Food and Agriculture Organization of the United Nations

Technical guidance on fall armyworm

Coordinated surveillance and an early warning system for the sustainable management of transboundary pests, with special reference to fall armyworm (*Spodoptera frugiperda* [J.E. Smith]) in South and Southeast Asia

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Foreword

Agriculture is a central pillar of most Asian economies, driving aggregate growth while providing nutrition, food security and livelihoods. Small-scale family agriculture has become indispensable for the integrated socioeconomic development of rural areas across South and Southeast Asia. Even though rice and wheat continue to be prime cereal staples, maize cultivation has steadily expanded over the past two decades. Maize has gained prominence because of minimum support prices, swelling market demand from animal feed or processing industries, and human consumption. Maize has also become a much-desired crop in settings where meteorological conditions, such as precipitation, have limited rice cultivation, and it is increasingly grown in peri-urban environments.

Since 2018, Asian maize production has been crippled by a highly mobile, voracious insect pest, the fall armyworm (FAW) (*Spodoptera frugiperda*). Native to the Americas, this noctuid moth has invaded both the continent of Africa and of Asia with its transboundary spread and proliferation encouraged by climate change, global trade and agricultural intensification. Since it arrived in Asia, FAW has lowered maize yields, diminished farmer profits and triggered an increase in pesticide use. As such, FAW is having serious negative socio-environmental impacts and is compromising food and nutrition security at the regional level. The current over-reliance on chemical crop protection equally affects biodiversity and ecosystem services, undermines the resilience of agrifood production, aggravates water pollution, and threatens human, animal and environmental health.

Multiple factors impede a swift and effective mitigation response to this transboundary pest. Throughout the Asia-Pacific region, the necessary human resources are lacking for pest surveillance, field-level monitoring, and early warning. Weak collaboration among local, national, and regional actors further lowers rapid response capacity and slows the diffusion of more sustainable crop protection technologies such as biological controls or integrated pest management (IPM). National capacities also need to be strengthened in fields such as applied research, farmer extension and stakeholder education.

In response to this situation, the Food and Agriculture Organization of the united Nations (FAO) has prepared this technical guidance on early warning systems (EWS) and sustainable management of the fall armyworm for 2022–2026. The guidance aim to attain a regionally coordinated management of FAW and to promote crop protection practices that protect human and environmental health. By doing so, FAO intends to support the restoration of maize yields, lift farmer incomes, safeguard food and nutrition security while alleviating the "One Health" burden of agrochemical use. This work emphasizes how an Asia-regional approach is highly appropriate to resolve FAW issues and is crucial to advance the uptake of good agricultural practices and IPM. This approach is also in line with the South Asian Association for Regional Cooperation (SAARC) and of the Southeast Asian Nations (ASEAN) Regional Agricultural Policies.

This technical guidance offer a systematic review of the FAW programmes across the Asia-Pacific region. This document thereby serves as a valuable compass for FAO and its development partners to identify opportunities for inter-country cooperation, capacity building and technical backstopping. As such, the necessary momentum can be built to defuse transboundary pests in a way that optimally benefits farmers, the environment and human society.

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Abbreviations and acronyms

ASEAN	Association of Southeast Asian Nations
BARI	Bangladesh Agricultural Research Institute
BCA	Biological Control Agents
BPH	brown planthopper
CABI	Centre for Agriculture and Bioscience International
CESAS	Cost, efficacy, safety, accessibility and scalability
CIMMYT	International Maize and Wheat Improvement Centre
CMD	Cassava Mosaic Disease
COVID-19	coronavirus disease 2019
DOA	Department of Agriculture
EWS	Early warning systems
FAD	Flavin Adenine Dinucleotide
FAMEWS	FAW Monitoring and Early Warning System
FAO	Food and Agriculture Organization of the United Nations
FAW	Fall armyworm
GIS	Geographical Information System
ICAR	Indian Council of Agricultural Research
IFN	Interferons
IPM	Integrated pest management
IPPC	International Plant Protection Convention
IRRI	International Rice Research Institute
ISPM	International Standards for Phytosanitary Measures
NBAIR	National Bureau of Agricultural Insect Resources (India)
PhilRice	Philippine Rice Research Institute
PPRI	Plant Protection Research Institute (Viet Nam)
PRA	Pest risk analyses
RCPC	Regional Crop Protection Center
SAARC	South Asian Association for Regional Cooperation
SEWR	Surveillance, early warning and response
SWOT	Strengths, weaknesses, opportunities and threats
UAHS	University of Agricultural and Horticultural Sciences (India)
USAID	United States Agency for International Development

Executive summary

Worldwide, maize is the third most important cereal after rice and wheat. It occupies 197 million hectares of planted area. Asia contributes to nearly 30 percent of global maize supplies, and area and production of the crop is rapidly increasing in the continent. Minimum support prices, swelling market demand from the animal feed and processing industries, as well as human consumption, have all led to increased maize production in zones where precipitation limits rice cultivation.

However, maize production is currently threatened by the arrival in Asia (in 2018) of the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) – a native to North America. It invaded India in 2018 and since then it has marched to most of the Asian countries. In 2019, its presence was confirmed in 13 Asian countries including Cambodia, China, India, Indonesia, Japan, the Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, the Philippines, the Republic of Korea, Sri Lanka, and Viet Nam. In 2020, it was confirmed in Australia, Timor-Leste and Papua New Guinea. In August 2021, it reached the Solomon Islands, posing a serious threat to other Pacific islands. FAW is a fast-dispersing, migratory, transboundary insect pest. While high FAW incidences have been reported on several crops in Asia, the most important economic damage caused is to maize (followed by sorghum). The FAW invasion threatens the food security of millions of family farms in Asia, with smallholder farmers being especially vulnerable. The negative economic impact of FAW is not only evident in yield loss: the pest also leads to a significant increase in insecticide applications, with associated health, environmental and cost issues. At the same time, resilience to FAW on the continent is currently weakened by the limited access to necessary tools, technologies and sustainable integrated pest management (IPM) practices for FAW. Thus, there is an urgent need to implement an effective approach to FAW management in Asia.

Recent analysis has revealed several strengths and weaknesses regarding managing FAW in Asia. Strengths include high awareness of the magnitude of the problem, an increasing inventory of biopesticides and the availability of emergency funds. Weaknesses include a lack of understanding of real yield losses caused by the pest, and a general lack of knowledge of the most effective and cost-effective measures for FAW management, as well as a lack of mass production of biological agents.

Extensive stakeholder consultations show that there is a need for the following regarding Asia's response to FAW:
- greater investment in research to develop sustainable FAW management options;
- validating different FAW management options and implementing large-scale demonstration of the most effective ones;
- developing a regional insecticide resistance management plan; and
- establishing a single coordinating body with multi-stakeholder representation for the region that coordinates the development and implementation of sustainable FAW management.

Further requirements are set out in the following paragraphs.

FAW is already fully established in tropical/subtropical Asia and seasonal FAW migrations also pose a serious threat for maize farmers in areas further north. Thus, a sound forecasting system for FAW needs to be established to alert farmers to the threat as early as possible. To be most effective, this system should function region-wide, but it should also operate at a local scale. It could use the FAW Monitoring and Early Warning System (FAMEWS) mobile app, which brings together locally collected data and provides advice to farmers on managing the pest.

International guidelines suggest several cultural control methods for the sustainable management of FAW, and many specific methods are recommended for Asia, including those making use of host plant resistance. However, these methods may not always be sufficient for FAW control (as well as being labour-intensive).

Conservation biocontrol approaches appear to be promising and more research is recommended on the impact of natural enemies. In this context, the avoidance of broad-spectrum pesticides is clearly of high relevance, so as not to put beneficial insects at risk.

Several effective biologically-based products are available in the region, and these should be given priority. Biocontrol practices must be tailored to regional challenges within an IPM framework. Further research is needed to identifying promising indigenous microbial and microbial isolates, and to develop pheromone technology.

It is further recommended that support be provided for local production units involved in producing biological control agents as locally available eco-friendly options for FAW management.

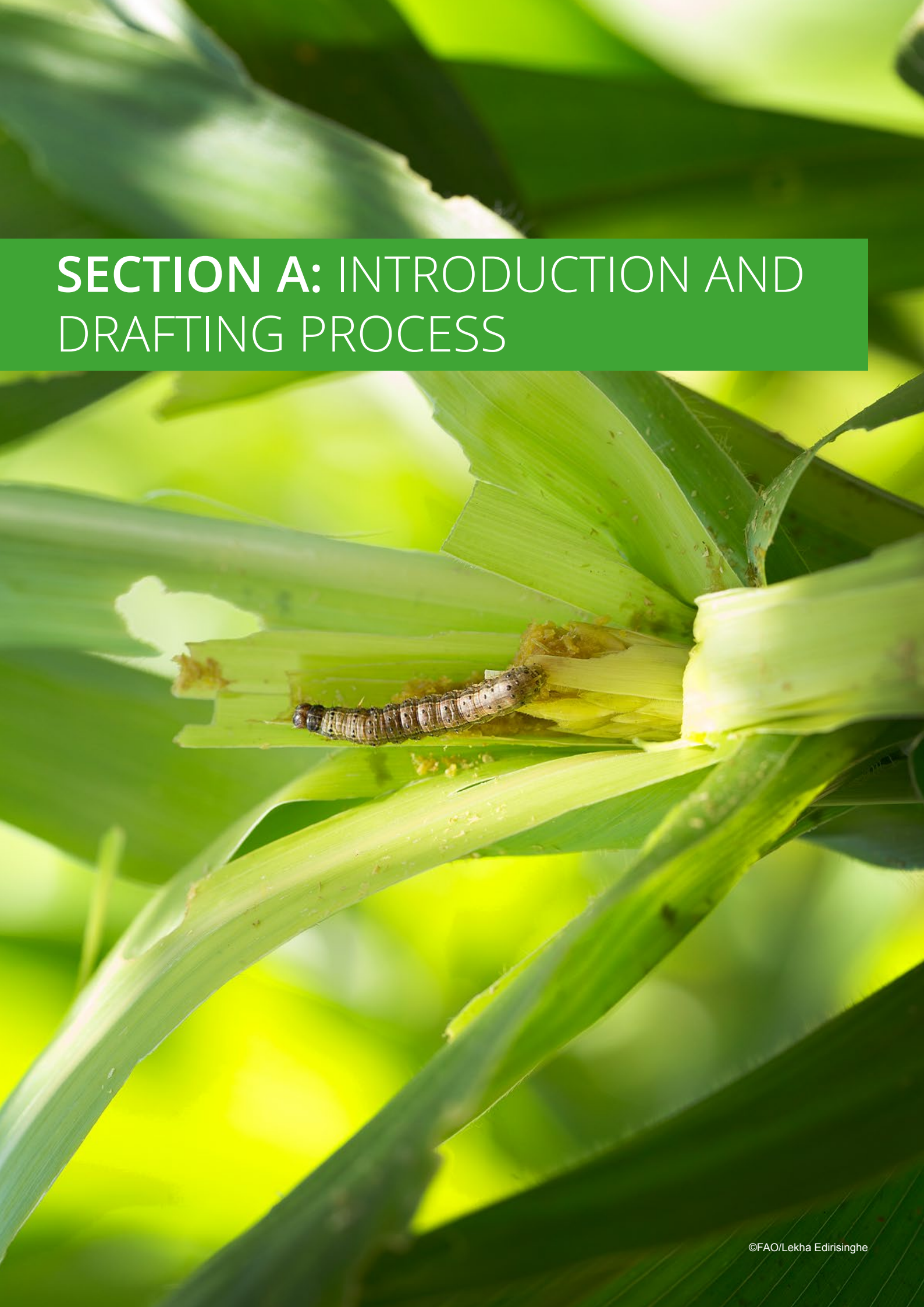
Monitoring is necessary to track the future evolution of FAW concerning pesticide resistance and host expansion. This should be used to tailor modified IPM.

Agro-ecological approaches should aim to minimize pesticide inputs and, where possible, be based on the least-toxic products available, to encourage conservation of biocontrol and avoid damaging human and environmental health. Finally, Asian maize growers should be made aware of key features of this new invasive pest, and appropriate control options. To this end, a large training programme should be implemented, the main content for which should be developed as a joint regional effort. Importantly, the focus needs to be on sustainability – both financially and environmentally. In line with this, the technical capacity of plant protection and extension systems in some Asian countries should be strengthened to allow for effective farmer training programmes and advisory services.

