Action on Invasives
Annual Report
2019

KNOWLEDGE FOR LIFE

Contents

Acronyms

ACES	African Crop Epidemiology System
AoI	Action on Invasives
AU	African Union
Bt	Bacillus thuringiensis
BNARI	Biotechnology and Nuclear Agriculture Research Institute
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Centre
CKAN	Comprehensive Knowledge Archive Network
COMESA	Common Market for Eastern and Southern Africa
CPC	Crop Protection Compendium
CSIR-SARI	Council for Scientific and Industrial Research - Savanna Agricultural Research institute
CSIR-CRI	Council for Scientific and Industrial Research - Crop Research Institute
DEVCO	Directorate-General for International Cooperation and Development (European Commission)
DFID	Department for International Development (UK)
DGIS	Directorate General for International Cooperation (Netherlands)
DOI	Digital Object Identifier
EAC	East African Community
EU	European Union
FAIR	Findable, Accessible, Interoperable and Reusable
FAO	Food and Agricultural Organisation of the United Nations
FAOSTAT	Statistical database of the FAO
FAW	Fall armyworm
FAMEWS	Fall Armyworm Monitoring and Early Warning System
HST	Horizon Scanning Tool
IAPSC	InterAfrican Phytosanitary Council
ICAR	Indian Council of Agricultural Research
ICIPE	International Centre for Insect Physiology and Ecology
ICT	Information and Communication Technology
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
IOBC	International Organisation of Biological Control
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
IPRRG	International Pest Risk Research Group
ISC	Invasive Species Compendium
KALRO	Kenya Agricultural and Livestock Research Organization
KEFRI	Kenya Forestry Research Institute
LMICs	Low- and middle-income countries
NBAIR	National Bureau of Agricultural Insect Resources
NISSAP	National Invasive Species Strategy and Action Plan
NPPO	National Plant Protection Organisation
PAD	Precision Agriculture for Development
PMDG	Pest Management Decision Guide
PPRSD	Plant Protection and Regulatory Services Directorate (Ghana)
PRA	Pest risk analysis
PRISE	Pest Risk Information Service
RAB	Rwanda Agriculture and Animal Resources Development Board
RPPO	Regional Plant Protection Organisation
RUE	Rabbit Urine Extract
SADC	Southern African Development Community
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable Development Goal
SMS	Short message service
TWG	Technical Working Group
US	United States
USAID	United States Agency for international Development
ZARI	Zambia Agricultural Research Institute

Introduction

Action on Invasives is a programme led by CABI addressing the growing problem of invasive species in agriculture and the natural environment. This is not a new problem, but climate change, trade and tourism are all exacerbating the situation and increasing the urgency for a co-ordinated and effective response at local, national and regional levels. Invasive species disproportionately affect vulnerable, rural communities and undermine sustainable development, so it is not surprising that the Sustainable Development Goals (SDGs) include a goal to "*introduce measures to prevent the introduction and significantly reduce the impact of invasive species on land and water ecosystems and control or eradicate the priority species*" (SDG 15.8).

It is internationally agreed that the overall technical approach to managing invasive species comprises three tiers: prevention (stopping them invading in the first place); early detection and rapid response (eradication and/or containment); and – for species that become permanently established – control and mitigation of the impacts. All too often it is the third tier that gets most attention, despite the fact that prevention is widely recognized as being more cost-effective. Action on Invasives is designed to enable countries and regions to adopt this three-tiered approach through four interrelated work packages:

- stakeholder engagement – fostering the right partnerships
- providing best practice solutions for invasive species
- community action – bringing information and action to scale
- knowledge and data – creating and using knowledge

The lead donors to the programme are the UK Department for International Development (DFID) and the Netherlands' Directorate-General for International Cooperation (DGIS). A number of organizations have also contributed to the aims of the programme in 2019 through supporting specific projects, including AgBiTech, the Food and Agricultural Organization of the United Nations (FAO), the Netherlands Ministry of Agriculture, Nature and Food Quality, and Provivi Inc.

While the aim of Action on Invasives is to strengthen overall capacity to tackle invasive species at a national level, a number of activities focus on specific priority species as examples or case studies. The first focus species were fall armyworm (*Spodoptera frugiperda*), *Tuta absoluta (*tomato leaf miner) and parthenium weed (*parthenium hysterophorus*). During 2019 opportunities were taken to add species including papaya mealy bug (*Paracoccus marginatus)* and the invasive tree *Prosopis juliflora*.

Similarly, part of national capacity involves regional and international collaboration, so Action on Invasives is working through selected countries as foci from which activities can be regionalized. The first participating countries in this regard were Ghana, Kenya, Pakistan and Zambia, in 2018, and in 2019 activities were also initiated in Rwanda and Bangladesh, both countries in which Plantwise has been operating successfully. This report describes progress during 2019, highlighting progress, lessons learned and next steps in each of the four work packages introduced above. It also reports evidence of early outcomes of the programme.

Monthly highlights

FEBRUARY

In Botswana, CABI hosts high level policy summit on invasive species.

MARCH

Evidence note 'Parthenium: Impacts and coping strategies in Central West Asia' is published

APRIL

First report of the biocontrol agent *Telenomus remus* attacking fall armyworm in Africa is published

MAY

CABI and partners publish technical brief for fall armyworm in Kenya

SEPTEMBER

Harmonized guidelines adopted for biopesticide registration in East African community

OCTOBER

Enhanced Pest Risk Analysis Tool launched, with free access for 97 low- and middle-income countries

DECEMBER

New portal added to the Invasive Species Compendium on *Fusarium* Tropical Race 4 of banana

Programme highlights

Stakeholder engagement

- Fall armyworm response plan developed for Bangladesh
- *Prosopis* management strategy drafted in Kenya
- Parthenium action plan being implemented in Pakistan
- Papaya mealybug action plan developed in Kenya and implementation commenced
- Ghana National Invasive Species Strategy and Action Plan finalized
- Africa continental invasive species strategy drafted
- High-level invasive species summit conducted in Botswana and recommendations endorsed at the CABI Review Conference
- Assessment of cost of invasive species in Africa in progress
- East African Community adopted harmonized guidelines for the registration of biopesticides and biocontrol agents
- Regulations on biological products for pest control reviewed in Ghana
- Methodology for a national invasive species system assessment developed, and piloted in Kenya
- Engagement with regional and international co-ordination activities on fall armyworm and invasive species

Best practice solutions

- Horizon scanning and prioritization of potentially invasive plant pests in Ghana
- Surveillance programmes in Pakistan confirmed the presence of *Tuta absoluta* and fall armyworm
- Biological control quarantine facility completed in Pakistan, and approved by the authorities
- Import to Pakistan of *Listronotus* beetles from South Africa for the biological control of parthenium. Host range tests in quarantine in progress
- Winter rust found attacking parthenium for the first time in Pakistan
- Papaya mealybug surveys in Kenya revealed high pest incidence and low populations of parasitoids, providing a strong basis for classical biological control

- Parasitism of fall armyworm is increasing in Africa, with over 12 parasitoid species found, providing opportunities for augmentative and conservation biological control
- Two parasitoids of fall armyworm from Latin America are being reared in quarantine in Switzerland. *Eiphosoma laphygmae*, which is potentially specific to fall armyworm, will soon be delivered to laboratories in Africa and Asia for further studies
- Several trials of non-chemical approaches tested in Ghana, Kenya and Zambia show some cost-effective results, suggesting that fall armyworm can be controlled without chemical insecticides
- Collaborations in Rwanda identified formulations of entomopathogenic nematodes suitable for large-scale field trials
- Surveys for natural enemies of *Tuta absoluta* in Zambia and Ghana identified the presence of predators and parasitoids that are successfully used as biocontrol agents in North Africa and other regions

Community action

- Socioeconomic surveys conducted in Zambia and Kenya to understand farmers' knowledge, attitudes and practices on fall armyworm, papaya mealybug and *Tuta absoluta* management
- Communication campaigns conducted in Pakistan, Kenya, Ghana, Zambia and Bangladesh through a variety of gender-responsive media and communication channels – 6.6 million people reached
- Farmers who heard the fall armyworm radio campaign in Zambia were more likely to use preventative control measures than they had been previously
- Fall armyworm technical brief approved by the ministries of agriculture in Kenya and Ghana, and widely disseminated across traditional and social media
- Framework for strategic development communications for invasive species outbreaks developed
- Area-wide management of fall armyworm piloted in eight communities in Kenya using various lower-risk control products
- Practicality of *Tuta absoluta* integrated pest management (IPM) products being assessed with farmers in Kenya

Knowledge and data

- Expanded Pest Risk Analysis (PRA) tool launched in October 2019 with a new species-initiated PRA workflow and improvements to user experience
- Gratis access to the PRA tool and Crop Protection Compendium (CPC) offered to national plant protection organizations (NPPOs) in 97 low- to middle-income countries
- Training on the PRA tool provided to five countries in Asia
- Over 2 million visits to the Invasive Species Compendium (ISC) in 2019 – 60% users under 35, 56% female
- New species portal launched on *Fusarium oxysporum* f.sp. *cubense* Tropical Race 4, an invasive disease of bananas
- Over 400 new factsheets published on the ISC, including 79 new Pest Management Decision Guides
- New background database system completed for managing species distribution data, delivering improved data to the ISC
- Annual visits to the Horizon Scanning Tool (HST) up by 13% compared to 2018
- New gender-responsive Action on Invasives Data Policy and Strategy developed

Stakeholder engagement: fostering the right partnerships

National, regional and international stakeholders in the public and private sector need to work together to achieve sustainable management of invasive species. Action on Invasives is building on and extending the linkages established through Plantwise and other programmes. Through such partnerships, effective policy, plans and practices can be developed and implemented.

Progress in 2019

National response plans for managing priority invasives

As in many countries, the arrival of fall armyworm in Bangladesh was met with much concern, and multiple efforts to address the situation have been initiated, including by the FAO and the International Maize and Wheat Improvement Centre (CIMMYT). In collaboration with the Bangladesh Wheat and Maize Research Institute, a workshop was convened bringing together senior personnel from national and international organizations including the national task force, to ensure a co-ordinated approach. The workshop was facilitated by CABI, CIMMYT and the Bangladesh Agricultural Research Institute. Priority areas for action identified were: awareness and knowledge enhancement; establishing a national monitoring and surveillance system; capacity building and policy issues for fall armyworm management; and research and development focusing on biological control (including classical biocontrol), microbials and other biorational methods. In 2020 Action on Invasives will support the elements of this action plan where others are not already doing so; additionally, CABI has been contracted by the FAO to assist with implementing some activities.

The invasive tree *Prosopis juliflora* is spreading in Kenya, and while some stakeholders are trying to manage it, others see it as a resource – for example as a source of energy. Through an ongoing collaborative research project with CABI, the Kenya Forestry Research Institute (KEFRI) identified the need for a national strategy and requested assistance from CABI. A workshop was therefore conducted to begin the process of developing a national strategy, involving key stakeholders from the Ministry of Environment and Forestry, KEFRI, the Kenya Forest Service, the National Environmental Management Authority, the Ministry of Agriculture and Livestock Development and the Council of Governors. CABI facilitated the workshop, which produced a draft strategy with five objectives: 1) enhancing awareness of *Prosopis juliflora* invasion and its impacts; 2) detecting and preventing new invasions; 3) managing established invasions and restoring degraded landscapes; 4) enhancing research and development; and 5) strengthening capacity, resource mobilization and co-ordination. The draft strategy will now be taken to wider stakeholder consultation.

The national parthenium action plan in Pakistan is currently being implemented; it comprises six short-term activities, 15 medium-term activities and nine long-term activities. Activities supported by Action on Invasives include collection of baseline data on the socioeconomic and human health-related impacts, as well as general awareness and perceptions, which were included in the parthenium Evidence Note prepared by the programme in 2018 and finalised in 2019. Work on biological control and communication campaigns for parthenium are reported on in later sections.

The papaya mealybug is native to Central America, but over the last two to three decades has spread to many other parts of the world. It reached East Africa in the last few years, and has been reported as causing significant damage. A survey was conducted in Kenya (see later sections), and the results were discussed at a workshop to identify best practice management options and develop a plan of action. Actions were agreed in relation to policy, regulations, farmer capacity, extension support and research. CABI was asked to support the plan in assessing existing natural enemies and the potential to implement classical biological control, which has been successfully used against the pest in West Africa and elsewhere.

National and regional strategies for managing invasive species

A National Invasive Species Strategy and Action Plan (NISSAP) provides an overall framework for a country to respond to the threat of invasive species. Action on Invasives has supported Ghana to complete its first cross-sectoral NISSAP, led by the Environmental Protection Agency, working with stakeholders in agriculture and other sectors. Hitherto, various policies noted the need for co-ordinated management of invasive species, and the basis for that is now in place. A draft NISSAP was reviewed and finalized through consultations with the relevant ministries, municipal and district assemblies, the private sector, academia and civil society. The completed strategy sets out the actions required by different stakeholders, including defined mechanisms for ensuring a co-ordinated approach. Implementation will commence in 2020.

At the continental level in Africa, CABI, the International Centre for Insect Physiology and Ecology (ICIPE) and the International Institute of Tropical Agriculture (IITA) have facilitated the development of a draft invasive species strategy with the African Union Commission (AUC). This has included consideration of a possible fund for emergency response to invasions such as fall armyworm, as requested by the AUC's Specialized Technical Committee on Agriculture, Rural Development, Water and Environment. Consultations have been held at the AUC, as well as with various stakeholders, and the first draft of the strategy was discussed at an AUC meeting in Douala. The strategy will be finalized in the first quarter of 2020.

