Issue #4

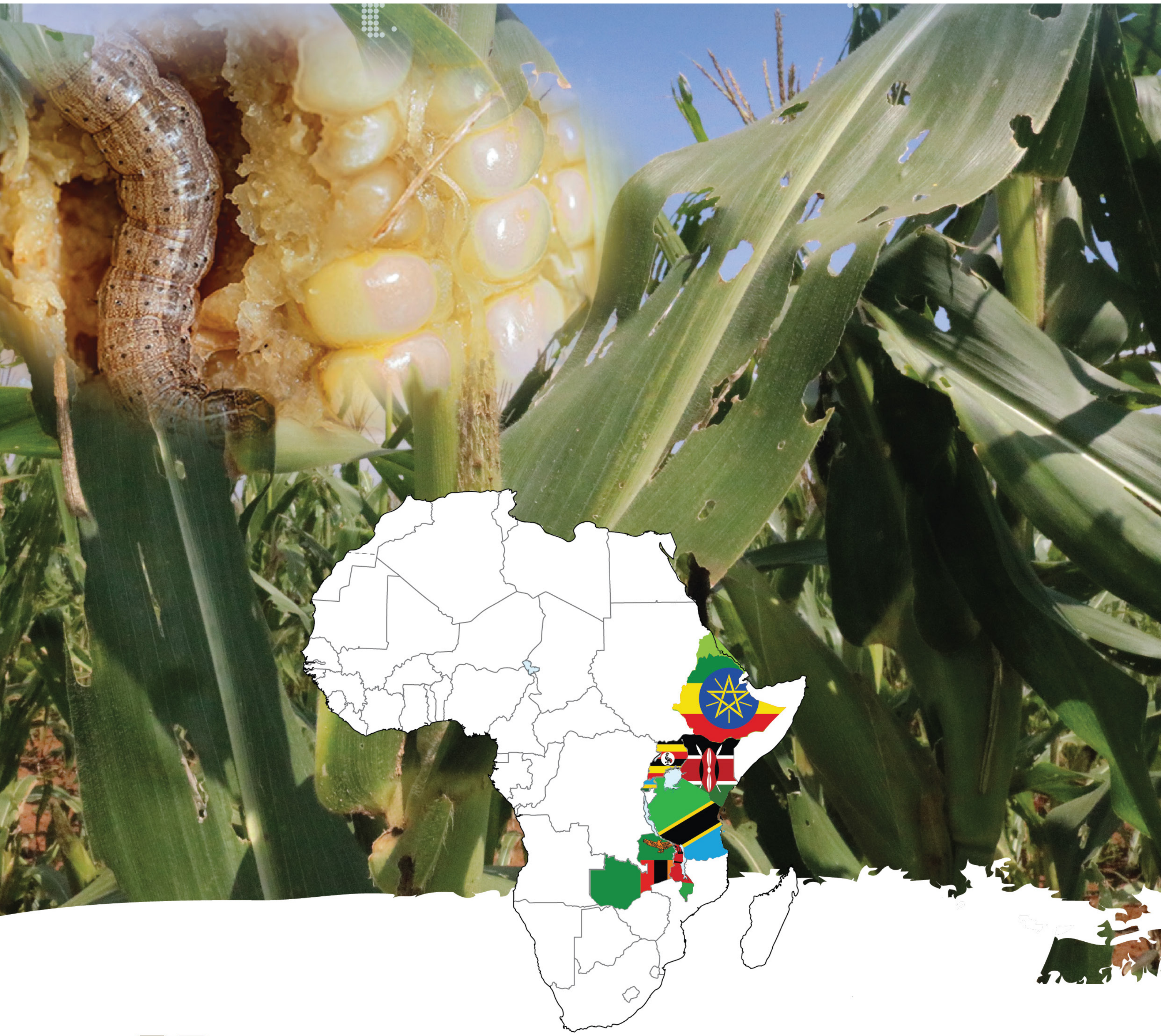
FALL ARMYWORM Monitoring

Structure of the Countries Profile

July - December 2022 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 July to December 2022. This profile is the 4th 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 portray the monthly (summed to quarterly) preinvasion and near-real-time predicted density of FAW and the areas at risk of attack at the country level. Each of these profiles further proposes country-specific actionable solutions, mitigations, 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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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

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

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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
IFPRI	International Food Policy 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)

BACKGROUND

Fall armyworm (FAW), *Spodoptera frugiperda*, is a moth native to tropical and subtropical regions of the Americas that has increasingly spread around the world over the last few years [1]including maize, rice, sorghum and sugarcane but also vegetable crops and cotton. It has a voracious appetite, and can reproduce and spread quickly given the right environmental conditions. Its larval stages are very destructive and are causing significant damage and yield losses globally. Nagoshi et al. [2] inferred from a genomic analysis that the strain of FAW prevalent in Africa prefers maize but can also feed on more than 350 other crops, including wheat, sorghum, millet, sugarcane, vegetable crops, and cotton. 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 as evidenced by its appearance in West Africa at the beginning of 2016 and reaching most African countries in 2017. It has also spread further to Near East and Asian countries, including Sudan, Egypt, Yemen, China, India, and Japan with FAW named as the top priority for key pest control in China for 2022. FAW has also been reported in Australia, Mauritania, Timor Leste, and the southern parts of Europe and North Africa could be next.

