



The Fall Armyworm: An Imminent Threat

New potential invasive species threats in South & South-East Asia
21-22 November 2018, Kathmandu



Overview

- Biology, life cycle
- Damage, yield loss, impacts
- Management

- Risk assessment
- Risk management

How did FAW reach Africa?



Destinations

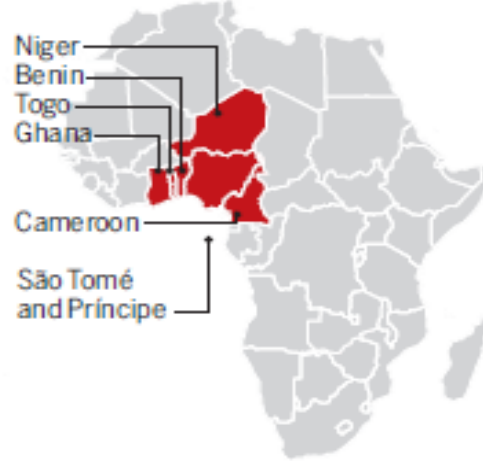


Rapid Spread of Fall Armyworm in Africa

January 2016



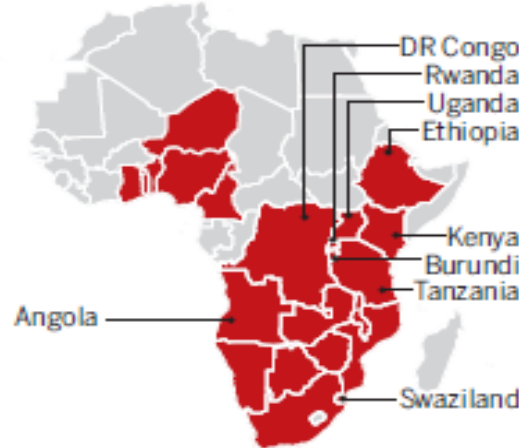
November 2016



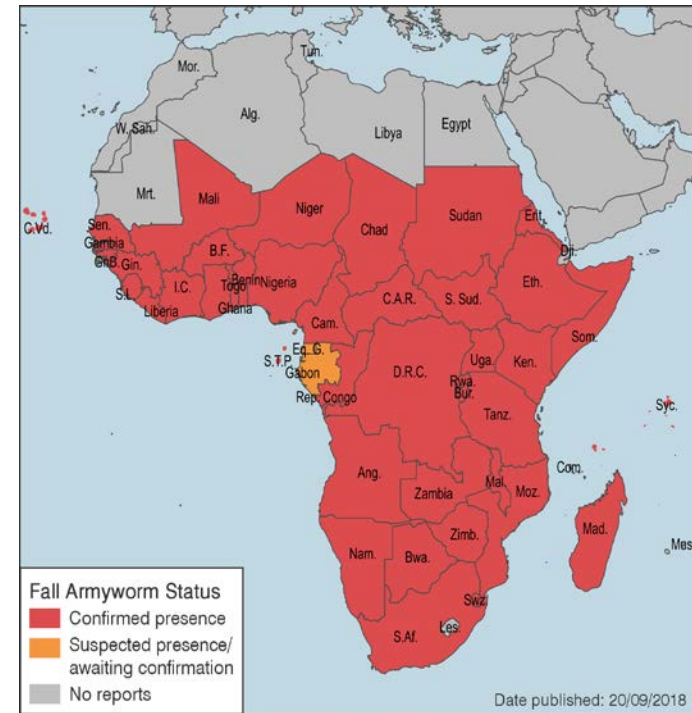
February 2017



April 2017

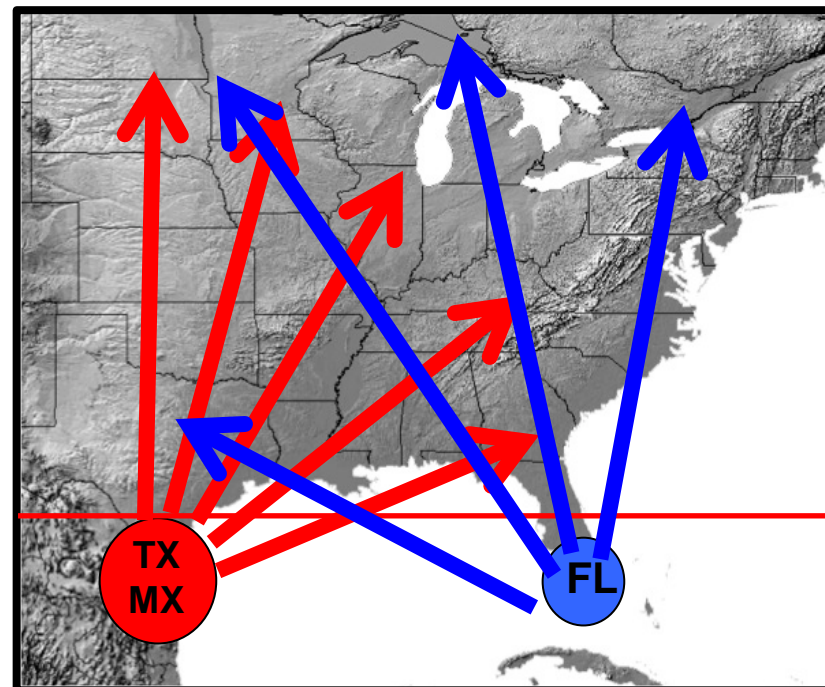
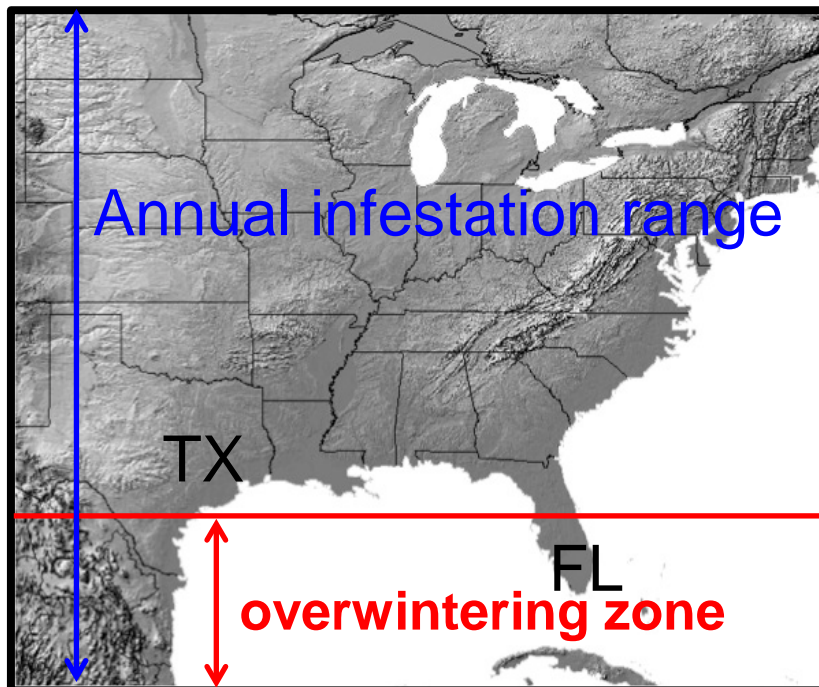


