Fall armyworm monitoring and modelling for effective management in smallholder context

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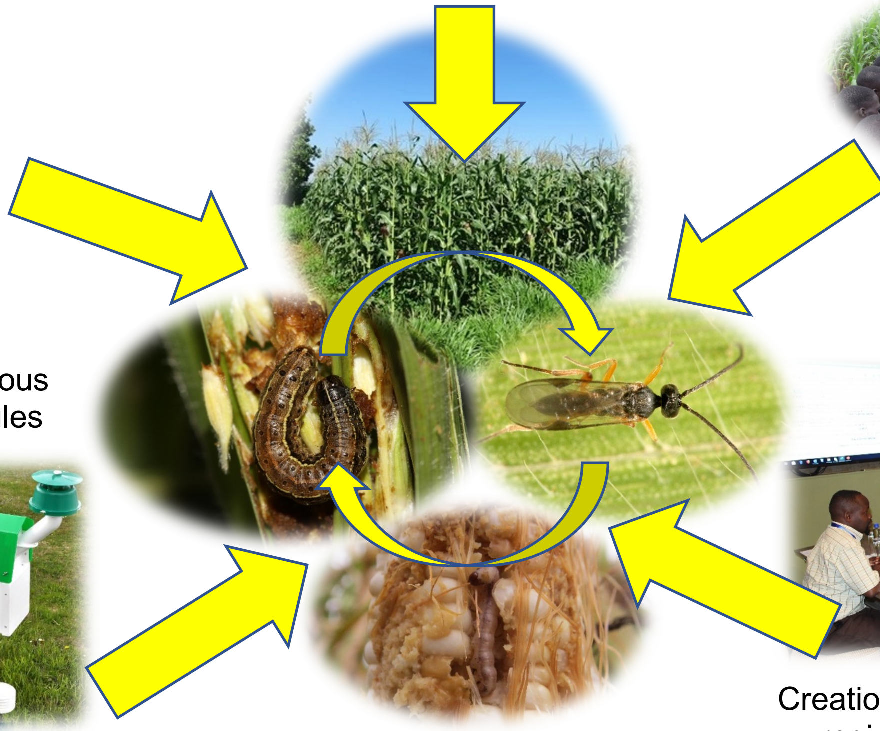
Fall armyworm (FAW) *Spodoptera frugiperda*

- *Fall armyworm invaded Africa in 2016 ravaging cereal crops across more than 40 African countries causing an annual loss of $6.25 b.*
- *A difficult pest to control in cereal fields, causing serious leaf feeding damage as well as direct injury to the tussle and cob.*

System-level integration and way forward

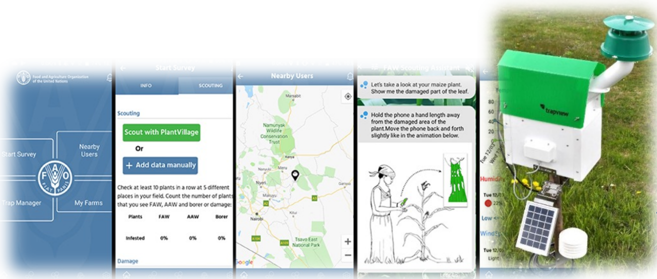
Safe biopesticides/judicious use of less toxic molecules

Resistant cultivars/hybrids



Building capacity and PPP partnerships for biological control

Creation of enabling policies at regional/continental level



Robust surveillance and monitoring mechanism

Monitoring

Community–based Fall Armyworm Monitoring, Forecasting, Early Warning and Management System (CBFAMFEW) in Eastern Africa

Objectives:

- To contribute towards "**increasing the resilience of livelihoods to threats and crises**" through strengthening community-based Fall Armyworm **monitoring** and **reporting** system,
- To enhance capacity building of the National Fall Armyworm Task Forces and Management Programmes,
- To ensure there is a **functional early warning systems** for Fall Armyworm Management as well as **improve information sharing and management** in the target countries.
- To **promote awareness** among the Fall Armyworm prone communities on **effective reporting** of Fall Armyworm through **continuous situation monitoring and data gathering**.






Target countries

- The project was implemented in 6 East African countries, targeting five maize growing districts in each country.

FAW Surveillance, Monitoring and scouting

Importance of surveillance and monitoring

- Monitoring, surveillance, and scouting are critical for the successful implementation of an effective IPM program;
- Prediction and assessment of the level and severity of an infestation allow timely mitigation of the problem using the fewest and safest interventions;
- Due to the short diapause and the number of host plants, surveillance of FAW is year-round;
- During the dry season, irrigated areas constitute reservoirs of FAW populations from which migration occur at the beginning of the rainy season.
- Monitoring and controlling the populations on off-season crops could be critical in reducing infestation on rain-fed crops

Importance of surveillance and monitoring

- **Surveillance** is the informal, passive detection of pests in an area mainly done at the farm level. Therefore, farmers in the field should be involved
- **Monitoring** means active tracking of the presence, population, and movement of a pest within a specified area or region. It is generally conducted by trained technical personnel who collect data to inform policymakers on the presence and severity of the pest across a given area

FAW Scouting

- **Scouting is the use of** science-based protocols by trained individuals (extension) to observe their own fields for the pest;
- Allows the farmer to assess pest pressure (intensity of FAW infestation) and crop performance in the field;
- To be able to monitor, farmers require knowledge on how to detect FAW, understand its lifecycle, the damage it causes on different stages of maize, and the threshold to apply insecticide.
- Scouting may be aided by the use of pheromone traps set up in the farmers' fields before planting throughout the growing season to trap male moths and catches recorded weekly

FAW scouting

Scouting is typically performed in order to evaluate both the economic risk of pest infestation and the potential efficacy of pest control interventions

What to look for when scouting

- The aim of scouting is early detection of the egg batches or young larvae which are easier to control
- Scouting should begin when the plants are small (VE–V3; Early Whorl) but since FAW completes its life cycle in 30–40 days and the first generation of FAW larvae generally attacks the seedlings, fields should be rechecked weekly at the seedling and Early Whorl stages.

FAW scouting

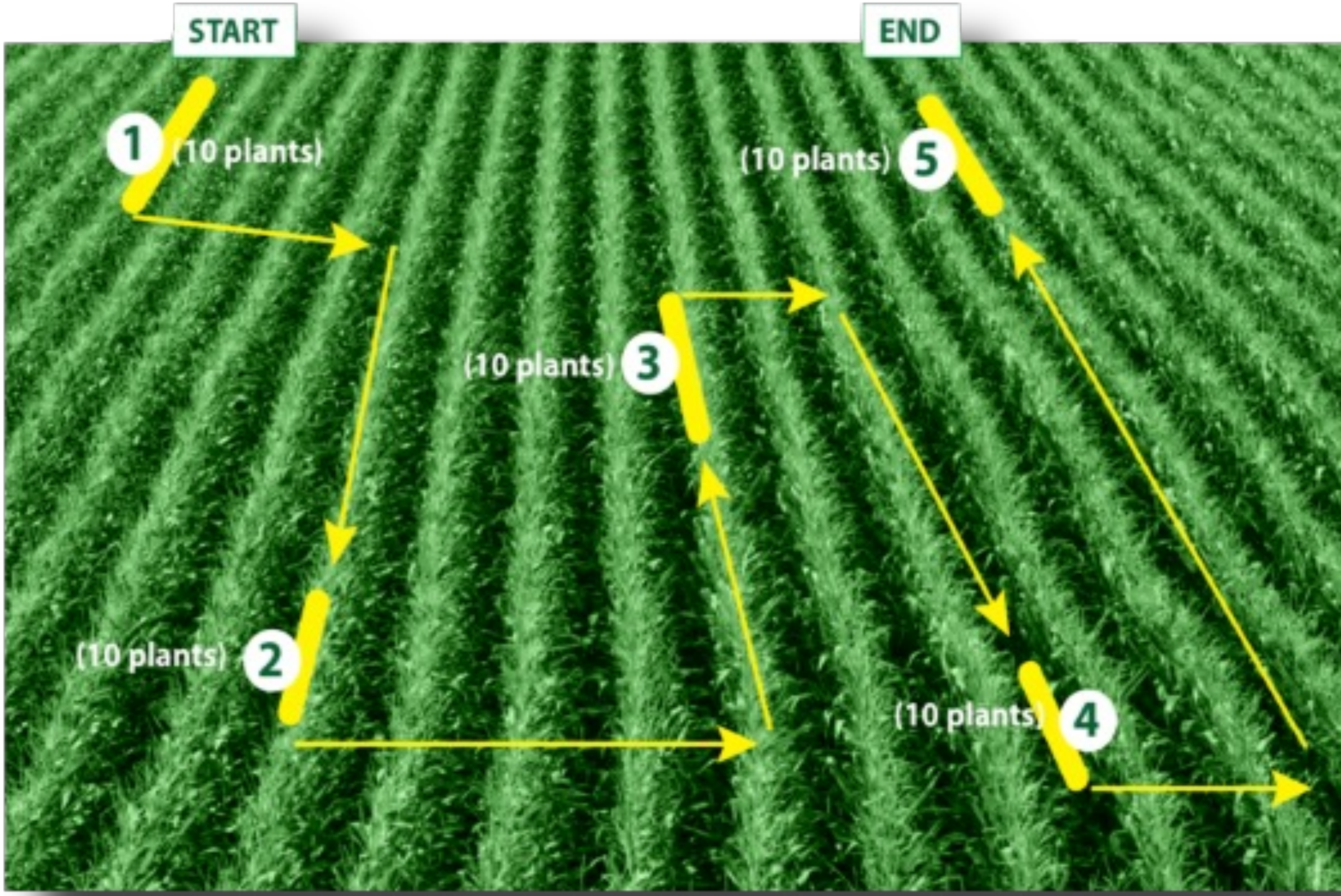
- Farmer scouts should look for *s*igns of FAW egg masses (presence or absence of egg masses even in the absence of damage), egg hatching and feeding by early-instar larvae such as leaf damage