Providing evidence of invasive species impacts to inform decision-making

An Invasive Species Policy Summit was held in association with CABI's Member Country consultation in February 2019 in Gaborone, Botswana. A number of keynote speakers and three expert panels presented and discussed the impacts of invasive species, technical solutions for their management and how to enable and scale solutions through policy. The 70 delegates included policymakers, research directors, the private sector and civil society from across Africa, as well as CABI's liaison officers from 19 member and prospective member countries. The summit urged countries to develop national invasive species strategies; establish national priorities; collaborate regionally; collect and use data and evidence; increase investment in addressing invasive species; and promote sustainable management. These recommendations were discussed and endorsed at the CABI Review Conference in September 2019. In support of the collection and use of evidence, CABI undertook to produce an up-to-date assessment of the overall cost of invasive species in Africa. The study has commenced and will be completed in 2020.

In Kenya the parasitic weed dodder (*Cuscuta*) was highlighted by the invasives sub-committee of the Plantwise steering committee as of increasing concern. A survey was undertaken to gather evidence on its impact in western Kenya, where it appears to be particularly invasive. Of the 116 respondents (46% female) 97% had experienced *Cuscuta* on their land, 82% considered it a major weed and 40% reported it causing a decrease in crop yields. Confirmation of the species is awaited, at which point an action plan can be developed.

Together with Plantwise, an initial study on the response to fall armyworm in Ghana was made with the aim of quantifying the benefit of implementing a planned and co-ordinated response. Based on data from CABI surveys, the Ministry of Food and Agriculture in Ghana and FAOSTAT (the statistical database of the FAO), the study sought to estimate the economic costs of fall armyworm in Ghana under different control scenarios. Three different scenarios were evaluated: one with no farmer-applied control measures, one with limited control measures and one with the proactive control measures used in Ghana in 2017. The results from this preliminary study indicate that the response reduced losses by around USD 15 million over the first year. Further work is needed to improve the methodology in order to produce more accurate estimates.

Promoting registration of biological-based solutions

The regulatory environment affects the availability of products for controlling invasives, including biopesticides and biological control agents. CABI is a member of the East African Community (EAC) Technical Working Group that has developed harmonized guidelines for the registration of biopesticides and biocontrol products. The aim is to provide a harmonized registration framework, facilitating mutual recognition and sharing of registration data. This should increase the consistency of registration, reduce costs, and so make registering biological products more attractive to private companies. The guidelines were adopted by the EAC Council of Ministers in September 2019, and member states were urged to implement them. Rwanda is keen to proceed with domestication of the guidelines, so a meeting was convened in Kigali for regulators in the country, including the Agrochemical Advisory Council, whose mandate includes approval of biological pesticides, to plan the implementation of the guidelines. Another meeting was held with agrodealers to explain the implications of the guidelines, with the aim of promoting applications for the registration of biological products.

In Ghana, where in 2018 the government promoted "biorational" products for fall armyworm management, a seminar was held with policymakers and others on the use of lower-risk products and biological control. Pesticide registration procedures have been reviewed to examine how they could be strengthened in the area of biological pesticides, and so make such products more readily available.

Action on Invasives has continued collaborating with AgBiTech and Provivi, two companies seeking to register low-risk biological products (a virus and a pheromone, respectively) for the control of fall armyworm. Field trials in support of registration have been completed, as well as other work with communities (reported below).

Building consensus on invasive species responses

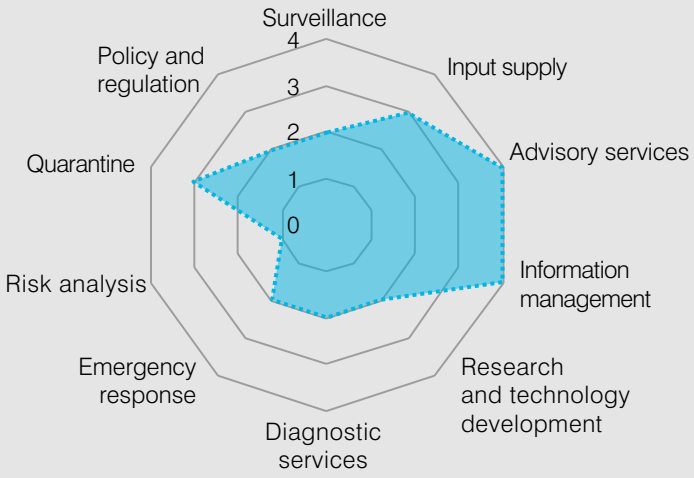
Drawing on approaches used in human health systems, experience in Plantwise, as well as various existing capacity assessment tools, a methodology for assessing the overall capacity of a country to respond to invasive species has been developed and tested in Kenya. The assessment provides both a baseline for future comparison and also a way of identifying where efforts to strengthen the system could be directed. The methodology has three steps: a desk review, a stakeholder workshop and key informant interviews. In Kenya it was found that while some of the different parts of the system may work well, overall co-ordination is lacking, and some sort of co-ordination body is required, with a legal basis and adequate representation from all sectors. An overarching strategy in line with international commitments is also needed (see the section on monitoring and evaluation for further details).

Contributions continue to be made to global co-ordination of initiatives against invasive species. CABI is a member of the Convention on Biological Diversity Inter-agency Liaison Group on Invasive Species, and observes at the International Plant Protection Convention (IPPC) Commission on Phytosanitary Measures and related meetings, such as the Technical Consultations of Regional Plant Protection Organizations (RPPOs). CABI is a member of the International Fall Armyworm Research for Development consortium led by CIMMYT, and contributes to the FAO's fall armyworm programme, and expects to be a member of the Technical Committee of FAO's new Global Action on Fall Armyworm Control.

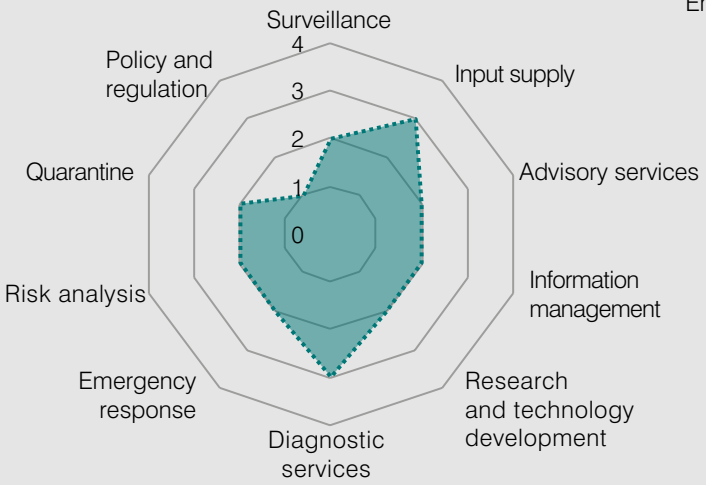
Assessing Kenya's invasive species system performance

Stakeholders assessed invasive species system performance of 10 functions using four indicators; i) availability, access and coverage, ii) acceptability, iii) timeliness, and iv) affordability. Each was assessed on a scale of 1 to 5 (low to high).

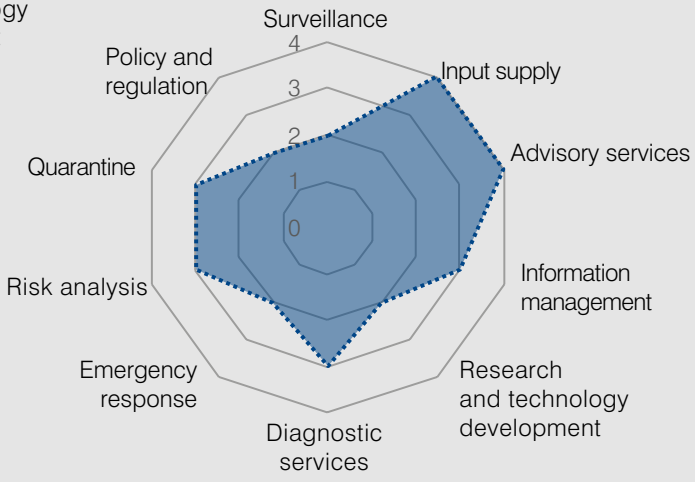
Affordability



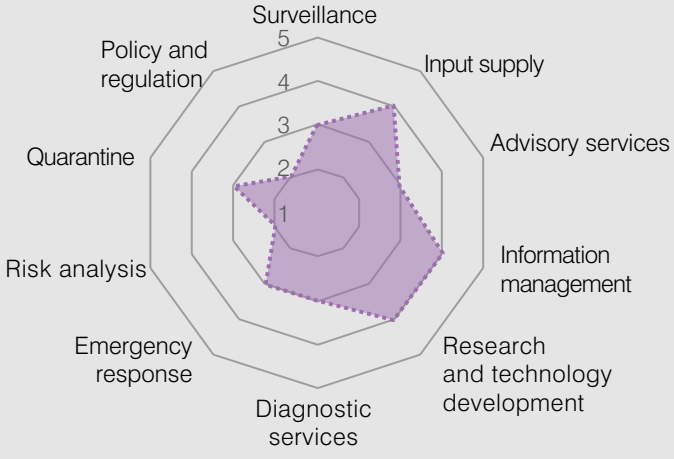
Timeliness



Acceptability



Availability, access, coverage



Lessons learned

The need for improved co-ordination amongst stakeholders has again come to the fore, such as during the finalization of the NISSAP in Ghana, and during the invasive species system assessment in Kenya. While many agencies play an important role in the management of invasive species, they are often working in isolation from each other. Generally, stakeholders acknowledge the need to have in place a co-ordination mechanism that enables all agencies with a relevant role to play their part. But lack of clarity in legal and institutional frameworks and mandates, as well as organizational rivalries, can all impede the establishment and functioning of such mechanisms.

The spread of fall armyworm (reaching Australia in early 2020) continues to highlight the importance of invasive species, simultaneously risking reinforcement of the single-species reactive rather than proactive approach. When resources are short, persuading governments to invest in prevention rather than response is still an uphill struggle.

The engagement CABI carries out with private sector companies on lower-risk methods for the management of invasive species is constructive. The key challenge remains the speed at which such products get registered, so while proper processes are necessary, work to establish and implement efficient regulatory processes is still important. The EAC harmonized regulations for biopesticides and biological control products do have a provision for fast-track registration of low-risk products, and implementation of this process is now required.

While the stakeholder engagement work package has a number of clear aims and activities, varying country contexts mean that there can be no blueprint for intervention. Rather, an adaptive approach is required, identifying and using opportunities and "policy windows" as they occur.

Next steps

Activities will continue in the four original Action on Invasives countries, and will be intensified in Rwanda and Bangladesh, where they were initiated in 2019. Activities will also start in Burkina Faso – having been delayed from 2019 for budgetary reasons.

Support for national and regional planning processes will be continued for prioritized species and for broader strategies. This will include support to establish appropriate co-ordination mechanisms, and assisting with the implementation of key activities falling within the scope of Action on Invasives.

Work to provide evidence and document the impact of invasive species will continue through individual species studies, as well as a large study on the overall economic impact of invasive species in Africa. This will also be linked to a separate initiative involving conducting a feasibility study for establishing a mechanism to regularly estimate the damage to crops from invasive and other pests (see Annex 1 – Associated projects).

Opportunities will be taken to support the development and implementation of regulatory frameworks that encourage the registration and use of lower-risk control products. In Pakistan the government has decided to phase out highly-hazardous pesticides, as long as safer alternatives can be found; however, there is no registration protocol for biological products. We will collaborate with an ongoing CABI project in Pakistan that is registering a biocontrol product for aflatoxin management to support the development of a biological pesticide registration protocol.

In East Africa we will support implementation of the EAC harmonized regional guidelines for registration of biopesticides and biocontrol agents.

The approach piloted in Kenya for assessing the country's capacity to respond to the threat of invasive species facilitated stakeholder engagement in defining and understanding the system as it currently stands and identifying areas for strengthening. In addition to following up in Kenya, the approach and tools developed will be applied in Bangladesh and Zambia.

Engagement with regional and global stakeholders in invasive species management will continue, with the aim of promoting the sharing of results, experience and lessons learned.

Providing best practice solutions for invasive species

Prevention, early detection and control of invasive species requires a set of technologies and processes that are efficient and effective for risk assessment, diagnostics, surveillance, eradication or suppression, and mitigation of impacts. Action on Invasives works with partners to strengthen capacities to develop, test and validate such solutions and practices through specific case studies.

Progress in 2019

Preventing invasive species: prioritizing potential plant pests in Kenya and Ghana

Horizon scanning was initiated in Kenya in 2018; this listed 126 species as potential invasive plant pests not yet present in the country. A paper describing the recommendations for prevention, surveillance and early detection of priority pests is being finalized. A similar prioritization was initiated in Ghana in October 2019, with 22 participants; 115 arthropods, 34 pathogens and 14 nematodes not yet present in Ghana were identified as potential invaders. An express risk assessment is being carried out for each species by at least three individual assessors, covering the likelihood of entry, establishment and spread, as well as the expected level of socioeconomic and environmental impact. At a second workshop in 2020, a final risk score will be determined through consensus, leading to a ranking of species according to their potential threat. For the high-risk species, actions such as full risk assessments, surveillance or contingency planning will be selected to mitigate the risks.

Detecting invasive species: surveillance for fall armyworm in Pakistan

By early 2019 fall armyworm had already spread to a number of Asian countries but was not yet reported in Pakistan. Surveys were carried out in May–October in three provinces, in collaboration with various organizations, following surveillance training workshops. Thirty-two districts were surveyed and larvae were sampled. Identifications were made on a morphological and molecular basis. Fall armyworm was found in two provinces, Punjab and Sindh, with high frequencies of occurrence in the latter. During the later surveys several species of parasitoids were also found. These surveys provided the first record of fall armyworm in the country, as well as a baseline for developing a national response plan.

Monitoring spread: surveillance for *Tuta absoluta* in Pakistan and Ghana

In Pakistan, a first survey conducted in 2018 indicated the first appearance of *Tuta absoluta* in the country. Following an action plan developed with national partners, further surveillance was undertaken in three other provinces (Balochistan, Sindh and Punjab) with the support of agriculture extension and research staff trained by CABI, to assess the spread of the moth and its potential impact on tomato production. These surveys showed that the pest is present in most regions, with serious damage observed in some fields. These data have been reviewed with national authorities and management plans are being developed.