September 2018



Erik Stokstad, Science, 5th May, 2017 and FAO 2018

FAW Migration in North America

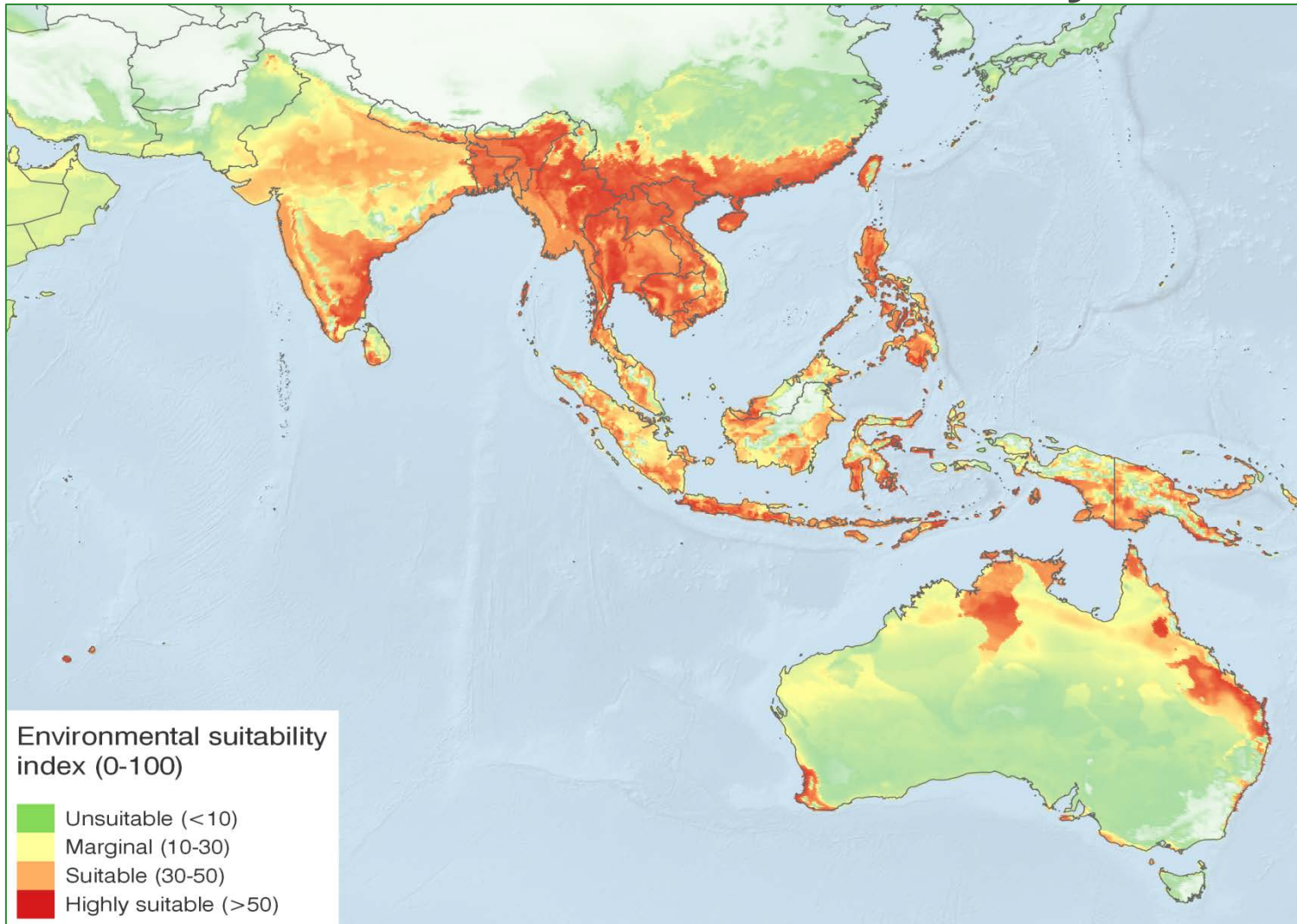


FAW does not survive freezing winters...
... but annually infests most of the United States and southern Canada

FAW overwinters in southern Florida, southern Texas and Mexico...
...then moves northward every year

FAW annually migrate 3000 km from March-September

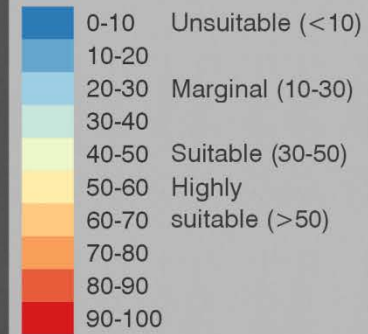
Threat to Asia: Environmental Suitability



Environmental suitability in Bangladesh

Fall Armyworm
(*Spodoptera frugiperda*)