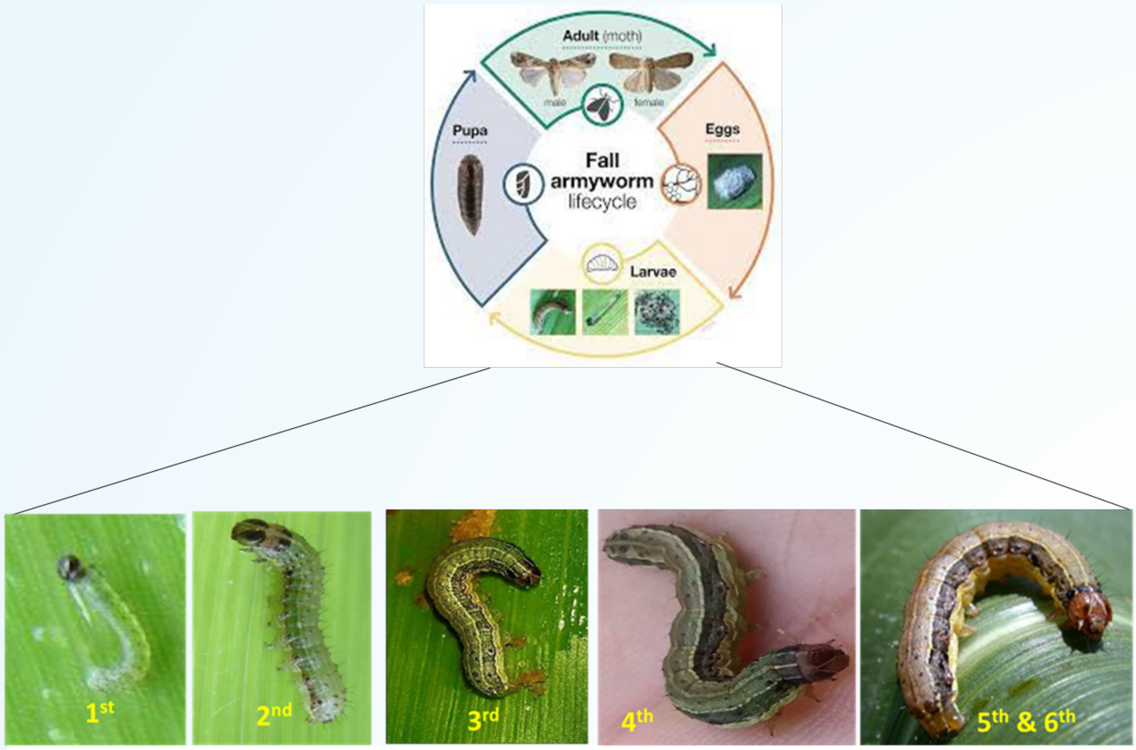
Based on 2018 estimates from 12 African countries, up to 17.7 million tons of maize are lost annually due to FAW on the continent – enough to feed tens of millions of people. The most direct impact of these losses affects mainly smallholder maize farmers, the majority of whom rely on the crop to reduce hunger and poverty. For instance, Zambia has reported that approximately 129,517 households and 96,222 hectares of maize have been intensively affected by FAW since 2016. As a control strategy, 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. Recent studies have shown the advancement in the identification of natural enemies of FAW in Africa which include *Cotesia icipe* among others. Guimapi et al. [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 allowing 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 armworm and different stages of the FAW larval instars

To help identify symptoms of fall armyworm, examine plants for: Leaf damage, including pinholes, windowing, and defoliation (Figure 2A, 2B, 2C).

- 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 2D, 2E, 2F, 2G)
- In some cases, FAW larvae cut the seedlings from the base of the stem like cutworm damage (Figure 2H)
- Bigger larvae graze on leaves, stems, tassel, silk, and seed, leave sawdust-like frass (droppings) in the whorlFAW Larvae hide themselves in plant whorls, particularly in maize and sorghum.
- 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)*

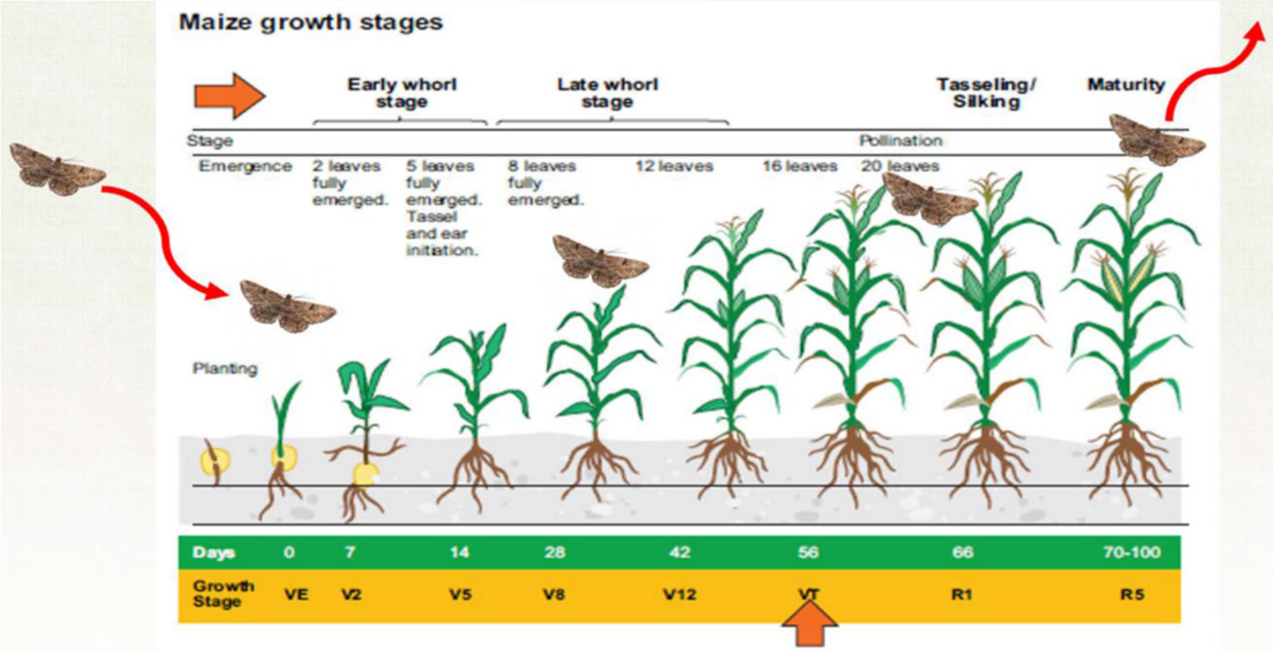


Figure. 3. Different FAW generation at different maize growth stages

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, Malawi, Rwanda, Tanzania, Uganda, and Zambia for the period July to December 2022 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 July to December 2022 have been characterized by a low, moderate, and high infestation. Generally, high to moderate infestation is likely to be detected in July. Moderate to high infestation is expected in September, particularly in southern Africa (Zambia and Malawi). A decrease in an infestation is expected in east Africa in the fourth quarter of the year between October and December 2022. The July to December period coincides with the harvesting and sowing of the main cropping period for the rainfed maize in southern Africa. However, most of the east African countries located to the North of the equator, i.e., Kenya, Uganda, and Ethiopia, will experience relatively low to moderate infestation within the third and fourth quarter of the year. The regional profile maps (Figure 4) demonstrated 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 staggered cropping calendar of the FAW host plant over the year, the control mechanism implemented on the farm and the availability of natural enemies.