In Ghana, the presence of *Tuta absoluta* has been reported since 2017. However, its distribution and impact were largely unknown. Surveys were carried out using pheromone traps and visual observations in nine regions of the country with the support of agriculture extension agents, who were trained for the surveys. The pest was found in all surveyed regions, indicating rapid spread.

Controlling invasive species: biological control of papaya mealybug in Kenya

First reported in Kenya in 2016 on the coast, papaya mealybug has since spread and gained pest status. Many farmers use chemical pesticides against the pest, which are often reported as ineffective, and no active ingredients have been registered against papaya mealybug in Kenya. Classical biological control has been used elsewhere, but not in East Africa, so to provide the basis for this approach, CABI and the Kenya Agricultural and Livestock Research Organization (KALRO) conducted a survey of farmers which sought to establish the presence and abundance of papaya mealybug and its natural enemies in eight counties, covering 141 farms. All counties were found to be affected. From 307 samples comprising 53,518 mealybugs, only two parasitoids emerged (*Anagyrus* spp). This level of parasitism is not sufficient to control the pest, providing justification for the introduction of the host-specific parasitoid *Acerophagus papayae*, which has been reported to be effective in West Africa and elsewhere. An application for the import and release of *Acerophagus papayae* will be made by KALRO through the Kenya Standing Technical Committee on Imports and Exports.

Controlling invasive weeds: biological control and IPM for parthenium in Pakistan

Research and development has focused largely on two biological control approaches to parthenium: improving the efficacy of the beetle *Zygogramma bicolorata*, and importing another beetle, *Listronotus setosipennis*, from South Africa. Testing and training on other IPM-compatible technologies are also in progress.

Zygogramma bicolorata is an effective biocontrol agent for parthenium in some areas of the world and is already present in Pakistan, but despite favourable climatic conditions in the southern part of the country it is currently only found in some northern districts. The life-cycle of *Z. bicolorata* in Pakistan is also out of synchronization with parthenium – the insect emerges too late from diapause to attack the weed before it flowers and sets seed. Methods to address these limitations have been investigated, including the manipulation of the diapause period to improve synchronization with parthenium, and by redistribution of *Z. bicolorata* through mass rearing and release in areas where it is currently absent. Laboratory trials conducted to influence diapause breaking in *Z. bicolorata* were successful, but the insects did not survive after release. The mass rearing of *Z. bicolorata* for redistribution to areas of Pakistan where it is currently absent is ongoing.

Listronotus setosipennis is a stem-boring weevil from South America previously introduced for parthenium control in Africa and Australia. The Pakistan authorities gave permission to import *L. setosipennis* to assess its host specificity under quarantine conditions. The new quarantine facility has been inspected and approved by the authorities, so *L. setosipennis* beetles were imported from South Africa and have been successfully multiplied in the facility. Host range tests are underway covering 28 plant species and/or varieties, including crops (e.g. sunflower) and native plants.

Parthenium winter rust (*Puccinia abrupta* var. *partheniicola)*, was reported for the first time in 2019 in Pakistan. Although the rust does not kill parthenium, it can reduce growth and seed production. However, the impact appears to be limited, most likely due to the timing of infection. Monitoring is currently ongoing to establish the role the rust might play in the control of parthenium in Pakistan

Manual removal of parthenium by farmers is potentially harmful due to the risk of dermatitis, so management options that reduce the need for manual control have been investigated. Trials have shown that available herbicides can provide effective control of parthenium, and field experiments have been conducted to determine the damage threshold of parthenium in maize fields. Preliminary results suggest that it is not necessary to remove 100% of the parthenium to avoid yield loss, thus reducing the need for manual removal and/or herbicides.

Controlling invasive species: biological control of fall armyworm using parasitoids and predators

Biological control is widely seen as a key component of IPM and involves three strategies: classical biological control, augmentative biological control and conservation biological control. All require a good knowledge of the natural enemies attacking fall armyworm in its invasive range, so studies are continuing in Ghana and Zambia, and have started in Pakistan and Bangladesh. Advice and diagnostic assistance is also being provided in response to requests from other countries in Africa and Asia. Surveys for parasitoids conducted with partners in Ghana and Benin (IITA) found 10 parasitoids, with average larval parasitism varying between 5% and 38% across regions. Similar surveys in Zambia carried out in collaboration with the Zambia Agricultural Research Institute (ZARI) and students from the University of Zambia found at least 10 parasitoid species. Average parasitism was very low (<5%), but the first results of the 2019–2020 season show that parasitism is increasing.

Development of an augmentative approach using the egg parasitoid *Telenomus remus* is continuing in Ghana in collaboration with the Plant Protection and Regulatory Services Directorate (PPRSD). The main challenge is to find an economically viable mass rearing system. Different methods and protocols to improve production are being trialled. In addition, other larval parasitoids are being assessed for their potential as augmentative biocontrol agents, such as *Coccygidium luteum*. Work on *Telenomus remus* will also be initiated in Pakistan and Bangladesh in 2020.

Research on the conservation and enhancement of natural enemies as part of IPM for fall armyworm continues, including studies in Ghana on the effect on natural enemies of spraying pesticides and biopesticides and intercropping with cowpea, groundnut and cassava. The lowest parasitism rates are in monocultures. However, trials have found no significant effects of pesticides and biopesticides on parasitism. In Zambia, studies on the effect of intercropping and planting dates on parasitism and yields are underway.

Studies on the natural enemies of fall armyworm continue in Latin America through collaboration with Plantwise partners in Bolivia, Brazil, Colombia, Ecuador and Nicaragua. The studies aim to assess the natural enemy complex in smallholder and organic farms, some of which produce maize with little or no insecticide use. Parasitism can be high, suggesting good prospects for classical biological control. Two parasitoids, *Eiphosoma laphygmae* from Bolivia and *Chelonus insularis* from Nicaragua, are now being reared in quarantine at the CABI Centre in Switzerland. Rearing techniques are being developed and specificity tests have started. So far, *E. laphygmae* has shown high specificity so is considered the main candidate for introduction in Africa and Asia. Permits to import it to IITA (Benin), Kenya and Pakistan have been procured or sought, in collaboration with national and international organizations, and, subject to approval, the parasitoid will be sent to these three countries in 2020.

Controlling invasive species: a nematode-based control for fall armyworm in Rwanda

Research on the biological control of fall armyworm using entomopathogenic nematodes is ongoing with the Rwanda Agriculture and Animal Resource Development Board (RAB) and the University of Neuchâtel. Thirteen laboratory bioassays with 34 strains of nine African, Mexican and commercial nematode species revealed that many of them can attack and kill fall armyworm. Further experiments on appropriate formulations of the nematodes are in progress, and extensive on-station and on-farm field trials will be undertaken in 2020. Another study will identify feeding stimulants or attractants to improve the efficacy of the nematode formulations.

Selecting an exotic biological control agent for introduction against fall armyworm

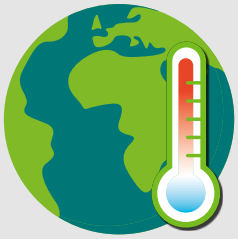
Action on Invasives scientists are studying the parasitoids (small wasps) that attack fall armyworm (FAW) in Latin America, with the aim of releasing a biocontrol agent in Africa and Asia. The studies are undertaken in quarantine laboratories and several criteria are considered when selecting the most suitable parasitoid species.

Impact in the area of origin

Many parasitoids attack FAW in the Americas. The most abundant and frequently encountered is *Chelonus insularis*, but several other parasitoids are frequently encountered and can reach high parasitism rates.

Specificity

It is vital that any introduced parasitoid is specific to FAW and does not have any negative effects on native insects. Specificity must be properly assessed in laboratory and field experiments because of the frequent occurrence of sibling species or biotypes varying in their host specificity.



Climate matching

Parasitoids of FAW differ in their climatic preferences and even within the same species, biotypes adapted to different climatic conditions may occur. It is therefore important to search for and select from regions that are climatically similar to the target region.

Empty niches in the parasitoid complex

Some native parasitoids have already adopted FAW in Africa and Asia. When possible, an exotic parasitoid should find an empty ecological niche in the region of introduction and competition with closely-related parasitoid species should be avoided

Controlling invasive species: IPM components for fall armyworm in Africa and Asia

Other IPM components have been tested against fall armyworm: in particular, biopesticides, cultural practices, pheromones and traditional control methods, with the aim of building sustainable IPM strategies to replace the chemical pesticides many farmers are using. Trials have been undertaken under the growing conditions experienced by smallholder farmers in Ghana, Zambia and Kenya, in collaboration with national research organizations.

Field trials have tested emamectin benzoate, maltodextrin, neem-based products, ash, soil and the locally produced soap alata samina at three sites in northern, central and southern Ghana, in collaboration with the Council for Scientific and Industrial Research – Savanana Agricultural Research Institute (CSIR – SARI), the Council for Scientific and Industrial Research – Crop Research Institute, (CSIR – CRI) and the Biotechnology and Nuclear Agriculture Research Institute (BNARI), respectively. Significant reduction of larval numbers and crop damage, and increased yield, was achieved with emamectin benzoate, a microbially-derived insecticide known to be efficient against fall armyworm. High effectiveness and a favourable cost–benefit ratio were also achieved with neem products. Maltodextrin was only partly effective, with a clear dose-dependent effect, and is also more expensive and so less cost-effective. Ash, soil and alata samina soap treatments were not effective at the doses and with the methods used. New tests with sand are planned based on Central American techniques which are considered effective in that region. Tests in Zambia also indicated the efficiency of neem products, including home-made preparations. Results from other experiments are still being analysed.

In trials in Kenya, fall armyworm baculovirus (Fawligen) was as effective as emamectin benzoate, and was more effective in larger-scale plots, showing the benefit of area-wide approaches. Also in Kenya, three communities trialled a mating disruption method (Pherogen) to investigate the feasibility of this technology for smallholder farmers. Those who used Pherogen still used a pesticide, but sprayed once in the season, instead of three times: there were fewer caterpillars, egg clusters and crop damage in the Pherogen-treated fields.

Controlling invasive species: biological control for *Tuta absoluta*

Surveys have been undertaken for natural enemies of *Tuta absoluta* that could be deployed in augmentative biological control, as applied in Europe and North Africa. Field surveys in Zambia, including research by an MSc student at the University of Zambia, found one parasitoid and several predators, including *Nesidiocoris tenuis,* which is an important predatory bug. In Ghana, surveys for natural enemies, supported by a Ghanaian PhD student, have also identified *Nesidiocoris tenuis*, as well as a parasitoid of the genus *Necremnus*. Both *Nesidiocoris tenuis* and *Necremnus* spp. are used elsewhere in the world to control *Tuta absoluta*.

Lessons learned

There is now enough evidence showing that biopesticides such as *Bacillus thuringiensis* (Bt), emamectin benzoate, viruses and botanicals are effective against fall armyworm and can be used instead of chemical insecticides. However, the cost and availability may currently constrain uptake. It must also be noted that some biopesticides can be toxic to organisms such as bees and aquatic animals, so they cannot be issued indiscriminately.

Prospects for biological control of fall armyworm (and other target Action on Invasives species) are promising but still require research, either because they have never been implemented anywhere or because there are geographic specificities and national regulations that require new investigations. It is often not possible to simply replicate successes achieved in other countries.

Biological control by augmentation of natural enemies or other biorational methods (such as mating disruption with pheromones or virus-based products) are often efficient but not necessarily cost-effective. For example, releasing *Telenomus remus* against fall armyworm can be effective but the challenge is to find a *Telenomus* production method that is cheap enough for use in smallholder systems, where the yields and prices obtained may be low.

Biological control timeline: parthenium and fall armyworm

Under Action on Invasives, work on the classical biological control of parthenium and fall armyworm is underway. By the end of 2019, both parthenium and fall armyworm were into the second phase.

PHASE 1: Identify, collect and prioritize suitable biological control agents

Listronotus selected as first priority

Studies ongoing in Latin America

PHASE 2: Determine safety and efficacy of prioritized agents

Tests on 28 non-target plant species ongoing in Pakistan

Applications for permits to begin testing in Africa and Asia submitted

PHASE 3: Obtain permission for release of the biological control agent

PHASE 4: Mass rear and release the biological control agent and follow up with post-release evaluation

Implementing classical biological control is difficult without adequate quarantine facilities. CABI's new quarantine facility in Pakistan will greatly facilitate the implementation of the biological control of parthenium weed, and also of fall armyworm and other invasive species, in Pakistan and potentially in the region.

Training in topics such as surveillance or biological control is particularly effective when attached to a specific practical activity, such as the surveys carried out to identify priority species in Pakistan.

Next steps

The lists of the potential invaders that have been produced through the horizon scanning activities in Kenya and Ghana are being used to organize mitigation actions, such as full risk analyses, surveillance programmes and contingency plans. A similar prioritization process will be organized in Pakistan and Zambia in 2020.

The classical biocontrol project against parthenium weed will continue with the weevil *Listronotus setosipennis*. Host specificity tests should be completed in 2020 for field releases in 2021, pending official approval. The redistribution of *Zygogramma bicolorata* in Pakistan will continue and the use of the winter rust will be considered.

The parasitoid *Acerophagus papayae* will be imported from Benin to quarantine in Kenya, with the support of IITA, with the aim of obtaining permission to release it for control of papaya mealybug.

Investigations into methods to conserve and enhance natural enemies of fall armyworm in smallholder maize cropping systems will continue in Ghana and Zambia, and will be initiated in Burkina Faso, Pakistan and Bangladesh. Similarly, *Telenomus remus* production systems will be studied in Ghana and Pakistan. In Bangladesh the use of other egg parasitoids (*Trichogramma*) will be promoted with the support of Indian scientists. The aim in these studies is to develop methods that are cost-effective.