Environmental suitability index

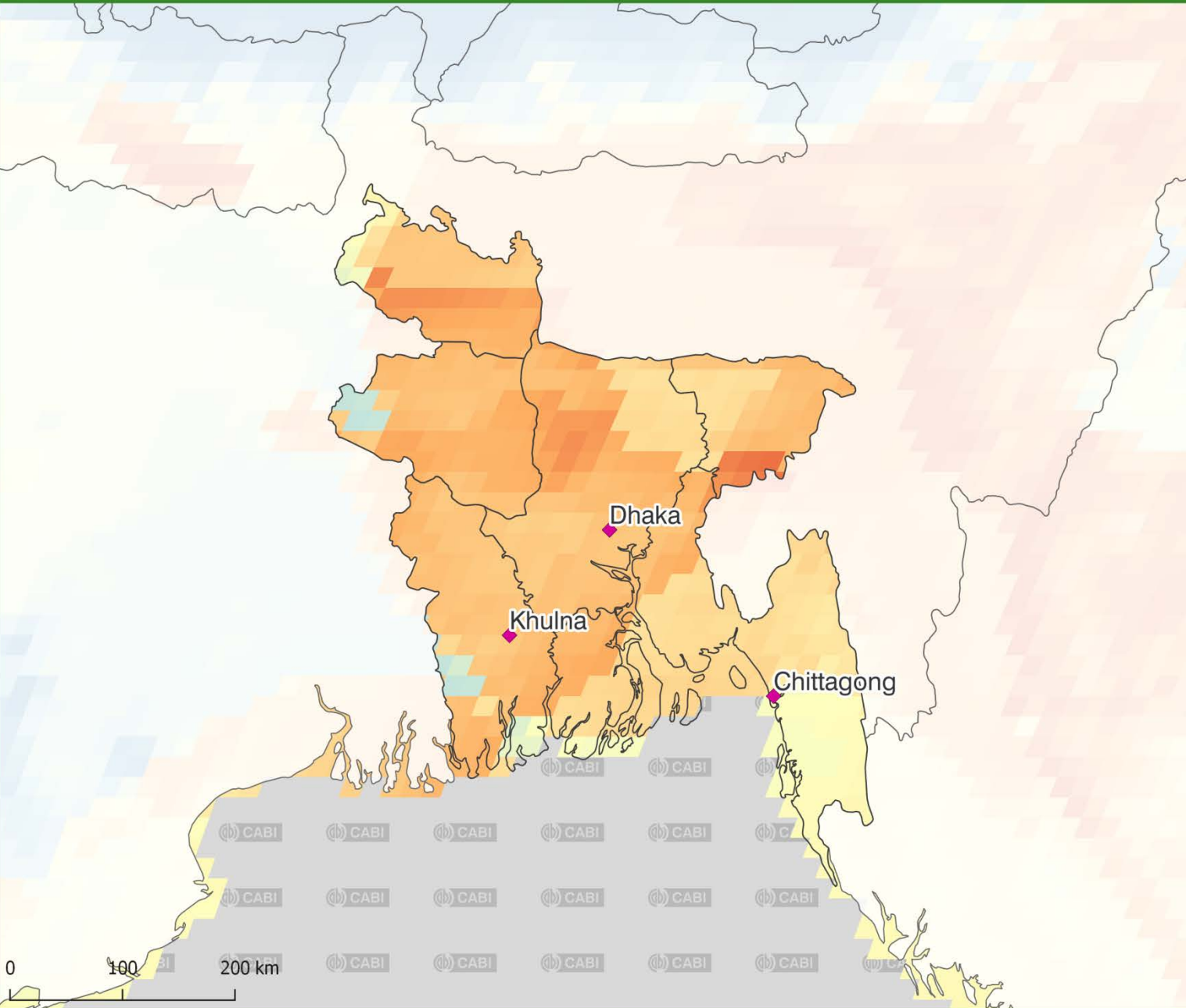


Environmental suitability index:
Generated from modelling by Dr
Regan Early (University of Exeter):

Forecasting the global extent of
invasion of the cereal pest
Spodoptera frugiperda, the fall
armyworm, Regan Early, Pablo
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Roger Day, bioRxiv 391847; doi:
<https://doi.org/10.1101/391847>

Date Published
22/08/2018

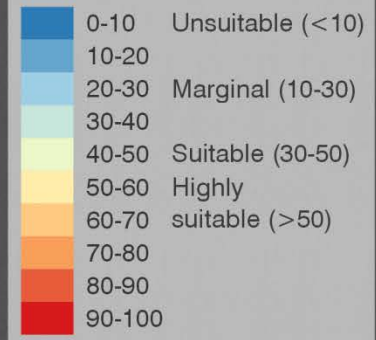
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Environmental suitability in Nepal

Fall Armyworm
(*Spodoptera frugiperda*)

Environmental suitability index

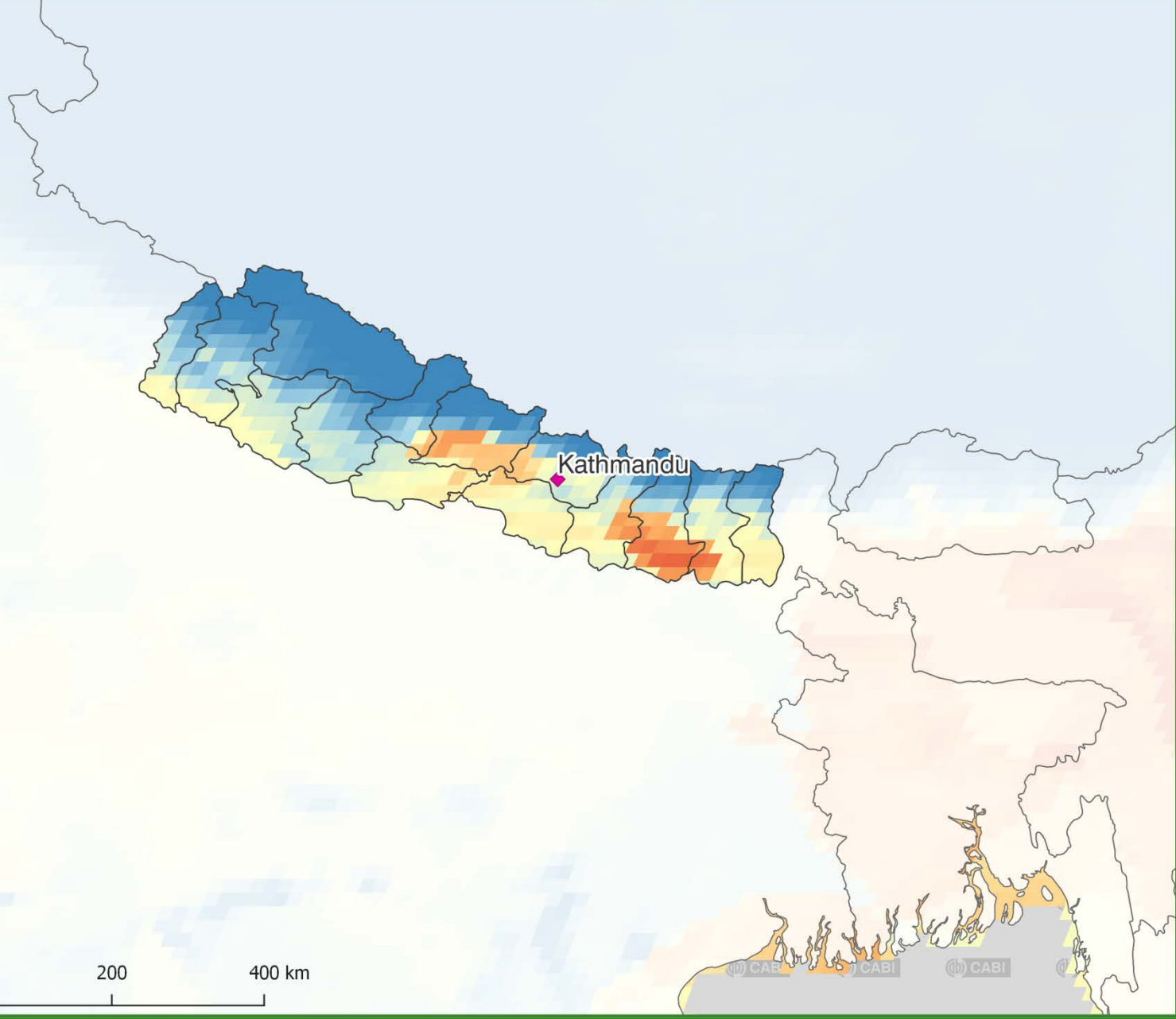


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Life Cycle

- Two strains (maize, rice)
 - Both strains in Africa, Asia
- Potential confusion with other pests of maize
- Field identification
 - Direct identification using morphological characters
 - Indirect identification through characteristic injury symptoms



Eggs

- Laid on the underside of leaves
- In Africa, usually found on leaf surface
- On young maize, may be laid on the stem
- 100-200/batch
- Up to 1000/female





Eggs darken when they
are about to hatch

Eggs Hatching

- All hatch about the same time
- Young larvae have dark heads





Larvae

- Neonate larvae (large black head and dark spots on the body)
- Easily identified as FAW from 2nd instar onwards
- Cause “windowing” on leaves
- 6 larval instars
- 6th instar causes most damage (>75%)

Field identification of FAW Larvae



- White inverted Y-shaped on front part of the head
- Pale or yellowish dorsal lines along the length of the body
- 4 dark tubercles on the dorsal side of the last abdominal segment