Figure 1. *A summary of the guidance developed for the sustainable management of the fall armyworm for Asia*

	**Stakeholder coordination and policy change** **Do** - undertake ecosystem analysis; establish a coordination body; develop an invasive species management strategy; develop a functional framework. **Don't** - put in place a mitigation strategy only after accidental introduction.
	**Strengthen surveillance, the early warning system and emergency preparedness** **Do** - implement basic phytosanitary functions; establish a rapid response system; conduct pest monitoring; engage in data collection and its use; undertake pest risk analysis. **Don't** - make decisions that are not based on in-depth data and science.
	**3.Increase advocacy, awareness and knowledge about fall armyworm** **Do** - conduct cross-sector coordination; conduct media engagement; design a communication framework. **Don't** - send out non-harmonized and/or unclear messages; disseminate volumnious non-scientific content.
	**Strengthen technical capacity of plant protection and extension system** **Do** - establish a regional network/database of FAW experts; develop a model for capacity building; customize modules. **Don't** - generalize modules to provide uniform learning across the region.
	**Integration of local agro-ecological approaches in current integrated pest management system for smallholders** **Do** - conduct surveys; research and scale up local practices; integrate local agro-ecological approaches in current IPM system for smallholders adopted by maize farmers to manage pest issues. **Don't** - discard local practices and impose IPM practices in a top-down approach.
	**Enhance implementation of integrated pest management for fall armyworm** **Do** - develop a management strategy; increase biodiversity; increase host plant resistance; conduct monitoring and scouting; apply biological control options; use low-toxic chemicals and restrictions; establish a knowledge bank. **Don't** - repeatedly and indiscriminately apply insecticides without adequate supervision; destroy natural parasitism or infected FAW larvae; spray at the first sighting.
	**Innovative research needs** **Do** - conduct a needs assesmment for improvisation after conducting a survey of impact on the adoption of current recommendations; research green products. **Don't** - make recommendations until the innovations are tested with regard to cost, efficacy, safety.

SECTION A: INTRODUCTION AND DRAFTING PROCESS



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1. Introduction

1.1. Background

Crop pests and diseases are responsible for 20 to 40 percent of losses to the world's agricultural production. In Asia, these comprise endemic pests, such as the brown plant hopper, beet armyworm and the yellow-spine bamboo locust, as well as invasive threats such as the fall armyworm (FAW) (*Spodoptera frugiperda*) (J.E. Smith), desert locust and tomato pinworm. The socioeconomic and environmental impacts of transboundary pests are substantial, with invasive pests annually causing very high economic yield loss. The risk to farmers of pest-induced losses is further exacerbated by global climate change, which alters the frequency and intensity of pest outbreaks, disrupts interactions between pests and their natural enemies and steadily weakens nature's biological control services. The movement of human beings and materials across the Asia region is also accelerating, increasing the dispersion of pests. In addition, pest impacts are more severe in intensified farming systems, such as Cambodia's western plains, Viet Nam's Mekong Delta, or the high-input farming systems of Nepal, Bangladesh and Sri Lanka. In these settings, pesticide overuse, removal of (semi-) natural habitats, and the proliferation of genetically uniform (clonal) crops have led to a degradation of agro-ecosystems. Under these conditions, transboundary pests thrive and farmers struggle to safeguard their harvests and sustain their often precarious livelihoods.

To mitigate the above transboundary pest threats, farmers in South Asia and the Asia Pacific region routinely resort to costly, environmentally disruptive measures. For example, the recent invasion of FAW has triggered increased application of pesticides, including aerial (drone) sprays and prophylactic use of neonicotinoid insecticides, in Southeast Asian countries. In China, chemical pesticide use in maize has reportedly risen six-fold since the 2018 arrival of this voracious pest (Zhao *et al.*, 2020). In the absence of regionally coordinated action, phytosanitary issues can rapidly aggravate farmers' poverty and vulnerability, stall rural development and broaden the environmental footprint of agriculture. These issues also increase the market prices of crops like maize, due to increases in the cost of production arising from pest management efforts. These impacts add to the recent disruption of South Asian and Southeast Asian rural livelihoods due to COVID-19.

In this context, a multi-pronged regional approach and coordinated efforts by responsible stakeholders are urgently needed to devise, validate and deploy ecologically based sustainable plant health solutions.

1.2. The need for technical guidance on transboundary pests

Countries in the South Asia and Southeast Asia region demonstrate different levels of interventions regarding transboundary pests like FAW. There is a need for a harmonized approach to research and development, data collection and to the use of data for surveillance. Moreover, cross-national learning, guided coordination and cooperation are at the nexus of effective early warning systems (EWS) and sustainable management for such pests. It is, therefore, vital to develop a regional strategy that integrates successful best practices to catalyse the preparedness and response system of countries in the region for future invasions.

In this context, the technical guidance set out in this document have been developed, setting out how nations in the region can deliver an Asia-wide coordinated response to priority transboundary pest threats such as FAW, including collaborating on an EWS for, and sustainable management of, such pests. The guidelines have been developed based on an analysis of the strengths, weaknesses, opportunities and threats (SWOT) in this area, and take account of existing systems (surveillance and early warning).

1.3. The regional response and current gaps

In response to the rapid spread of FAW in Africa and Asia, the Food and Agriculture Organization of the United Nations (FAO) developed a robust FAW Programme for Action and Framework for Partnership in collaboration with many partners and mobilized over USD 15 million to put these plans into action. Many of the results and documents relating to these plans are available on FAO's FAW website.

Pre-emptive efforts to coordinate FAW activities commenced in Bangladesh even before FAW was able to migrate and invade, with the United States Agency for International Development (USAID) and the International Maize and Wheat Improvement Centre (CIMMYT) convening stakeholders to initiate appropriate policy and strategies in September 2018.

The first regional consultative meeting on FAW in Asia was organized by FAO in Bangkok in March 2019. This meeting made some significant recommendations, including on surveillance, research and extension in relation to FAW on maize. The Centre for Agriculture and Bioscience International (CABI), CIMMYT, the South Asian Association for Regional Cooperation (SAARC) and a few other organizations have also initiated needs-based programmes relating to the regional management and control of FAW. CABI-SE Asia, in collaboration with the Philippine Rice Research Institute (PhilRice), has conducted online training on the diagnosis, surveillance, monitoring and management of FAW

Despite these coordinated efforts, there have been gaps in the response to the FAW invasion of Asia. So far, there is no single platform that can bring nations together to conduct coordinated actions across the region. In the absence of such a platform, SAARC is currently acting as the coordinator for collaborative research on FAW, and facilitates the exchange of information across Member Nations, in technical partnership with the national and international organization. Moreover, the Association of Southeast Asian Nations (ASEAN) has a regional FAW task force that has developed action plans for the region and holds regular discussions among Member Nations on how they can best coordinate their response to the pest.

1.4. The regional response and current gaps

Surveillance and the use of digital tools

Since eradicating FAW is not practically possible, the only efficient approach to managing the pest is applying area-wide IPM. This will be feasible only if there is a well-structured regional strategy in place on the surveillance of, and the EWS for, FAW. Surveillance (where different countries in the region all collect and share surveillance data), a regional approach to research (to avoid duplication), and a regional approach to pesticide registration, as well as a regional identification service to identify natural enemies of FAW (including race profiling, etc.), should be a focus across the nations of the region. Proper scouting protocols should also provide farmers with the information necessary to avoid treatments that are not economically justified. Additionally, scouting and action thresholds should be built into the regional strategy prior to initiating pest management options for FAW, especially in regard to the use of chemical pesticides.

Community-based surveillance can play an important role in terms of sourcing information on and understanding the intensity of, infestation. Various programmes in the region, such as farmer field schools and plant clinics, can help in developing the FAW forecasting and early warning information that can enable farmers in both FAW breeding areas and along migration pathways to mitigate FAW infestation by applying the proper measures at the proper time.

In this context, there is a need for capacity building for surveillance, covering factors such as FAW natural mortality, predators, parasitoids, entomopathogens, etc. in order to arrive at scientific management decisions.

Digital tools can also be useful in managing FAW across the Asia region, though some countries may not have the financial resources or skilled human resources needed to effectively utilize this technology. Capacity building on digital tools is currently limited and very few trainings are being provided across the region on using the tools that are available for FAW surveillance (which include FAW monitor, FAMEWS, Plantix, etc.). Interventions are, therefore, needed to build capacity on using digital tools at the national and community level, with the ultimate aim of having a dashboard that provides information on FAW incidence in particular regions at the micro level.

Collecting data and disseminating information on pests

Data collection, which requires coordination between different stakeholders, is a major constraint in larger countries in the region. However, in general, all countries have made strides in regard to improving data collection.

Currently, various methods are used to disseminate pest information. Extension mechanisms like farmer field schools and plant clinics are used for this purpose, as are media like television, radio, video and printed materials, which can maximize outreach by private media organizations and agricultural information systems within ministries of agriculture. Various communication workshops have also been used to develop technical briefs on pests.

Eco-friendly and sustainable management of FAW

Work carried out in different parts of the world indicates that there are different options for managing FAW. The choice and success of IPM are determined by five criteria: cost, efficacy, safety, accessibility and scalability (CESAS). Small-scale and medium-scale farmers face the challenge that management costs can be prohibitive or the options may not be practically available. For sustainable IPM, if chemicals are used, it is vital to use those that are safe for the ecosystem and ecosystem services, such as pollination and biological control through natural enemies of pests.

Globally, initial attempts to manage FAW have always used synthetic insecticides. Understanding of conservation biological control and its contribution towards the reduction of FAW populations is currently lacking in South and Southeast Asia. There is a lack of availability of biocontrol products at the farm level, and business models do not exist for rural enterprises working in this area. However, some countries, such as Bangladesh, have taken timely steps in issuing emergency registration for biopesticides and chemicals that are relatively safe for the beneficial organisms and to make the products more available at the farmer level.

FAW extension guides have been prepared by several organizations, such as FAO, CABI, CIMMYT, and others (FAO and DPPQS, 2021). One example is the fall armyworm in Asia: A Guide for Integrated Pest Management (Prasanna *et al.*, 2021). These guides have been used by countries to develop management strategies for pests. They emphasize appropriate ready monitoring and scouting protocols.

1.5. Scope and objectives of the technical guidance

The overall objective of these guidelines is to contribute to setting up an FAW surveillance system and a framework for the efficient and effective management of FAW in South and Southeast Asia. Although the focal countries selected for gathering information to support the drafting of the guidelines were Bangladesh and India in South Asia and Cambodia, Indonesia, the Philippines and Viet Nam in Southeast Asia, the findings, as set out in the guidelines, have wider application at the regional and global level.

The specific objectives of the guidelines are:

1. to support the development of a regional FAW surveillance system;

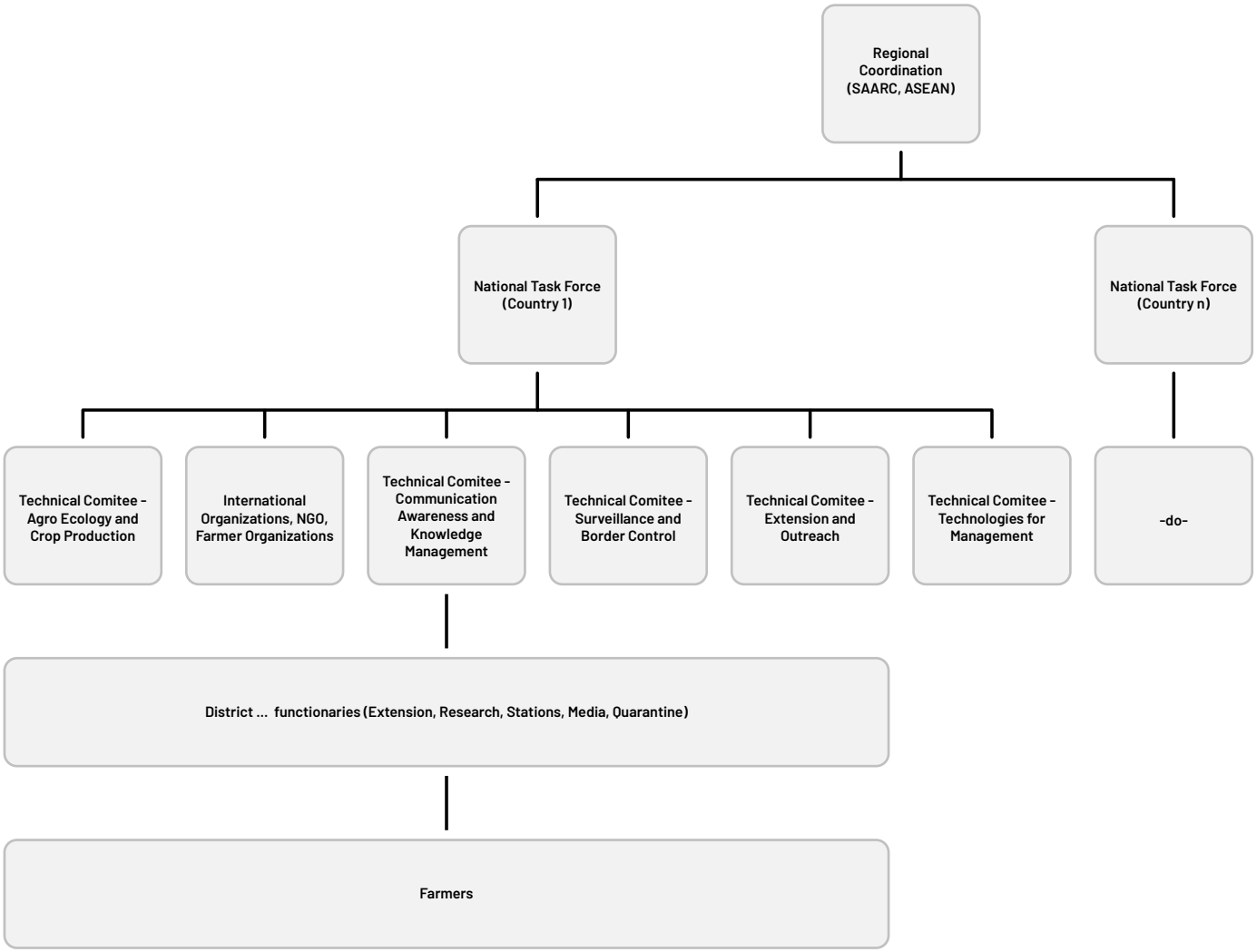
2. to support countries in the region to implement sustainable, IPM-based measures to manage FAW populations in areas affected year-round as well as seasonally;

3. to support the co-ordination of regional and national policies, standards and measures to reduce the risk of FAW outbreaks; and

4. to contribute towards reducing socioeconomic and environmental risks due to FAW infestations and damage in the region.