- Pin holes “window-panes”, frass, ragged and torn leaves, destruction of leaves in funnels, silk, tassel, and ear damage, holes in the ear and pupae in the soil

How to do scouting

- In the field, as shown in the figure below, walk in a letter ‘W’ pattern, covering the entire area

Scouting techniques and protocols



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Scouting techniques and protocols

- Randomly select 5 plots each comprising 20 consecutive plants in a row, and examine each selected plant within the plot for leaf-feeding damage symptoms and the presence of larvae and/or egg masses;
- Focus on the newest two to three (2–3) leaves emerging from the whorl as this is where the FAW likes to feed and where FAW moths lay eggs.
- For the late whorl stage examine the newest three to four (3-4) leaves emerging from the whorl plus the emerging tassel;
- Record the number of plants (out of 20) with fresh window panes or infested whorls;
- At later stages, FAW larvae hide in the leaf axils, at the base of the developing ear/cob, and/or in the tip of the ear and silks

Scouting techniques and protocols

- Determine % infestation for each of the five plots and then calculate the mean plot infestation;
- Separately determine the number of egg masses and larvae per plant (or plot) and the respective means. (Zeroes should be written down against un-infested plants; omitting un-infested plants will overstate pest densities);
- Search for eggs usually on the underside of leaves of grasses and cereal crops.
- It is advisable to search for eggs immediately after trap catch;
- The egg mass is usually in layers or a batch of 100-200 in number covered by white hairs

Scouting techniques and protocols

- Heavy rain showers can kill the 1st, 2nd, and 3rd instar larvae and even though the damage is present in the field, many larvae may have died;
- Scouts should record any rainfall on the scouting form;
- Search for pre-pupae/pupae should be made by digging -5cm into the soil;

- **SAFETY**: always first determine whether the field has been treated with insecticide and if so, when and with what active ingredient and rate;
- Scouts should check pesticide labels for re-entry Intervals and avoid getting exposed to hazardous levels of pesticide by not scouting in a field that is not safe for re-entry after a recent pesticide application.

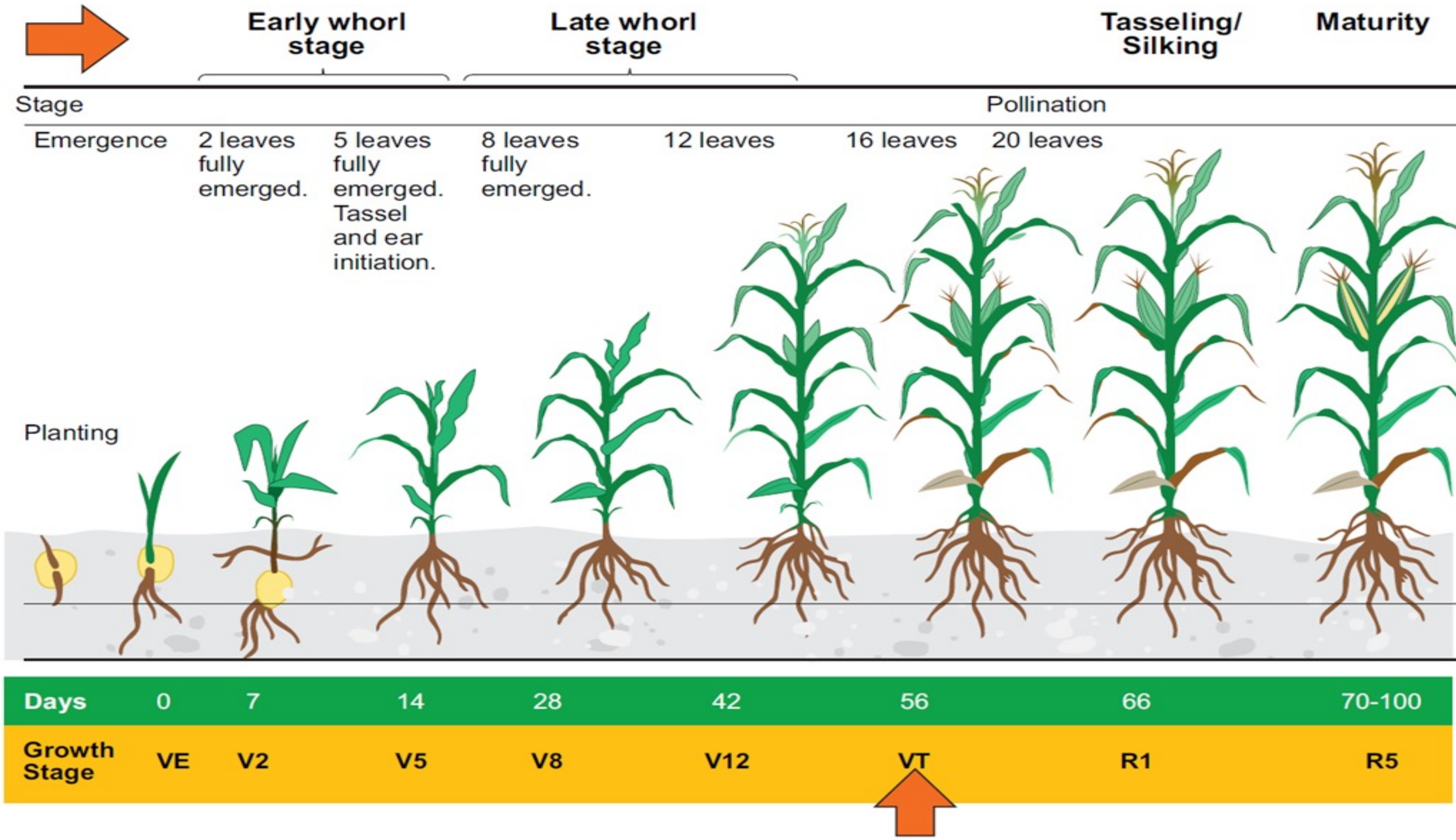
Assessing Infestation levels

- Each selected plant will need to be examined carefully for the presence of egg masses and other pest stages;
- The % of plants in a field showing typical damage symptoms as well as the presence/ absence of eggs and larvae is calculated using the formula below;

% FAW infestation=(no. of infested plants/total number of plants) ×100

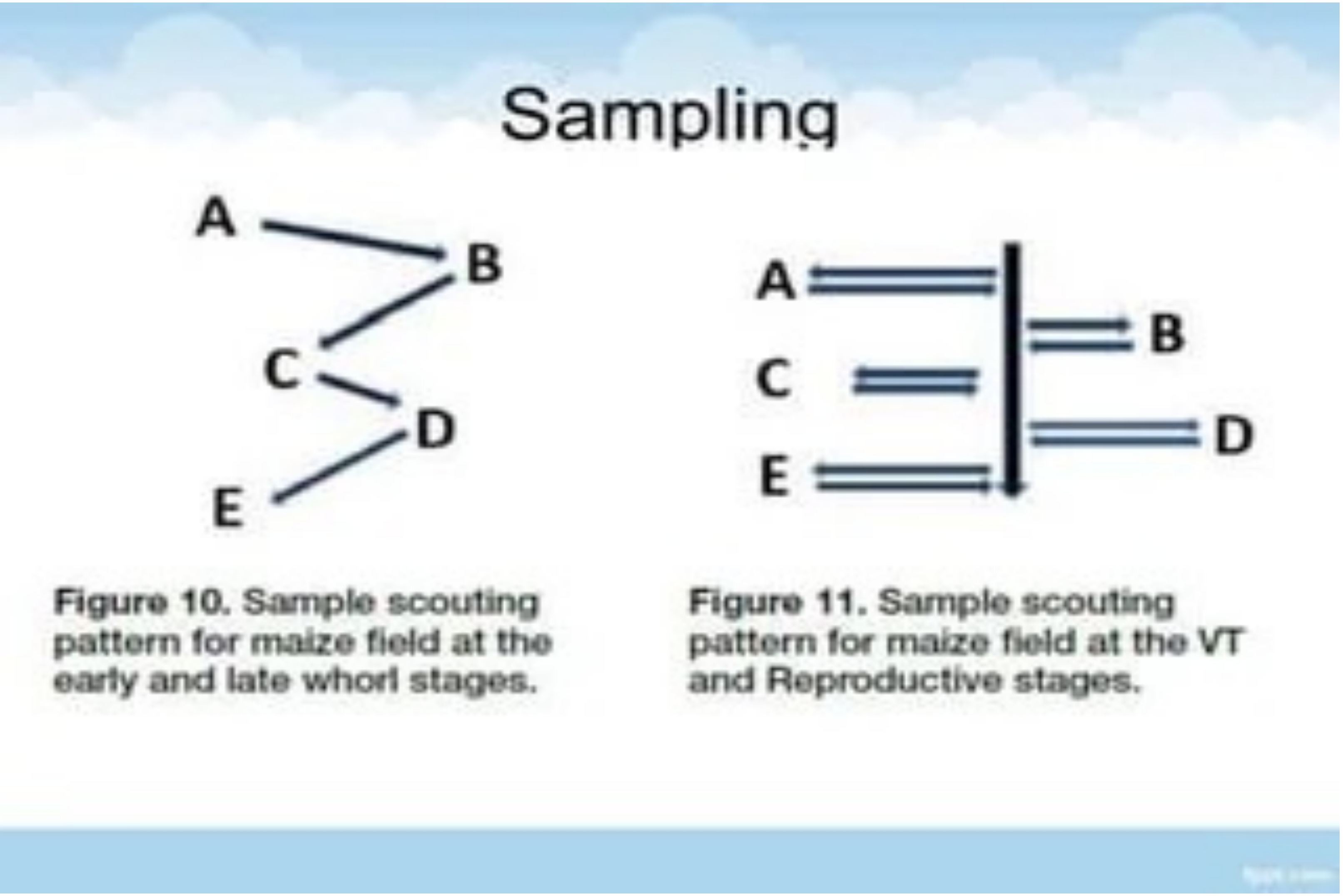
- The absence of plant damage symptoms DOES NOT imply that FAW infestation will be zero as only the egg stage may be present on the plant selected;
- Data on the assessment of other pest species e.g stem borers should be collected as well.