Larva of FAW





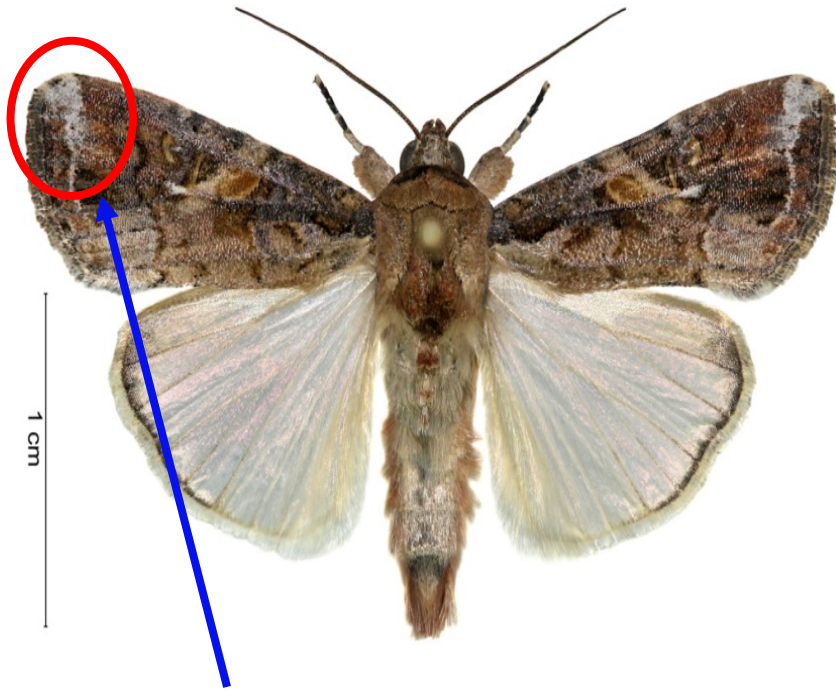
FAW Pupa

- Usually in soil
- Difficult to find

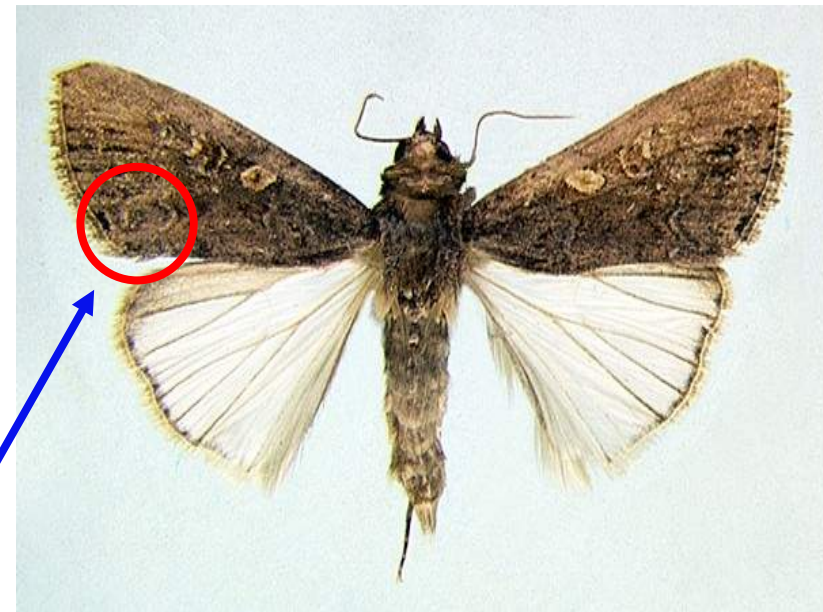


Adult FAW

Not to be confused with
African armyworm (bottom)