The key audiences for the guidelines are summarized in the figure below.

Figure 2. *Three-tier hierarchy of stakeholders at regional, national and local levels who form the audience for the guidelines.*



2. Approach to drafting the guidelines

The approach to preparing the document has strongly adhered to the guidelines provided by FAO (FAO, 2021a) contextualizing them to the region and also complimenting sub-regional action plans such as the ASEAN FAW Action Plan. Initially, a desk review was conducted using the general guidelines and all possible information was gathered on the level of awareness of regional stakeholders regarding the following areas: FAW infestation levels; damage to maize; natural enemies observed; plant protection measures; and national and regional management actions taken in response to the pest. This review identified the relevant institutes and resource persons working on FAW. A list of stakeholders and institutes was collated, and an email was sent to each resource person seeking their permission to proceed further in sharing their knowledge and data to develop the guidelines. A survey questionnaire was also developed to obtain information that could not be gathered through the desk review. In the next step, key informants were identified based on their knowledge and based on recommendations from various organizations. Online interviews were then conducted with these informants to understand knowledge gaps in regard to surveillance and sustainable management. Thereafter, based on the key informant interviews and the responses to the questionnaires, a SWOT analysis was conducted. The results of this analysis were validated and endorsed by key informants in validation workshops that were conducted in each focus country to make sure that the collated information was valid for the region as a whole. Understanding the weaknesses of countries made it possible to craft guidelines that can be implemented in each country, and to customize those guidelines.

3. Results of the drafting process

3.1. SWOT analysis

A SWOT analysis was conducted to analyse strengths, weaknesses, opportunities and threats in the focus countries and the region regarding FAW management. The aim was not necessarily to identify solutions but rather to understand what can reasonably be expected to be achieved. The analysis of strengths and weaknesses focused more on current processes, human resources, physical and financial resources, policy, etc. while the analysis of opportunities and threats focused on external factors, such as infestation in adjoining regions, market and economic trends, political and economic regulations, etc. The results of the national SWOT analyses are shown in the figures below, while the overall conclusions derived from them at a regional level are provided in Box 1.

Figure 3. *SWOT analysis for Bangladesh*

Strength	Weaknesses	Opportunities	Threats
Government is committed to the development of agriculture and supportsmeasures taken by MoA Round year cultivation of Maize in the country can speed up process of researchand standardizingtechnologies MoA has stablished an NIF for FAW which takes the single coordination body through which all the FAW related issues must pass Fast-track mode established as a registration pathway for biopesticideand low toxic pesticides General awareness of biopesticides is im proving amongst farmers The product range of biopesticides has increased up to 100 products National agricolture policy provides guidelines for good agriculture practices Department of agricultural extension provides real-time information tostakeholders DA responsible for surveillance and early response has good linkage with all research research institute BWMRI) who are engaged in response strategy development	Limited knowledge for the mass multiplication of a few Biocontrol agents (BCAs) Lack of manpower for field surveys Lack of im proved technology, instrumentsand funding in regional research under BARI Data collected via FAW monitor irregularly used	There is emerging interest and investment by donors to fund a mega project for FAW management	Lack of effective and/or timely communication with and action by neighboring countries where FAW infestation may originate

Figure 4. *SWOT analysis for India*

Strength	Weaknesses	Opportunities	Threats
Extensive identification of several Biological control agents BCAs fitare effective against FAW Availability of sufficient funding and facilities for research on FAW control and management Existence of Indian council of agriculture (ICAR), which is providing technical support to farmers in half te country Increased farmer knowledge on the use of harmful effects of over using insecticides makes FAW resistant to insecticides Development of software for data management by Univecsity, of agriculture sciences (UAS) -Raichur is usedin universities for data management Documentation of the presence of pete, ter, 25 known natural enemies of FAW The country has biocontrol laboratories At district level which can be strengthened to increase BCAs for farmers	Lack of concrete local evidence of the social andeconomic benefits of the use ol biopesticides/BCAs Lack of sufficient efforts to adequatel mass multiply the natural enemies of FAW the feld level and to train farmers Agro-dealers mostly in favour of chemical products due to high sales volumes Convincing the agro dealers to stock biopesticides and BCAs Outcomes of biopesticide usate varie w depending on varying factors including weatherconditions. Farmers are not aware this and as such are put off by non standard outcomes Lack of transparency in Data sharing Information from research fadings not always available in al local languages Frequent updating of threshold level lacking	Economic threshold levels (ETLs) for other crops and pests already exist, making it easierto study and adapt these for FAW Providing subsidies on biopesticides will attract farmers to buy biopesticides	Lack of effective and/or timely communication with and action by neighbouring countries where FAW, infestation, may originate Sub-standard and unregistered biopesticides. BCAs and other products found in the market Over use of chemical pesticides which can result in resistance and environmental degradation Lack of transfer of various strategies for managing and controlling FAW developed by research

Figure 5. *SWOT analysis for the Phillipines*

Strength	Weaknesses	Opportunities	Threats
DOA is capacited and takes quick action in responding to FAW for corn fields. It also provides emergency funds to support yield protection if FAW is reported in rice Department of Agriculture (DOA) has a very good action plan for management of FAW in corn and is being implemented Pesticides are currently the alternatives for FAW management Regional Crop Protection Center (RCPC) collects data from the municipal level and then gives data to higher level to BPI Plant quarantine department inspects all agricultural commodities Capacity building programs are prevalent	Tools unavallable for early detection There is no real time monitoring of fields There is little information on non-chemical management options Lack of capacity to estimate the real extent of vield loss and damage Lack of concrete evidence of the effectiveness of pheromones traps and usage Lack of field monitoring systems	Willingness by BPI &. RCPC to work together and collate. This can strengthen local surveillance Existence of different institutes and departments that are willing to coordinate Country ha naturally existing occurring NE agents e.g. soll born agents	Farmer apathy towards biopesticides arising from the use of sub-standard quality product Infiltration of unregistered bioproducts on the local market

Figure 6. *SWOT analysis for Indonesia*

Strength	Weaknesses	Opportunities	Threats
Government invests heavily in FAW research and Government has good policies in place to address FAW issues Government has taken a mandate to reduce pesticide use National working group WG / expert group under Directorate of Food Crop Protection, Ministry of Agriculture is a single coordinating unit Infrastructure for data collection has been put in place Actions based on data collected is prevalent for EWS There is transparency in data sharing - with most stakeholders in the Plant health System able to access data collected and results	Insufficient resources and manpower as VIntere well as limited capacity building Insufficient technical expertise to follow systematic way of monitoring pheromones and its results/efficaxy Limited resources for working on other host crops rather than corn Data collection is difficult owing to large geographical areas FAW data is being collected only from Corn and their threshold still under research	Interest and willingness of international organisations such as FAO to work with government in surveillance and management options Existence of other hosts from which data can be collected and research conducted	Farmer over reliance on chemical controls

Figure 7. *SWOT analysis for Viet Nam*

Strength	Weaknesses	Opportunities	Threats
Protocols for FAW in place with DPP National level Single Coordinating cell for FAW exists Some capacity building with farmers on surveillance has been done Strong infrastructure to carry out research on biocontrol and alternates to chemicals Good model for the dissemination of research findings Private Sector investment in research exists	*Limited resources for research and training farmers* *Limited funds for surveillance and knowledge-based tools*	Availability of standardised protocols developed for FAW and established thresholds Interventions by international organisation with know-how from the region Availability of commercialised biocontrol agents for FAW	Overlapping outbreaks of other pest and diseases like *Tuta absoluta* and Cassava mosaic virus disease Farmer over rellance on chemicals

Figure 8. *SWOT analysis for Cambodia*

Strength	Weaknesses	Opportunities	Threats
Budgets released from government to take action for FAW management. Have own surveillance system with local protocols on conducting surveillance. Country is member of IPPC follow ISPM - brown planthopper (BPH), Cassava Mosaic Disease (CMD) are some examples. Country is strong on Interferons (IFN) implementation through Flavin Adenine Dinucleotide (FAD) affiliation. Pesticide law in place that regulates inputs Including biopesticides. Pest controt best practices are being issued after trials followed by demonstration of the efficace of the product. Farmer to farmer interactions strong and facilitated.	Low capacity in pest identification, surveillance and knowledge management. Limited number of product available in local markets. No specific policy on FAW management. Limited budget. Time consuming paper based surveillance system still in place. Lengthy government procedures for utilisation of budget leads to lack of action on the ground.	Neighbouring countries engaged and ready for regional coordination.	

Box 1: *Key takeaways from the regional SWOT analysis*

- There is a need to consider having a single regional coordinating body that would bring together all approaches for managing FAW, and that then works to establish trials to validate them, while also leading toward their implementation.
- There is a need to develop a regional insecticide resistance management plan.
- There is a need for greater investment in research and development.
- There is a need for validation and large-scale demonstration of different management options.
- In regard to the socioeconomic context, there is a need to showcase technologies for FAW management and control.
- There is a need for multi-stakeholder representation in task forces in order to determine the affordability, accessibility, environmental safety and scalability of proposed management tools.
- Demonstrations and trials should be piloted first in a few countries, with successes then scaled up across the region.

3.2. Results of stakeholder consultations

This subsection summarizes the main points that were noted in the stakeholder consultations.

Monitoring

- **Surveying FAW on other crops**. Though FAW has a predominant preference for maize, it has a reasonably vast host range and thus monitoring must be carried out for other crops too.
- **Obtaining IPM advice based on scouting**. It is paramount that extension personnel are trained on the scientific way of scouting (using smartphone web applications), identifying the target pest correctly, recording infestation and damage, transferring this data, and seeking expert advice on whether to intervene with management options.
- **Different levels of monitoring and their purposes**. Monitoring in a field has at least two potential purposes: (1) helping the farmer decide if/when treatment might be required; and (2) providing information to an aggregator of such information (at local, national, regional and international levels) for other uses, such as forecasting seasonal changes. These are quite different scenarios. The former occurs mostly locally and has no regional requirement, while the latter is a regional activity (but might provide additional information to support on-farm decision making).
- **Digital interventions**. In many developing countries in South Asia and Southeast Asia, initial hesitancy to shift to phone-based apps from field notebooks is observed but this is usually temporary. One of the advantages of phone-based apps is that they can be integrated with GPS. This system can validate observations and facilitate precise monitoring from a distance.
- **Sharing data**. Data transparency is often a matter of concern in regard to monitoring but it must be encouraged in the larger interest of sustainable IPM.
- **Addressing emergencies**. Unexpected challenges, such as the COVID-19 pandemic, can affect the process of conducting area-wide surveillance and decision making for sustainable management. It is necessary to estimate the optimum sampling number/size so as to ensure a realistic estimation of infestation and damage.

Sustainable practices

- **The existence of multi-disciplinary stakeholders**: Stakeholders in regard to FAW in the region are diverse in terms of their mission and mandates, as well as their type. A multi-disciplinary approach should be applied in controlling and managing FAW in the region, with different stakeholders bringing to the table their different resources, knowledge and expertise.

- **Lack of farmer representation**: While it is positive that most countries in the region have established focal forums for FAW, such as task forces overseeing control of the pest, a key weakness of many of these structures is the lack of farmer representation within them.