Maize growth stages and Action thresholds



Maize growth stages (Modified from Clarrie Beckingham, 2007 Early whorl stage (VE–V6) 20% (10–30%). ≥5% plants have egg masses, ≥20 . plants show damage (window panes and pinholes), larvae present. Continue monitoring, and consider further treatment if more young larvae appear . Late whorl stage (V7–VT) 40% (30–50%). Tassel & Silk Stage (R1–R3 (No spraying)

Maize growth stages and Action thresholds

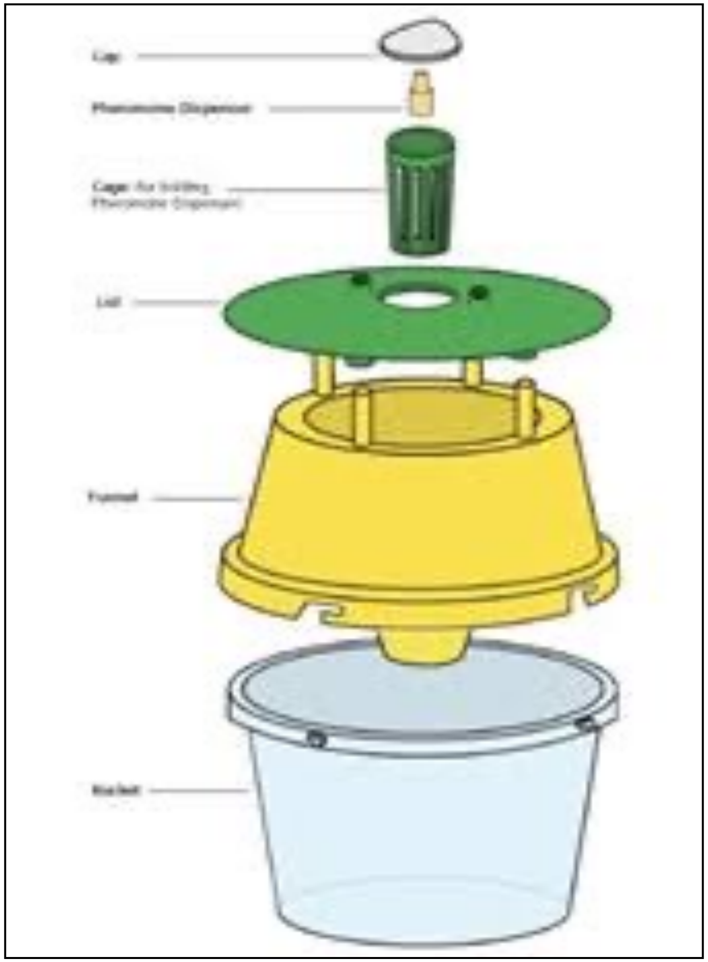


Monitoring with pheromone traps

- The pheromone attracts (usually) male insects. Because pheromones can travel by air over very long distances, their use is very useful for monitoring FAW presence;
- However, some pheromone lures also attract a limited number of non-target moths;
- The Universal Bucket Trap is normally used. However, the trap currently widely used in Africa for FAW monitoring is the Delta trap with a sticky pad, on which the pheromone dispenser is placed;
- Adult moths will get attracted to the pheromone and get stuck on the sticky pad when they enter the trap;
- The data from the traps is recorded on the FAO early warning FAMEWS platform. However, moth counts can remain low (less than one month per trap per day) even during an outbreak.
- There may be no moths in the trap even though a significant percentage of plants are infested with FAW; Moth counts indicate the presence of FAW in the area but do not indicate the level of egg-laying intensity.

Monitoring with pheromone traps

- One can detect the presence and build-up of FAW in a particular area by using pheromone traps, and if need be, increase scouting.
- Pheromones are natural compounds that are emitted by female FAW moths to attract male moths for mating.
- Synthetic compounds that mimic natural FAW pheromones (lures) are placed in traps to attract and trap male moths, which are caught in the round bucket and killed by the insecticide placed at the bottom.
- Funnel or bucket is the preferred type of trap for FAW.
- Moths that are caught are then counted.



Data recording templates and submission

Day	Date	Number of Moths	No. of larvae	No. of damaged plants
Monday				
Tuesday				
Wednesday				
Thursday				
Friday				
Saturday				
Sunday				
Total				

Other Data to be Collected

- Maize Variety
- Date of Planting
- Crop intercropped with Maize
- Date of onset of rains
- Other crops attached by Fall armyworm
- Other weeds attacked by Fall armyworm

Data collection Apps

- Usually, farmers recognize the presence of FAW in their fields after the larvae have reached the fourth instar when it is too late to undertake control operations
- An early warning system could enable farmers to monitor their fields on time and detect larvae when they are still young before they hide in the funnels
- The FAMEWS (Fall Armyworm Monitoring & Early Warning System) mobile app has been developed by FAO to be used on a low-cost smartphone for data collection and sharing within Africa

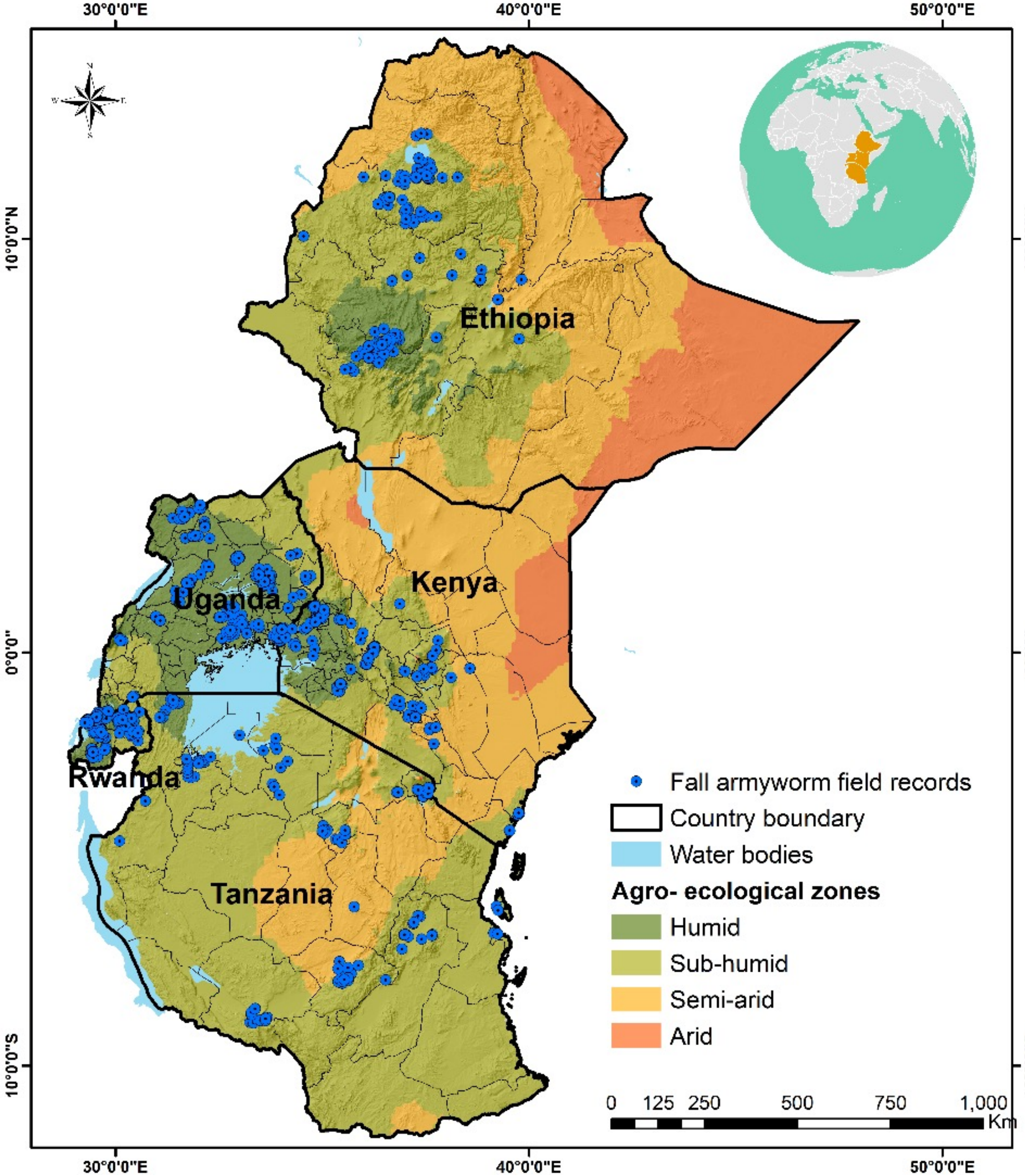
FAMEWS (Fall Armyworm Monitoring & Early Warning System)

- This mobile app can be used by farmers, scouts, community focal points, agriculture extension agents, plant protection officers, and others to collect and record information when scouting fields and checking pheromone traps for FAW

- It is meant to be utilized in all countries affected by FAW. When cell service or the Internet is available, data is transmitted to a centralized cloud-based server for validation by nationally designated FAW focal points before it is made available for mapping, analysis, and early warning via a web-based global platform