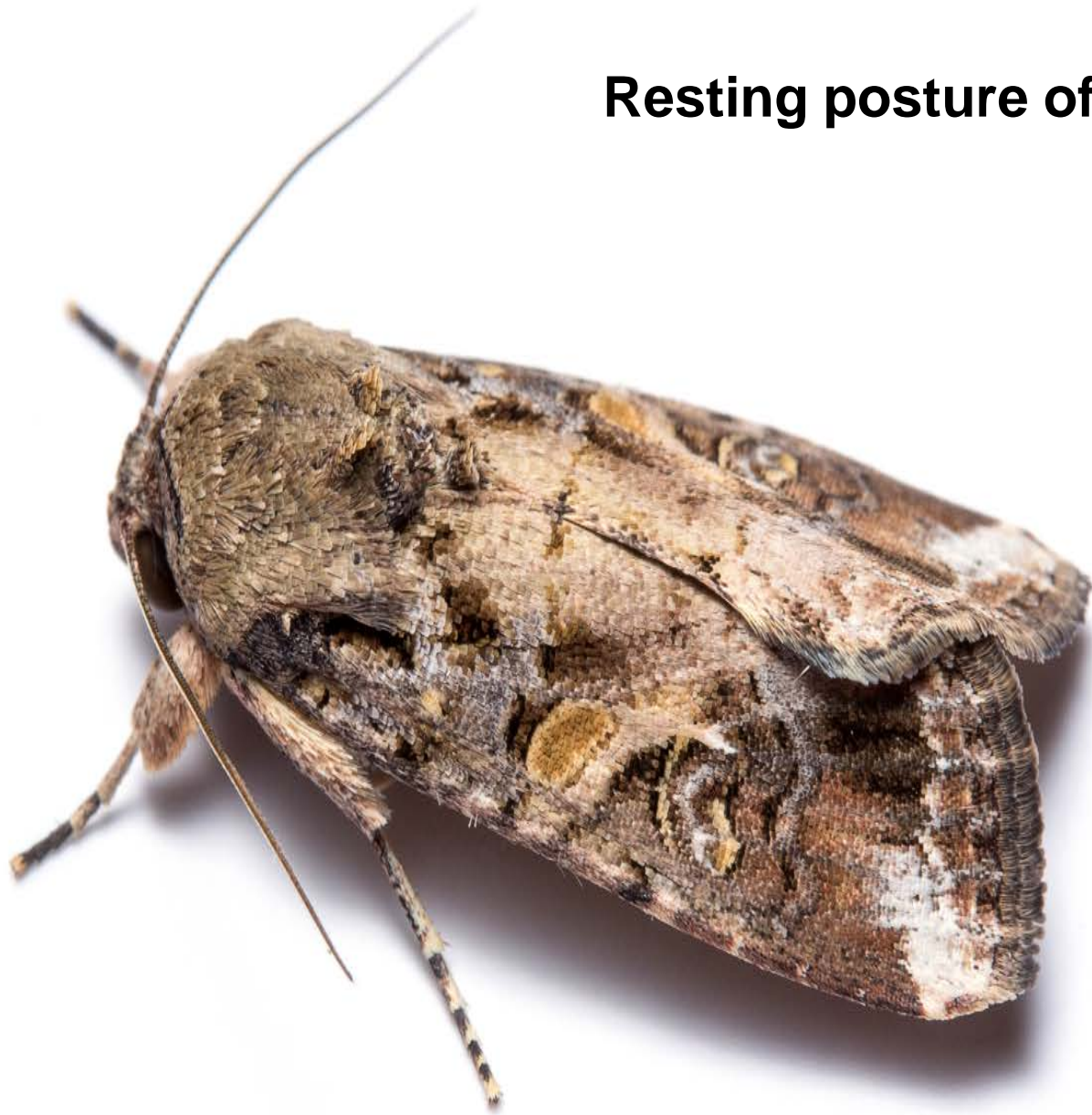


Male moth with
conspicuous white
spot on tip of
forewing



Kidney-shaped mark
on forewing

Resting posture of FAW moth

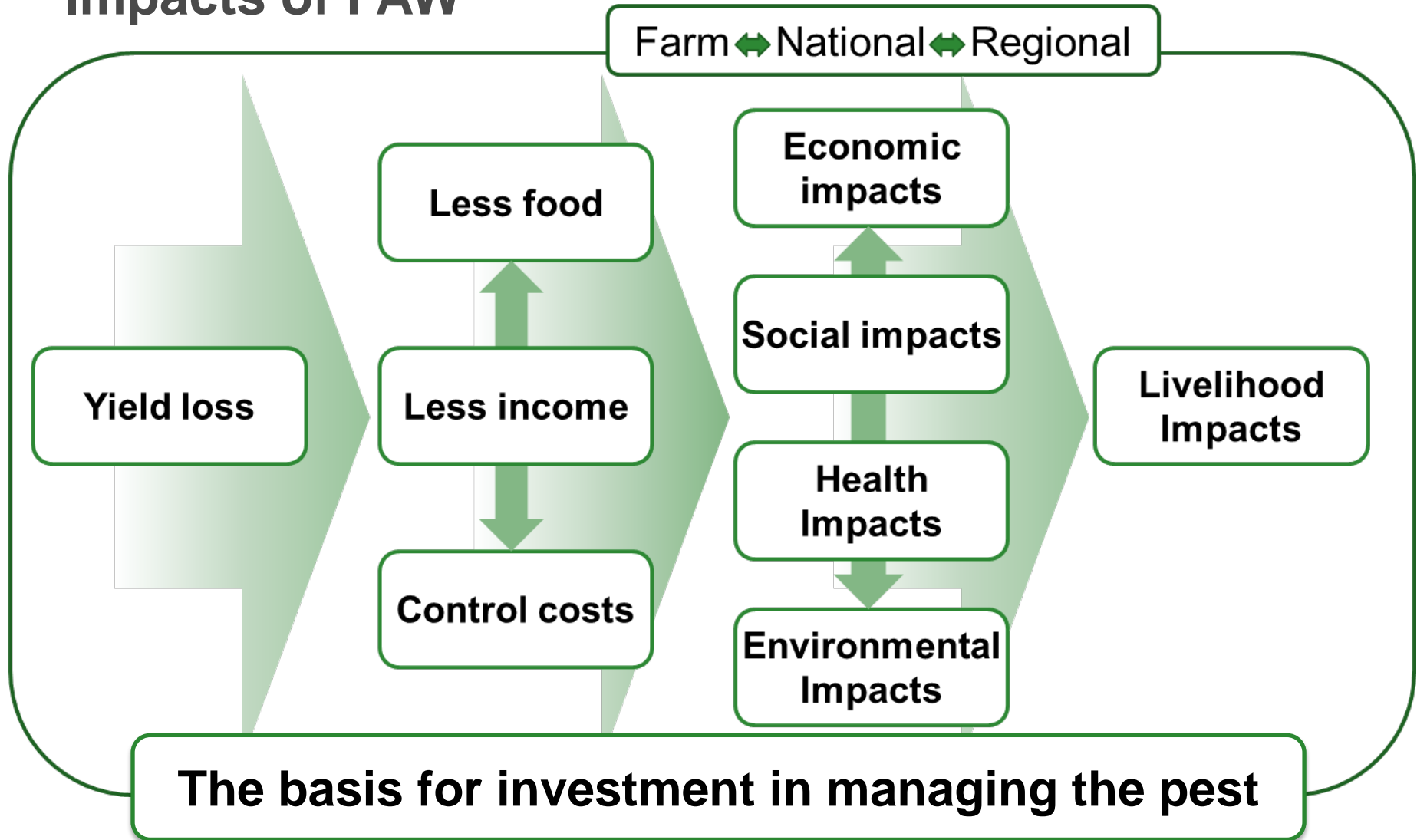




Life History Key Features

- Migrate (in pre-oviposition period)
 - Reach areas not suitable year round
- Females mate & lay multiple times
- Overlapping generations within a crop
 - Generation time 1-3 months, depending on temperature
- Cannibalistic behaviour (1-2 larvae/plant)
- Larvae hide/feed in funnel, emerge at night
- No diapause

Impacts of FAW



Symptoms may start as early as V3



FAW symptoms on the leaves



“Window-paning” (also caused by stem borers)



Initial leaf holing can progress to ragged torn leaves





Symptoms

- 100% FAW foliar damage under artificial infestation in screenhouse
- Unlikely to happen under normal conditions
- Early attack can cause “Dead heart”, death of young plants



Symptoms of FAW

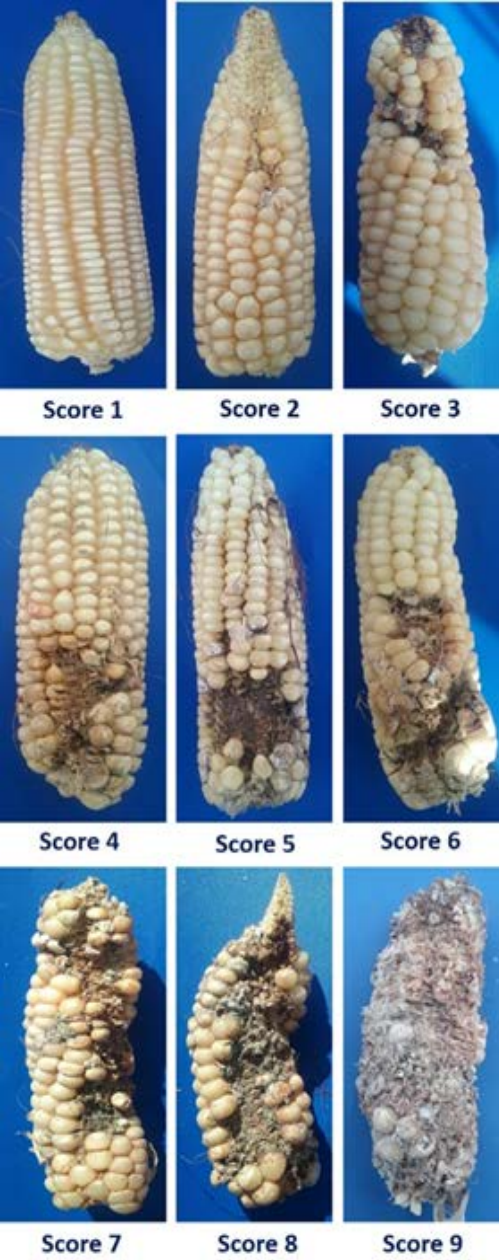


- Destruction of leaves in funnel
- Faecal matter
- Large leaf holes
- Cob damage



Maize cob damage

- Maize cob damage needs confirmation by examining larvae – other pests cause similar damage
- Damage to the cob may also result in aflatoxin contamination