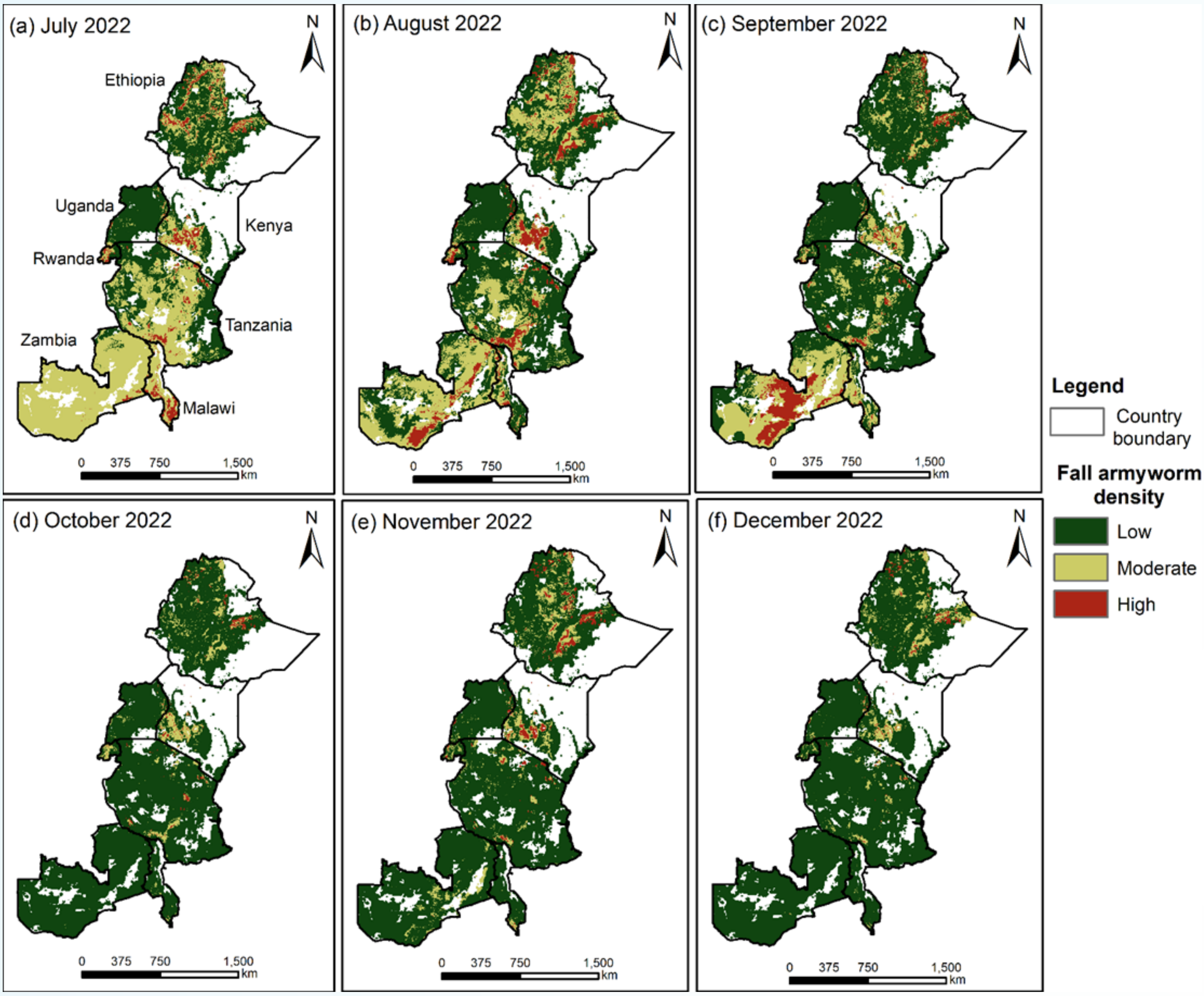


Figure. 4: Monthly probability of occurrence and predicted density of the fall armyworm (FAW) in Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda, and Zambia for the period July to December 2022. The maps were produced using the random forest model and data from the representative concentration pathway (RCP4.5) data provided by Envidat (https://www.envidat.ch/#/metadata/chelsa_cmip5_ts).

FAW RISK AND SPREAD PREDICTION IN ETHIOPIA

July to September 2022

Between July to September, most cereal crops are at the vegetative and flower initiation stage, and between October to December, these crops are harvested in Ethiopia. It is predicted that FAW occurrence will be high in Mekele, Desse, Dire Dewa, Harer, Hawasa, and Gondar areas. Most central and western parts of the country. Few eastern parts where maize and sorghum are cultivated will experience a moderate infestation of FAW. These areas include Bahir Dar, Welkite, zones bordering Addis Ababa, Jimma, and Jijiga. The high infestation predicts an average of FAW moths > 30/km^2 while the mild infestation approximates between 11 – 30/km^2 FAW moths in a maize field which is significant enough to cause yield losses between 20 – 80% while <10/km^2 is low.

October to December 2022

Between October to December, most of the areas shall experience low infestation compared to the period of July to September due to the reduction on the host availability. FAW infestation shall be high in Desse, Hawasa, and Dire Dawa, and moderate in most areas bordering Addis Ababa, Bahir Dar, Mekele, Jimma, Gondar, and Jijiga. However, most of the cereal growing areas will experience low infestations. In general, the farmland area under FAW infestation is expected to reduce during harvesting periods October to December (Figure 5).