Data collection Apps

When used widely, the app will be essential in gaining a better understanding of the current distribution of FAW in different areas and how it is changing over time and space, to improve knowledge of its behavior, and enable extension agents to provide meaningful guidance and early warning to smallholder farmers so they can manage FAW sustainably in their fields.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Ethiopia
Kenya
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Rwanda
Tanzania
Fall armyworm field records
Country boundary
Water bodies
Agro- ecological zones
Humid
Sub-humid
Semi-arid
Arid
0 125 250 500 750 1,000
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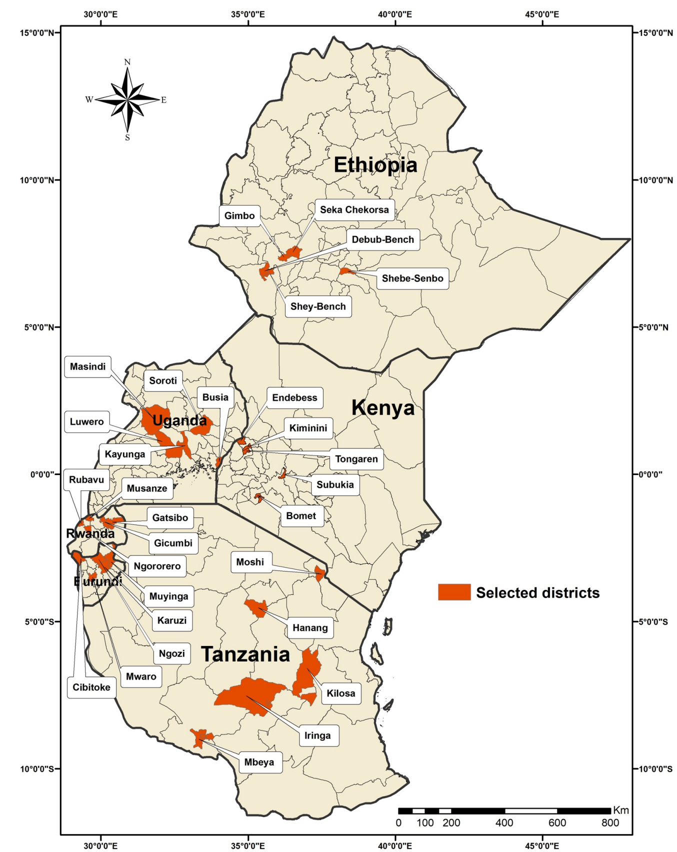
Ethiopia
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Seka Chekorsa
Debub-Bench
Shebe-Senbo
Shey-Bench
Kenya
Masindi
Soroti
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Endebess
Luwero
Uganda
Kiminini
Kayunga
Tongaren
Rubavu
Musanze
Subukia
Bomet
Gatsibo
Rwanda
Gicumbi
Moshi
Ngororero
Burundi
Muyinga
Karuzi
Hanang
Ngozi
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Mwaro
Cibitoke
Kilosa
Iringa
Mbeya
Selected districts
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01
BAGE
CLASSIC

Field monitoring and delivering tools in Rwanda

Modelling

Evidence-Based Decision Making through FAW Monitoring, Forecasting and Early Warning

EUROPEAN UNION

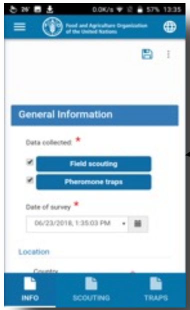
Informed decision
- Plan
- Prioritize
- Prepare

Pheromone Trapping

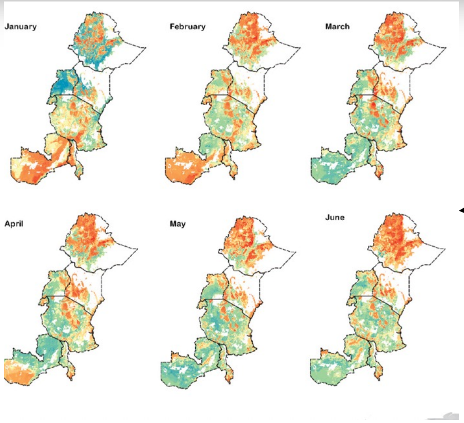
Effective Field Scouting

Adult and larvae scouting

GAP and cultural	Push-Pull	Legume intercropping	Biopesticides and Biorationals	Natural enemies



Data Transmission using FAMEWS



Newsletter
Modelling and dissemination

Informed stakeholders
- Citizens
- Farmers
- Extension
- Policy
- Researcher

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Harnessing data science to improve integrated management of invasive pest species across Africa: An application to Fall armyworm (*Spodoptera frugiperda*) (J.E. Smith) (Lepidoptera: Noctuidae)

USAID

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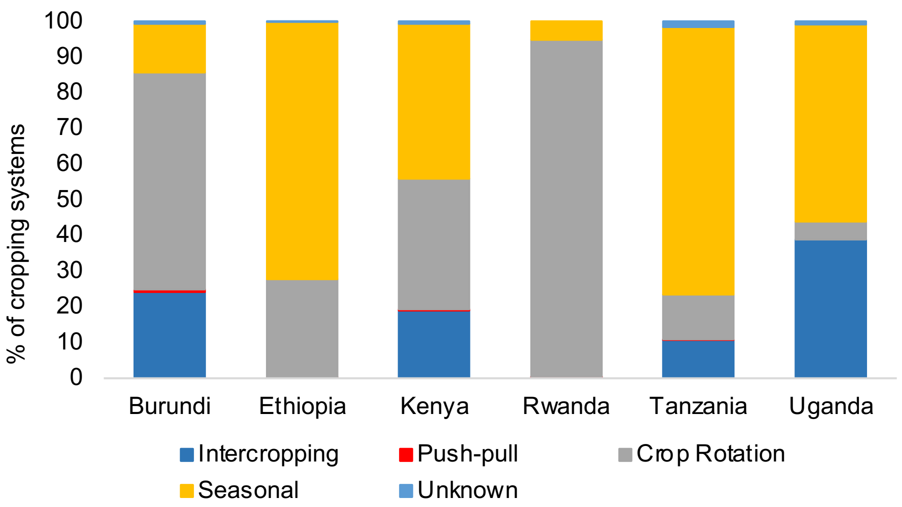
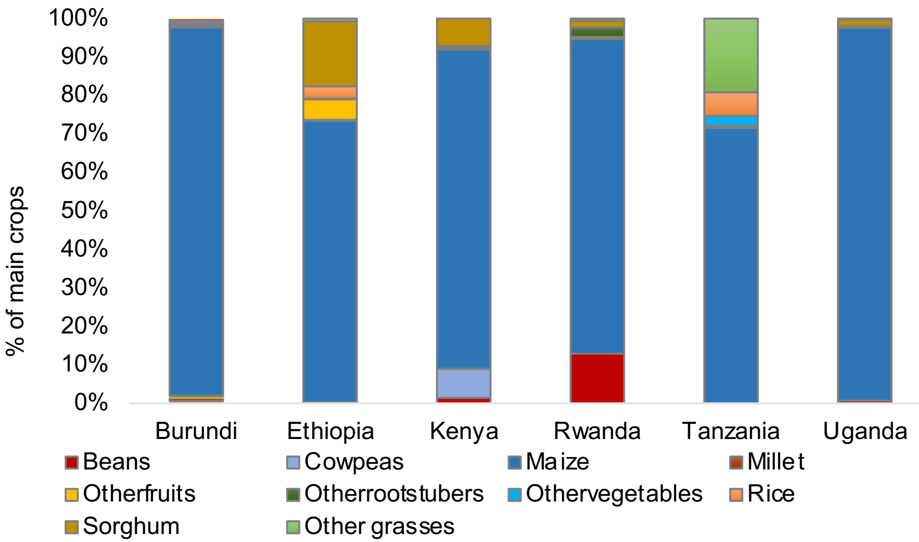
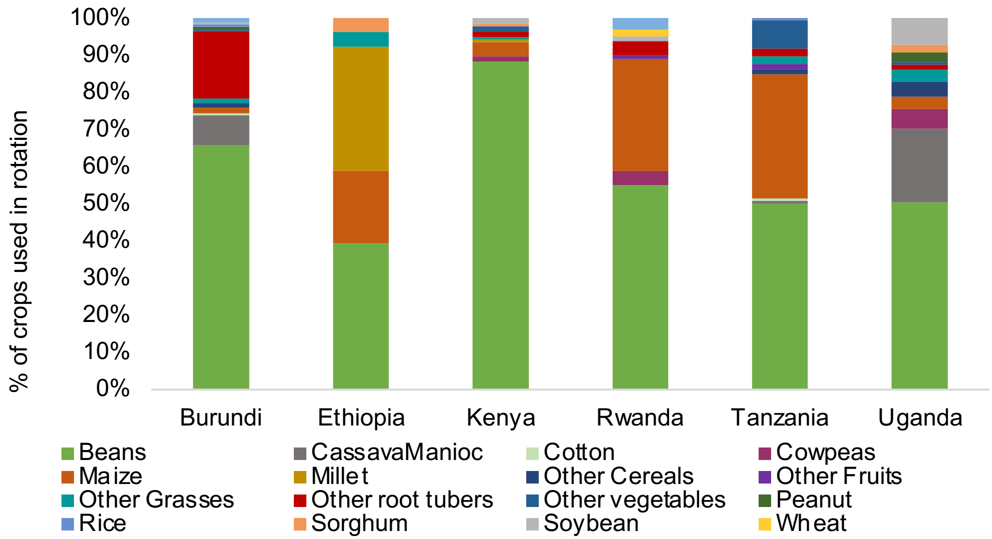
Cropping Systems: Main and Rotation in East Africa