- **Low use of biopesticides**: Biopesticides are not readily available in the market, with chemical pesticides often more readily available with agro-dealers. Countries also lack specific policies for the use and regulation of biopesticides. There is a need to create awareness on the use of biocontrol agents, and also to make sure they are available.

- **Insufficient deployment and usage of digital tools**: Digital technology, apps and tools are recognized by all stakeholders in the different countries as key for effectively tackling FAW. Such tools have been used by countries in relation to locusts for decades. However, use and deployment of digital technology in the management of FAW has not yet taken hold, due to a lack of focal co-ordinating bodies, a lack of sufficient funding (to provide digital tools for all extension services, for example), a lack of knowledge of how to use such technology, and/or poor network connectivity in some parts of the region.

- **Limited cross-country/cross-border collaboration**: Although it was mentioned by some stakeholders, cross-border collaboration does not currently seem to be a priority. This could be because most key informants interviewed have local and/or specific geographical mandates within their countries, and do not look beyond the country boundaries.

Plant quarantine

Plant quarantine is an issue in the region. There is a need to improve diagnosis in this area so that it is on a par with that in developed countries.

- **Point of entry**: Many airports and harbours in the region do not have scientific phytosanitary measures in place for the movement of live plant materials within and between countries.

- **Advanced diagnostics**: Molecular diagnostics need to be strengthened across developing countries.

- **Role of quarantine**: Preparedness is key in managing invasive species like FAW. There is a need to put in place an anticipatory database on possible invasive pests. Firefighting methods also need to be in place as a national policy. Quarantine measures should focus on mitigating the spread of invasive species within countries and across the region.

Reporting and communication

- **Early reporting**: Many countries in the region do not immediately announce the presence of an invasive pest, fearing the possible impact on trade and export, etc. This hinders the dissemination of information on the presence of invasive pests and facilitates their spread and dispersal, which increases crop losses.

- **Risk communication**: Countries have a national reporting obligation under the International Plant Protection Convention (IPPC). This is usually for new pests but it also covers the risk of FAW in any place and at any time. Often, however, countries do not fulfil this obligation. Delay in accepting the presence of FAW and procrastination in destroying the initial infestation is one of the reasons why the pest has spread so quickly.

Policy

One of the major weaknesses in the South and Southeast Asia region is the fact that the focus on mitigating the impact of FAW has been restricted to the individual country level or to a narrow geographical area.

- **Early intervention and preparedness**: Task forces have generally been constituted late in the region after FAW had become well-established.

- **Regional co-ordination**: There is currently very little appreciation of the need for a regional approach to FAW.

Financing

- **National funds for research**: Many countries in the region are currently facing financial difficulties. Moreover, funds allocated to research have been diverted to fight COVID-19. As this situation is likely to continue for the next few years, the lack of funding for managing FAW in the region remains a concerne.

SECTION B: TECHNICAL GUIDANCE

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4. Recommendations by key area

Based on the learnings regarding the current status of FAW management in the countries consulted, the following key areas and related recommendations are proposed.

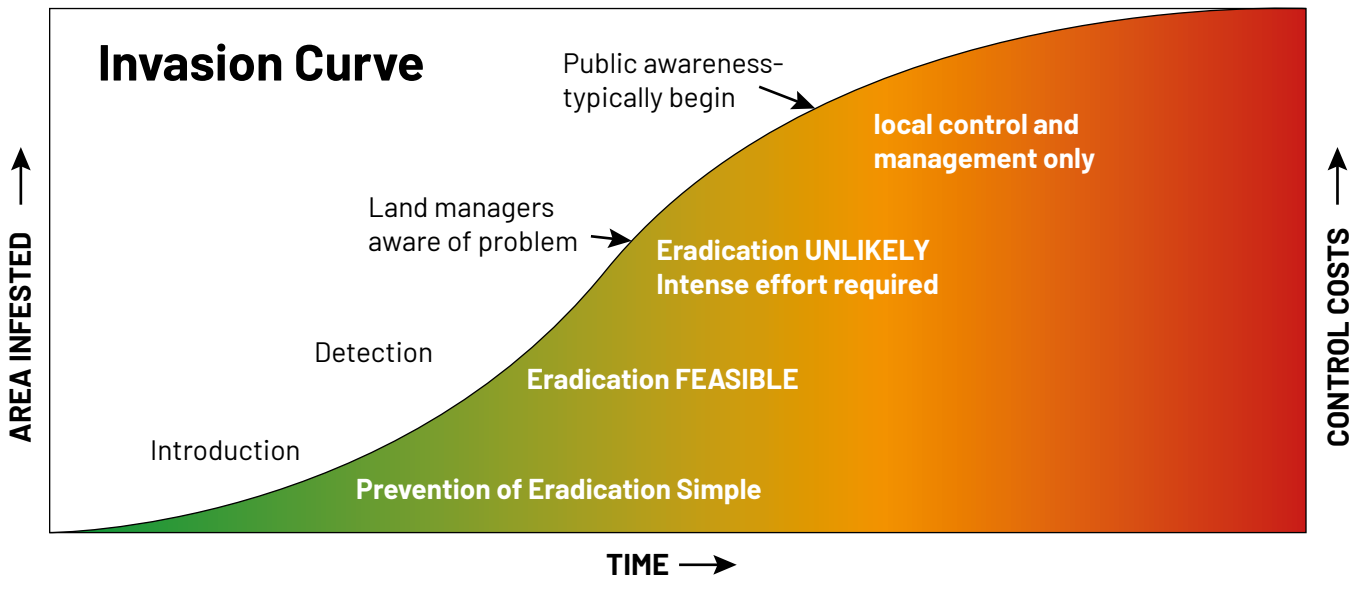
4.1 Key Area 1: Stakeholder coordination and policy change

To ensure successful implementation of IPM of FAW, a policy intervention is necessary to establish a centralized single window for preparedness and a decision-making body that facilitates interaction, monitoring and timely action on all invasive pests, including FAW, is needed. Similarly, there should be coordinated policy intervention at the regional and national levels on sharing information about the presence of invasive pests. Regional stakeholder coordination and cross-sharing of data on invasives, as well as sharing lessons learned during their management, are critical. Sharing information on the identification of natural enemies, molecular sequences, and mass multiplication protocols will also limit the duplication of work across countries in the region. If they are shared region-wise and country-wise, large data can be used to conduct a meta-analysis to highlight the similarities and differences in regard to the extent of damage, crop loss, management efficacy, yield and socioeconomic impact. This is vital to identify gaps in FAW management.

The recommended actions under the Key Area 1 are as follows:

- **Develop a methodology for conducting assessments of invasive species system ecosystems**: Develop a methodology for assessing the system for managing invasives, and then conduct such an assessment to establish the baseline against which changes in the responsiveness of the system can be assessed at a later date if required.
- To define the invasive species system and its functions and actors it is useful to consider the progression of an invasive species as it invades a new country or territory. Consideration of the actions needed at each stage of the invasion curve (Figure 9) to control or manage an invasive species can help to produce a list of functions and actors that are involved in the system. For example, the invasion curve set out in Figure 9 defines four management stages: prevention, eradication, containment and long-term or asset-based management. In addition, the Guiding principles for the prevention, introduction and mitigation of impacts of alien species that threaten ecosystems, habitats or species (CDB, 2002) (see Figure 10) provide guidance on what an invasive species system within a country should aim to deliver, and therefore what functions and actors should be part of the system.

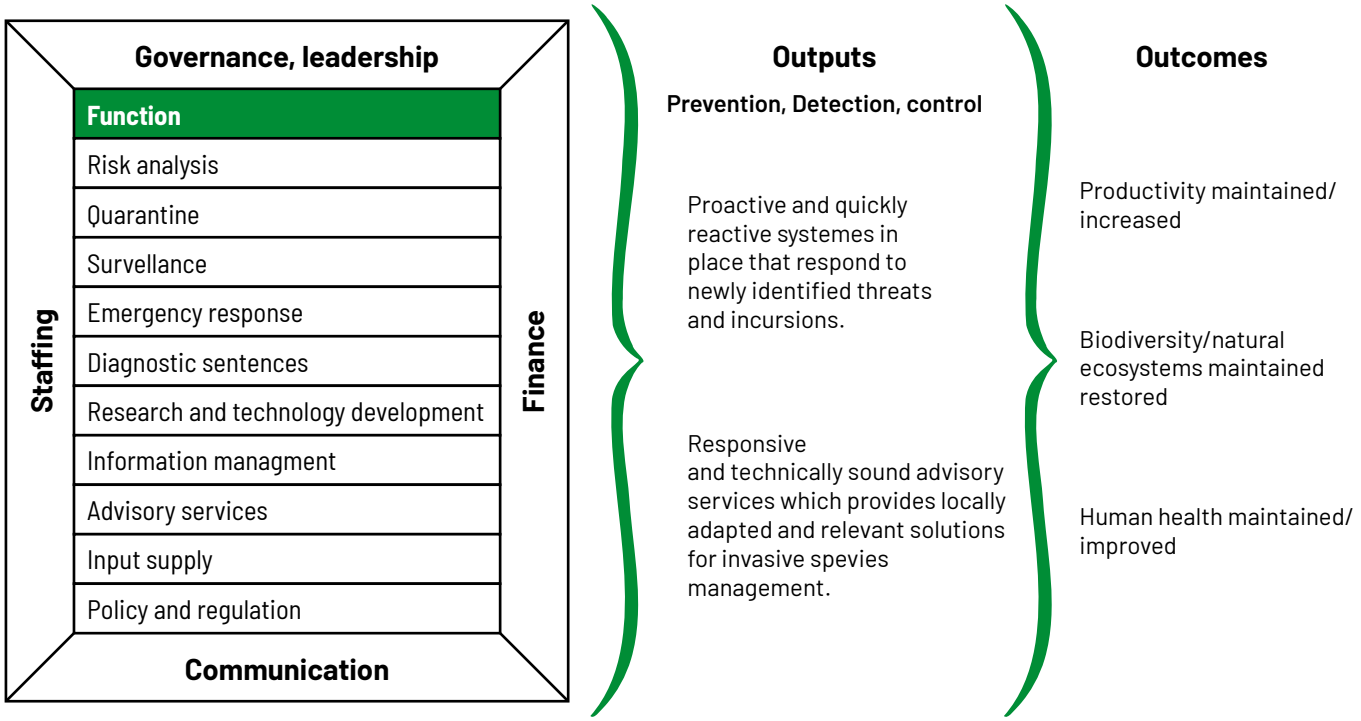
Figure 9. *Strategies for addressing invasive species in relation to the phase of invasion*



Set up a single national coordination body, which should have a central role in the management/mitigation response to an invasive species threat in the country. The coordinating body must have adequate representation from all sectors involved in invasive species management and the ability to effectively bring all stakeholders together to rapidly increase the profile of the invasive species issue. In addition, a member of this body should represent the country in a similar regional co-ordinating body for the South Asia and Southeast Asia region as a whole.

- **Develop an invasive species management strategy** that adopts a multi-species approach.
- **Establish a permanent body** that will be responsible for regulating the system for managing invasive species in the country. This can be a national task force for FAW.
- **Set up a conceptual framework** that sets out the actors working within each of the functions within the invasive species management system (see Figure 10).

