTAL ORGANIZATION PLAYERS

The United Nations Food and Agriculture Organization (FAO)

Food and Agriculture Organization of the United Nations

The United Nations Food and Agriculture Organization (FAO) (https://www.fao.org/fall-armyworm/en/) launched the pioneering Global Action for Fall Armyworm Control as an urgent response to the rapid spread of FAW. The three-year global initiative takes radical, direct, and coordinated measures to strengthen prevention and sustainable pest control capacities at a global level. It complements and boosts ongoing FAO activities on FAW. Global Action has established a global coordination mechanism for an open and collaborative dialogue toward science-based solutions. It has also supported the establishment of National Task Forces on FAW, and the mobilization of resources for applied research geared towards practical and efficient solutions.

Centre for Agriculture and Bioscience International (CABI)

CABI

CABI (www.cabi.org) has been taking action against FAW through two key programs: Action on invasive pests, using the Plantwise program, and other projects on responding to emerging threats. Their work includes international and national response planning, biological control research and development, mass extension, and diagnostic services through:

1. Outreach - Communication campaigns on FAW using SMS platforms, printed materials, video messages, and radio programs to support national extension services and global small-holder farmers.
2. Research - CABI and associated national partners have tested the effectiveness of biopesticides, botanicals, and traditional methods for controlling FAW in African countries.
3. Invasive species compendium - they provide a dedicated portal of the latest news, research, practical extension materials, videos, and other resources related to invasive pests.

International maize and wheat improvement center (CIMMYT)

CIMMYT
International Maize and Wheat Improvement Center

CIMMYT (www.cimmyt.org/) develops and distributes improved maize varieties to partners and farmers worldwide. CIMMYT develops easy-to-produce, best-bet hybrids, elite maize lines, and improved open-pollinated varieties, as well as science-based recommendations for varietal targeting and improved productivity in target regions including pest-resistant maize varieties.

International Institute of Tropical Agriculture (IITA)

IITA
Transforming African Agriculture

IITA (www.iita.org) works on both biotic and abiotic factors which affect maize production including pests and diseases such as the FAW, downy mildew, rust, leaf blight, stalk, ear rots, leaf spot, maize lethal necrosis (MLN), maize streak virus (MSV and the parasitic Striga weed. Striga is also a major problem, particularly in sub–Saharan Africa (SSA) with the potential of reducing yield by up to 60–92%. IITA also focuses on resistant maize varieties and soil health parameters.

B. NATIONAL RESEARCH INSTITUTION PLAYERS

- Ethiopian Institute of Agricultural Research (EIAR)
- Kenya Agricultural and Livestock Research Organization (KALRO)
- Tanzania Agricultural Research Institute (TARI)
- National Agricultural Research Organization (NARO)
- Rwanda Agriculture Board (RAB)
- Department Of Agricultural Research (DARS) - Malawi
- Zambia Agriculture Research Institute (ZARI)

C. PRIVATE SECTOR PLAYERS

Real IPM Real IPM (https://realipm.com/) was founded in 2003 and globally provides and supplies high-quality predatory mites and biopesticides. Their products are based on living organisms which are either microorganism occurring naturally in the soil or predatory mites found in the wild. They have global rights to several isolates of Metarhizium under license from icipe and use these isolates together with our own to provide large- and small-scale farmers with comprehensive crop protection solutions. ICIPE 7 and ICIPE 78 have been commercialized and are readily available on the market.		**Russell IPM** Russell IPM (https://russellipm.com/) develops integrated pest management (IPM) technologies and supplies pheromones, traps, and pest management materials across the globe. Their full product range works to protect all stages of the food system supply chain using systems that help to reduce the use of chemical pesticides to maintain a safe, secure, sustainable, and eco-friendly way of protecting food and other products from pest damage. One of the key products for FAW control is the pheromone traps, lures, and biopesticides.
Kenya Biologics Kenya Biologics Ltd. (www.kenyabiologics.com/) provides farmers with affordable and efficacious environmentally friendly pesticides as pests are getting more resistant to chemicals. They provide green, safe, and cost-effective farm inputs that help to grow and protect the farmer’s crops and environs responsibly. This ultimately supports sustainable food production and improves the safety of food and drinking water in Africa. Their key product of FAW control is pheromone traps, lures, and biopesticides.		

SEED PRODUCER AND SUPPLIERS' COMPANIES

SEED PRODUCER/SUPPLIER COMPANY	COUNTRY	CONTACT NUMBER	EMAIL
East African Seed Co. Ltd	Kenya / East Africa	+254722207747	info@easeed.com
Simlaw Seed Company	Kenya / East Africa	+254722200545	customercare@simlaw.co.ke
Advantage Crops Ltd	Kenya	+254715519922	advantagecrops@gmail.com
Barenbrug	South Africa	+27(0)21 979 1303	info@barenbrugsa.co.za
Barenbrug/ Heritage Seeds	Australia	+61(0)397014000	export@barenbrug.com.au
Mukushi Seed Company	Zimbabwe	+ 263 7828 080 080	info@mukushiseeds.com
Alexis Business Limited	Rwanda	+250 788 807 839	alexisbusinessltd@gmail.com
Bayer Malawi Ltd	Malawi	+265 (0) 999 510 463	deniseuclidm.kachiko@bayer.com
Institut des Sciences Agronomiques du Burundi (ISABU)	Burundi	+25722227349	info@isabu.bi
Tropical Seeds LLC	Miami USA	+1 954 7536301	www.tropseeds.com

REFERENCES

[1] P. Abrahams, T. Beale, M. Cock, N. Corniani, R. Day, and J. Godwin, "Fall armyworm status: Impacts and control options in Africa: Preliminary evidence note," no. April, p. 18 pp, 2017.

[2] R. N. Nagoshi et al., "Genetic studies of fall armyworm indicate a new introduction into Africa and identify limits to its migratory behavior," Sci. Rep., vol. 12, no. 1, pp. 1–12, 2023, doi: 10.1038/s41598-022-05781-z.

[3] P. B. Timilsena et al., "Potential distribution of fall armyworm in Africa and beyond, considering climate change and irrigation patterns," Sci. Rep., vol. 12, no. 1, pp. 1–15, 2023, doi: 10.1038/s41598-021-04369-3.

[4] R. A. Guimapi et al., Harnessing data science to improve integrated management of invasive pest species across Africa_ An application to Fall armyworm (*Spodoptera frugiperda*) (J.E. Smith) (Insecta_ Lepidoptera_ Noctuidae). Elsevier, 2023.

[5] S. De Alwis, Z. Hou, Y. Zhang, M. H. Na, B. Ofoghi, and A. Sajjanhar, "A survey on smart farming data, applications and techniques," Comput. Ind., vol. 138, p. 103624, 2023, doi: 10.1016/j.compind.2023.103624.

[6] D. N. Karger, D. Schmatz, G. Dettling, and N. E. Zimmermann, "High resolution monthly precipitation and temperature timeseries for the period 2006-2100." EnviDat, 2019, doi: http://dx.doi.org/10.16904/envidat.124.

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