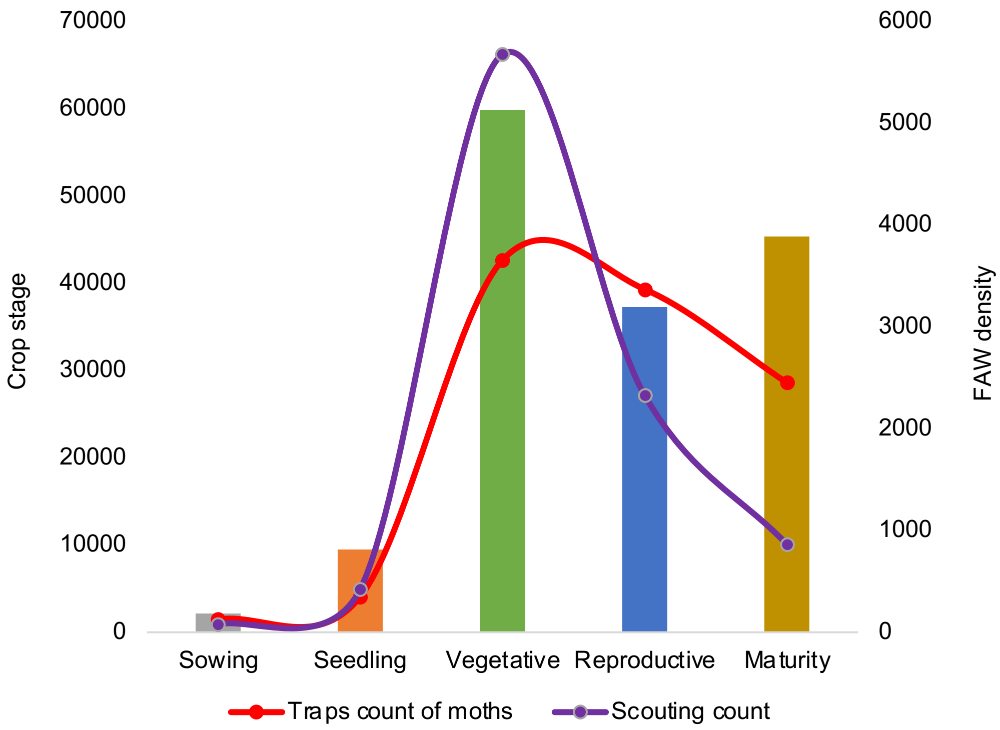


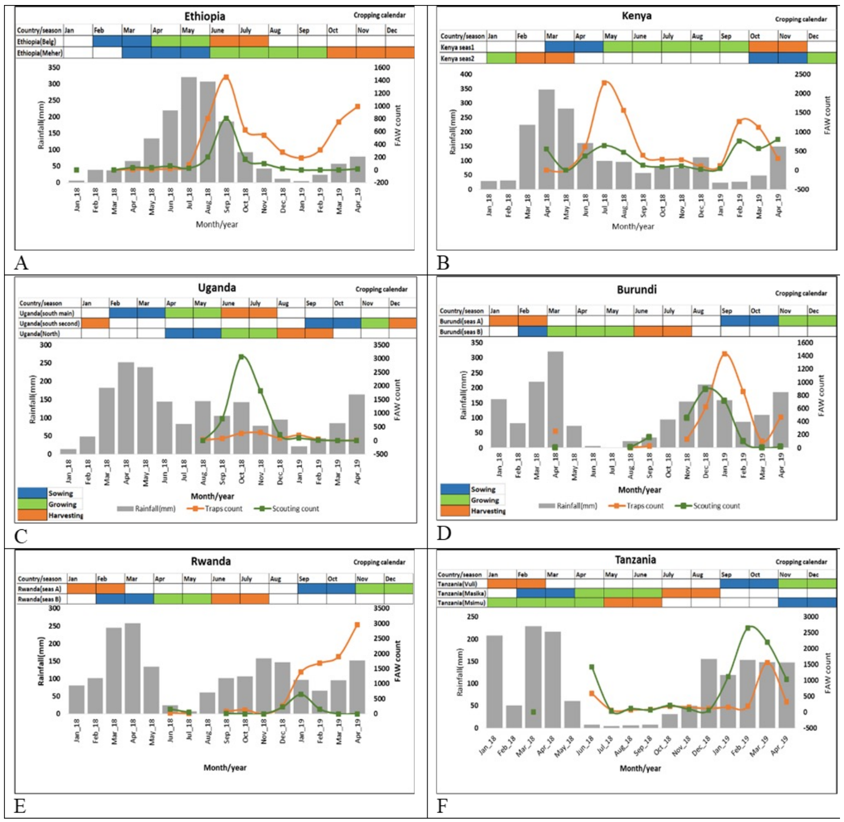




The farming and cropping systems are very diverse in East Africa and these have a direct bearing on FAW incidence.

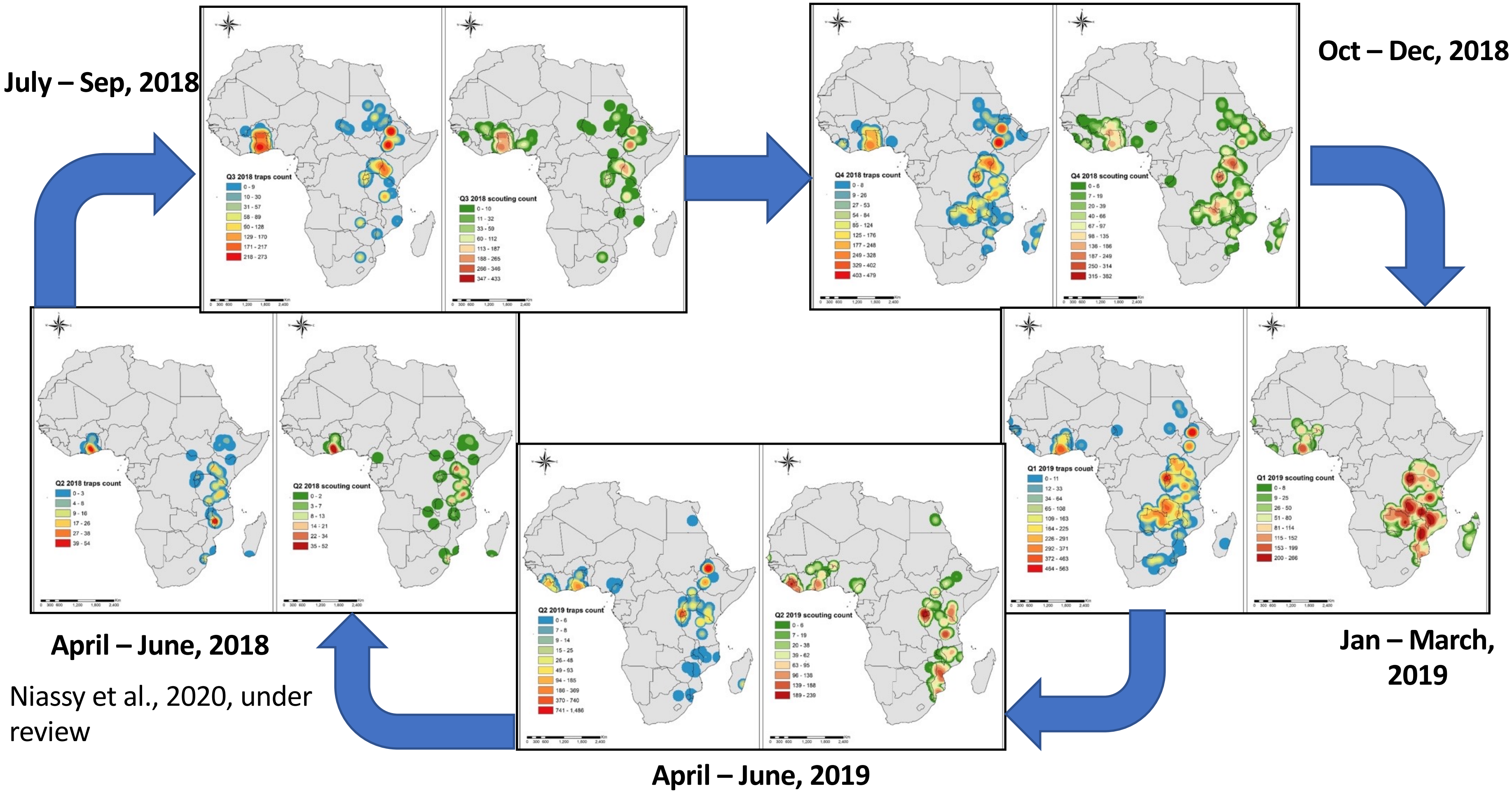
Crop stage and Rainfall influence on FAW dynamics in a season length





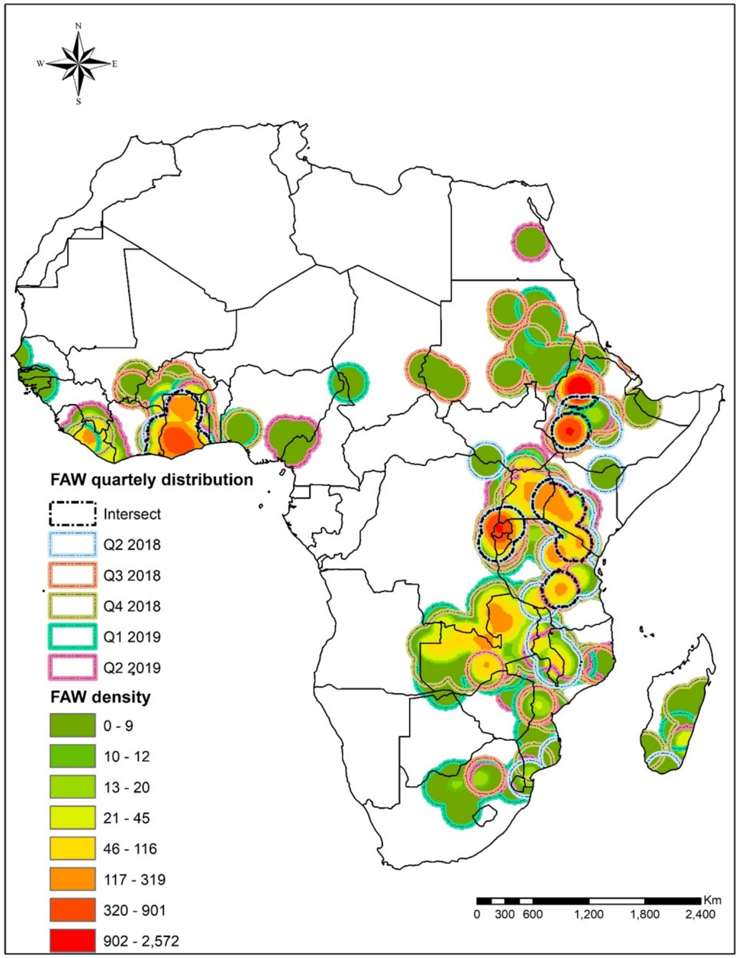
Rainfall (Water availability + Mechanical control) and Soil health are important factor influencing FAW incidence and crop performance.