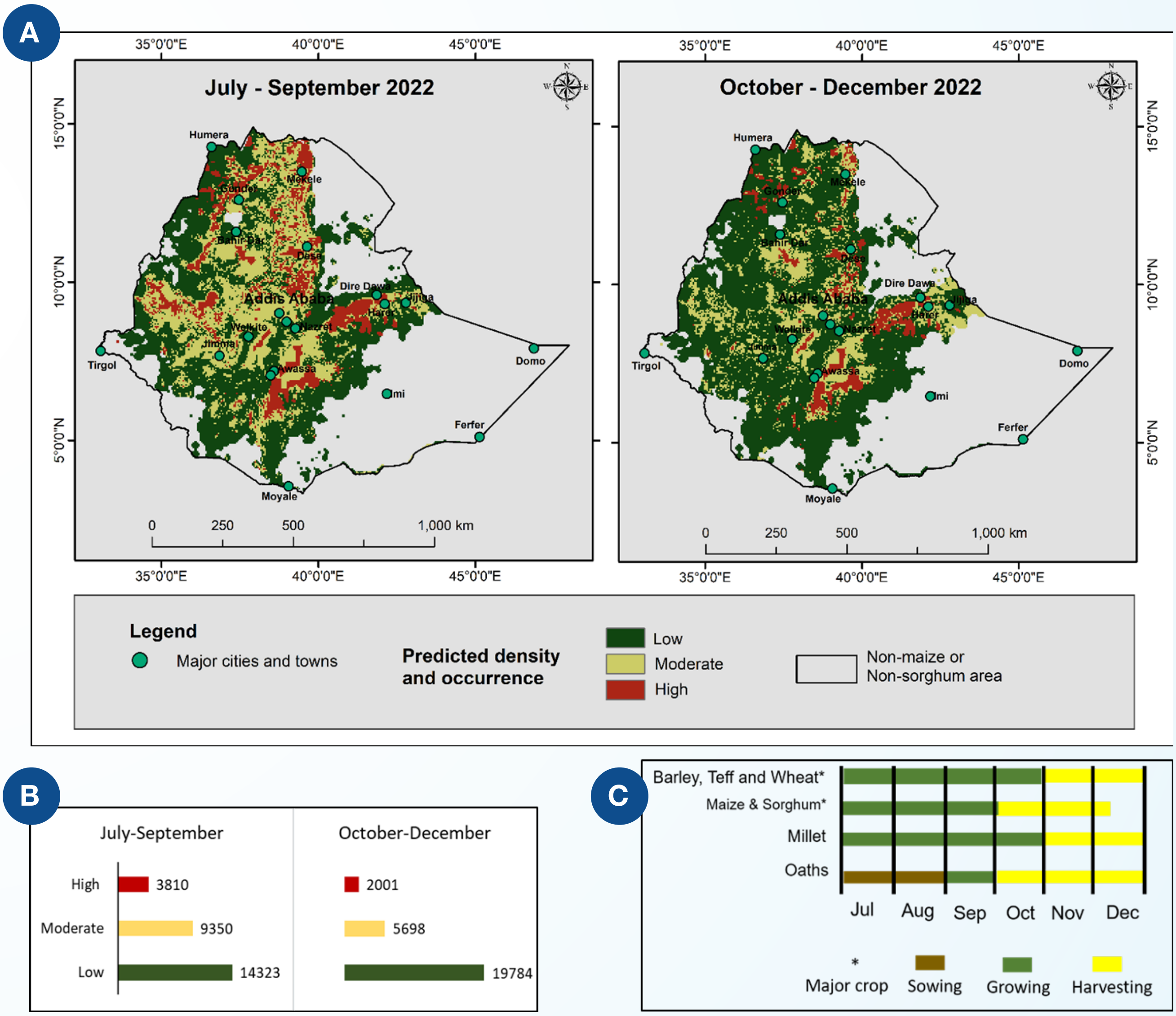


Figure 5. A) Fall armyworm spread prediction map (top), area of land under infestation in km^2 (bottom left) and cereal crop calendar (bottom right) between July to December 2022 in Ethiopia, B) Infestation level area coverage and C) the cropping calendar.

FAW RISK AND SPREAD PREDICTION IN KENYA

July to September 2022

Between July to September, the maize and wheat will be at their vegetative stage, FAW occurrence is expected to be high in Nakuru, Naivasha, areas bordering Nairobi, and western parts of Kenya, especially in areas bordering, the eastern areas of Kisumu, and Migori, while being moderate in Usenge, Kisumu, Namanga, Lodwar and Taveta. However, low FAW occurrence shall be expected in Coastal regions (Mombasa, Kilifi, and Lamu), Garissa, and Lodwar (Figure 6).

October to December 2022

Between October to December, most cereal crops have been harvested and farms are farrowed for the next growing season. However, parts of areas around Nakuru and Naivasha will likely experience moderate to high infestation, while FAW infestation will potentially be low in most cereal-growing areas.

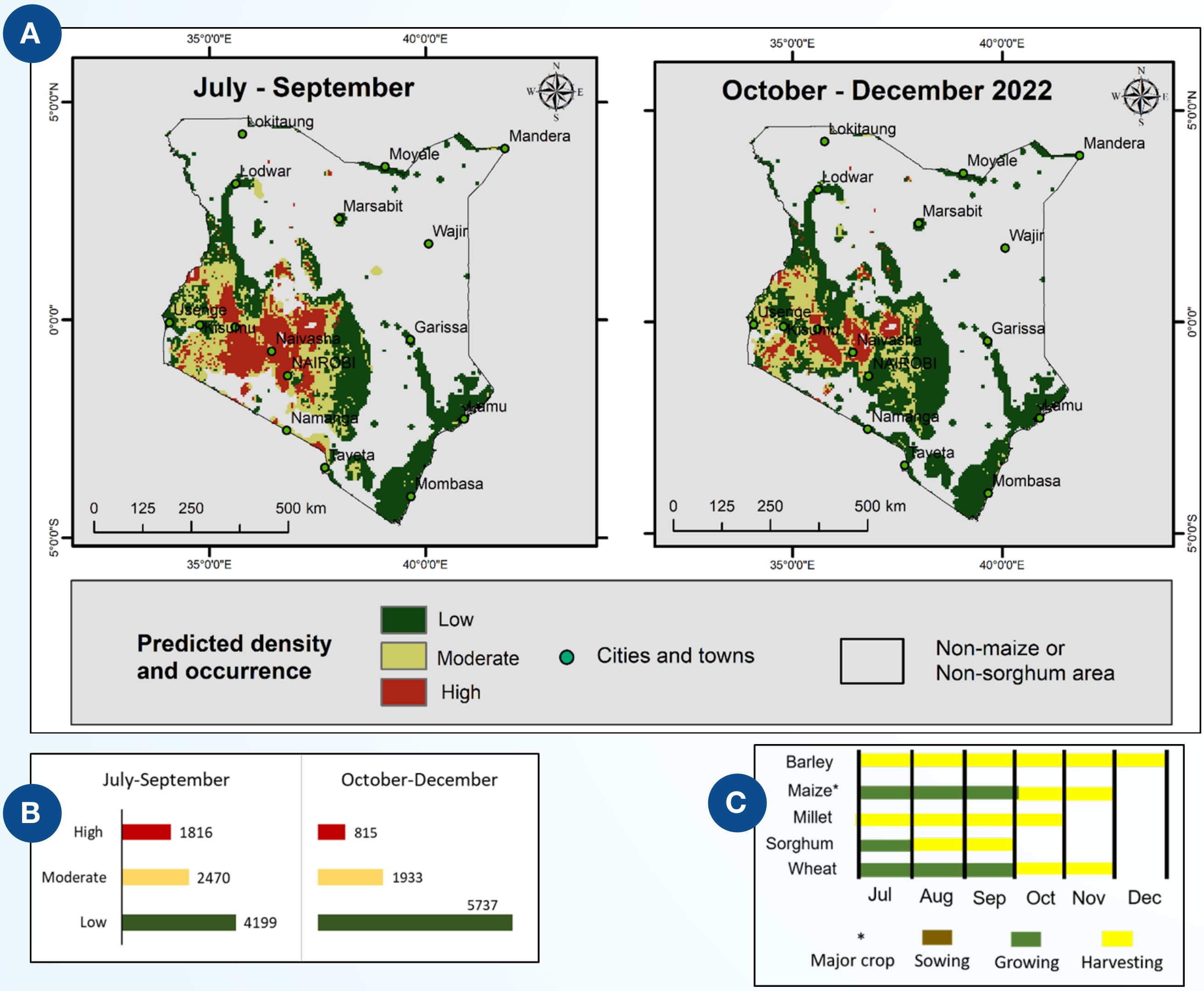
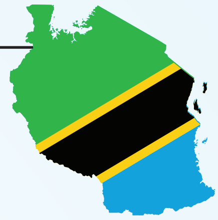


Figure 6. A) Fall armyworm spread prediction map, B) Infestation level area coverage in km^2 and C) the cropping calendar between July to December 2022 in Kenya.