Yield Loss

Polyphapous

- >350 reported hosts, Graminae preferred
- Maize seems the most susceptible

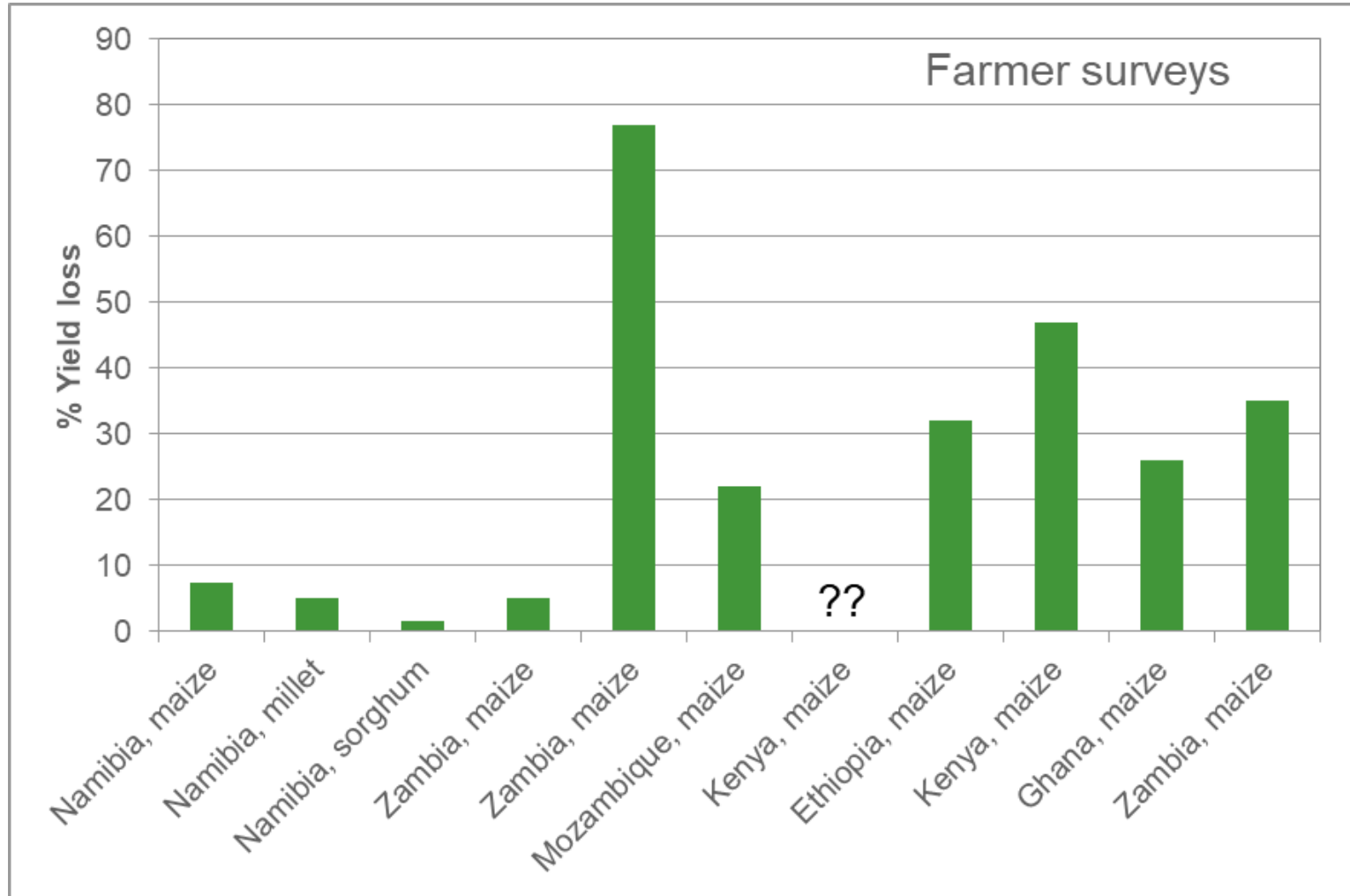


Reported losses (maize)

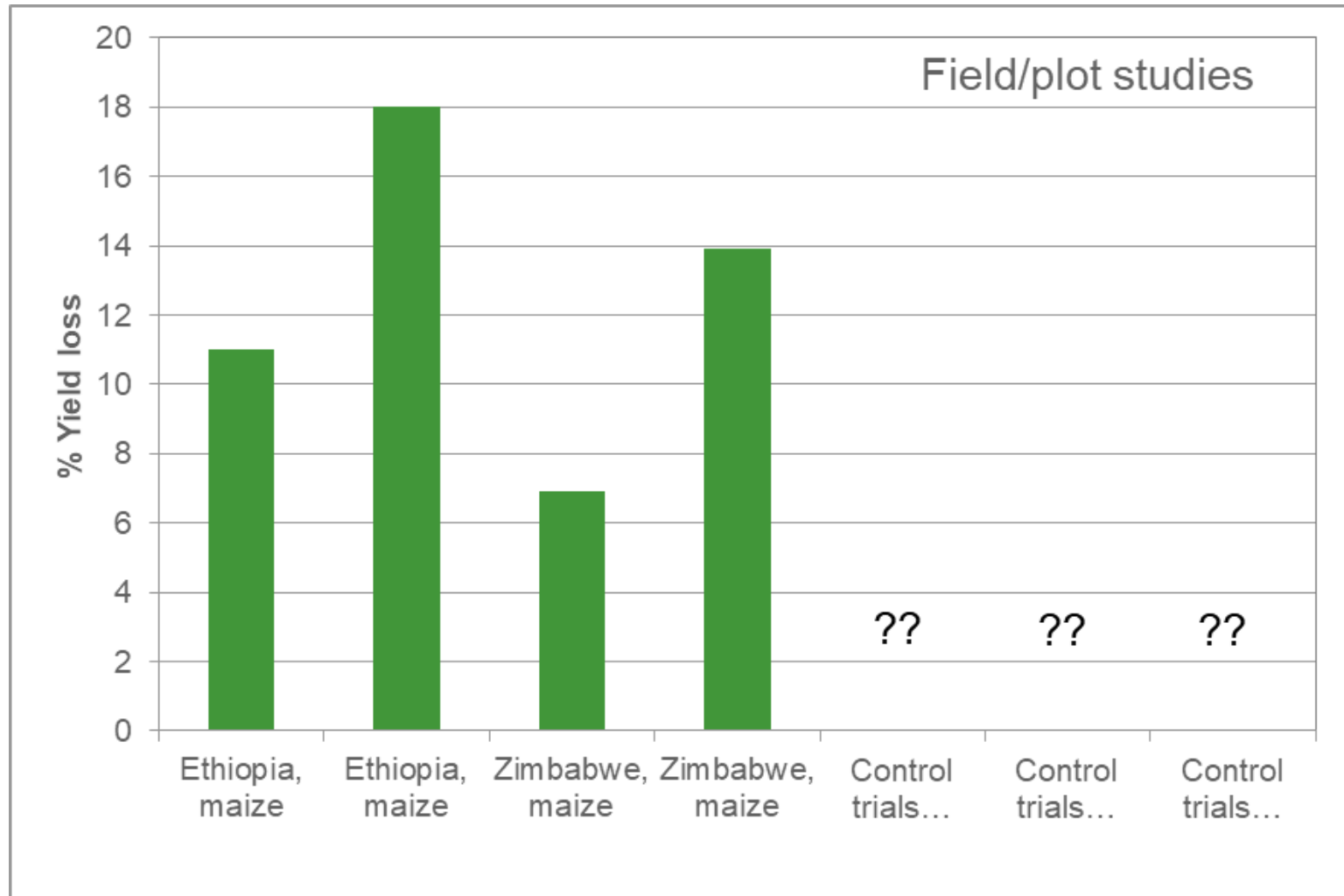
- Nicaragua: 15-73% (high infestation) (Hruska & Gould, 1997)
- Brazil: 34% (high infestation) (Cruz & Turpin, 1983)
- US: 17% (20-100% infestation) (Lima et al., 2010)
- Africa: Almost all major damage on maize
- Results of assessments very variable