The parasitoids *Eiphosoma laphygmae* and *Chelonus insularis* will be sent to Benin, Kenya and Pakistan for host specificity tests, and, if positive, applications for releases will be prepared. Investigations will continue in Latin America to identify other candidate biocontrol agents, as well as to document traditional methods used by smallholder farmers to control fall armyworm, which will be trialled in Ghana. The collection of pathogens held at CABI UK will be screened for possible new biocontrol solutions for fall armyworm. The work on the use of entomopathogenic nematodes against fall armyworm in Rwanda will continue, with extensive field trials and the identification of feeding stimulants or other attractants.

Methods to use predators and parasitoids of *Tuta absoluta* in African farming systems will be developed and implemented in Ghana, Kenya and Burkina Faso. In addition, surveys for natural enemies of *Tuta absoluta* will be carried out in Pakistan and a national management plan will be developed with the national authorities.

Community action: bringing information and action to scale

This work package aims to achieve large-scale implementation of best practice solutions, adapted to community contexts and needs. The programme works in partnership with rural communities and local actors to understand the socioeconomic context, strengthen extension and advisory activities, facilitate the widespread uptake and adoption of appropriate control practices and document the costs of invasive species, as well as the benefits to communities of managing them.

Understanding farmer contexts

Three socioeconomic surveys were conducted on invasive species in Africa. The findings are informing the design of gender-responsive communication campaign messages and the selection of appropriate information dissemination pathways for reaching different types of farmers according to socioeconomic status, gender and age.

In Kenya papaya farmers were surveyed to understand the impact of papaya mealybug, their perceptions on management, and their use of agricultural information. Control is dominated by the use of unregistered pesticides, with farmers spraying on average four times per season. The mealybug is widespread, with over 50% yield loss experienced during serious infestations, at an estimated cost of KES 230,000 (USD 2,300) per hectare, so more cost-effective solutions are required.

As the baseline for a study on the practicality of IPM for *Tuta absoluta* (see below), 80 tomato farmers (69 men and 11 women) were interviewed in Nairobi and Kajiado counties. Corroborating the work reported in the *Tuta absoluta* Evidence Note, farmers reported heavy use of pesticides, as they considered it to be cost-effective. Spraying is generally undertaken on a calendar basis rather than in response to pest infestation levels or economic thresholds. Pest control costs (pesticide purchase and labour for spraying) averaged KES 84,565 per hectare, and accounted for nearly 58% of all production costs. While most farmers still made some profits, the increasing production costs affect business sustainability, while the heavy use of pesticides also has negative environmental and human health impacts.

In Zambia a household survey was undertaken to evaluate the previous season's communication campaign on fall armyworm, including obtaining updates on the household economic impacts caused by the pest and farmers' responses as previously assessed. This is reported in the "Monitoring and evaluation" section of this report.

Strategic and national communication planning

Through the Communication, Awareness and Knowledge Management Technical Working Group (TWG), which CABI leads under the FAO fall armyworm programme, a framework for strategic communication during pest outbreaks was developed, based on experience with fall armyworm. Partners from Kenya, Ghana and Zambia, as well as international organizations and communication experts, developed the framework, which highlights the communication challenges faced by governments during a pest outbreak and provides a set of concepts, guiding principles and tools for planning strategic communication interventions in support of response efforts. The document is aimed at government policymakers and decision-makers and others responsible for designing and implementing responses to pest outbreaks. It supports guidance given by the IPPC on phytosanitary measures for pest surveillance, risk identification, reporting and management, and complements the recently published IPPC Guide to Pest Risk Communication.

A national fall armyworm communication strategy was developed in Kenya to support and align communication approaches in the management of fall armyworm, focusing primarily on the needs of farmers growing maize. Given that fall armyworm has been present in Kenya since 2017 the government and other partners have already conducted a number of outreach activities to support extension services in helping farmers fight the pest. The initial priority of making farmers aware of the pest and how to recognize it is now less relevant, so the current focus of communication is on IPM approaches. The strategy therefore outlines how to fill current communication gaps, the key messages, and the responsibilities of different stakeholders.

Communication campaigns across Asia and Africa

In Pakistan, as a result of a successful pilot awareness campaign on parthenium in Sheikhupura District in 2018, a national campaign targeting all provinces was conducted in 2019. The campaign was agreed by 38 high-level stakeholders from across Pakistan, and was executed in an inclusive manner through multiple media and communication channels to ensure maximum reach and impact.

The campaign worked with the Department of Agriculture Extension, Research, Livestock, Education to conduct training of trainers workshops. Those who had been trained then carried out mass extension campaigns on the ground. A total of 462 (437 men and 25 women) master trainers were trained and 33,400 (31,040 men and 2,360 women) farmers were reached. The trainings discussed management options, including manual removal and safer use of pesticides

A television campaign was also conducted, showing video documentaries and public service messages on three national TV channels, with an estimated viewership of over 3 million people. Public service messages on the management of parthenium were aired from 9 to 11 am, selected to target women at home. Other TV channels were selected to target the general public at 6 to 7 pm, the overall peak viewing time. Digital and print press were also engaged through curated briefings and press packs, focused on awareness and management of parthenium. These campaigns were estimated to have reached over 3 million individuals across the country.

A social media campaign was also initiated as part of the national campaign: messages on the management of parthenium were highlighted through the Facebook and YouTube platforms in order to reach a diverse audience. Twenty-four public service messages were disseminaed via the "CABI Invasives" Facebook page over the course of 12 weeks. The aim was to target the general public, including farming communities, and other agriculturalists, in a gender-responsive manner. The messaging received considerable interest and provoked dialogue and questions on control and the origin of the problem. A video was shared through the "CABI Invasives" YouTube channel and related invasive species channels. Overall, there were 30,274 direct interactions with the social media content (likes and shares on Facebook, and views on YouTube), whilst the total advertising campaign reach is estimated at close to 2 million individual accounts.

An urban element to the campaign was conducted in Islamabad to sensitize people on parthenium's negative impacts. Public awareness stalls were erected in popular city locations, such as public parks and markets. Overall, 9,757 people (7,217 men and 2,540 women) were reached. Youth were targeted through activities in schools, colleges and universities across the country, using the "Root it out" message. This included the provision of literature (flyers and booklets) and practical demonstrations on school grounds, reaching a total of 6,761 students

(3,976 boys and 2,785 girls). A permanent diorama to highlight parthenium's impacts on crops, livestock, human health and biodiversity was installed at the Pakistan Museum of Natural History to educate the general public.

Stands were taken at the Pakistan Horti Expo in January 2019 and the Punjab Agri Expo in June 2019 to raise awareness on parthenium for private and public sector agriculturalists. Overall, 11,685 people (9,639 men and 2,046 women) visited the displays, and over 40,000 leaflets were printed and disseminated at the stands, as well as at trainings and other events.

In Ghana, Kenya and Zambia mass extension campaigns were designed and implemented to deliver messages on fall armyworm management. The campaigns built on work done in the previous year, and emphasized the importance of preventative measures, scouting for early detection, cultural management practices, and responsible use of pesticides.

In Zambia, an 18-week radio campaign was implemented during the 2018/19 growing season. The radio messages were pre-recorded and translated into all seven national languages of Zambia, as well as English, and aired on national radio and on six regional radio stations. Partners in the campaign included the Ministry of Agriculture (through the National Agricultural Information Services), ZARI, the National Union of Smallholder Farmers of Zambia, the Zambia Environmental Management Agency, CropLife (a plant science industry body), and the University of Zambia. The total reach is estimated at 1.4 million individuals.

In Ghana a campaign on fall armyworm management was conducted via SMS (15,710 individuals reached) and video screenings (6,948, including 1,980 women, reached), while in Kenya SMS messages were delivered through a partnership with Precision Agriculture for Development (PAD), reaching an estimated 55,445 individuals.

Facilitating access to best practice solutions

Best practice solutions, particularly biological approaches, may be most effective when implemented over a larger area than an individual farm. This requires farmers to work together using agreed methods. This approach was piloted in eight communities in Kenya, involving large-scale demonstrations of lower-risk products: *Metarhizium* (fungus), Fawligen (baculovirus), Nimbecidine (neem), Pherogen (pheromone), Bt (bacterium) and rabbit urine extract (RUE – registered in Kenya as a foliar feed but included, as farmers claim it can control fall armyworm). 309 farmers participated in activities covering 154 acres, and indicated they felt safer handling the various products compared to pesticides. Farmers reported reduced cost of pesticides, particularly women farmers who usually hire men for pesticide application but who could apply products such as Pherogen themselves. Field scouting by extension workers also showed reduced infestation and severity.

Mating disruption (Pherogen) was demonstrated in an additional three communities in Kenya (Bungoma, Baringo and Machakos), aimed at understanding the suitability of the technology for smallholder farmers. The proportion of farmers using pesticides was reduced from 100% in the first season to 72% in the second season, and the frequency of spraying was reduced from an average of three times per season to once, reducing costs. During an after-action review, the technology's effectiveness was highly rated by the farmers who trialled it. In general, farmers felt the technology was easy to apply and saved labour, as well as enabling them to avoid exposure to pesticides while performing other tasks in the treated fields.

The suitability and practicality of IPM approaches is also being tested for *Tuta absoluta* control in two areas of Kenya. The work is a collaboration with Koppert, using their products Mirical (a predatory mirid, *Macrolophus pygmaeus*) and Tutasan+Pherodis (a pheromone-based trapping system). Two farmer field days have been conducted at the trial sites so far, with more planned by 10 farmers chosen to host open field demonstrations. Three small-scale greenhouse tomato growers have also been selected as demonstration sites. The cost–benefit of the IPM approach is being determined, while also collecting information from farmers on the practicalities.

In Pakistan, communities were engaged in the redistribution of the beetle *Zygogramma bicolorata*, previously introduced and established in some areas as a biological control agent for parthenium. Over 3,000 beetles were redistributed to four districts of central Punjab, which is severely affected by parthenium. The community members were trained by 48 public and private sector officers to identify the biocontrol agent and understand its mode of action so that they can avoid killing it, and so they will be ready to take part in future releases.

Lessons learned

Communication strategies, targeted technical materials and wide-ranging campaigns in Pakistan and in Zambia have improved awareness of identification, prevention, detection and control of parthenium and fall armyworm. Whilst some work has already been conducted on the impact of communication campaigns on farmers' knowledge, attitudes and perceptions (see the "Monitoring and evaluation" section for the evaluation of the Zambia campaign), more work is needed to ascertain how the change in behaviour that has resulted reduced the impact of the invasive species.

Social media campaigns can work well through targeted advertising. However, this must be used judiciously as the message posting can also be taken over by people promoting their own theories or wrong advice (parthenium being seen as a beneficial plant, for example). Social media campaigns need to consider not only the messages that are promoted but also the feedback that is provided through the comments section.

Results from 2018 indicated that many farmers are aware of biological control products, but few use them, constraining opportunities for area-wide management. The fall armyworm area-wide management trials were designed to introduce the products to farmers and give them the opportunity to try them out. Initial results are positive but the strategy needs to be further developed as participants were self-selected and so were already positively inclined to using biological products. However, it is known that a primary source of farmers' information is other farmers, so the expectation is that wider awareness will have been developed in the participants' communities.

Next steps

Communication activities will continue, with the aim of changing farmers' and others' behaviour in regard to how they perceive and manage individual invasive species, particularly fall armyworm and parthenium. The approach will be to work with partners on messaging to maximize reach, and to broaden the promotion of lower-risk control methods and products. Further work will be undertaken to document the impact of the campaigns, based on socioeconomic and household surveys, as well as analysis of mass media audience figures. In Pakistan communication activities will also include policy engagement, focusing on local quarantine measures to limit the spread of parthenium.

Work with communities to develop area-wide management of invasives will continue, focused particularly on the use of biological approaches for fall armyworm, including agronomic practices such as synchronized planting and pest monitoring. Based on the experience this year, wider engagement of community members by facilitators will be used to ensure larger numbers of farmers are involved over larger areas. Weekly fall armyworm population data will be collected in parallel to the farmers' observations.

The practicality and cost-effectiveness of IPM approaches will be assessed in the *Tuta absoluta* demonstration trials in Kenya, as well as in the fall armyworm trials in the best practice solution work package. Opportunities to improve the availability and affordability of lower-risk control products will be investigated.

Knowledge and data: creating and using knowledge

This work package is developing processes to create, exchange and use online/offline content, information and data at the regional, national and local level. Novel information tools have been developed to support diagnosis, risk analysis and regulation using globally relevant information resources and complementing Plantwise processes. New tools are fully integrated into CABI's existing information infrastructure to allow for the most efficient delivery to meet the needs of end users.

Progress in 2019

Using the Pest Risk Analysis decision support tool

Pest risk analysis (PRA) is central to managing the threat of invasives cost-effectively. In 2018 a tool to support PRA was developed in line with international standards and with extensive input from users, for analysing the risks associated with commodity imports. In 2019 activities have aimed to support use of the tool, as well as to expand and enhance it. The tool was presented at the 14th session of the IPPC Commission on Phytosanitary Measures, delegates to which constitute the primary user group for the tool. It was announced that to facilitate use of the tool by the countries that need it most, gratis access to the Crop Protection Compendium (CPC) (on which the tool is based) would be provided to National Plant Protection Organisations (NPPOs) in 97 lower- and middle-income countries. The countries' official contact points were informed, and 69 of the NPPOs took up access to the tool. They have been supported through webinars, remote training and regional workshops. The tool was also presented and discussed at the International Pest Risk Research Group (IPRRG) meeting. In October the upgraded PRA tool was launched, with a new species-initiated workflow and several further improvements, including reference management. User interviews have been conducted to collect evidence of outcomes from the use of the tool (see below) and to assess priorities for future development. One development was released in December, allowing users' changes to pest lists to be saved and used in later PRAs.

Fall armyworm research collaboration portal

Work has started on developing an online fall armyworm research collaboration portal. The aim is to promote more effective sharing of ongoing research, reducing duplication and stimulating new partnerships and research areas. A scoping phase has been completed, including evaluation of similar initiatives in other sectors and identifying the challenges around open science. Potential technologies have also been assessed. Terms of reference have been developed for an international steering committee, and key organizations and individuals from the fall armyworm research community have been invited to join the steering committee, which will start meeting in early 2020.