FAW RISK AND SPREAD PREDICTION IN TANZANIA

July to September 2022

The period between July to September constitutes a period of harvesting of cereals and the furrowing of lands in Tanzania. Prediction map of FAW occurrence between July to September indicates a potentially high infestation in areas around Mdandu, Marangu, and Kisiwani, while infestation will likely be moderate in most parts of the country especially Mhango, Langido, Ilunga, Mwimbi, Segere, Mgende, Manda and Kwekivu. This is likely because of the availability of the maize host plants or moderate because of the growth stage of host (Figure 7)

October to December 2022

Between October to December 2022, most cereal growing areas will experience a low infestation. There will be low incidences of moderate to high infestations. 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/km^2 while the moderate infestation approximates between 11 – 30/km^2 FAW moths in a maize field which are both significant enough to cause yield losses between 20 – 80%.

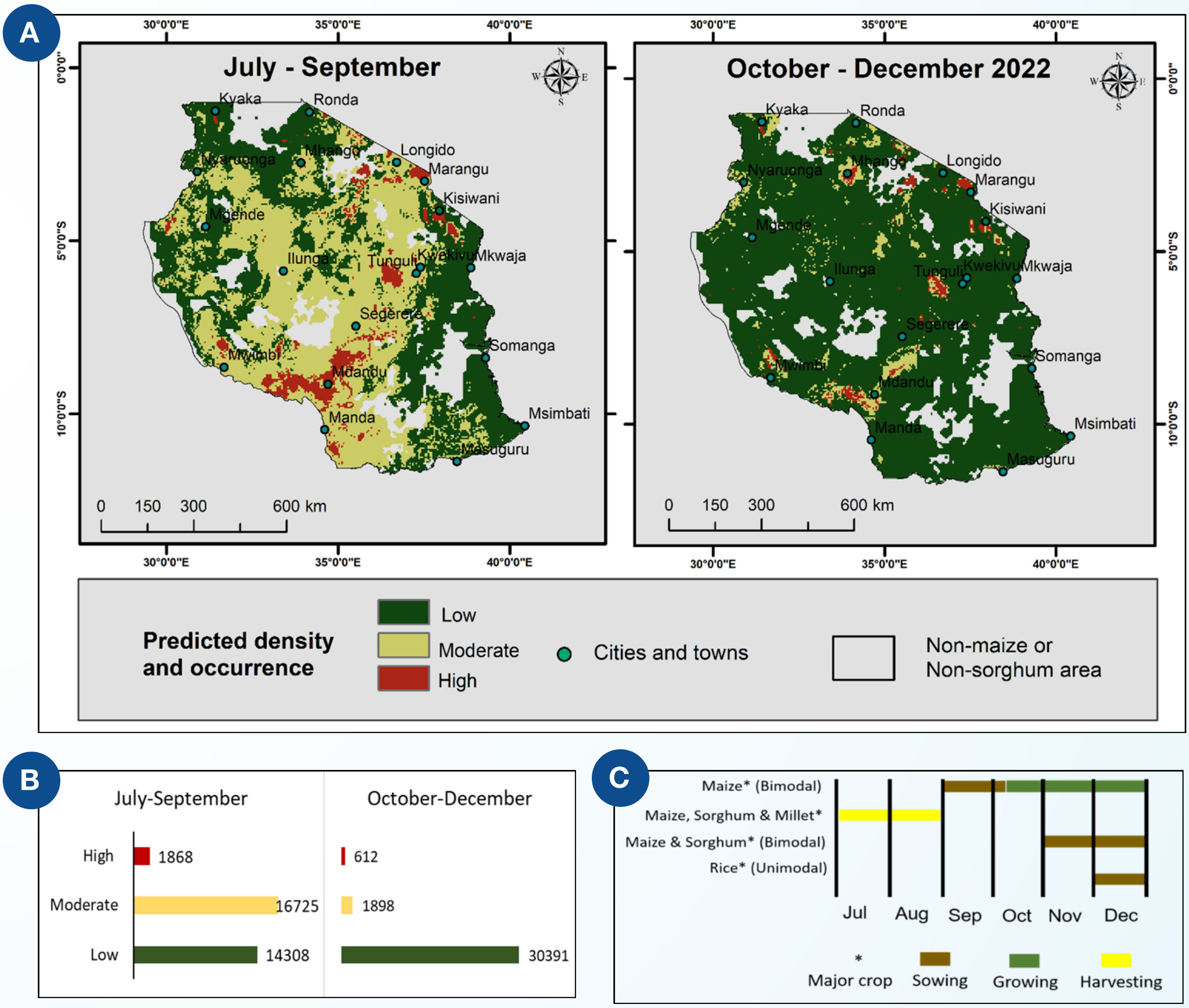
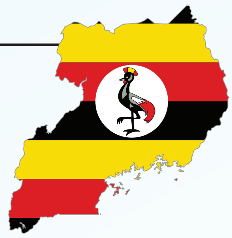


Figure 7. A) Fall armyworm spread prediction map, B) Infestation level area coverage in km^2 and C) the cropping calendar between July to December 2022 in Republic of Tanzania.



FAW RISK AND SPREAD PREDICTION IN UGANDA

July to September 2022

July to September in Uganda coincides with the harvesting season of maize and millet. FAW infestation is anticipated to be low 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). This low infestation is likely because of the unavailability of the maize host plants or moderate because of the growth stage of the host.

October to December 2022

During this period, most areas will continue to experience a low infestation. 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 a slight change in the acreage of lands under infestation of FAW during periods of July to September compared to the October to December 2022 period (Figure 8).