FAW Yield loss estimates in Africa



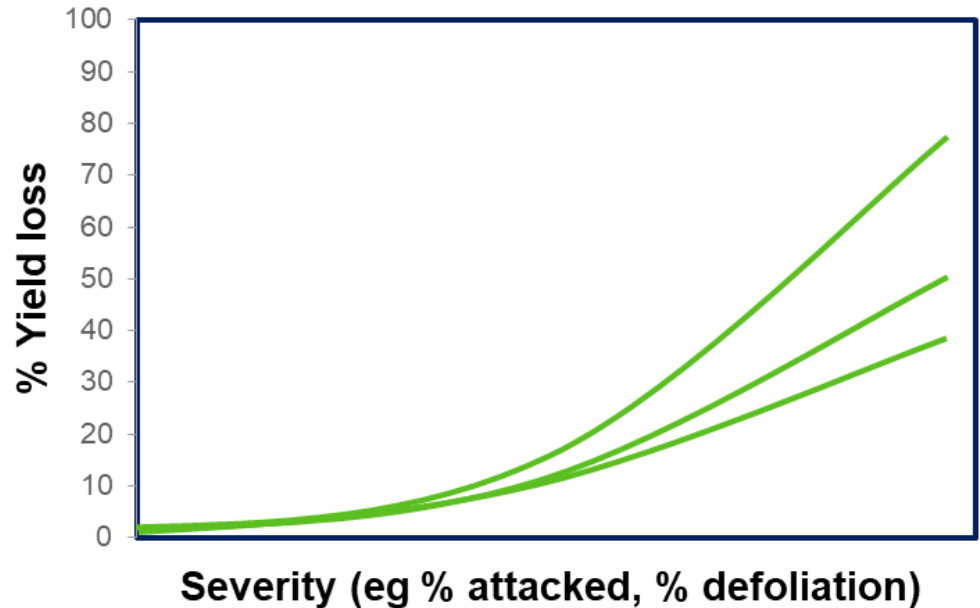
FAW Yield loss estimates in Africa



Damage relationship

Affected by

- Time of attack
- Crop
- Environment
- Tolerance of plant
 - Maize can withstand some attack





Key messages on damage, impacts

- Damage can look severe but maize can recover from some attack
- Yield loss can be severe, but is uneven
- Most damage in Africa on maize
- Farmer estimates of yield losses probably overestimates (lack of experience)
- Controlling when the cost of control is more than the value of the crop saved is wasting money!



Control

Options (Americas, Africa)

- Efficacy
 - Safety
 - Sustainability
 - Practicality
 - Availability
 - Cost
-
- Integrated Pest Management (IPM)



Pesticides

- Numerous: All levels of hazard (WHO Classification) and many modes of action
- Brazil has about 40 registered
- Different states in US give different recommendations (including some Class 1)

Effectiveness: Effective when used correctly.

- Rotate different types to reduce risk of resistance developing
- Spray early or late in the day
- Best to spray young larvae: Monitoring needed
- Spray into funnel



Monitoring

- Visual survey (scouting)
 - 20 consecutive plants from 5 random points
 - Example thresholds (crop/stage):
 - $\geq 25\%$ plants show damage, larvae present
 - 20% whorls infested (in 1st 30 days)
 - Depends on crop value, control cost & efficacy
 - What thresholds to use?
- Pheromone traps (monitoring)
 - Different versions of pheromone and traps commercially available
 - Different pheromones may catch differently
 - Not a good indicator of population size
- FAO FAMEWS App and platform



Pesticides

Africa

- Widespread use (availability, registered for other moths, used elsewhere)
- Reports of pesticides not working – why?

Constraints

- In the Americas resistance to carbamates, organophosphates, pyrethroids
 - No evidence in Africa yet
- Spray application requires equipment, water (200-400 l/ha)
- Need for protective equipment
- Newer, lower risk products more expensive



Host Plant Resistance

Effectiveness

- Some potential

Africa

- CIMMYT have lines that offer partial resistance, breeding in progress

Constraints

- Multiple other traits required (eg disease resistance)
- Susceptibility of currently favoured varieties in Asia?



GM Crops

- Genetically Modified crops containing Bt genes

Effectiveness

- Effective, widely planted in Americas (Maize, cotton, soya)

Africa

- Few countries have approved GM crops so far; Bt Maize only planted in S Africa
- Asia?

Constraints

- “Refuge” crops required to reduce risk of resistance
- Resistance to the Cry1F protein (group) in Bt Maize, with some cross resistance to CryA.



Biological pesticides, biorationals

Biopesticides, microbials, macrobials, botanicals, biochemicals

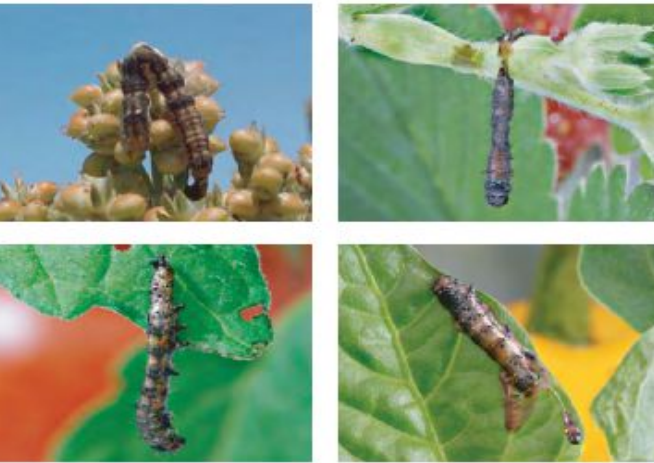
Study for Africa

- What is registered for FAW in Americas
- What is available in Africa
- What evidence for effectiveness
- Safety, sustainability

Priorities for Africa

- Microbials: FAW NP Virus; *Bacillus thuringiensis*
- Botanicals: Azadirachtin/neem; Pyrethrins*
- Sex pheromones
- Macrobials: *Trichogramma spp.*
- Biochemicals: Lufenuron*, Methoxyfenozide, Oxymatrine, Silicon dioxide, Spinetoram*, Spinosad*

*Not target concerns



Technical Manual



Virus-based biopesticide

- Naturally occurring virus: SfMNPV
- Products available: AgBiTech has factory in Texas

Effectiveness

- Effective when used correctly. Host specific, very low non-target risks

Africa

- Trials ongoing (AgBiTech)
- Andermatt registered Littovir (for *S littoralis*).