Sourcing and delivering up-to-date invasives information

The Invasive Species Compendium (ISC – **www.cabi.org/isc**) received over 2 million visitors in 2019. Over 400 new management factsheets, identification guides, manuals, reports and videos were added to the ISC in 2019. These included 79 new Pest Management Decision Guides, providing actionable management advice for key pests, such as fall armyworm, in newly invaded countries. A new species portal was added to collate information on *Fusarium oxysporum* f.sp. *cubense* Tropical Race 4 (TR4), including a newly commissioned and published datasheet. The three existing portals were kept up to date with new content and data on the species, and the fall armyworm portal is widely referenced by other organizations and websites. To improve access via search engines, improvements were made to the search engine optimization of the pages, to help bring users searching for this content to the portal pages. Ten new datasheets were commissioned under Action on Invasives in 2019, and an additional 50 datasheets were refined and published. Eight datasheets received detailed expert reviews, including parthenium weed and papaya mealybug. Throughout the year, hundreds of datasheets were updated with new or edited hosts and distribution data as invasive species either continue to move to new areas and hosts, or are successfully controlled. Two training webinars were conducted to build capacity on the use of ISC and the Horizon Scanning Tool (HST), which was launched in 2018.

Managing and using invasive species distribution data

A new master database of pest and invasive species distribution data has been developed to improve the collation and editing of distribution data on invasive species and delivery of these data to decision support tools. The database has a full user interface and editing system, allowing CABI editors to complete bulk uploads of datasets straight into the database. The database now feeds data real-time to the ISC, improving the efficiency of the delivery of up-to-date information to users. The database also supports increased granularity and brings together data from different sources in a common format, creating opportunities for improved data delivery and visualization. As part of this upgrade, thousands of data points have been reviewed and cleaned, improving the quality of data being delivered through the suite of tools that the database now supports.

Developing and implementing the Action on Invasives data strategy

The Action on Invasives Data Policy and Strategy was developed at the beginning of 2019 to define practices related to the creation, handling and communication of data, information, and knowledge arising from the programme. The policy commits to the publication of all key data arising from Action on Invasives, and states that data should, where appropriate, adhere to the FAIR (findable, accessible, interoperable and reusable) data principles. All survey data should be disaggregated by gender, and data collection methods should appropriately sample and survey the perspectives of women and men. In order to connect more invasive species datasets with different data users, further datasets were added to the **Invasives data portal in CKAN** in 2019, including the data collected as part of the Action on Invasives evidence notes. A link to the data portal was added to the ISC and was promoted to invasive species researchers, resulting in increased usage. Detailed tutorials and guidance documents were also added to the portal to demonstrate how users can contribute to, and benefit from, the data communities. Feedback from users showed that a crucial requirement of the tool was to assign unique identities to the data, so a new feature was developed which assigns datasets uploaded to the CKAN data portal with a Digital Object Identifier (DOI), the international standard for uniquely identifying objects.

Planning sustainability of knowledge and data tools

A sustainability model was developed for the products, tools and initiatives undertaken by the Knowledge and Data work package. This considered each component separately and outlined how the longevity of the resources would be secured, so that users of the tools would continue to benefit beyond the current Action on Invasives programme. With this in mind, many of the resources have been built upon existing and supported tools and infrastructure, such as the development of key species portals as an addition to the ISC. In some cases, such as the new distribution database, developments have been taken up by CABI's broader knowledge business and embedded into other initiatives and workflows, which will continue to serve users beyond the life of the programme. In the case of the PRA tool, users who do not qualify for gratis access will pay a small increase to their CPC subscription to access the tool, which will raise funds for maintenance. Beyond 2020, there are some components that will require additional funding, including championing the sharing of invasive species datasets. An analysis of costs for each component has been included in the model to demonstrate the resources required.

Lessons learned

The PRA tool provides a valuable framework for completing a PRA, but users of the tool commonly request further training on the PRA process itself. Low confidence with the PRA process may explain why some users do not move beyond pest list generation to the assessment of the different risk elements. One approach to address this situation is to incorporate training on the tool with PRA capacity building by other organizations. Additional guidance, examples and in-context help would also benefit users.

RPPOs provide PRA training to their members, but the business model developed for the PRA tool did not initially consider access for, and engagement with, RPPOs. Closer collaboration with RPPOs is therefore envisaged, including consideration of providing gratis access. At the same time, RPPOs will be engaged to support their use of the tool within their training programmes, and within their member NPPOs' workflows.

Over 80% of visitors to the ISC arrive through a search engine. In the second quarter of 2019 the ISC saw a reduction in traffic which was related to a change in how search engines were indexing the ISC, and therefore how the ISC appeared in searches. Since resolving this issue, the search engine optimization for the website has been improved so that ISC pages appear in all relevant user searches. This has been reflected in a substantial increase in visitors. During the two-month period before the change was made, visits were up only 8% on the same period in 2018. During the two months after the change was implemented there was a 25% increase in visits compared to the previous year.

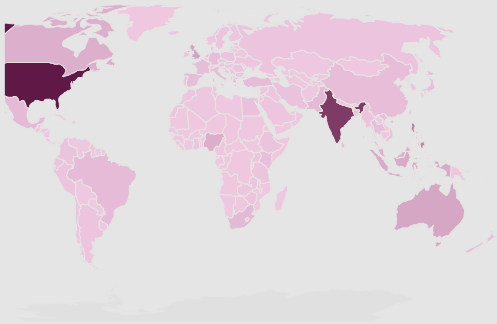
Efforts to contact researchers remotely about possible sharing of their data through the CKAN site have had a low success rate. Researchers are naturally cautious about sharing data, but when provided with more information, including the interests of the programme and the potential benefits for them of sharing data, there is more willingness. This will be taken into consideration in the development of the fall armyworm research collaboration site.

The development of the distribution database involved compiling data from multiple different sources and this revealed some data quality issues within the structure of literature references. As a result of the new infrastructure, the data related to thousands of distribution records have been improved, and users now see cleaner data in CABI decision support tools.

Countries using invasive species knowledge and data to inform management

CABI's knowledge tools have had extensive reach in 2019, offering information on the identification, distribution, risk, and management of invasive species.

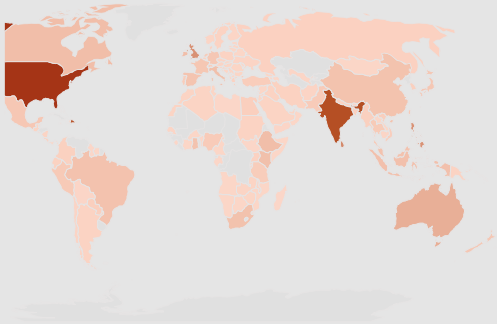
Invasive Species Compendium



Sessions
- 100,000 – 400,000
- 50,000 – 100,000
- 10,000 – 50,000
- 5,000 – 10,000
- 1,000 – 5,000
- <1,000

Total sessions	2,073,994
Total countries	193
(of which LMICs)	119 (62%)

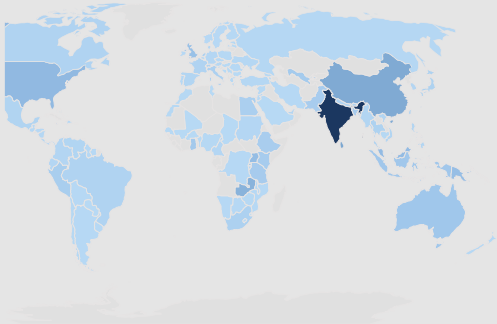
Horizon Scanning Tool



Sessions
- 500 – 1,000
- 250 – 500
- 100 – 250
- 50 – 100
- 20 – 50
- >20

Total sessions	7,540
Total countries	157
(of which LMICs)	91 (58%)

Pest Risk Analysis Tool



Sessions
- 500+
- 250 – 500
- 100 – 250
- 50 – 100
- 20 – 50
- <20

Total sessions	5,470
Total countries	129
(of which LMICs)	72 (56%)

Next steps

The PRA tool will be improved based on feedback gathered from users. The first area of focus will be to streamline the login process for users accessing the tool using the voucher system. This method of access has been more popular than originally envisaged due to the need to access the tool from multiple locations, which makes the traditional method of access via IP recognition less suitable. Further improvements to the tool will be prioritized based on user feedback, including consideration of options for supporting the individual probability assessments with additional data and information. Support resources will also be reviewed and updated to increase user self-help.

An analysis of the way that users interact with the ISC, including the species portals, has been completed, and this will inform improvements to be made to the platform in 2020. With the distribution database feeding more and more granular distribution information to the ISC, there is an opportunity to improve the way these data are presented to users. The ISC search functionality will also be improved, and further search engine optimization work will be implemented to increase organic visits to the site. A new portal will be added if or when a new invasion indicates a need.

The fall armyworm research collaboration portal will be developed on the basis of individual consultations with the international steering committee members and other key informants. A preliminary site will be established, and, through existing networks, a wide group of fall armyworm researchers will be engaged to ensure the site suits their context and needs.

The Action on Invasives Data Policy and Strategy will continue to form the basis of data-focused activities, which will promote FAIR data sharing through the data portal. Progress made with building communities for sharing data on key invasive species will be built upon with further datasets included, with DOIs and promotion through other initiatives. This will be taken further for fall armyworm, for which the dedicated site for researchers to share research updates will be launched. Based on the lessons learned, a significant community engagement effort will be undertaken.

The new distribution database enables the upload of large datasets, which was a key requirement of the tool during its development. This functionality will now be used for more frequent imports of distribution information from various partner organizations, improving the decision support tools and compendia. This will be a major step forward in increasing efficiency and improving the information and decision support users receive.

Monitoring and evaluation

The Action on Invasives logical framework contains indicators for each output (work package), and progress against these has been reported in the preceding sections. The programme's purpose is to strengthen system capacity to prevent, eradicate, control and manage priority invasive species at the local, national and regional levels. Three indicators are identified for this purpose or outcome:

- the number of men, women and youth utilizing and/or benefiting from best practice solutions
- the number of countries using invasive species knowledge and data to inform operations for invasive species management
- the number of countries/regions that are more responsive to invasive species threats and the need to implement control measures

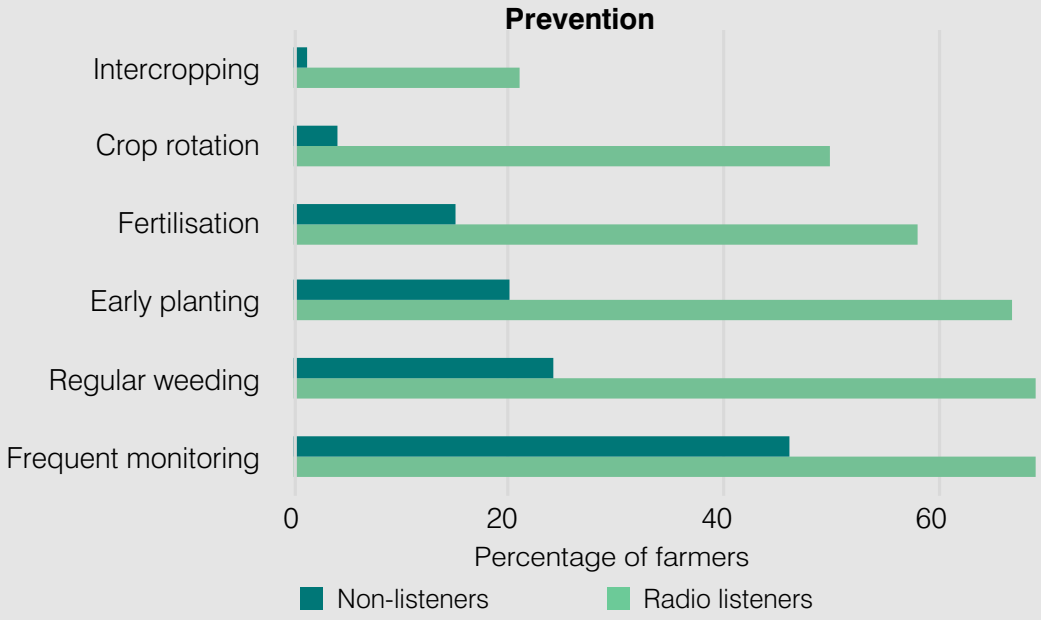
Some areas of work require longer than others before outcomes can be expected, but here we report evidence that change is occurring.

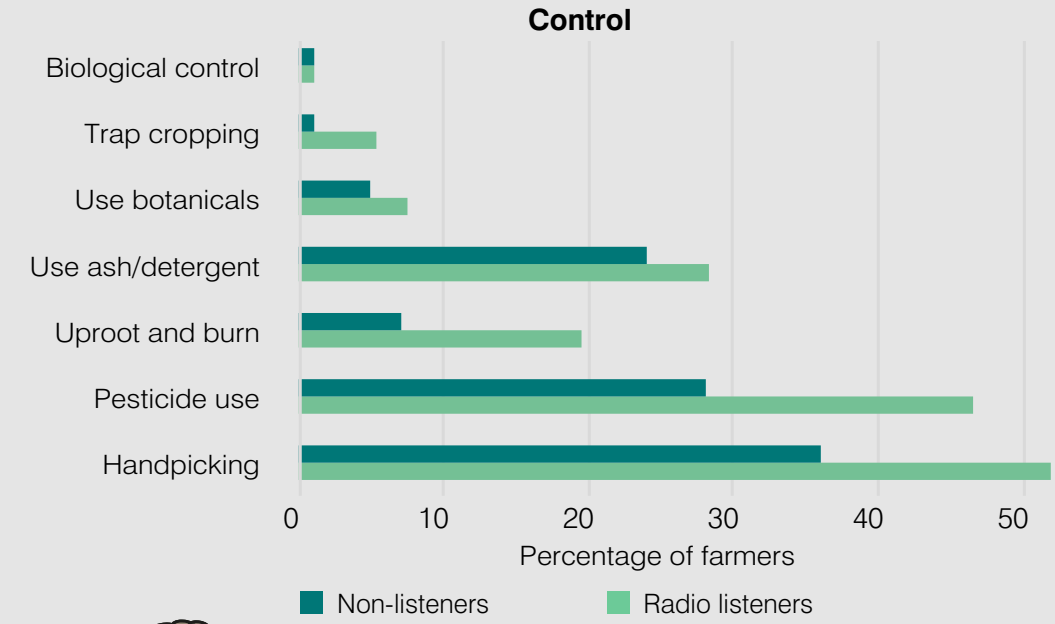
Number of men, women, youth utilizing and/or benefiting from best practice solutions

A first step in the impact pathway by which people benefit from using best practice solutions is delivering information on recommended practices. As already reported, communication campaigns have been undertaken in five countries (Pakistan, Bangladesh, Kenya, Zambia and Ghana). The campaigns reached an estimated 6,602,635 people, 102,448 directly and 6,500,187 indirectly (see Table 1). Data provided by the mass media organizations were not disaggregated by gender or age.