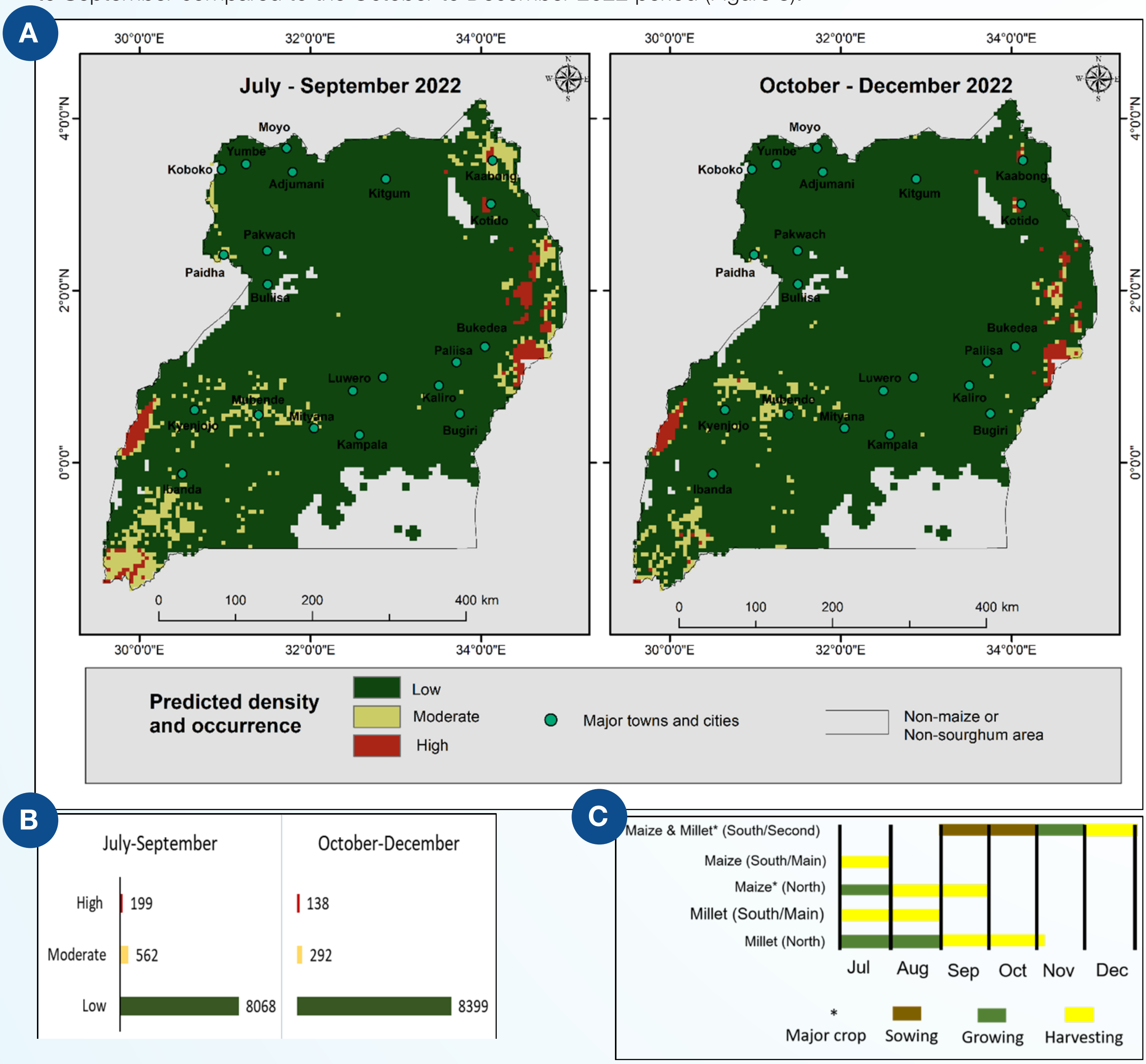


Figure 8. A) Fall armyworm spread prediction map (top), B) Infestation level area coverage in km^2 and C) the cropping calendar between July to December 2022 in Uganda.

FAW RISK AND SPREAD PREDICTION IN RWANDA

July to September 2022

July to September constitute the harvesting period and furrowing season of maize and sorghum in Rwanda. FAW infestation is expected to be high, particularly in the northwestern (Rubavu and Musanze), Central (Gicumbi and Muhanga), southwestern (Nyamagabe, Nyanza, and Huye), and eastern (Rwamagana) regions. FAW infestation is low in Rubavu. Moderate infestation is anticipated in Karongi and Rwamagana while most parts of cereal growing regions of Rwanda shall experience low infestations. This is likely because of the availability of the maize host plants or moderate because of the growth stage of host (Figure 9).

October to December 2022

From October to December, high infestations are expected in most parts of northwestern (Rubavu and Musanze), and southwestern (Nyamagabe). Low to moderate infestation is in most parts of sorghum and maize growing regions. Low infestation is due to the lack or low presence of maize and sorghum plants during this period. There will be a reduction in the acreage of land under high infestation by FAW in the period from October to December.