Fall Armyworm dynamics assessed using the CBFAMFEW-FAMEWS data



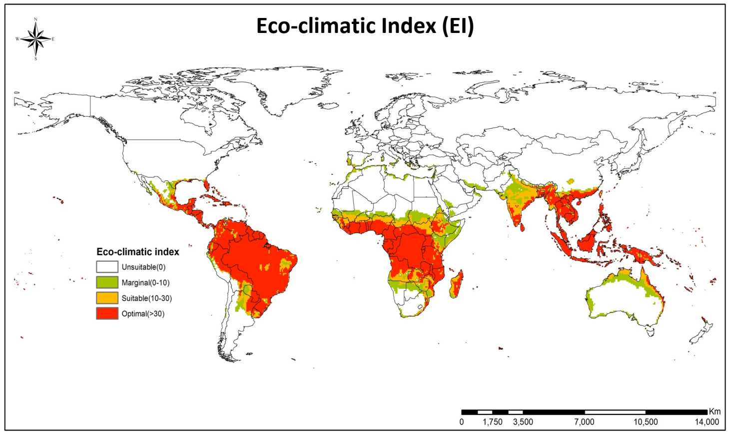
Niassy et al., 2020, under review

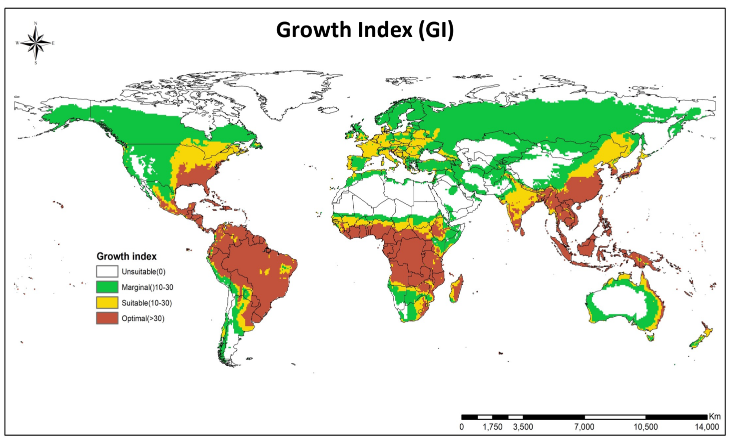
Spatial and temporal infestation of fall armyworm



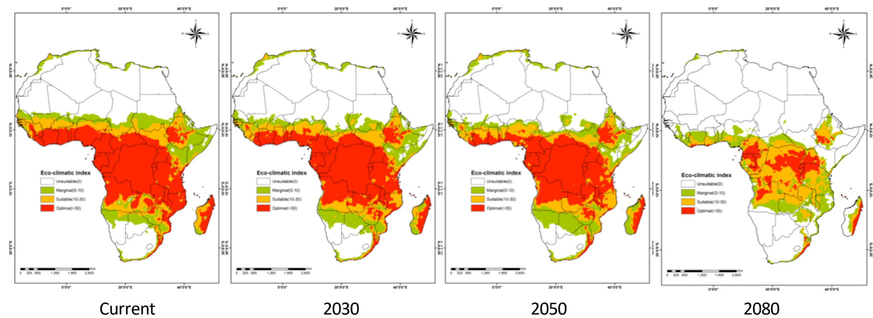
The combined map of the year-round FAW occurrence reveals remarkable hotspots with high FAW prevalence

Prediction of current and future suitability for FAW in Africa – CLIMEX-based modelling

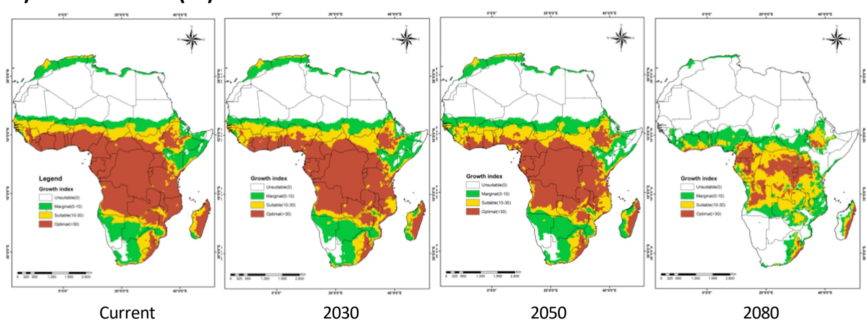




a) Ecoclimatic index (EI)



b) Growth index (GI)

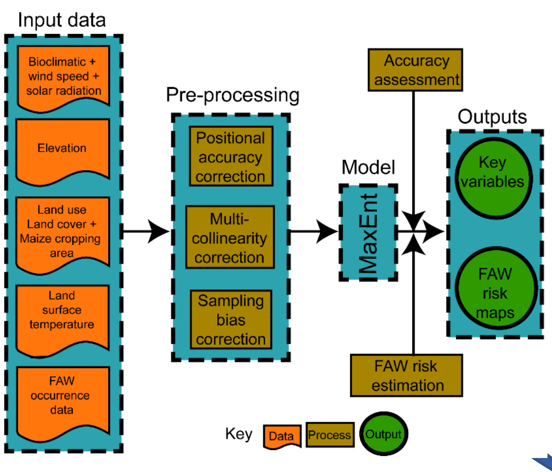


Bipana et al., Scientific Report

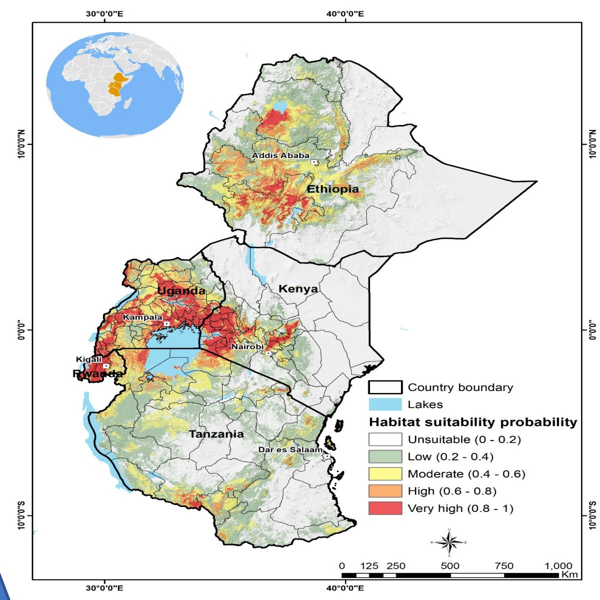
1 Assessed FAW build-up and establishment localities, using a species distribution modelling algorithm

❖ The modelling and data science activities refined and fine-tuned the FAW suitable habitat maps (developed in 2021) using more field observations to predict FAW build-up and establishment localities in the project countries