Radio campaign changing farmer behaviour in managing fall armyworm

Both male and female radio listeners were significantly more aware of fall armyworm issues and more likely to adopt management practices than non-radio listeners, particularly agronomic practices such as frequent monitoring, intercropping and rotating their crops. Whilst their use of pesticides was higher, they were more likely to use lower-risk products.





Overall, the fall armyworm radio campaigns reached almost 1.5 million farmers.

Table 1: Number of farmers reached via communication campaigns across five countries

Extension method	Farmers reached			
	Total	Male	Female	Unknown
Direct reach				
Training workshops, face-to-face communication and social media interaction (Pakistan, Zambia and Kenya)	102,448	57,186	14,117	31,145
Indirect reach (Mass extension campaigns)				
Television (Pakistan)	3,018,500			3,018,500
Radio (Zambia)	1,427,600			1,427,600
Social media (YouTube and Facebook in Pakistan)	1,958,860			1,958,860
SMS/video messaging (Kenya and Bangladesh)	71,155			71,155
Village-level video screenings (Ghana and Bangladesh)	24,072	1,980	2,062	20,030
Total	**6,602,635**	59,248	16,097	6,527,290

The next step on the impact pathway is that those who receive the information use it. A household study was undertaken in Zambia to assess changes in farmers' knowledge, attitudes and practices in relation to fall armyworm – particularly their adoption of advice given through the radio campaign. In total, 250 male and 215 female farmers were interviewed in four provinces in Zambia. Results showed that 49% of the respondents listened to the radio programmes on fall armyworm aired during the 2018/19 cropping season.

Both male and female radio listeners were significantly more aware of fall armyworm and more likely to adopt management practices than non-radio listeners. The majority of male and female listeners reported the information as "very useful". Listeners were significantly more informed than non-listeners on the problem of fall armyworm, its identification, and management methods that can be used to control it. The infographic (page 35) shows that this resulted in greater use of all types of activities against fall armyworm, including both lower-risk control methods, as well as pesticides. However, the greatest differences were in the use of agronomic practices, and the frequent monitoring of the fields.

The radio campaign thus appears to have contributed to improving farmers' knowledge of fall armyworm, and to changing their fall armyworm management practices. While radio has several advantages as a communication channel, other methods can also be used where radio has disadvantages. For example, the campaign messages were pre-recorded and did not give room for interaction during the airing, so combining radio campaigns with phone-ins would be beneficial.

Number of countries using invasive species knowledge and data to inform operations for invasive species management

The infographic (page 30) indicates the use of the ISC, PRA tool and HST worldwide. Some countries have now had the opportunity to use the PRA tool for nearly a year, so a pilot study was conducted to begin to understand what outcomes may be occurring as a result of its use. Users in two NPPOs in Africa were interviewed; during the interviews information was also gathered on how the tool could be further improved. While the tool was designed to allow a full PRA to

be conducted, it appears that users are finding value in it without completing a PRA. A key step in a PRA is creating a list of all pests on a commodity that are recorded from an exporting country but which are not present in the importing country, and which therefore may pose an invasion risk. The PRA tool does this automatically, saving much time, and users report using this function even when not proceeding to conducting a full PRA. Uses of the PRA tool include providing the basis for a rapid assessment to provide feedback on potential risks to clients, which may then be followed up by a detailed analysis; as a quick check when issuing phytosanitary certificates for exports; for learning whether certain pests are associated with a specific commodity; and for checking and generating import conditions. All this is possible because the tool generates the lists of pests easily, and then provides a link to detailed information in the Crop Protection Compendium. Thus, from this small sample there is evidence that the tool is improving phytosanitary operations in ways other than purely carrying out a formal risk analysis. Follow-up studies on the use of the PRA tool and the ISC will be conducted in 2020.

Number of countries/regions that are more responsive to invasive species threats

In 2019 a study was conducted to develop an approach for describing and evaluating the responsiveness of a country to the threat of invasive species. A methodology was developed to provide an indication of opportunities for strengthening the invasive species system as well as a baseline against which a later application of the methodology would be able to document changes in responsiveness. The methodology involved a desk review, a stakeholder workshop and key informant interviews, and draws from capacity assessment tools and methods in related fields, including plant and human health. The role each stakeholder plays in 10 key functions is examined, and the performance of the system as a whole is evaluated, using four criteria (see infographic in the "Stakeholder engagement" section, page 13).

The methodology was then used in Kenya in 2019 to assess the country's responsiveness to the threat of invasive species. Results show that some parts of Kenya's invasive species system are operating more effectively than others, but not necessarily against all criteria. For example, a score of 4 was agreed for advisory services for both affordability and acceptability, but against timeliness and availability/access the score was only 2. Other parts of the system are perceived as more generally weak, such as policy and regulation, scoring only 1 or 2 for all four criteria.

Similarly, some stakeholders make strong contributions to some functions, but less so to others. Often they work in relative isolation, with unclear mandates, roles and responsibilities with regards to invasive species management. There are weak linkages and infrequent interactions between actors and where interactions do occur they are often on an unofficial, ad hoc basis, rather than institutionalized.

Stakeholders concluded that there is a need for Kenya to develop an invasive species strategy adopting a multi-species approach, followed by the establishment of a permanent body or mechanism responsible for co-ordination. Key recommendations included the need for a review of the current national policy framework and existing mandates in order to merge various efforts, harmonize mandates and identify who could take the lead in co-ordination. The co-ordinating body should be provided by a government agency to ensure policy advancement is backed by law, perhaps including the establishment of an overarching inter-ministerial committee. Furthermore, the co-ordinating body should have adequate representation from all sectors involved in invasive species management, and should possess the ability to effectively bring all stakeholders together.

The methodology for assessing the invasive species system facilitated stakeholder engagement in clearly defining and understanding the system in Kenya as it currently stands. Defining functions and indicators and conducting a participatory evaluation built consensus on priority needs and opportunities, and the results will be taken forward in Kenya in 2020.

Next steps

With the full Action on Invasives programme now having been in operation for two complete years, in 2020 more resources will be devoted to assessing outcomes.

Further studies will be undertaken to understand and document the way the ISC, PRA tool and HST are being used, through analysis of site analytics data, followed up with key informant interviews and surveys. In the case of the ISC we will assess who is using the resource and the information, and how the information has informed invasive species management operations, particularly in relation to priority invasive species such as fall armyworm.

In Ghana a farmer survey will be conducted, similar to the one conducted in 2017, to assess how farmers' behaviour may have changed in managing the fall armyworm, whether on-farm losses have been reduced, and to what any changes can be attributed. Effects of government decisions on farmer behaviour, such as the distribution of biopesticides, will be assessed. At the same time, a qualitative assessment will be made of how the country's response to fall armyworm has changed over a three-year period, what factors have led to those changes and what lessons can be learned for responding to future invasions.

Further evaluation of communication campaigns will be conducted, particularly in Pakistan on the extensive campaign conducted in 2019. The evaluation will examine the impact of both the nationwide mass media campaign, as well as the more direct face-to-face communication, involving training extensionists.

Prevention of an invasive species is usually more cost-effective than eradication following invasion, which in turn is more cost-effective than ongoing management once the species is established. However, in some cases, such as fall armyworm, prevention and eradication may be extremely difficult. Thus, if policymakers are to be convinced to invest in prevention, clear guidance is required on the circumstances in which it pays. As well as providing this guidance, in 2020 methods for demonstrating the value of prevention and rapid response will be assessed using case studies, building on the bio-economic modelling approaches used in Plantwise.

The methodology for assessing the capacity of a country to respond to invasive species will be repeated in two further countries. As well as providing a baseline against which changes can be assessed in the future, the method will assist in identifying and securing consensus on priority areas for intervention.

Table 2: Financial summary (in GBP thousands)

languages.

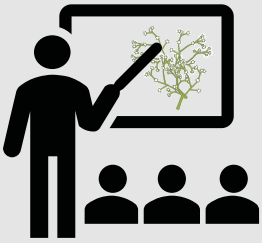
To coincide with the policy summit on invasive species in February, the Action on Invasives website was refreshed, with the aim of increasing the visibility of the programme's resources, improving the website speed and simplifying how the content is presented. The new design also allows easier navigation for all devices. This led to an increase in annual visitor numbers to the website (+18%, to over 40,000) and a significant increase in visitors to the Invasives Blog (+58%, to over 19,000). Followers on social media channels also grew by 25%, to 17,500, across Twitter, Facebook and LinkedIn.

Medium-term opportunities

Action on Invasives was conceived to build on the Plantwise programme, and has benefited from both conceptual and operational synergies with that programme. After 10 years of Plantwise implementation in more than 30 countries, needs have changed and the impacts of climate change are being felt around the world, with rural communities in developing countries bearing the brunt. Farmers are facing increasingly severe climate impacts including drought, increased

Raising awareness of parthenium in Pakistan

Throughout 2019, Action on Invasives harnessed the potential of mass communication channels to reach those affected by the noxious weed, parthenium. Training sessions, public service messages, school visits, and social media have not only been supporting farmers but also the wider public on how to identify and manage parthenium.

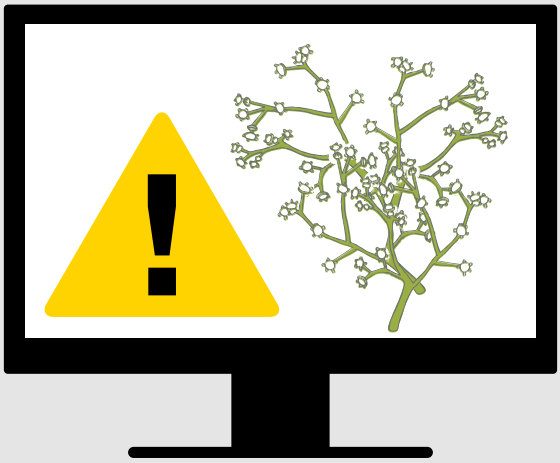


462

Master trainers were trained to carry out mass extension campaigns on the ground

33,400

Farmers were reached through rural support



3 million+

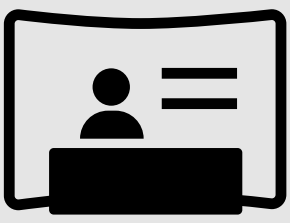
People viewed public service messages aired across three national TV channels

30,274

Likes, shares, and views on social media

6,761

School students took part in practical demonstrations and received flyers and booklets



11,685

People visited exhibition displays at events, taking **40,000** leaflets

9,757

People reached through stalls in city locations like public parks and markets

Publications

Programme-funded

Agboyi LK, Mensah SA, **Clottey VA**, **Beseh P**, Glikpo R, **Rwomushana I**, **Day R** and **Kenis M** (2019). "Evidence of Leaf Consumption Rate Decrease in fall armyworm, *Spodoptera frugiperda*, Larvae Parasitized by Coccygidium luteum." Insects 10, no. 11: 410. **https://www.mdpi.com/2075-4450/10/11/410**

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Tambo JA, **Day R**, **Lamontagne-Godwin J**, **Silvestri S**, **Beseh PK**, **Oppong-Mensah B**, **Phiri NA**, Matimelo M (2019). "Tackling fall armyworm (Spodoptera frugiperda) outbreak in Africa: an analysis of farmers' control actions." International Journal of Pest Management **https://www.tandfonline.com/doi/full/10.1080/09670874.2019.1646942**

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Other papers relevant to Action on Invasives

Harrison RD, Thierfelder C, Baudron F, Chinwada P, Midega C, **Schaffner U** and Van den Berg J (2019). "Agro-ecological options for fall armyworm (Spodoptera frugiperda JE Smith) management: providing low-cost, smallholder friendly solutions to an invasive pest." Journal of Environmental Management 243: 318–330. **https://www.sciencedirect.com/science/article/pii/S0301479719306097?via%3Dihub**

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Rwomushana I, **Lamontagne-Godwin J**, **Constantine K**, **Makale F**, **Nunda W**, **Day R**, **Weyl P**. and **Gonzalez-Moreno P** (2019) "Parthenium: impacts and coping strategies in Central West Asia". CABI. **https://www.invasive-species.org/wp-content/uploads/sites/2/2019/04/parthenium-Evidence-note_FINAL.pdf**

CABI (2019). "Framework for Strategic Communication during Pest Outbreaks: Learning from fall armyworm. First Edition". 45 pp. Licence: CC BY-NC-SA 3.0 IGO **https://www.plantwise.org/FullTextPDF/2020/20207800001.pdf**

Williams F, **Murphy ST**, **Beseh P** and **Lamontagne-Godwin J** (2019). "Have actions taken to control fall armyworm reduced the economic cost experienced in Ghana?" CABI Study Brief 31 Impact. DOI: **https://dx.doi.org/10.1079/CABICOMM-62-8108**

Annex 1: Associated projects

Potential invasion of fall armyworm in Switzerland

In the Americas, fall armyworm is able to migrate thousands of kilometres every summer and to cause damage in temperate regions. Thus there is some concern that seasonal outbreaks could occur in Central Europe, including Switzerland, from populations migrating from the Mediterranean basin. This project, funded by the Swiss Federal Office of Agriculture, is conducted in close collaboration with the five partners of an EU Euphresco project on the potential introduction, spread, damage and control of the pest in Europe. The project started in 2019 and aims to: use models to assess the risk that fall armyworm establishes itself in, or regularly migrates to, Switzerland; review management methods and highlight those that are appropriate for temperate climates where the moth is a temporary migrant; and assess potential biocontrol methods available in Switzerland.