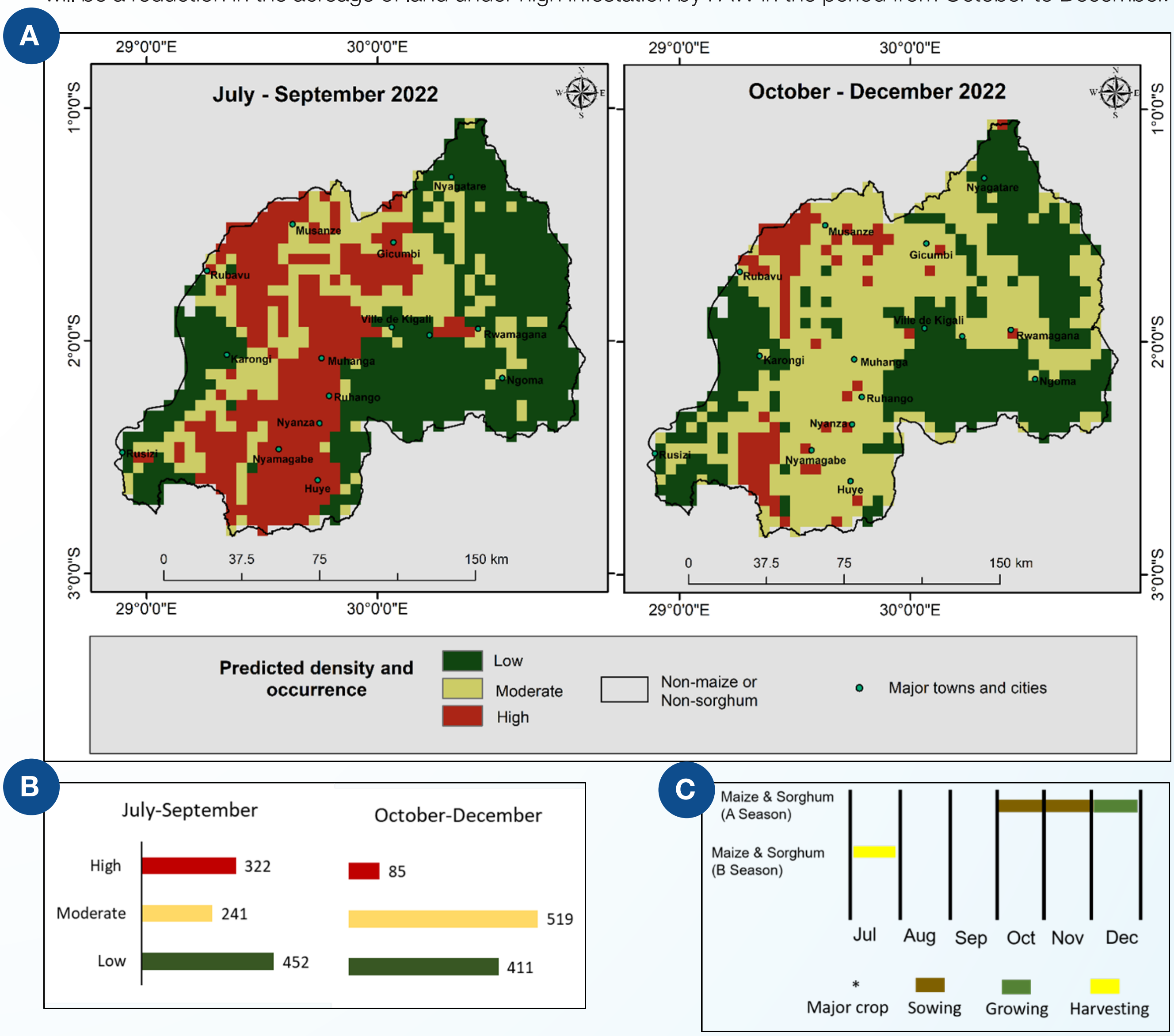


Figure 9. A) Fall armyworm spread prediction map, B) Infestation level area coverage in km² and C) the cropping calendar between July to December 2022 in Rwanda.

FAW RISK AND SPREAD PREDICTION IN MALAWI

July to September 2022

The prediction map of Malawi between July to September indicates a potential 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. This is likely because of the availability of the maize host plants or moderate because of the growth stage of host (Figure 10).

October to December 2022

Between October to December, this period coincides with the sowing seasons for cereals. The entire country of Malawi will experience a low infestation rate and spatial coverage of FAW. The area of land under high and moderate FAW infestation is expected to be reduced significantly, while the area of land under low FAW infestation is likely to increase from October to December 2022.

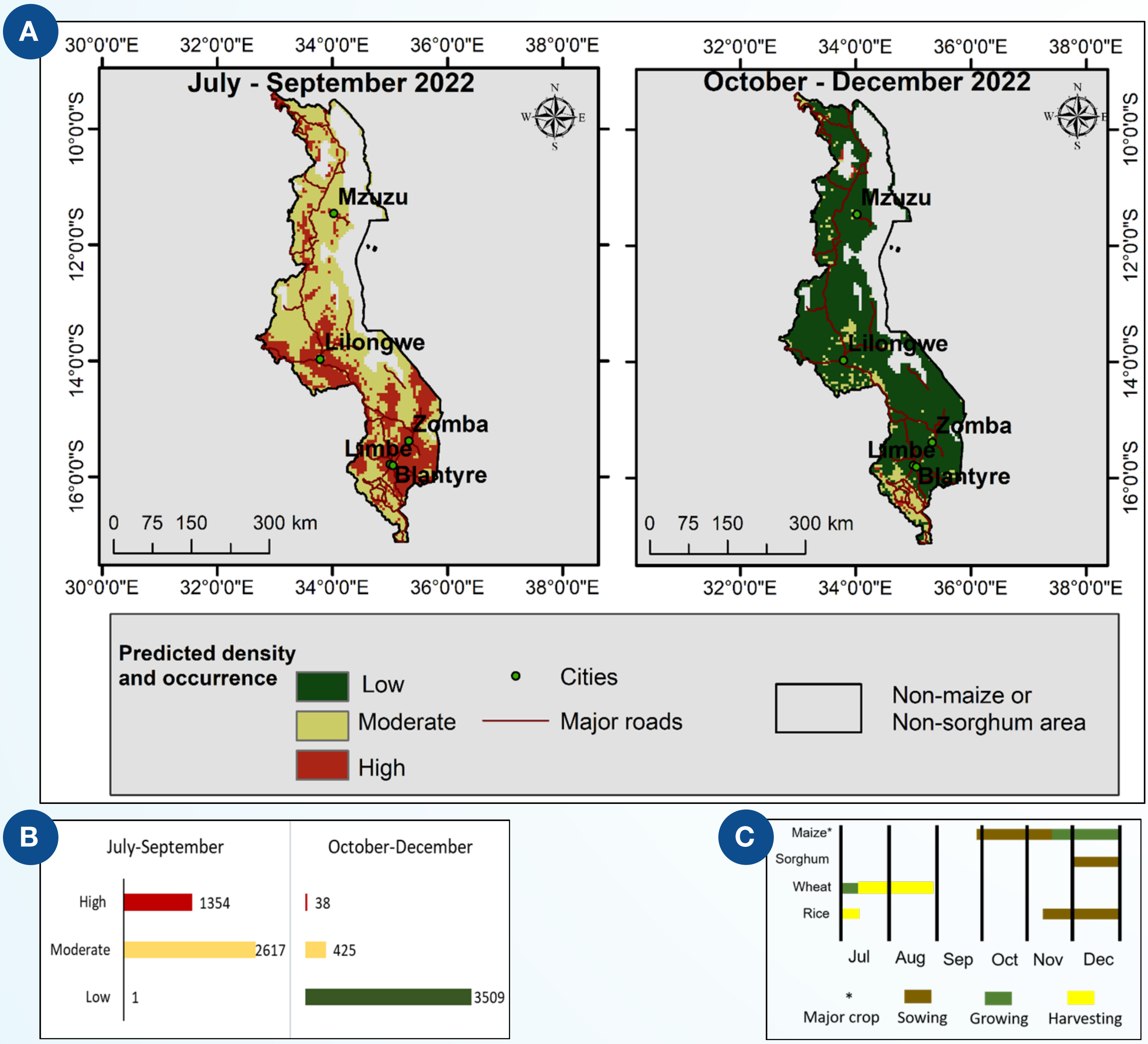
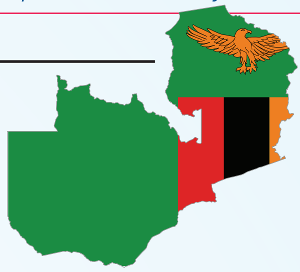


Figure 10. A) Fall armyworm spread prediction map, B) Infestation level area coverage in km^2 and C) the cropping calendar between July to December 2022 in Malawi.



FAW RISK AND SPREAD PREDICTION IN ZAMBIA

July to September 2022

Between July to September 2022, this period coincides with the active vegetative stage of wheat. FAW infestation is likely to be high around Lusaka, Chirundu, and Chipata. Most other cereal growing areas are expected to experience moderate FAW infestation because of the unavailability of host crops and likely unfavorable climatic conditions for the FAW (Figure 11).

October to December 2022

The period from October to December coincides with the sowing season for cereals. The prediction map indicates that at this period, there will be low FAW infestation in Zambia. The area of land under high and moderate FAW infestation is expected to reduce significantly, while the area of land under low FAW infestation is likely to increase from October to December 2022.