Figure 10. *Invasive species system components*

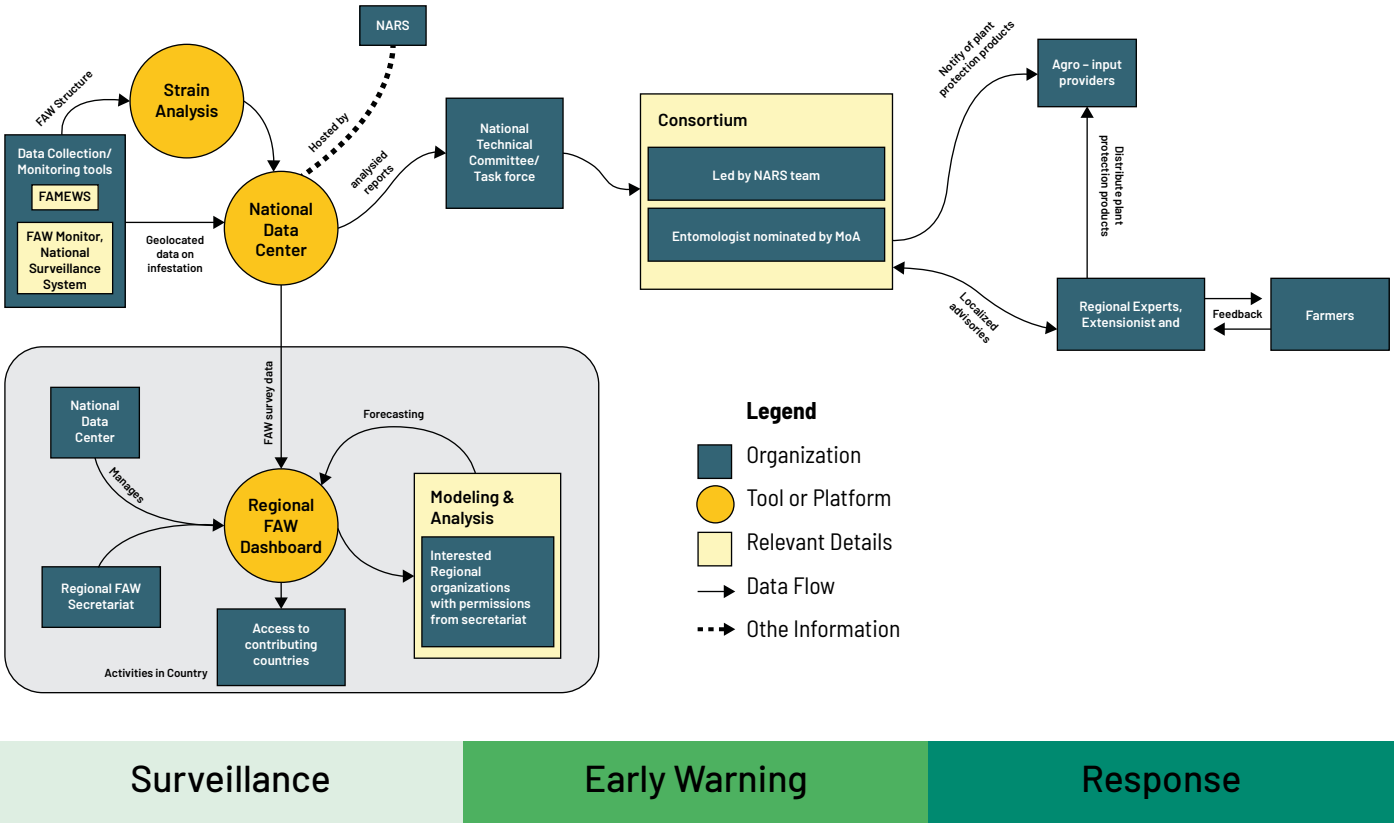


Based on Danielsen and Matsiko, 2016 and CABI, 2018.

4.2. Key Area 2: Surveillance, EWS and emergency preparedness

FAW is established largely in Asia (with probable exceptions in Central and North-East Asia). In the context of FAW, strengthening surveillance and emergency preparedness is relevant in the region where the invasion has not yet taken place. Early warning is significant for population outbreaks in both year-round breeding areas and areas along FAW migration pathways. The following figure depicts the elements of a functioning surveillance, early warning and response (SEWR) system.

Figure 11. *SEWR system for transboundary pests*



Adapted from ACES landscape analysis – CABI, 2020.

The recommended actions under Key Area 2 are as follows:

Ensure that basic phytosanitary functions are implemented

At each surveillance point, the following basic phytosanitary functions should be implemented: identification of pest risk; surveillance; pest diagnosis; import regulation; export certification; transit regulation; and emergency response. This will enable pest management to be well-targeted, cost-effective, and adjusted based on the population density of the location. This will help to avoid the implementation of calendar-based pest control measures, depending on whether a pest is regulated or non-regulated. Monitoring is also crucial to determine population dynamics, to compare infestation levels between sites and to evaluate the effectiveness of controls.

Institute a rapid response system to limit the economic, social and environmental impacts of FAW introductions

Individual FAW introductions must be detected, evaluated and, if deemed necessary, contained as quickly as possible to prevent the introduced population from spreading to other areas. This can reduce the size and duration of regulatory quarantines.

Emergency action refers to a prompt phytosanitary action that is undertaken in a new or unexpected phytosanitary situation. It may constitute a series of co-ordinated activities involving one or more organizations to respond to an FAW incursion into new areas and to bring an emergency under control. Emergency response actions, public outreach and education and inter-organizational communication and co-ordination are key to FAW management. Financial resources and regulatory support are key to responding to phytosanitary emergencies efficiently and effectively, especially if eradication is difficult or impossible.

Establish pest monitoring and an EWS

Pest monitoring and an EWS should be established in each country in the region. This should include field data collection at the farmer level that can then be shared with relevant stakeholders for early warning. Improved collection, recording and transmission of field data is the basis for an efficient and effective national EWS. It should be possible to access information from an online pest database linked to the Geographical Information System (GIS) through the national plant protection organization's website. Stakeholders with internet connectivity should be able to query and display field data on a map, in order to conduct a simple visual analysis of the current specific pest situation. Within the GIS it should be possible to conduct a more complex analysis of the field data, combined with accessing satellite-based rainfall estimates, crop maps and calendars. The online pest database should be established and strengthened to be able to automatically disseminate e-alerts, e-bulletins and pest advisories to stakeholders at all levels via SMS, text blast and email. This will assist in producing FAW management and early warning products that meet the needs of all stakeholders.

Monitoring should be as simple as possible and will require close coordination among grassroots-level extension staff. Monitoring may need to be more intensive in areas where maize is intensely cultivated, whereas it can be less intense in areas where maize is not always growing. Monitoring and surveillance should cover real-time weather data and the percentage of parasitism, pathogens, nematodes, etc. In tropical and subtropical areas, monitoring FAW is more important than the EWS due to continuous cropping and the establishment of pests in those areas. Other hosts of FAW beyond maize should also be monitored by scientists to understand if the pest is expanding its host range and if this could cause serious crop loss. For example, FAW has caused significant loss in finger millet and rabi sorghum in Karnataka and so there needs to be continuous monitoring of these crops in India, as well as of rice in the Philippines.

Harmonize phytosanitary regulations and conduct pest risk analyses

While countries in South and Southeast Asia have porous borders and often engage in transboundary trade, adequate phytosanitary precautions are not always the norm in the region. Implementing national phytosanitary programmes can contribute to harmonization between contracting parties. The International Standards for Phytosanitary Measures (ISPMs) are intended to harmonize the phytosanitary measures that are applied in international trade, and signatories to the ISPM should abide by its regulations to achieve this end.

Applying phytosanitary measures results in higher standards. Such standards must be technically justified through pest risk analyses (PRAs). When conducting PRAs for FAW, the analysis should consider all possible pathways for invasion by FAW, i.e. host crops, seeds, planting materials, packaging materials, transportation methods and as a hitchhiker through natural means (since FAW is migratory). Guidance for undertaking a PRA is provided in ISPMs 2, 11, 14 and 21.

It can be useful to use a web-based tool for conducting PRAs, such as the CABI PRA Tool. Such tools should provide access to the relevant available information and a framework for the PRA process that is closely aligned to international standards.

Systematic scanning of the invasive pests that are on the horizon, using tools such as the Horizon Scanning Tool, can also help countries prepare for future invasions by pests that are currently impacting neighbouring countries and regions.

Commit to exchanging parasitoids among nations

There should be a policy commitment to exchange parasitoids among nations. This is essential in order to effectively manage FAW, especially as high infestation in one region or country will impact other countries in the pathway of FAW migration.

4.3. Key Area 3: Advocacy, awareness and knowledge about FAW

This Key Area is aimed at government policymakers and decision makers who are responsible for designing and implementing response mechanisms about pest outbreaks, as well as other key users. The recommendations under this area support the guidance given by the IPPC on phytosanitary measures for pest surveillance, risk identification, reporting and management, and they also complement the recently published *IPPC Guide to Pest Risk Communication*.

The recommended actions under Key Area 3 are as follows:

- Establish coordination among ministries (agriculture, finance, information and communication).
- Ensure media work closely with national plant protection organizations to produce accurate and consistent reports on pest outbreaks, and particularly regarding responding to misinformation as it emerges.
- As part of communications planning, conduct a needs assessment to collect data about the context, characteristics and gender specificities of communities, communication habits, available resources, existing media, ongoing development communication initiatives, and internal and external communication flows.
- Establish a communication strategy. This should set out systematic communication activities that are implemented based on a well-thought-out methodology and using a variety of tools and channels. The strategy should identify the specific objectives to be met and should provide a reference document against which communication activities can be measured and evaluated. (See Box 2 on the principles to be observed when designing a communication framework for pest outbreaks.)
- Prioritize training for extension staff, agro-dealers, farmer groups, and the media to promote accurate, balanced, clear and well-targeted messages. Communication training specifically on outbreaks should involve senior managers and policymakers, who are often required to make decisions about communication planning and budgeting in such scenarios.
- Engage multiple actors involved in agricultural advisory services, including the farmers themselves, through platforms such as farmer field schools, field days, agricultural shows, plant health rallies, mobile plant clinics and farmer-to-farmer training.

Box 2. *Key principles to be observed when designing a communications framework for communicating on pest outbreaks.*

Timeliness
Pest outbreaks generate confusion, disorientation and misunderstandings. If not properly and promptly addressed they can elicit stress and anxiety, as well as cause significant social disruption and loss of trust and confidence in government's responses. Timely and strategic communication cannot be improvised.

Participation
Stakeholders should be encouraged from the very beginning to contribute with ideas and take the lead in the communication process. This will develop a sense of responsibility - and ownership - for the outcomes of the adopted control methods.

Inclusiveness
Participation can only be achieved if all concerned parties are given the opportunity to do so. Being part of an outbreak planning process does not guarantee "active participation". Communication planners should be sensitive to community roles, gender differences and the needs of marginalized groups.

Goal-orientation
DevCom approaches in outbreak situations should explicitly spell out the goals they intend to attain along with the required tools and methodology.

Trust and credibility
Opinions are shaped by personal experiences, values and attitudes, rather than official communications and data. Understanding these and communicating through trustworthy information sources are critical in an outbreak response. Informing and involving stakeholders early in the management of the pest outbreak can help in building trust and credibility, minimize rumours and increase confidence in government's actions.

Dialogue
Dialogue among farmers, extension workers, scientists and policy makers are the necessary ingredient in building trust, sharing knowledge and ensuring mutual understanding.

Accuracy
Policy makers and response team managers need accurate and timely evidence to evaluate complex issues and propose the most suitable solutions for providing technical support and securing the necessary funding. Good communication can positively influence decision-making processes, reduce the information overload, mitigate conflicting messages and avoid duplication of efforts.

Relevance
Too often, critical messages in emergencies and outbreaks fail their purpose because they were either communicated in an inappropriate format or through an inaccessible channel. The information exchanged or disseminated must be specifically tailored to the intended audiences.

Source: CABI, 2019.

- Institute an internal communication framework that will facilitate information sharing across various government departments and levels of government, research organizations and extension actors.
- Raise farmers' awareness and knowledge of FAW to increase their willingness and capacity to participate in management.
- Increase budgetary allocations to the operations of the plant health regulatory authorities.
- Identify and involve all relevant stakeholders in regional integration and help them to appreciate the need for a regional and national commitment to addressing the threats posed by invasive pests such as FAW, and their impact on food security, trade and the economy.

4.4. Key Area 4: Technical capacity of the plant protection and expansion system

Increasing technical and institutional capacities is key to the successful and sustainable management of pests. Box 3 lists the areas where capacity must be built in Southeast Asia.

Box 3: *Key areas for capacity building*

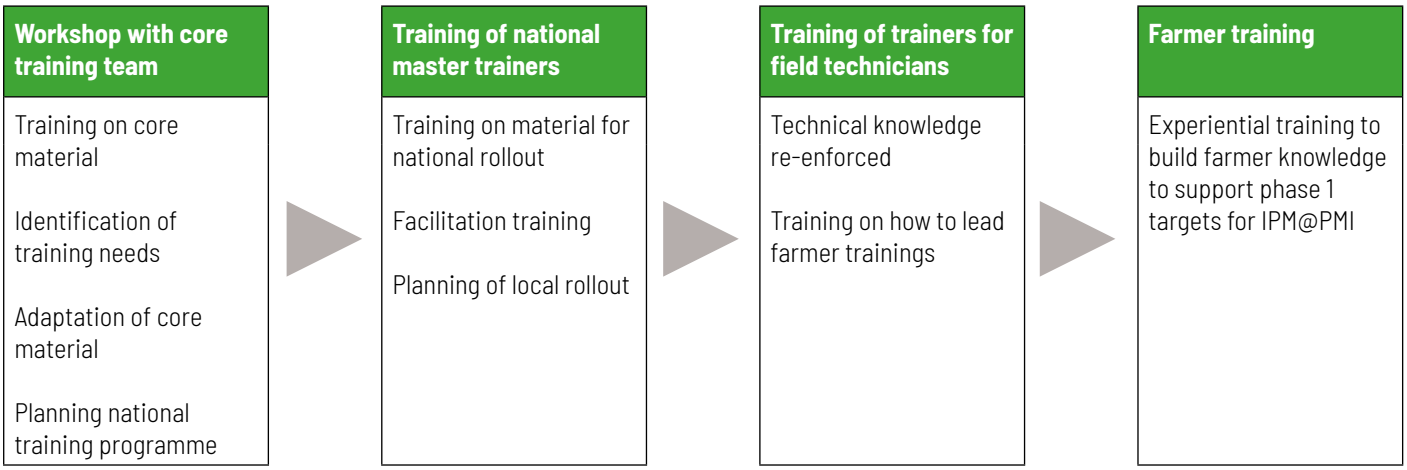
- Molecular diagnostics.
- Mass production of host pests and their natural enemies.
- Conducting lab bioassays and field trials.
- Field diagnosis and giving good recommendations.
- Data management.
- Writing extension messages.
- Monitoring and evaluation at the implementation level.
- Communication at the grassroots level.