Ecological niche modelling



Model accuracy = 0.87



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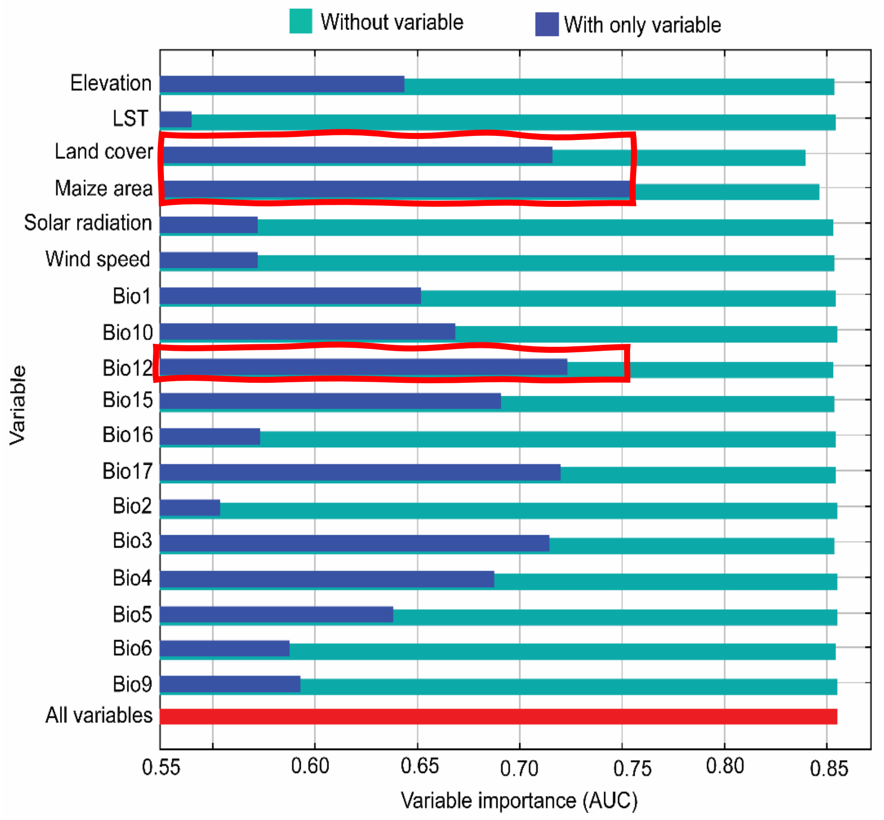
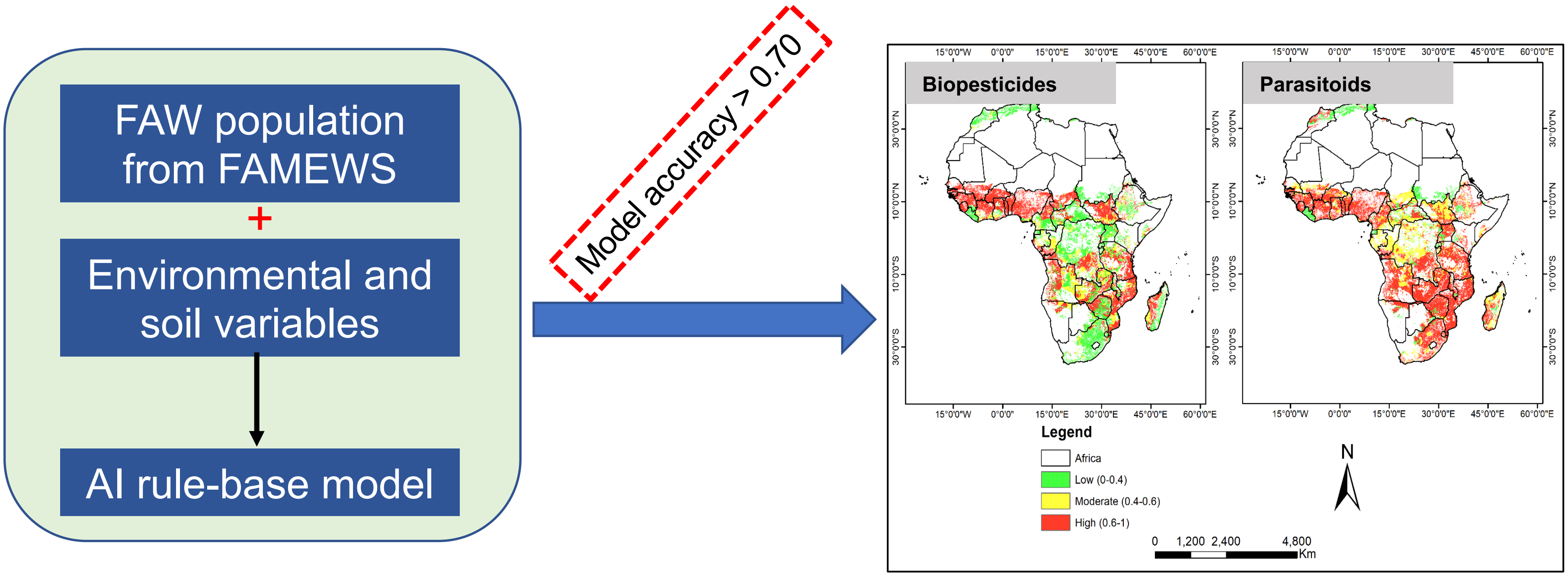


2 Predict the suitable sites for applying biopesticides and releasing parasitoids using a data science AI approach



It is found that parasitoids would be efficient in most maize-grown areas, while biopesticides would only be efficient in some areas

3 Developed an index to identify suitable areas for push-pull technology (*Desmodium intortum* and *Brachiaria Brizantha*)

Desmodium and *Brachiaria from* + GBIF

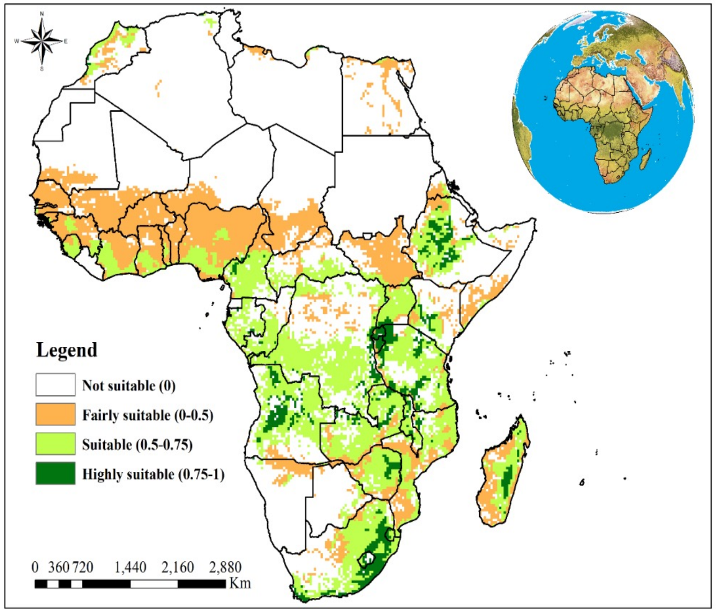
Environmental and soil variables

↓

Ecological niche model (MaxEnt)

→ AI rule-based model

Model accuracy >0.90



It is shown that vast regions in Tanzania, central Ethiopia, western and central Kenya, and southern Rwanda are conducive to push-pull.

Conclusions and way forward

- Monitoring is critical and all country, regions should embark into this activity

- Data from monitoring provide essential information of pest bioecology and its population dynamics

- Synthesized Data from Monitoring also guides on the best moments and sites to deploy our best best technologies.

- Models can help stakeholders and actors plan their activities better

- The developed index could be improved with farmers' indigenous knowledge

Publications

Global Ecology and Conservation 35 (2022) e02056

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Harnessing data science to improve integrated management of invasive pest species across Africa: An application to Fall armyworm (*Spodoptera frugiperda*) (J.E. Smith) (Lepidoptera: Noctuidae)

Ritter A. Guimapi[a,b,1], Saliou Niassy[a,2], Bester Tawona Mudereri[a,c,3], Elfatih M. Abdel-Rahman[a,4], Ghislain T. Tepa-Yotto[d,e,5], Sevgan Subramanian[a,6], Samira A. Mohamed[a], Karl H. Thunes[a,b,7], Emily Kimathi[a,8], Komi Mensah Agboka[a,9], Manuele Tamò[d,10], Jean Claude Rwaburindi[f], Buyung Hadi[f], Maged Elkahky[f], May-Guri Sæthre[g], Yeneneh Belayneh[h], Sunday Ekesi[a], Segenet Kelemu[a], Henri E.Z. Tonnang[a,*,11]

Publications

Manuscript File

Click here to view linked References

Computational biogeographic distribution of the fall armyworm (*Spodoptera frugiperda* J.E. Smith) moth in eastern Africa

Elfatih M. Abdel-Rahman*, Emily Kimathi[a], Bester Tawona Mudereri[a], Henri E.Z. Tonnang, Raphael Mongare, Saliou Niassy and Sevgan Subramanian

International Centre of Insect Physiology and Ecology (*icipe*), P.O. Box 30772-00100, Nairobi, Kenya.

[a] Equal contributing authorship.