Classical biological control against fall armyworm

As part of a project that aims to establish the joint MARA China – CABI European Laboratory in Delémont, Switzerland, the SDC is co-funding the classical biological control of fall armyworm, in particular the surveys and studies on parasitoids of the pest in its area of origin in Central and South America. Surveys are being carried out in collaboration with various national partners in Bolivia, Nicaragua, Colombia, Ecuador and Brazil. The project has also financed a Chinese post-doctoral fellow to study the parasitoids in quarantine in Switzerland.

Utilizing remote sensing technology to map parthenium in Pakistan

Led by the University of Manchester and funded by the UK Science and Technology Facilities Council, this project aims to: develop methods for mapping and monitoring the distribution of parthenium; strengthen capacity to utilize remote sensing technologies and satellite data; and create and disseminate parthenium distribution data for policymakers' decision-making in agriculture, livestock and human health. The project is mapping the potential versus actual range of parthenium across Pakistan, allowing identification of areas that are more or less infected than the habitat suitability indicates, thus guiding mitigation efforts. The project will provide a tool for monitoring changes to parthenium infestation in the country. In 2019, field assistants carried out land surveys in different habitat types, with data collected from more than 4,000 sites. By combining the ground data with remotely sensed imagery from Sentinel-2, algorithms are being developed that can extrapolate parthenium distribution for the whole country. To help predict the potential further spread, and to target areas for action, the team has also been developing distribution models. In addition, the University of Manchester is developing a low-cost quadcopter camera that can provide further information on actual distribution of parthenium.

Pest Risk Information Service (PRISE)

CABI's PRISE project has been working in Kenya, Ghana and Zambia, and is now also working in Malawi. PRISE's goal is to offer pest risk alerts so that preventative, rather than curative, pest management measures can be taken, improving the efficacy and efficiency of control interventions. To achieve this, PRISE is developing pest models driven by earth observation, weather and field data, which allow identification of areas at greatest risk of pest build-up. This information can then be disseminated as actionable advice: for example, "after planting, wait x number of days before taking action against pest y". Pests for which models are being developed include fall armyworm and *Tuta absoluta*. In Kenya, such alerts were disseminated in 2019 by PAD, integrated into a calendar-based series of crop management advisory SMS. Results of this pilot are due in March 2020. Following this, scale-up of this approach to cover a broader range of pests in the mixed-maize cropping system (maize, tomato and beans) will be carried out in Kenya and Ghana during the main cropping season. PAD is the service provider that Action on Invasives has worked with in the communication campaigns.

Imperial College/Reading University "Tiger Team"

Part of doctoral training at Imperial College London and Reading University involves 'Tiger Teams': groups of doctoral students who work with an outside organization on a topic not directly related to their doctoral work. One such team of three students with backgrounds in agriculture and ecology has been working with CABI on improving the potential distribution maps for parthenium in Pakistan. The team collated over 13,000 data points on parthenium occurrence from 14 different sources, which were used to create a global climate suitability map. This output was used in a regional distribution model for Pakistan, together with landscape and habitat variables. Grasslands and field margins showed a higher likelihood of parthenium presence, while forests and planted fields had the lowest probability. The team is currently writing a paper for publication in a refereed journal.

Pilot roll-out of Fawligen in South Sudan

A partnership between CABI, AgBiTech, FAO, the United States Agency for International Development and CIMMYT has worked with 500 farmers in South Sudan to conduct trials on the use of Fawligen, a biopesticide containing the naturally occurring fall armyworm nucleopolyhedrovirus. The application of Fawligen resulted in an average maize yield gain of 63%, or 0.81t/ha, compared to untreated fields. The increased production was equivalent to over USD 600/ha, which more than covered the USD 72/ha cost for applications of Fawligen. Of the participating farmers, 86% felt that applying the product was very easy, and 67% felt that crop damage due to fall armyworm was lower than in the previous season. Nearly 95% of the farmers indicated that they would be willing to buy Fawligen if it were available at a nearby stockist.

CABI/FAO collaboration on fall armyworm in Botswana

During 2019, CABI was contracted by FAO, through a project funded by the Government of Japan, to support the Government of Botswana in the sustainable management of fall armyworm, which in 2017 had affected nearly 27,000 ha of crops. CABI trained 37 Ministry of Agriculture personnel as trainers of trainers in fall armyworm management, and held four district-level trainings, in which a total of 88 agricultural extension staff were trained. Manuals on fall armyworm developed in 2018 during a CABI/FAO collaboration in eastern Africa were distributed to the trainees to assist them in delivering the training to farmers. Over 400 copies of the CABI/FAO fall armyworm pocket guide were distributed to frontline extension workers and farmers.

CABI/FAO collaboration on fall armyworm in Bangladesh

FAO Bangladesh contracted CABI in November 2019 to support activities aimed at enhancing capacity for monitoring and managing fall armyworm in the country. CABI held a workshop for professors from the agricultural university, the Bangladesh Agricultural Research Institute, and the Bangladesh Wheat and Maize Research Institute, to contextualize the CABI/FAO training manual developed in eastern Africa in 2018. CABI also held a communication workshop with diverse stakeholders to harmonize management recommendations for fall armyworm, which were then used to develop communication materials for dissemination in 2020. CABI also deployed FAO's FAMEWS app for capturing surveillance data, and in 2020 there are plans to test an automated pheromone trap for monitoring fall armyworm populations.

Emergency response to address fall armyworm in India through the deployment of proven IPM technologies for its management

A project is being undertaken with the Indian Council of Agricultural Research's National Bureau of Agricultural Insect Resources (ICAR-NBAIR), including both research and awareness raising on IPM technologies for fall armyworm. Fall armyworm populations in different parts of India were sampled, and 28 were assessed as belonging to the "R" strain and four to the "C" strain of the pest, though variants of both strains were also seen. Surveys for natural enemies found the egg parasitoids *Trichogramma* spp and *Telenomus remus* (also found in Africa), an egg larval parasitoid *Chelonus* sp. and several larval parasitoids and predatory bugs. Training was conducted to familiarize farmers with protocols that could help them harness and augment the mortality due to fall armyworm's natural enemies, and on-farm IPM trials are being conducted. Communication materials have been developed with four universities in Karnataka, translated into six languages, and have been disseminated to farmers via mass extension campaigns in three states.

The Global Burden of Crop Loss initiative

The **Global Burden of Crop Loss** initiative (funded by the Bill and Melinda Gates Foundation) aims to provide rigorous, authoritative evidence on impacts, causes and risk factors of crop loss due to crop pests. This will enable funding, policy and research efforts to more efficiently secure farmers' livelihoods by allowing them to grow more and lose less of what they produce. Inspired by the **Global Burden of Disease** for human health, the initiative will improve the ability to predict the impact of emerging threats, allocate resources between pests, understand likely plant health impacts of climate change, and systematically develop investment in, and capacity of, plant health systems.

BioProtection Portal

The **CABI BioProtection Portal** is a free online resource that aims to enable users to identify, source and correctly apply biocontrol and biopesticide products for specific crop-pest problems. The portal has been developed by CABI in partnership with Koppert Biological Systems, Syngenta and e-nema, and with funding from the Ministry of Foreign Affairs of the Netherlands, the SDC, the African Development Bank and DFID. The portal is particularly beneficial for growers wanting to replace chemical pesticides with biological products in order to meet market or export standards, satisfy consumer demands for healthier and safer food, and reduce pressure on the environment. The aim is for the portal to become a global resource for information on biocontrol and biopesticide products. During 2019, the technology for the portal was developed, the front-end user interface was designed and tested, and specific content was loaded for the first portal country (Kenya), in readiness for an official launch in February 2020.

Annex 2: Conference/workshop attendance

A number of meetings, workshops and conferences were attended during the year, at many of which a presentation was given covering one or more aspects of the Action on Invasives programme, as follows:

- 9th International Workshop on Biological Control and Management of Eupatorieae and other Invasive Weeds, Putrajaya, Malaysia, 19–22 March
- FAO fall armyworm Consultative Meeting in Asia, Bangkok, Thailand, 20–22 March
- International Entomological Congress organized by Department of Entomology, University of Agriculture, Faisalabad, Pakistan, 8–10 April
- COMESA Sanitary and Phytosanitary Thematic working group, and SPS sub-committee meeting, Nairobi, Kenya, 8–11 April
- Interagency Liaison Group on Invasive Species organized by the United Nations Convention on Biological Diversity, Paris, France, 3–4 June
- 6th Pan-African Conference on SPS Regulations and Science-Based Risk Analysis, Tanzania, 10–11 June
- African Union 15th CAADP Partnership Platform Meeting, Nairobi, Kenya, 11–14 June
- First Annual Meeting of the Central Africa Taskforce of NPPOs and Partners, Cameroon, 18–20 June
- Workshop at African Union Commission – Department of Rural Economy and Agriculture on Emergency Fund for Invasive Species and the African Continental Strategy for Invasive Species, Ethiopia, 29–30 August
- International Pest Risk Research Group 13th Annual Meeting, Globalization and Pest Invasions: Emerging Risks and Vulnerabilities, Poznań, Poland, 3–6 September
- Plant Biologicals Network for Africa workshop, South Africa 10–11 October
- 27th meeting of the IOBC-Global International Working Group on Ostrinia and Other Maize Pests, Engelberg, Switzerland, 14–17 October
- 31st Technical Consultation among RPPOs, Abuja, Nigeria, 21–25 October
- Forest Invasive Species Network for Africa (FISNA) workshop, Forest Entomology: Implementation of Biological Control, Pretoria, South Africa, 3–5 November
- International Conference on Climate-Smart Agriculture: The Way Towards Sustainability, organized by Muhammad Nawaz Sharif University of Agriculture, Multan, Pakistan, 26–27 November
- Workshop on fall armyworm surveillance and local management practices, Egypt, 3–10 December
- Workshop on fall armyworm organized by the African Union – Inter African Phytosanitary Council AU-IAPSC, Yaounde, Cameroon, 7–10 December
- 12th Steering Committee and the 28th Session of AU- IAPSC's General Assembly, Douala, Cameroon, 16–21 December

Annex 3: 2019 milestones

● on track ■ minor delay ▲ major delay

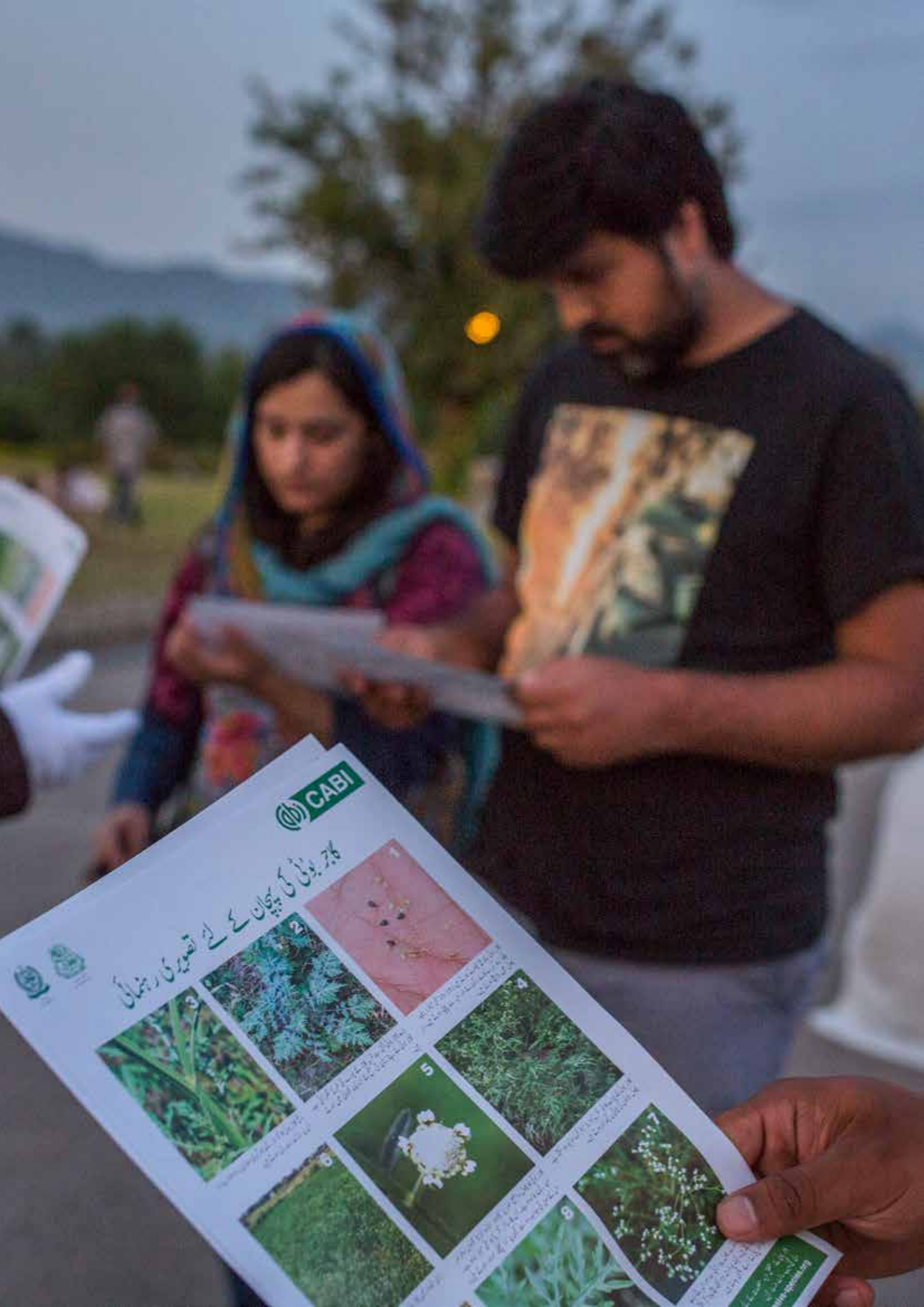
Milestones: stakeholder engagement	Date due	Status	Comments
Programme initiated in seven countries (cumulative) and 2020 country action plans developed	Q4	■	Action on Invasives now initiated in six countries (Ghana, Zambia, Kenya, Rwanda, Pakistan, Bangladesh); a budget reduction prevented start of work in Burkina Faso
Policymakers/decision-makers informed of options for reducing impact of invasive species using lower-risk control methods and products	Q4	●	Lower-risk options for sustainable management of fall armyworm in Ghana promoted through a seminar and draft policy brief. Lower-risk options promoted in international fora, including the Invasive Species Summit (Botswana) and the 28th Session of AU-IAPSC's General Assembly
High-level summit conducted with Member Countries on invasive species impacts and actions needed	Q1	●	Summit conducted in Botswana in February 2019. 70 delegates (14% women), including policymakers, researchers, the private sector and civil society from across Africa. Summit recommendations were endorsed at the CABI Review Conference
Surveillance initiated for at least one priority invasive species in two countries	Q3	●	Surveillance for fall armyworm distribution and abundance in Pakistan completed with public and private partners. Surveillance to compile hosts and geographical distribution of *Tuta absoluta* conducted in Ghana
National response plans developed for two prioritized invasive species	Q3	●	Response plan for parthenium in Pakistan completed and shared. Response plan for fall armyworm in Bangladesh completed and shared
NISSAP finalized and implementation initiated in one country; development of NISSAP commenced in one other country	Q2	■	NISSAP for Ghana completed and approved. Opportunities for developing a NISSAP for Rwanda identified. Kenya stakeholders have recommended development of a NISSAP
Development and implementation of two regional invasive species strategies facilitated	Q4	■	Invasive species strategy for Africa nearing completion. Support for African Union on the creation of an emergency fund for managing invasive species. Joint proposal prepared with the Southern African Development Community (SADC) for an initiative including development of national and regional invasive species strategies
Opportunities identified for streamlining regulations for testing, validation and registration of lower-risk pest control products in two countries	Q3	●	Supported development of EAC harmonized regional guidelines for testing and registration of biopesticides, approved by the Council of Ministers. Meetings on new guidelines with regulators and agrodealers in Rwanda. Review of national guidelines for registration of biological control agents in Ghana, and of pesticide registration procedures in Pakistan