The recommended actions under Key Area 4 are as follows:

Link regional capacity building to national capacity-building efforts.

- Establish a model for capacity building. This model should include the following steps: needs assessment, training of master trainers, cascading training to field technicians, quality assurance, and backstopping of rolled-out trainings (William and Constantine, 2019).
- Training of trainers and cascading training to the ground-level officers is recommended. The figure below sets out the steps involved in developing and rolling out an IPM training programme.

Figure 12. *Steps in developing and rolling out an IPM training programme.*



Based on Bateman et al., 2016.

- Use specific institutes within national agricultural research systems in the region as resource **centres** for human resources development on biological control and traditional and molecular identification techniques for FAW and its natural enemies. Examples of these institutes include the Indian Council of Agricultural Research (ICAR) and the Bangladesh Agricultural Research Institute (BARI).
- Establish a regional network/database of FAW experts in South and Southeast Asia.
- Use the research collaboration portal for FAW to facilitate information sharing and the sharing of ongoing research.

4.5. Key Area 5: Integrating local and agro-ecological approaches in the current IPM system for smallholders

Agro-ecological approaches, which can be low-cost, sustainable and smallholder-friendly (Wyckhuys and O'Neil, 2010), should be promoted as a core component of IPM programmes for FAW, in combination with crop breeding for pest resistance, classical biological control and selective use of safe pesticides (Harrison, *et al.*, 2019). Table 1 summarizes agro-ecological practices that have been implemented worldwide and that have been adopted to some degree in Asia as well, evaluating their suitability for use in the region (as reflected through stakeholder consultations).

Table 1. *Agro-ecological practices suited to different stages of the FAW life cycle, and their suitability for adoption in Asia.*

Practice	Stage of insect/mechanism	Global reference	Suitability for Asia and the Pacific region (Tested/practiced)
Field level			
Push and pull technology and night-time light traps	**Adult** – Repelling through intercrop Desmodium and attracting with border crop Napier (to avoid egg laying in the field)	Gebreziher and Gebreyesus, 2019	Fodder grass, like Napier, is popular in the Pacific region. Brachiaria can serve as an alternative. Reduced FAW incidence in Asia to 20–30% of current level (Bakthavatsalam, 2020)
Ecosystem services (wasps, ants, flooding)	**Pupal** – Harvested over 90% of FAW pupae in farmers' fields. Wasps hunt hidden prey due to their ability to burrow down and pull out concealed prey	Harrison *et al.*, 2019; Sumner, 2020	To be evaluated in Asia. Flooding has been successful in countries like Bangladesh
Diversifying farm environment, cover crops and soil fertility management	**Larval**, **pupal** – Nutrient management and increasing soil predators	Baudron *et al.*, 2019	Cover crops like red amaranth (Amaranthus cruentus) or even spices such as coriander (Coriandrum sativum) have recently been applied
Host plant resistance	**Egg and larval stages**	He *et al.*, 2021	Bt-Maize has been introduced in the Philippines and Viet Nam. CYMMIT has hybrid lines with FAW tolerance coming from a conventional breeding pipeline
Early maize planting	**All stages** – FAW development and the number of generations that may attack maize are at least partly controlled by temperature	Early *et al.*, 2018	Winter maize in Asia, particularly in subtropical and tropical areas, can be established as an irrigated crop and can enable farmers to avoid rapid pest development and attack as maize matures during cool winters (Krupnik, 2021)
High-yield short-duration crops	**All stages** – Can be used to accelerate maturation and harvest	Krupnik *et al.*, 2018	These are increasingly becoming available in Asia
Removal of weeds and intercropping; growing companion crops (legumes)	**Larval** – Disrupting larval ballooning effect, reduces the ability of adult females to identify and lay eggs in the crop, shown to reduce pest damage	Rojas *et al.*, 2018; Harrison *et al.*, 2019; Altieri, 1980; Rwomushana *et al.*, 2018; Baudron *et al.*, 2019	Maize intercropping is common in Asia (Yadav *et al.*, 2020), such as with cowpea (Vigna unguiculata), pigeon pea (Cajanus cajan) and soybean (Glycine max)
Maintaining refugia – non-sprayed maize – adjacent to cultivated crop	**Larval**, **pupal** – Reduces resistance; increases natural enemies in ecosystem	Gras *et al.*, 2016	Bird perches are commonly erected by pushing small tree branches into the soil in rice fields to encourage pest suppression (Krupnik, 2021); research in Asia is limited
Landscape level			
Young forest near cultivated maize	Increases the prevalence of natural enemies in ways that benefit farmers	Boyles *et al.*, 2011	Farmers in Asia – at least in more complex landscapes with smaller fields and patches of forest and agroforestry systems – are benefiting in some way from the ecological service of pest control. In mountainous areas young trees are often grown in fields cleared during slash-and-burn agriculture (Mertz *et al.*, 2009)

The recommended actions under Key Area 5 are as follows:

- Survey local levels to identify interventions that are implemented by smallholders, in order to research, validate and refine these interventions.
- Conduct systematic research on the effect of early planting on the establishment of FAW pest pressure build-up during the cropping cycle.
- Plan trials in upscaling programmes to gain an understanding of how the performance of different options varies geographically.
- Work with a multi-disciplinary team to integrate agro-ecological practices into IPM systems as a cost-effective package for smallholder farmers.
- Conduct multi-year and multi-location studies on insect resistance management, especially in the Asia Pacific region, where Bt has been introduced.
- Conduct co-ordinated research to examine the efficacy of different intercrop configurations for FAW control in Asia.
- Evaluate technologies like push and pull and approaches like maintaining refugia using the CESAS model.
- Ensure higher-level policy action and resource allocation to bring about change at the political as well as at the community level, to encourage the maintenance of forests near maize cultivation.

4.6. Key Area 6: Implementing IPM for FAW

IPM refers to combining pest management techniques in order to reduce the need for synthetic pesticides. IPM packages are aimed at reducing yield losses and the huge expenditures incurred by farmers to purchase pesticides. They are also intended to mitigate the health and environmental risks associated with the use (and misuse) of such synthetic pesticides. Overall, the use of IPM strategies can increase the market competitiveness of the Southeast Asia region and, as a result, elevate the income and livelihoods of people involved across value chains. However, there are a few prerequisites for successful implementation of IPM for FAW that need to be considered (see Box 4), including monitoring pests and damage.

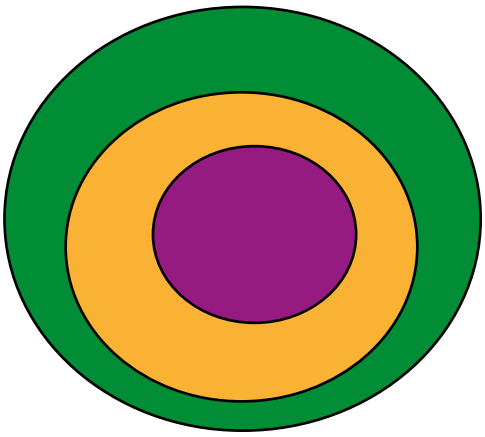
Box 4: *Prerequisites for successful implementation of IPM for FAW*

1. An assessment of current management practices for FAW and their effectiveness.
2. Understanding the status of training of farmers and field extension officers on current management practices for FAW.
3. Knowing which products have received regulatory approval for FAW management, and their current availability in the country (versus the proven biocontrol agents in FAW's native region).
4. Knowing what types of synthetic and biological pesticides are active ingredients in the registered products.
5. Understanding major challenges to achieving sustainable and effective management of FAW in the country.
6. Understanding the status of biologically based management of FAW in the country.

The sound management of FAW requires the use of several tactics targeting different stages of the pest's life cycle. The recommendations under this Key Area 6 relate to implementing these tactics for IPM for FAW:

1. **A management strategy**. Due to FAW's migratory nature, it is recommended that a management strategy include three approaches (as shown by the three colours in Figure 13 below).

Figure 13. *Management strategy for FAW.*



Epicentre of infestation or first infestation. The key is to destroy the first-generation using safe, green pesticide products if they affect a small area.

Surrounding radius. Prophylactic control measures in areas that are likely to get infested. Not much in the case of Asia where FAW has largely infested throughout the region.

Regular monitoring in areas that are not yet infested. Especially along FAW migration pathways.

Table 2 provides some recommendations for managing FAW at different stages of its development.

Table 2. *Scientific recommendations for different stages of FAW and the suitability of their implementation in Asia*

Target stage	**Behaviour and niche**	**IPM tools**	**Status in Asia** (Safety/ Cost / Accessibility)
Eggs	Underside of the leaves; in clusters; milky white – turn blackish just before hatching; covered with hairs.	Natural enemies like egg parasitoid – *Trichogramma* spp. *Telenomus remus*, etc. (Shaiba *et al.*, 2019)	**Extremely safe**. Well tested. Cost depends on production type. Widely researched and mass-produced in laboratories in Asia. Produced in some state laboratories in India. Some small and medium-sized enterprises in countries like Bangladesh and India also make these parasitoids available across a wide area.
Small larvae	Hatch in clusters and create a window-paning effect by scraping the leaves. They drop down the leaves, suspending themselves on a silken thread, and are blown to other plants by the wind.	Virus Neem formulations Parasitoids	**Extremely safe.** Species-specific. **Cost**. Variable accessibility, Entomopathogenic virus is registered and commercialized in Bangladesh. Parasitoids are commercially available in some countries in Asia, while neem formulation is widely available throughout the continent.
Medium larvae	They gradually move to the upper part of the plant. Only one or two larvae are found in a whorl, due to their cannibalistic nature. A large amount of frass is present, which dries and resembles sawdust.	Entomopathogenic nematodes, fungus (*Metarhizium* spp) and bacteria (Bt) (Varshneya *et al.*, 2021)	**Extremely safe**. Species-specific. **Cost**. Unknown accessibility, Effective strains are screened, tested and multiplied at lab scale. Large demonstration plots have proven their efficacy. Some of the bioagents like Bt are commercially available in a few countries.
Adult	Adult FAW is nocturnal. They have very strong fliers and can cover up to 100 km in a night. Females are bigger than males and lay eggs – generally on the underside of the leaf.	Pheromone for monitoring and mass trapping (Esteban *et al.*, 2020)	**Extremely safe**. Species-Specific. **Cost**- USD 0.57/lure- variable. **Accessibility** Pheromone lures and traps are widely available throughout Asia through commercial firms. They are generally used for monitoring though their effectiveness for mass trapping has yet to be proved. Some trials on their use for mating disruptions are in progress.

2. **Increasing crop diversity**. In the Southeast Asia region, maize is often cultivated by several small and medium-sized farmers over one stretch. This constitutes mono-cropping and is an ideal situation for pest expansion, both in terms of intensity and damage caused. As an alternative, mixed farming with legumes as an intercrop should be included as part of the package of practices recommended for the region.