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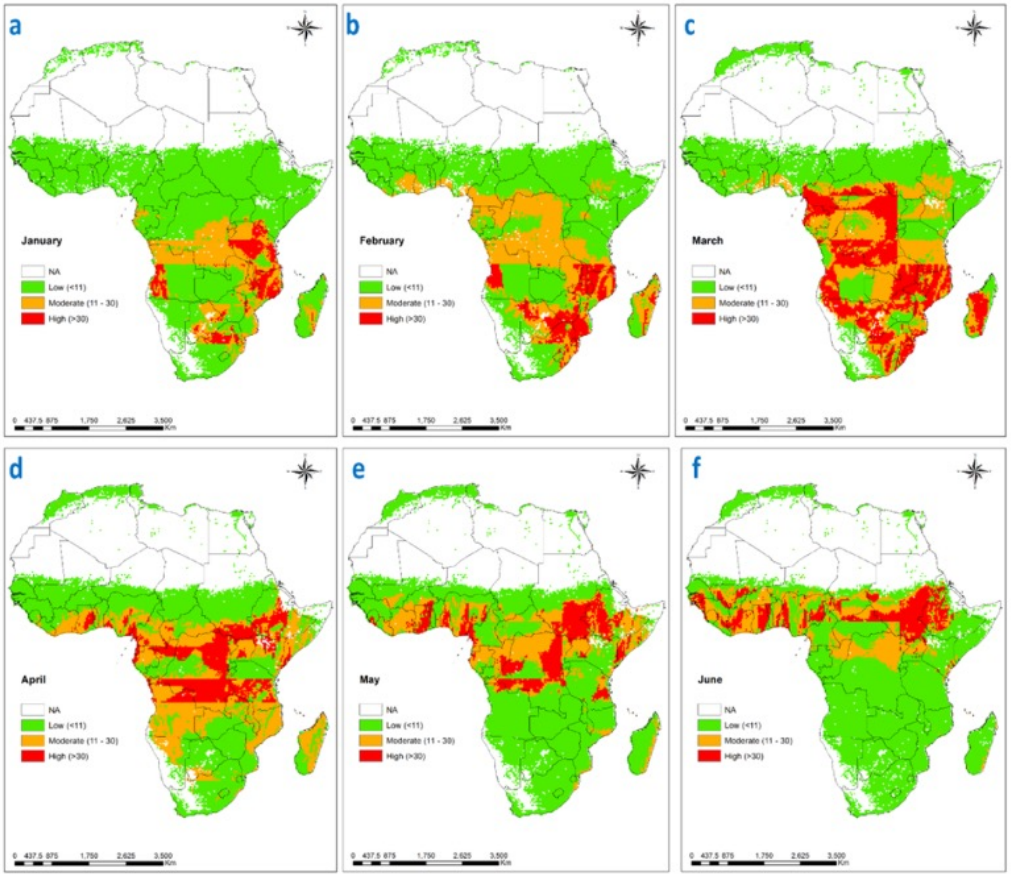
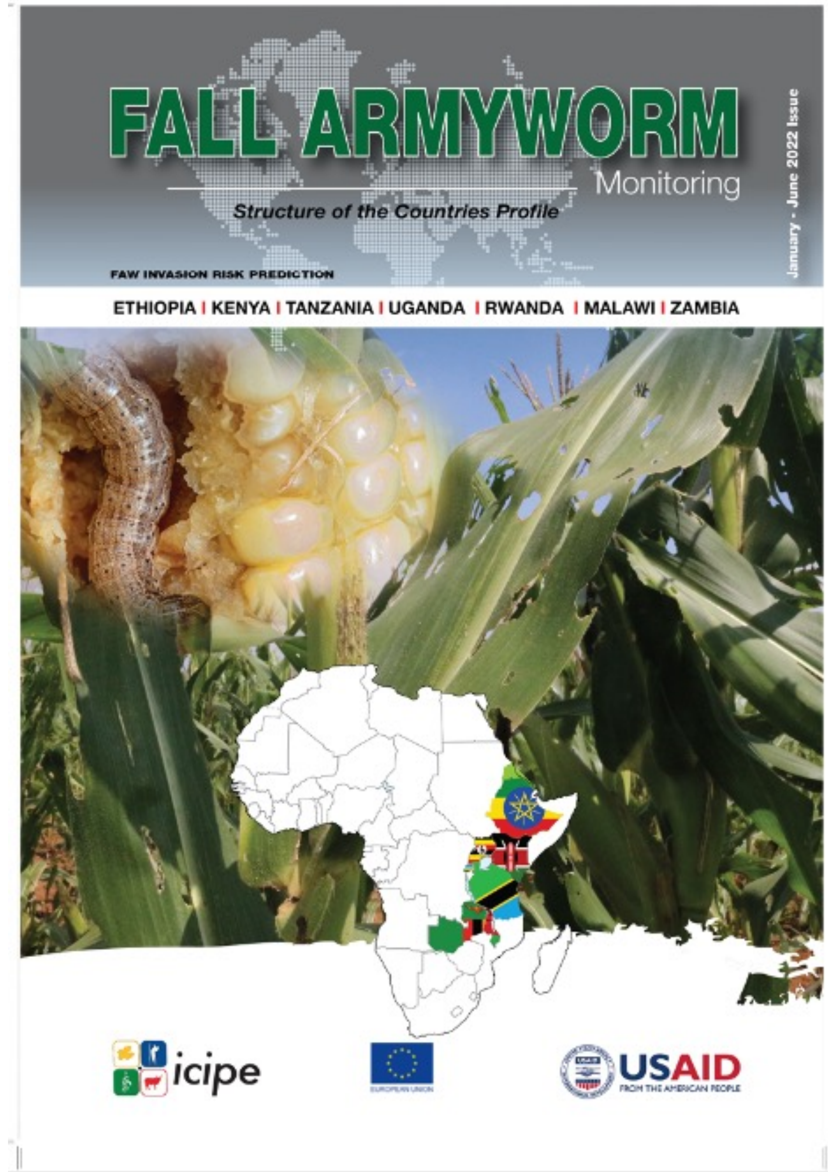
Harnessing data for fall armyworm infestation prediction in Africa





PLOS ONE

RESEARCH ARTICLE

Bioecology of fall armyworm *Spodoptera frugiperda* (J. E. Smith), its management and potential patterns of seasonal spread in Africa

Saliou Niassy[1*], Mawufe Komi Agbodzavu[1,2], Emily Kimathi[1], Berita Mutune[1], El Fatih M. Abdel-Rahman[1], Daisy Salifu[1], Girma Hailu[1], Yeneneh T. Belayneh[3], Elias Felege[4], Henri E. Z. Tonnang[1], Sunday Ekesi[1], Sevgan Subramanian[1]

1 International Centre of Insect Physiology and Ecology, Nairobi, Kenya, 2 International Institute of Tropical Agriculture (IITA), Kinshasa, DR Congo, 3 DCHA/OFDA, Washington, D.C., United States of America, 4 Desert Locust Control Organization for Eastern Africa (DLCO-EA), Ethiopia

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Abstract

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OPEN

Potential distribution of fall armyworm in Africa and beyond, considering climate change and irrigation patterns

Bipana Paudel Timilsena[1✉], Saliou Niassy[2], Emily Kimathi[2], Elfatih M. Abdel-Rahman[2], Irmgard Seidl-Adams[1], Mark Wamalwa[2], Henri E. Z. Tonnang[2], Sunday Ekesi[2], David P. Hughes[1], Edwin G. Rajotte[1] & Sevgan Subramanian[2]

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agronomy

MDPI

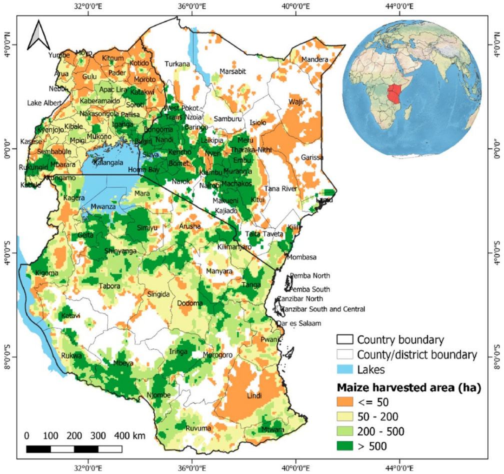

Figure 1. Map of the study area overlaid on the maize harvested area (ha).

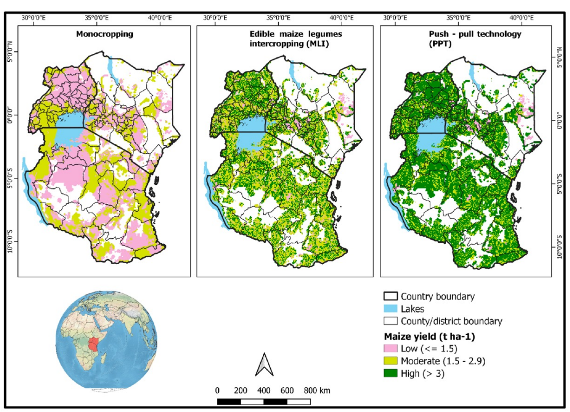

Figure 3. Graphical representation of potential maize yield (t ha^{-1}) under monocropping, maize legumes intercropping (MLI), and push-pull technology (PPT) systems predicted using rainfall and temperature variables.

Article

Data-Driven Artificial Intelligence (AI) Algorithms for Modelling Potential Maize Yield under Maize–Legume Farming Systems in East Africa

Komi Mensah Agboka [1,2,*], Henri E. Z. Tonnang [1,*], Elfatih M. Abdel-Rahman [1], John Odindi [2], Onisimo Mutanga [2] and Saliou Niassy [1]

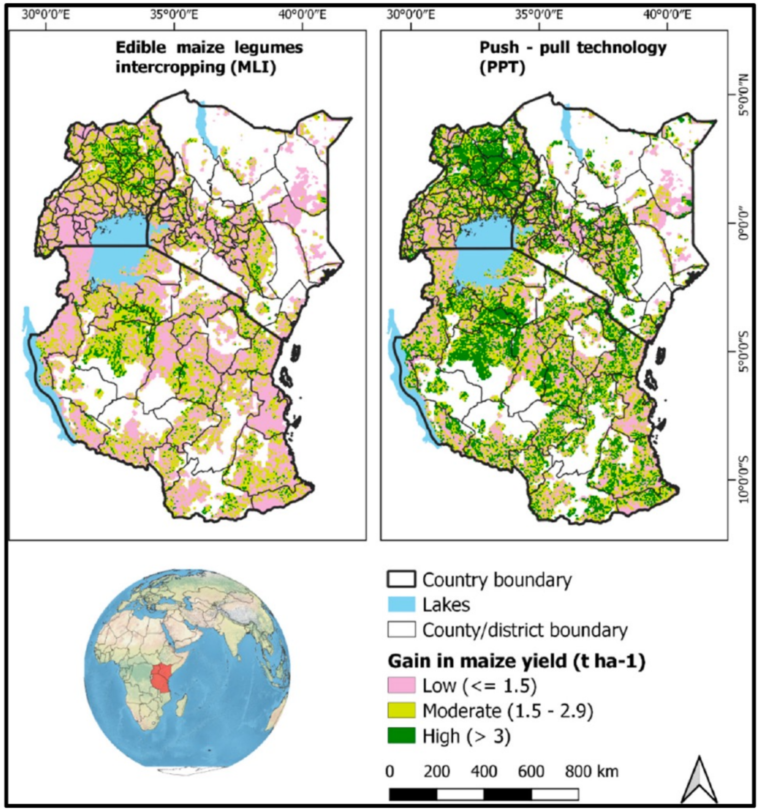

Figure 4. Geographical representation of gain in maize yield (t ha^{-1}) as a result of using the maize legume intercropping (MLI) and push-pull technology (PPT) systems in comparison with the monocropping system.

Thank you

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BMZ Federal Ministry for Economic Cooperation and Development

CIM Centre for International Migration and Development
a joint operation of GIZ and the German Federal Employment Agency

cirad Agricultural Research for Development

Government of Côte d'Ivoire

Conservation International

CNHR Consortium for National Health Research

CS&S Code for Science & Society

DAAD Deutscher Akademischer Austausch Dienst
German Academic Exchange Service

DANIDA

DFG Deutsche Forschungsgemeinschaft

ECC-SDCOH

Embrapa

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IDRC CRDI

IFAD Investing in rural people

IFS International Foundation for Science

iie

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IRD Institut de Recherche pour le Développement France

Innovate UK

IVCC Combating Insect Borne Disease

JRS Biodiversity Foundation

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