Milestones: stakeholder engagement	Date due	Status	Comments
Producers of at least four lower-risk prioritized control products facilitated in registration procedures	Q4	■	Registration trials for Fawligen (virus), and for Pherogen (pheromone) completed in Kenya with an accredited national institution, now awaiting approval for full registration. Trials on Maltodextrin in Ghana were conducted, but the results were mixed so it is not clear if registration is possible
Methodology for assessing invasives response capacity developed and tested in one country	Q4	●	Methodology developed and tested in Kenya through stakeholder workshop in September. Final report completed
Invasive risk assessments and risk prioritization implemented in at least two countries	Q3	■	Ghana prioritization carried out as planned, but plans for another country shelved until 2020 due to budget reduction
Risk management (prevention and rapid response) procedures researched and developed in at least two countries for priority invasive species	Q4	■	Implementation of risk management procedures following risk prioritization in Kenya delayed. Rapid response to fall armyworm in Pakistan supported following detection during surveillance
IPM-compatible technologies researched, developed and validated for at least three invasive species to support delivery at scale in four countries in Asia and Africa	Q4	●	Classical biological control and cultural control research on parthenium conducted in Pakistan. Classical biological control research conducted in Latin America and Switzerland on fall armyworm; two candidate agents now in culture. Fall armyworm natural enemies researched for conservation and augmentation biocontrol. Fall armyworm biorationals, biopesticides and entomopathogenic nematodes tested in Africa. Biocontrol research activities for *Tuta absoluta* conducted in Africa. Classical biological control research conducted in Kenya on papaya mealybug
Invasive species management research capacity increased in at least three countries	Q4	●	Pakistan: Training of field staff on surveillance methods for fall armyworm. Zambia: one MSc student at the University of Zambia and one in UK, plus training of three interns at ZARI. Ghana: Several students involved in the studies; 22 scientists trained on prioritization of plant pests. Training of 20 African researchers on classical biocontrol of forest pests. Students and young researchers involved and trained in Pakistan, Rwanda, Bolivia, Nicaragua, Brazil and China
Household study on fall armyworm impact updated to assess revised scale of household economic impacts, and scale of farmers' adoption of advice	Q3	●	Household survey conducted with 465 households in Zambia

Milestones: stakeholder engagement	Date due	Status	Comments
Best practices for management of invasive species promoted for uptake by communities; 3 million (cumulative) rural households reached >500,000 receiving and acting on CABI info on fall armyworm and control options	Q4	●	Communication campaigns in five countries (Pakistan, Bangladesh, Kenya, Zambia and Ghana) reached an estimated 6,602,635 people: 102,448 directly and 6,500,187 indirectly
Baseline and impacts documented for at least one additional invasives species	Q4	●	Socioeconomic survey of impacts of papaya mealybug conducted in Kenya
Two country communication strategies for a priority invasive species developed in Africa and one in Asia	Q4	●	Communication plans developed for Kenya, Pakistan and Bangladesh. Strategic framework for communication on invasive species developed
Two technology briefs on managing a prioritized invasive updated and popularized (Africa)	Q3	●	Technical briefs completed on fall armyworm in Ghana and Kenya (second edition)
Multisectoral invasive species management training conducted in at least three countries	Q4	●	798 trainers trained (79 women and 719 men) in parthenium and fall armyworm management, including identification and biological control practices in Pakistan. Additional training as above under best practice solutions
Pilot community area-wide invasive pest management plans developed (four in Africa, two in Asia)	Q4	■	Community participatory testing of six technologies for the management of fall armyworm in Kenya. Partnership with Koppert to demonstrate Macrolophus pygmaeus (Mirical) effectiveness for *Tuta absoluta* management on-farm. Nearly 100 community awareness sessions held on natural enemy conservation for parthenium management in Pakistan (4,850 persons, 50% female), with release of over 3,000 Zygogramma beetles (biocontrol agent)
Twenty factsheets/Pest Management Decision Guides developed for key invasive species and published on the ISC and Plantwise Knowledge Bank	Q4	●	79 new Pest Management Decision Guides finalized and published on the ISC and Plantwise Knowledge Bank, in five languages
Forecasting/distribution models for one invasive species refined	Q4	●	CLIMEX model for papaya mealybug developed. Reading University Tiger Team refined distribution maps for parthenium, creating a global climate suitability map
ISC maintained and updated; at least one new species portal added	Q4	●	2.1 million visits to the ISC in 2019 (60% of users were under 35; 56% female). 13,000 visits to fall armyworm portal. 328 management factsheets, 53 videos, 20 reports, 12 ID guides and six manuals added. New portal for Fusarium wilt of banana Tropical Race 4

Milestones: stakeholder engagement	Date due	Status	Comments
PRA tool launched and used by quarantine/plant protection staff in eight countries (cumulative)	Q4	●	Launch of enhanced PRA tool, with pest-initiated analysis. Gratis access to the CPC and PRA tool offered to 97 countries. 34 NPPOs have logged in, 13 are regular users. PRA tool training conducted for five countries in Asia
Additional data from other work packages, CABI projects and external sources integrated into information management system	Q4	●	CABI CKAN site set up containing 40 datasets (30 public) with communities for priority invasive species
Action on Invasives open data strategy developed and implemented, including feedback process in respect of newly acquired information	Q4	●	Data strategy developed and implemented in CKAN. Engagement with Plantwise data sharing workshops
Biopesticides portal available as a website and downloadable app with information for 15 countries; partnership agreements with at least 10 biocontrol manufacturers	Q4	●	Taken out of the Action on Invasives programme due to a new funding structure in 2019
Upgraded Distribution Database released, feeding the ISC	Q4	●	Distribution database system completed and implemented. Now feeding the ISC with more up-to-date information
Seven published papers	Q4	●	Seven papers published in 2019
Model for financial sustainability of knowledge and data resources developed	Q4	●	Sustainability of individual tools considered during development and sustainability included in data strategy. Sustainability plans compiled for each component, including maintenance costs
Plantwise and Action on Invasives programme funding of GBP 15 million for 2019–2021 secured from existing and new donors	Q4	▲	Top-up funding from DGIS (EUR 2.8 million) for Action on Invasives and Plantwise. Netherlands Ministry of Agriculture funded a project on *Tuta* biocontrol in Kenya (EUR 100,000). Action document for CABI's new flagship programme submitted to EU DEVCO (EUR 6 million) for contracting. SDC provided EUR 310,000 to co-finance the development of the BioProtection Portal. Add-on funding for Action on Invasives from DFID (GBP 1 million), as well as a GBP 820,000 bonus payment. Pitched for GBP 4.96 million two-year extension of multi-year agreement to co-fund proof-of-concept phase of CABI's new flagship programme

Milestones: stakeholder engagement	Date due	Status	Comments
Awareness raising conducted with donor country desks in Africa and Asia to ensure ownership and linkages to relevant initiatives and support to Plantwise / Action on Invasives collaborators	Q4	●	Donor country desks visited in Kenya, Zambia, Rwanda, Malawi, Ethiopia, Ghana, Bangladesh and Pakistan. EU delegation in Kenya wishes to explore funding beyond 2020, EU delegate to African Union interested in CABI's SPS backstopping in relation to future African Union free trade
Action on Invasives annual report submitted to donors and presented at annual Plantwise/Action on Invasives donor forum	Q2	●	Report completed in March 2019. Presented at Donor Forum in the Hague, Netherlands, 9 May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Annex 4: 2020 milestones

Stakeholder engagement	Timing
Programme initiated in seven countries (cumulative)	**Q4**
National response plan developed for two prioritized invasive species in Africa, and one species in Asia	**Q2**
National technical working group for invasive species institutionalized in two countries in Africa	**Q2**
Processes for streamlining regulations for registration of lower-risk products facilitated in Africa and Asia	**Q3**
Programme monitored in six countries as an integral part of Plantwise planning and implementation	**Q4**
Partnerships strengthened at international, regional and national levels for the management of invasive species	**Q4**
NISSAP implemented in one country and opportunities for developing a NISSAP in one additional country initiated	**Q3**
One continental invasive strategy finalized and disseminated widely among relevant partners and implementation assessed in two countries	**Q2**
National invasive species system response capacity assessed in two countries	**Q2**
Best practice solutions	
Invasive risk assessments and risk prioritization implemented in at least two countries	**Q4**
Risk management (prevention and rapid response) procedures researched and developed in at least two countries for priority invasive species	**Q4**
Biological control methods against parthenium weed researched, developed and validated for application in one country	**Q4**
Biocontrol and other IPM-compatible technologies against fall armyworm researched, developed and validated to support delivery at scale in five countries in Asia and Africa	**Q4**
Biological control and other IPM-compatible technologies researched, developed and validated for at least two additional invasive plant pests to support delivery at scale in three countries in Asia and Africa	**Q4**
Invasive species management research capacity increased in at least five countries	**Q4**
Community action	
5 million (cumulative) rural households reached with new knowledge on climate-smart pest and invasive species management; >500,000 receiving and acting on CABI info on parthenium and fall armyworm and control options	**Q4**
Baseline survey and socioeconomic impacts of one invasive species documented and disseminated	**Q4**
Two technical briefs on key invasives developed and popularized in local language in two countries	**Q4**
Five community area-wide management plans for control of fall armyworm implemented, utilizing at least two new best practices in Africa and Asia	**Q4**
At least two evaluations of communication and community engagement campaigns in two countries	**Q4**
Campaign for policy engagement on parthenium in one country initiated	**Q4**
Knowledge and data	
Invasives PRA tool enhanced and used by quarantine/plant protection staff in 35 countries (cumulative); evidence to demonstrate impact collected and disseminated	**Q4**
Open source collaborative platform for fall armyworm evidence and actions developed	**Q4**
Upgraded invasives knowledge platform launched with improved data visualization; at least 2.5 million visits	**Q4**

ISC content and data maintained and updated, including 600 updated datasheets and 10 new datasheets published; one new species portal added	**Q4**
Refine Distribution Database; integration of at least three new datasets feeding decision support tools	**Q4**
Promote and expand information management system with data from CABI projects and external data in line with Action on Invasives data strategy	**Q4**
30 papers (cumulative) published in academic literature	**Q4**
Fund-raising and market development	
Engage with donors on CABI's new global programme that will incorporate Plantwise and Action on Invasives to secure new programme funding of GBP 15 million for 2020–2023 from existing and new donors	**Q4**
Support fund-raising from in-country donor country desks in Africa and Asia to secure co-support for implementation of CABI's new global programme, as well as ensure ownership and linkages to other relevant initiatives	**Q4**
Action on Invasives annual report submitted to donors and presented at annual CABI donor forum	**Q2**

CABI's **Action on Invasives** programme aims to protect and improve the livelihoods of 50 million poor rural families impacted by invasive species through an environmentally sustainable, regional approach to comprehensive biological invasion management.

Action on Invasives is supported by:

UKaid
from the British people

Ministry of Foreign Affairs of the Netherlands

Contact

To find out more and discuss how you can get involved in this exciting new initiative, contact either of the following:

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