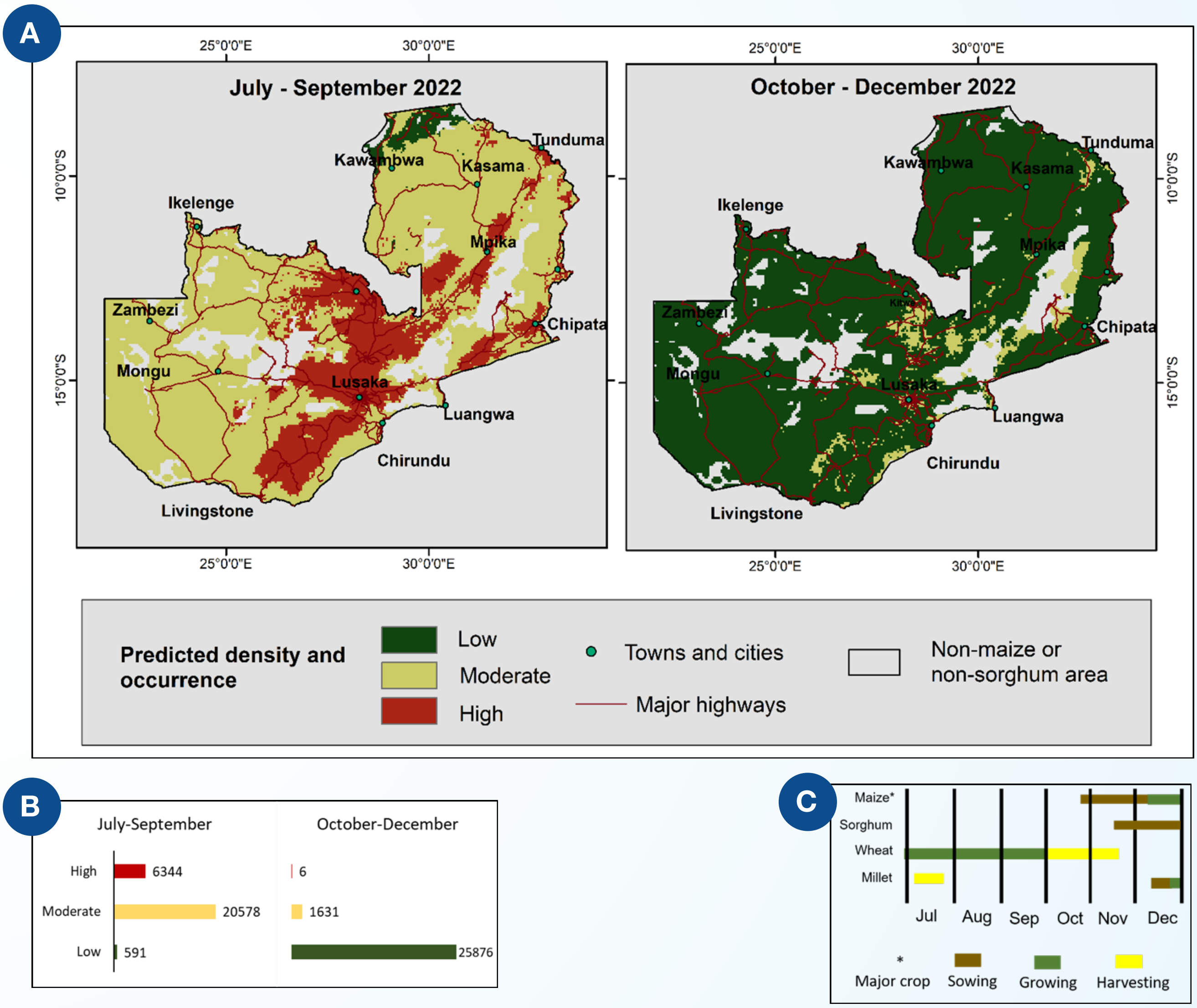


Figure 11. A) Fall armyworm spread prediction map, B) Infestation level area coverage in km² and C) the cropping calendar between July to December 2022 in Zambia.

MODELLING METHODOLOGY

Data

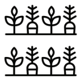
The reference FAW locational and density data were obtained from the Food and Agriculture Organization (FAO). These data are continuously collected using the FAW Monitoring and Early Warning System (FAMEWS: http://www.fao.org/fall-armyworm/monitoring-tools/famews-mobile-app/en/) which is facilitated 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 – 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). 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 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 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/km^2), moderate (11-30/km^2), and high (>30/km^2). These three infestation levels were informed by the quantile classification analysis of the input density data obtained from the FAMEWS.

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 smallholder farmers. 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

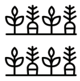
					
Rwanda	Support certification and accreditation for established GAP in the country. Establish National programs to promote the adoption of GAP	Integrate Push-Pull into the National Extension system. Officially roll out a scaling strategy technology for adoption	Sensitize policymakers on the effectiveness 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 Bor 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 & fungus of FAW eggs and larvae: *Trichogramma chilonis*, *Telenomus remus*, *Cotesia icipe*) *Entomopathogenic fungus* (EPF): Metarhizium & Beauveria
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/Production 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, EIAR, MOA, ATA – Ethiopia	Seeds: Training: Ministry, DARS, TLC in Malawi RAB, FH, SAC- Rwanda. ZARI, KATC, SAC- Zambia, MOA- Kenya, EIAR, MOA, ATA – Ethiopia	Training: Ministry, DARS, TLC in Malawi RAB, FH, SAC-Rwanda ZARI, KATC, SAC- Zambia, MOA- Kenya, EIAR, MOA, ATA – Ethiopia	Training: Ministry, DARS, TLC in Malawi RAB, FH, SAC- Rwanda ZARI, KATC, SAC- Zambia, MOA- Kenya, EIAR, 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 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	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. 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.	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	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/production of parasitoids/ EPF

					
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 practiced. 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 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 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 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 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.	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 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.

OTHER INSTITUTIONS WORKING ON FAW CONTROL AND MONITORING

The United Nations Food and Agriculture Organization (FAO)

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 (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 (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 (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.

PRIVATE SECTOR PLAYERS WORKING ON FAW CONTROL AND MONITORING

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.


Push-pull plot


Cotesia icipe

Biopesticide containing spores of *M. anisopliae.*

Natural enemies

FAW populations are naturally regulated by other beneficial insects such as predators and parasitoids in a process referred to as biological control. *icipe* and partners have identified indigenous natural enemies such as *Cotesia icipe* that target larval stages and *Telenomus remus* and *Trichogramma chilonis* that parasitizes eggs killing up to 45%. These natural enemies can be mass-produced and released in the environment.

Biopesticides

icipe and partners have identified two *Metarhizium anisopliae*-based biopesticides,

Icipe 7 and *Icipe* 78 which cause disease and significant mortality to FAW eggs or larvae. In the field, these products are equally effective as synthetic pesticide. These products are commercialized in partnership with private sector partners and registered with regulatory authorities in East Africa.

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		
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	
Institut de l'Environnement et de Recherches Agricoles (INERA)	Burkina Faso		

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