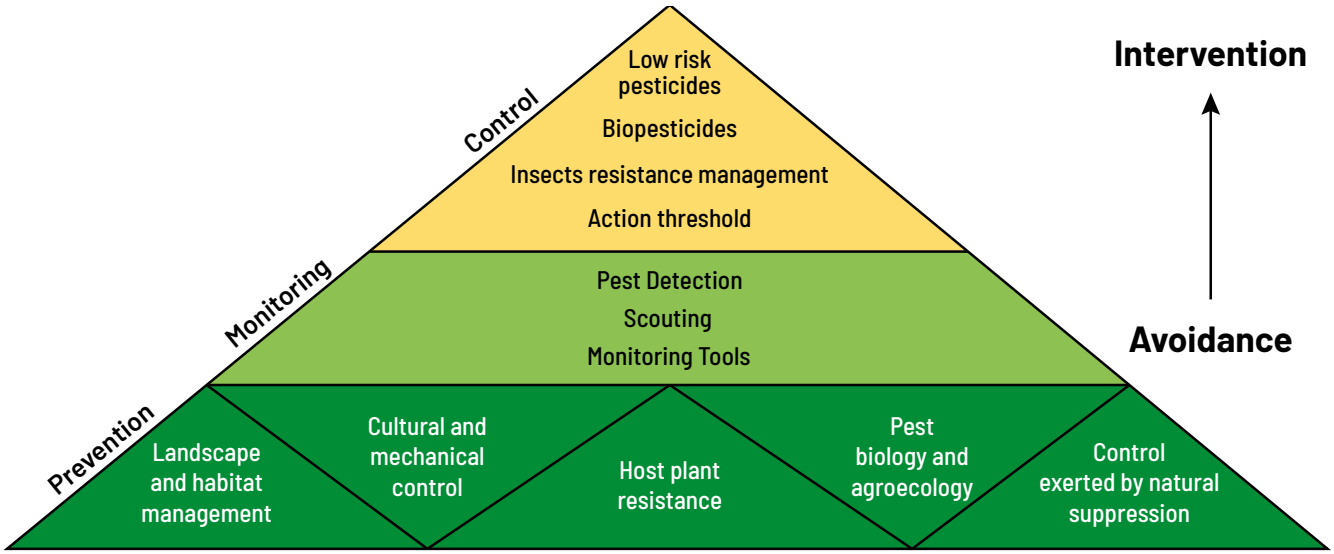
3. **Host plant resistance**. The centrepiece of IPM is host plant resistance, but it takes a long time to arrive at durable resistance. There should be a focus on research through marker-assisted selection using crop wild relatives to integrate desirable resistant traits and transgenic maize. This offers the most ecologically and economically effective IPM strategy for FAW.

4. **Monitoring and scouting**. It is imperative to create awareness among farmers on how to identify FAW damage in the field through scouting, assessing the pest population and its threat to the crop, and making informed decisions on when and when not to apply a pesticide. Reactive interventions must be used only after proper field scouting for the pest has taken place. Scouting can be done following the standardized protocol, following a W pattern or using counts of moths caught in pheromone traps. Scouting is preferred to the use of pheromone, however, as the landholdings in the region are rather small and FAW, being a long-range flier, may be attracted by pheromone and lay eggs in previously uninfested fields. Area-wide monitoring using traps is recommended. With technological advances, automated solar traps, which have been successfully used in Bangladesh, can be used in the rest of the region and adopted for guided monitoring of FAW through regional extension departments at the local level.

5. **Biological control options**. The importance of conservation biological control for FAW management should be understood better in the region. FAW has many natural enemies and many of those were shown to cause substantial mortality in the first year after FAW invaded Asian countries. Surveys to measure the impact of natural enemies should be supported, ideally coordinated across the region. Actions to enhance natural enemy populations should also be supported, such as growing flower strips. Several biopesticides are efficient for FAW control, including products based on neem or Bt. These can be included in IPM strategies. Other agents are currently being researched, such as egg parasitoids from the genus Telenomus and Trichogramma, as well as predators. Results appear promising but it needs to be stressed that the release of natural enemies must consider the agronomic and social-economic contexts that farmers have to deal with in respective countries.

6. **Use of low-toxic chemicals and restrictions regarding pesticides**. Pesticides should be selected judiciously and used only when necessary, as part of a holistic IPM strategy. Pesticide attributes, such as environmental safety, selectivity and environmental persistence, should be considered in the decision-making process. Figure 14 describes the process of decision making, following the IPM principles

Figure 14. *IPM pyramid*



Adapted from Naranjo, 2011.

7. **Knowledge bank**. It is recommended a knowledge bank be established to bring together knowledge about all potential invasives, including FAW, providing full details on their biology, host plants, dispersion potential, and natural enemies (such as predators, parasitoids and pathogens), etc. In the case of FAW, much more must be learned about the ecology, natural enemy regulation, and mass multiplication of beneficial organisms and, above all, there is a need for a realistic assessment of crop losses in different agro-ecological zones.

Box 5 sets out the elements of a successful IPM strategy for FAW.

Box 5: *A successful strategy for implementing IPM*

- *Prevention or avoiding pest infestations* using a combination of eco-friendly approaches at the field, farm and landscape levels, such as cultural control (especially timing of planting), landscape management and host plant resistance all supporting conservation biological control.
- *Implement routine scouting* to identify and respond quickly to pest infestations when they occur.
- *In the event of a pest infestation exceeding the action threshold*, suppress the pests using the most efficacious and low-toxicity pesticides as possible to minimize the potential risks to human and animal health, the environment and the natural enemies of the pest.
- *Provide scientifically validated, evidence-based choices* to farmers on how to mitigate safely and effectively the potential damage to their crop(s) from a specific pest or combination of pests. Cost, efficacy and safety (environmental and human) should be evaluated for each option.
- *Minimize the amount and toxicity of chemical pesticides* applied to achieve control of the pest.
- *Incorporate new, practical findings* as they become available for continuous improvement.
- *Manage insect resistance* to pesticides by minimizing their use.
- Test and formulate a cost-effective IPM package for management of FAW, and test and use agro-ecological options to avoid routine action threshold management of FAW.

4.7. Key Area 7: Innovative research

IPM refers to combining pest management techniques in order to reduce the need for synthetic pesticides. IPM packages are aimed at reducing yield losses and the huge expenditures incurred by farmers to purchase pesticides. They are also intended to mitigate the health and environmental risks associated with the use (and misuse) of such synthetic pesticides. Overall, the use of IPM strategies can increase the market competitiveness of the Southeast Asia region and, as a result, elevate the income and livelihoods of people involved across value chains. However, there are a few prerequisites for successful implementation of IPM for FAW that need to be considered (see Box 4), including monitoring pests and damage.

Research in relation to managing FAW can be basic, strategic or applied. Surveys of farmers' knowledge, attitudes and practices/perceptions are also important to capture farmers' traditional knowledge relating to managing pests where an understanding of which can help improve pest management decisions.

The recommended actions under Key Area 7 are as follows:

- **Conduct basic research** on molecular detection of the invasive FAW, biotype or distinct populations or race profiling, so that valuable time is gained for the IPM decision support system. An understanding of the molecular characteristics of FAW populations can help researchers to understand introduction and migration patterns, predict host plant preferences, understand issues of pesticide resistance, and design management practices for the insect. There is currently a serious dearth of good taxonomic support to precisely identify the natural enemies of FAW. While natural enemies are often identified, mass-multiplied, and released, there is a lack of statistically valid linear and nonlinear ecological modelling to understand predator-prey relationships. Such modelling should be developed. In addition, there is a need to research how varying climatic conditions and maize-growing seasons influence FAW breeding and behaviour. This will help nations in the Southeast Asia region to better develop contextualized response strategies for FAW.

- **Conduct strategic research** that links EWS, rapid decision support and coordinated IPM of FAW. There is a need to conduct a life-table analysis to understand the weak links in the armour of FAW. This could be supported by the use of a genomic database.

- **Conduct applied research** in other areas of research that are needed. This includes action research to develop different IPM packages for different agro-climatic conditions in the region and research on the migration behaviour of FAW populations. To achieve Sustainable Development Goals 2, 12, 13 and 15 it is vital to develop a consortium of biopesticide pellet-based formulations (EPN+Metarrhizium+Bt, + corn flour). Basic and strategic research is needed on fine-tuning the ideal combination and concentration, the formulation, the application method, as well as the effect on natural enemies of FAW, etc. There is also a need for intense systematic surveys to locate regions where the natural incidence of entomopathogen (like Metarhizium sfNPV) infestation is persistent around the year and at high intensity. Establishing a biocontrol facility at such locations could ensure mass multiplication and supply of FAW's natural enemies, with requisite quality assurance

4.8. Overarching remarks

Annex 4 provides a pest management decision guide for FAW on maize that sets out a sequence for implementing the preceding recommendations in the order of prevention, monitoring and control.

The above recommendations have been made in consultation with relevant regional stakeholders who are responsible for implementing them. Success in implementing these recommendations depends on precautions and care being taken, and on building capacity at different levels of operations. Table 3 summarizes the "dos" and "don'ts" to be kept in mind when implementing these recommendations.

Table 3. *Dos and don'ts when implementing the recommendations for sustainable management of FAW*

	DOs	DON'Ts
1	Do constitute a multi-disciplinary unified centralized task force for the management of all invasives, consisting of entomologists, plant pathologists, nematologists, agronomists and socio-economists.	Don't fail to institute a centralized task force at the national level, as not having one can delay the emergency response to any pest invasion.
2	Do constitute a think tank or a special task force to suggest the best course of action.	(For policymakers) Don't make decisions that are not based on in-depth data and science.
3	Do conduct horizon scanning and promote knowledge of losses/ impacts caused by potential invasive threats in neighbouring countries/regions.	Don't implement a mitigation strategy only after accidental introduction. Don't suppress information on the presence of an invasive. Don't conduct poor communication. Don't procrastinate regarding initiating management actions.
4	Do use all methods to eradicate the epicentre of an invasive outbreak as a first step.	Don't use alternate methods of control that will facilitate remnant populations surviving or move live specimens or cultures from one region to another region. Don't leave crop residue in the field itself. Don't refuse to share information about invasives with an adjacent region or country.
5	Do use IPM practices if the pest has become established over a large area or has become endemic (like FAW).	Don't use insecticide as the first option if the pest has become established over a large area or has become endemic (like FAW).
6	Do sow uniformly across the region.	Don't engage in staged planting.
7	Do sow maize with a suitable legume as an intercrop.	Don't engage in mono-cropping of maize.
8	Do scout for the presence of FAW and follow the standard economic threshold level when doing so. Do use pheromone traps for monitoring.	Don't spray at the first sighting of FAW.
9	The first 45 days of maize are susceptible crop stages so do limit control options to this phase of crop growth.	Don't assume pheromone is not effective if FAW adults are not seen (as this could be due to weather or other reasons).
10	Do observe parasitism and entomopathogenic infection.	Don't apply FAW control measures after 45 days for maize.
11	Do use safer pesticides, such as neem, Emmamectin benzoate, etc, that are relatively safe for the environment.	Don't destroy natural parasitism or infected FAW larvae.
12	Do rotate the use of insecticides. Wherever possible, do focus spray on the whorl and don't spray on maize after 45 days.	Don't apply an insecticide just because it is expensive.
13	Do rotate the use of insecticides. Wherever possible, do focus spray on the whorl and don't spray on maize after 45 days.	Don't repeatedly and indiscriminately apply insecticides. Don't spray the entire crop always and don't spray beyond 45 days after germination.
14	Do follow suitable post-harvest intervals and re-entry intervals especially on baby corn, sweet corn and fodder maize.	Don't use hazardous chemicals without adequate supervision and safety precautions.

5. Technical assistance and resource mobilization

There is a need for technical and scientific support from international research institutes, such as CIMMYT, CABI, the International Rice Research Institute (IRRI) and other research institutes at the national level that can address the needs of the region. ICAR and the national research system in India can support the region in addressing diagnosis, identification and human resources development. Management of FAW at the regional level will require the financial support of organizations such as the Asian Development Bank, Australian Funds for International Agricultural Research, USAID, the World Bank, FAO, the SAARC secretariat, and many international research institutes such as IRRI, CIMMYT and the International Crops Research Institute for the Semi-Arid Tropics.

6. Monitoring and evaluation

6.1. Monitoring and evaluation at country level

To ensure effective monitoring of FAW in each country in the South and Southeast Asia region, a task force should be created consisting of entomologists from research institutes, university professors, extension professionals and (importantly) policymakers. This could be just a small think tank. The help of retired knowledgeable officials should be solicited wherever needed. This group should constantly evaluate the monitoring of the severity of infestation, crop loss, area of spread, control measures, resistance and the development of new races. The team should include an official who is responsible for coordinating with the regional team, or a regional coordinator, to interact with countries in order to ensure knowledge transfer.

In each country, there is also a need for an organization that is responsible for collecting, managing and interpreting large datasets that can be used to conduct consolidated analyses at the national and regional levels. Social scientists should also be appointed to address issues relating to socioeconomic impacts.

In addition, there should be clear monitoring of work that has been carried out, and of the planning for the next phase of work. This will require a uniform data collection template, on-time uploading of data to a central database, scientific evaluation of hypotheses regarding agro-ecological technologies and other eco-friendly approaches, etc. It is also important to execute technical and financial monitoring to evaluate the progress of the work. Evaluations should include possible diversion of funds, duplication of research, delays in implementation, reporting of submission delays, and other factors. Also, a template should be developed for monitoring and evaluating the progress of projects. Finally, information should regularly be disseminated by issuing extension e-bulletins and pest advisories, and by publishing research papers

6.2. Monitoring and evaluation at the regional level

Regular regional monitoring should be carried out virtually as well as often as once every six months in a direct meeting of stakeholders. The focus of the meetings should be how to manage FAW at a regional level, drawing on the experience and cross-learning from different regions and countries. Every effort must be made to facilitate diagnosis, human resources development and regional analysis based on meta-analysis. The meetings should be convened and co-ordinated by SAARC, ASEAN and FAO in collaboration with international development organizations like CIMMYT, CABI, etc.

The pattern of evaluation for scientific and technical progress at the regional level should focus more on mutual coordination and cooperation between countries for managing FAW at the regional level. Helping other countries in regard to diagnosis, identification of natural enemies, sharing beneficial, and human resources development should be the criteria. As far as possible, regional evaluation, regional socioeconomic analysis and impact analysis should be the target for evaluation,

Regional platforms should facilitate regional outputs and outcomes, to ensure a global linkage, through experts from each country. Centralized management and a dashboard for implementation, coordination, and data management is needed to ensure knowledge sharing on which decisions for management can be taken. Responsibility for this should rest with SAARC/ASEAN at the regional level, while at the national level one responsible official nominated by the government should take responsibility for coordination within the country and for liaising with international organizations for regional coordination.

6.3. National forums and national task force meetings

At the national level, the relevant stakeholders from each of the technical committees from affected districts should meet once a year to share their experiences of managing FAW and using this technical guidance. This forum should also throw light on the constraints as well as the usefulness of the recommendations in a specific scenario, so that changes can be discussed by a specific technical committee, leading to recommendations that can be presented to the national task force.

A national task force meeting should be held within a month of the national forum. The task force is the steering committee, which would evaluate the recommendations presented by the technical committee regarding the criteria of cost, efficacy, safety, accessibility and scalability, and which would make a decision on the changes to be made to the implementation of the guidance . The steering committee would then issue directives through heads of technical committees and corresponding district heads to revise the guidelines to ensure they remain suitable for the region.

6.4. Publications: national and regional

Publications that combine data and analysis across regions and countries are one way of understanding FAW severity, crop loss, natural controls, decision processes, bottlenecks and policy guidances, which can help in the effective management of FAW regionally and globally. Publications also foster better understanding and exchange of ideas among scientists from different countries, which serves as a foundation for future collaboration and cooperation. Some assistance will be needed concerning written content prepared by regional international organizations.

6.5. Impact analysis: social and economic impact, and direct and indirect benefits

Impact analysis of the implementation of the guidance is critical from both an output and an outcome point of view. It is crucial to evaluate, using verifiable indicators, the success in managing FAW by following the guidances. Such analysis will help stakeholders to understand the impact on yield loss and the level of infestation due to FAW under various dimensions: socioeconomic, environmental, livelihood and gender. The impact analysis should also consider the impact of FAW on subsidiary production lines, like the food and processing industry, which is a vital link to animal husbandry and is dependent on maize for fodder.

Impact analysis requires careful planning before and after the implementation of projects, to document and monitor various indices, including those that address the Sustainable Development Goals. National systems in South Asian and ASEAN nations will be better served if the impact analysis is carried out by a third party to ensure an unbiased result. When conducting impact analyses it is vital to observe the general trend while appreciating differences across regions and countries

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Annex 1: List of institutions consulted

Below is a list of the institutions and stakeholders who were engaged in key informant interviews and that participated in regional consultations, as part of the development of these guidances.

Stakeholders engaged in FAW SEWR

1. Bangladesh Agricultural Research Institute (BARI), Bangladesh
2. National Bureau of Agricultural Insect Resources (NBAIR), India
3. The University of Agricultural and Horticultural Sciences (UAHS), India
4. Bayer India Pvt Ltd, India
5. Ispahani Pvt Ltd, Bangladesh
6. Universitas Gadjah Mada, Indonesia
7. Bureau of Plant Industry, Philippines
8. Plant Protection, Sanitary and Phytosanitary Department, General Directorate of Agriculture, Cambodia
9. National Crop Protection Center, University of the Philippines Los Baños, Philippines
10. Philippine Rubber Research Institute, Philippines
11. Plant Protection Research Institute (PPRI), Vietnam Academy of Agricultural Sciences, Viet Nam
12. Pest Forecasting Institute, Indonesia
13. University of Philippines, Philippines
14. International Maize and Wheat Improvement Centre (CIMMYT), Kenya

In addition, independent consultations working in the agricultural sector from several countries in the region were consulted.

Annex 2: List of stakeholders consulted in the regional consultations/guidance validation workshop

No.	Name of stakeholder	Country
01	Dr S.N. Alam, independent consultant	Bangladesh
	Dr N.K. Dutta, Bangladesh Agricultural Research Institute (BARI)	
	Dr Shaef Ullah, Bangladesh Agricultural University	
02	Dr Sharanabassappa Deshmukh	India
	Dr Kalleshwaraswamy	
	Dr Ankita Gupta	
	Dr Shashank	
	Dr Suby, Indian Institute of Maize Research	
	Dr Shekhar, J.C.	
	Dr D.K. Nagaraj	
	Dr S.J. Rahman, Professor Jayashankar, Telangana State Agricultural University	
	Dr Yubak Dhoj GC	
	Dr M. Farooq	
	Dr Kavita Gupta, National Bureau of Plant Genetic Resources	
03	Dr Ravi Joshi	Southeast Asia
	Dr Gil Magsino	
	Dr Lieum Nguyen	
	Dr Dewi Sartiami	
	Dr Alison Watson	
	Dr Nhat Le	
	Dr Ananda	
	Dr Trin thi Xuan	
	Dr Muhammad Azrai	
	Dr Kieu Nguyen	

Annex 3: Guiding principles for managing invasive species

Guiding principles	Description
General	
1. Precautionary approach	• To identify and prevent unintentional introductions. A strategy is applied when making decisions on intentional introductions, eradication, containment and control measures for established species.
2. Three-stage hierarchical approach	• Prevention of invasive species introduction should be prioritized. • On introduction: early detection and rapid action, including eradication. • If these are not possible, containment and long-term control measures should be implemented. Prevention is generally the most cost-effective and environmentally desirable management method.
3. Ecosystem approach	• For an invasive species management strategy.
4. The role of countries	• Countries should recognize the possibility of their activities as a transboundary invasive species risk. • ctions to minimize the risk, including by sharing appropriate information within the region.
5. Research and monitoring	• Research and monitoring should be undertaken by countries, including baseline taxonomic surveys of biodiversity, and general and targeted surveys for invasive species that involve local communities and others. • Research should include the history, ecology, biology and impacts (ecosystem, social, economic) of invasive species.
6. Education and public awareness	• Public awareness is key to the management of invasive species. There should be an aim to carry out education and public awareness-raising on the causes and risks of invasive species, including for control and management measures, especially with local communities and other groups.
Prevention	
7. Border control and quarantine measures	• Border measures, quarantine procedures, early detection systems and regional coordination measures should be put in place to control unintentional introductions and regulate authorized introductions, based on national legislation and policies. • The measures should be based on risk analyses of invasive species and staff should be trained to implement the measures.
8. Exchange of information	• Countries should contribute to the development of databases and information systems on invasive species, which should be widely shared and disseminated. • Information should include inter alia ecology of invasive species, threats to neighbouring countries, ecology and control methods. Information on a state's import requirements should be shared.
9. Cooperation, including capacity building	• Cooperative efforts may be required between two or more countries, such as neighbouring countries and trading partners, including sharing information on invasive species, development of bilateral/multilateral agreements, capacity building programmes and cooperative research efforts.
Introduction of species	
10. Intentional introduction	• Intentional introduction should only be made with authorization, based on risk analysis for the invasive species. • Only species that are unlikely to threaten biological diversity should be permitted, and authorization should be based on a precautionary approach.
11. Unintentional introduction	• Countries should put in place statutory and regulatory measures to prevent unintentional introductions of invasive species, as well as to strengthen the associated institutions and agencies. • Sufficient resources should be made available. Common introduction pathways should be identified and risk analyses conducted on these pathways.

Mitigation of impacts	
12. Mitigation of impacts	• States should take appropriate measures (eradication, containment, control) to reduce the adverse effects of invasive species. • Methods must be safe for humans and the environment, and acceptable to stakeholders in affected areas. • Measures should be taken at the earliest invasion stage possible.
13. Eradication	• The best opportunity for eradication is in the early stages of invasion so early detection systems focused on high-risk entry points can be critical. • Community support can be essential in carrying out eradication efforts, especially when developed in consultation with communities.
14. Containment	• Where eradication is not feasible, containment of an invasive species is an option. • Regular monitoring is needed, and rapid action is required if new outbreaks are detected.
15. Control	• Measures the focus on reducing the damage caused by, and the number of, invasive species. • Integrated management approaches are often required, including mechanical, chemical and biological control and habitat management.

Annex 4: Pest management decision guide for the fall armyworm on maize

PEST MANAGEMENT DECISION GUIDE: GREEN AND YELLOW LIST

Fall Armyworm (FAW) on Maize

Spodoptera frugiperda

Fall Armyworm eggs (David Jones, University of Georgia, Bugwood.org)

Fall Armyworm larvae (Robert J. Bauernfeind, Kansas State University, Budwood.org)

Adult moth (Robert J. Bauernfeind, Kansas State University, Budwood.org)

Prevention	Monitoring	Direct Control	Direct Control	Restrictions
• Early planting with the first rains as Fall Armyworm (FAW) populations build up later in the crop season. • Avoid planting at different times as this provides a continuous source of food for FAW. • If available, plant maize varieties with resistance to FAW. • Use short duration maize varieties. • Ensure balanced fertilizer for healthy and vigorous maize plants, so that they can compensate for pest damage. • Keep the area around the plot free of weekly grasses. • Plant hedgerows of leguminous trees or parental flowering plants around the fields, to the extent possible, to provide shelter to beneficial insects, predators and birds. • Intercrop maize with compatible and less susceptible crops such as beans • Consider seed treatments when likelihood of occurrence is high (see yellow direct control)	• Start scouting as soon as maize seedlings emerge. • Scout 10-20 consecutive plants in 5 different locations in the field and calculate % of infestation. • Pheromone traps can complement field scouting for FAW, especially on large farms where manual scouting may be difficult. Use 10 traps/ha. • Look for signs/ symptoms of FAW feeding. FAW larvae are extremely hard to find when they are small. At the last instars (4-5) needs 50 times more food then early stage. Look for FAW feeding signs/symptoms in the central emerging leaves (whorl): light coloured patches ("window panes") and elongated holes. Look for accumulation of FAW excreta in the whorl. • Decision point: At early whorl stage (knee high), act if >20% of plants are damaged. At late whorl stage (shoulder high), act if >40% of whorls are freshly damaged. At tassel and silk stage, do not spray pesticides.	• Hand-collect and destroy egg mass and larvae. • Use pheromone trap @5 per acre for mass trapping of moth. • At early crop stage (15-30 days) release egg parasitod Trichogramma pretiosum @3 cards (50000 eggs)/acre – two times at 15 days interval. Release Bracon hebetor wasps at a rate of 800-1200 wasps/ha which will kill FAW caterpillars. • Spray entomopathogenic fungi: Metarhisium rileyi (= Nomuraea rileyi) @2-3 grams per liter or Metarhisium anisopliace @3 gms/1 Note: Spray should be directed into the leaf whorls. • Application of 5% NSKE/4% neem soap @2ml/l/Azadirachtin 10000 ppm @2ml/l to kill neonate larvae. • If available Use virus-based biopesticide SfNPV (100ml/100l of water in 1 ha). First at initiation of pest infestation and subsequent 2 sprays at 10 days interval. Use Spinosad @0.4ml/l of water.	Seed treatment using cyantraniliprole 19.8% + thiamethoxam 19.8% FS @6ml/kg of seed offer protection for 15 to 20 days of crop growth.	• WHO class U (unlikely acute hazardous in normal use).
			Spray any of the chemicals below if pest reaches action threshold- Spray Emamectin benzoate 5 SG @0.5g/l of water or	• WHO class II. IRAC MOA 6. PHI 10 days. Mainly act by ingestion/ has contact action too. Highly toxic to honey bees.
			Spinetoram 11.7 SC @0.5ml/l of water or	• WHO class IV/U. IRAC MOA 5. PHI 14 days. Contact and stomach poison. High bee toxicity.
			Chlorantraniliprole 18.5 SC @0.4ml or	• WHO toxicity class U (unlikely acute hazardous in normal use). REI1/2d, PHI 3 d. MAX 2 sprays/ season.
			Thiamethoxam 12.6%+lambda cyhalothrin 9.5 ZC @0.5ml per liter of water	WHO class II (moderately acute hazardous). REI- 1 d, PHI- 14 d. Max 1 spray/season. Toxic to many beneficial insects and to aquatic organism.
			Note: Spray should be directly into the leaf whorls. At tassel and silk stage, do not spray insecticide. • For fodder maize no insecticides can be recommended except biopesticides.	

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