Constraints

- Only kills *Spodoptera* (?stacked viruses)
- Registration of an exotic insect pathogen
- Cost?

Bacillus thuringiensis (Bt)

- Spray based on a naturally occurring bacterium
- Main subspecies used: *kurstaki* and *aizawai*

Effectiveness

- Effective: genetic modification has been used to try and improve its efficacy

Africa

- Available, some testing done showing efficacious

Constraints

- In the Americas resistance has been reported to Bt-based products





Botanicals

- Commercial products (eg neem) and plants with insecticidal and/or antifeedant effect on FAW
- “Home brews”

Effectiveness

- Commercial products effective
- Local concoctions variable

Africa

- Commercial products available
- Reports of farmers’ successes

Constraints

- No residual effect
- Home-production is labour intensive; resource limitations



Rearing/release of parasitoids

- Mass rearing and release of parasitic wasps (~100,000/ha). Egg parasitoids *Trichogramma pretiosum*, *T. atopovirilia*, *Telenomus remus*

Effectiveness

- Reported as effective. Not clear how widespread

Africa

- No trials conducted for FAW

Constraints

- Might not be cost effective
- Practicalities of rearing





Rearing/release of predators

- Mass rearing and large scale release of insect predators. *Doru luteipes* (earwig) and *Orius insidiosus* (pirate bug)

Effectiveness

- Not clear. Brazil recommends *Doru*. *Orius* is commercially produced; not clear if used for FAW.

Africa

- No trials have been conducted

Constraints

- May not be cost effective





Pheromones

- Synthetic mimics of the female moth's sex pheromone used to mass-trap males or disrupt their mate-finding

Effectiveness

- Little use; reduced spray requirement reported for mass-trapping

Africa

- Trials starting on mating disruption with Provivi (cheap pheromone synthesis)

Constraints

- Control with pheromones works best at large scale



Classical biological control

- Introduction of a natural enemy (often from pest's area of origin)

Effectiveness

- Can be highly effective. FAW egg parasitoid *Telenomus remus*, used in Caribbean. Already in Africa, Asia

Africa

- CABI making surveys for new candidates in Latin America

Constraints

- The agent may fail to establish or establish but have little effect



Cultural Control Methods

- Many including: Plant early, use early maturing varieties, intercrop maize & beans, remove weeds, remove/destroy crop residues, rotate with non-hosts, ploughing/cultivating to expose larvae & pupae, handpicking egg masses and larvae, applying sand sawdust or soil in the whorl (with ash/lime)

Effectiveness

- Unlikely to provide adequate control alone. Observations in Africa support intercropping, on-farm biodiversity, low tillage

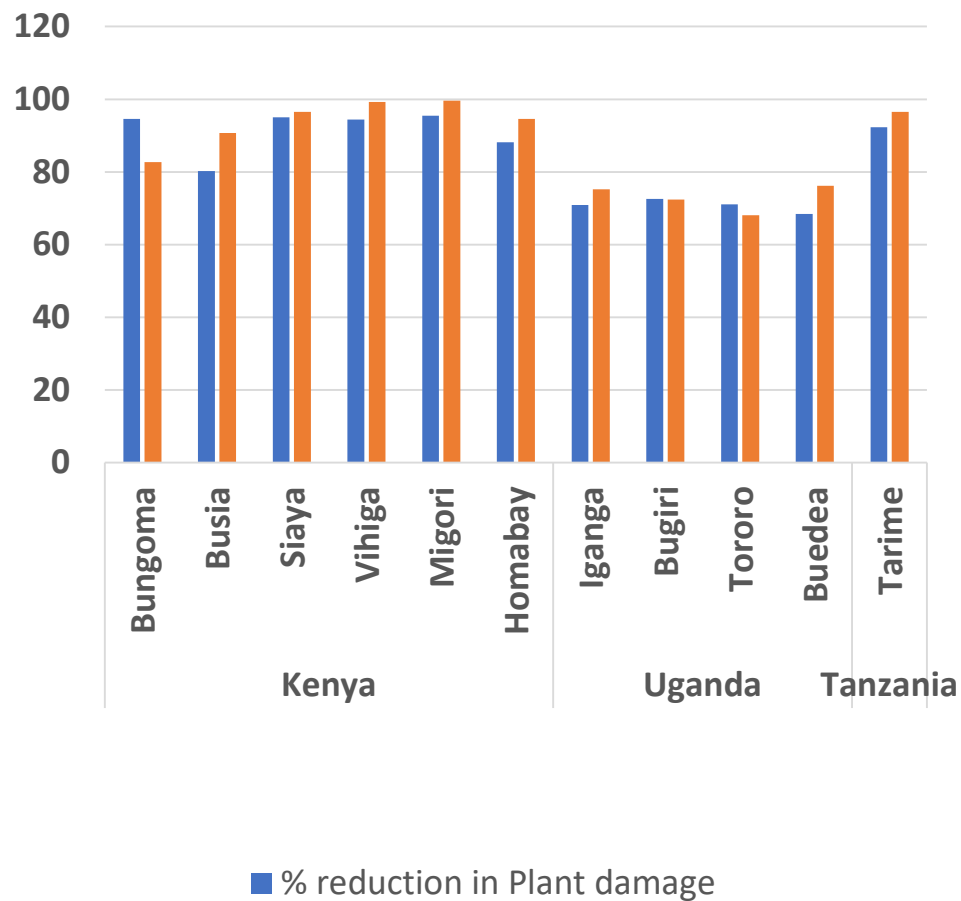
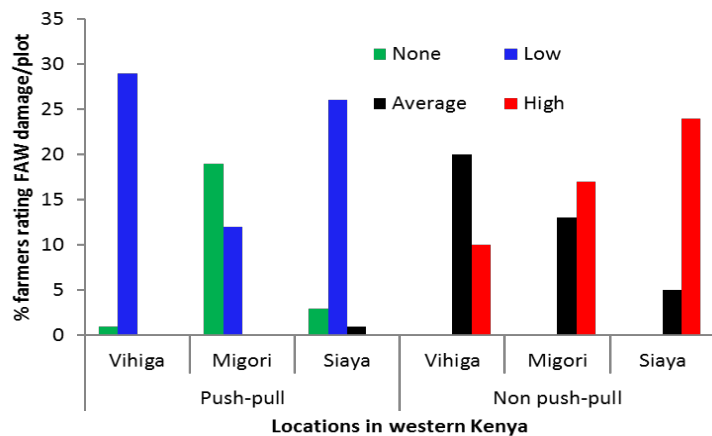
Africa

- Cultural methods are being recommended and used
- Handpicking common
- Debate over which are worth promoting

Constraints

- Can be labour intensive
- May be yield penalties

“Push-Pull”





Natural control

- Large numbers of natural enemies in Americas
- In Africa various parasitoids already found
 - *Telenomus remus*
 - *Cotesia icipe*
 - *Palexorista zonata*
 - *Charops ater*
 - *Coccygidium luteum*
 - Up to 70% parasitism in some cases
- Need to maintain/encourage
 - Avoid early spraying
 - Maintain plant diversity
 - Providing food sources

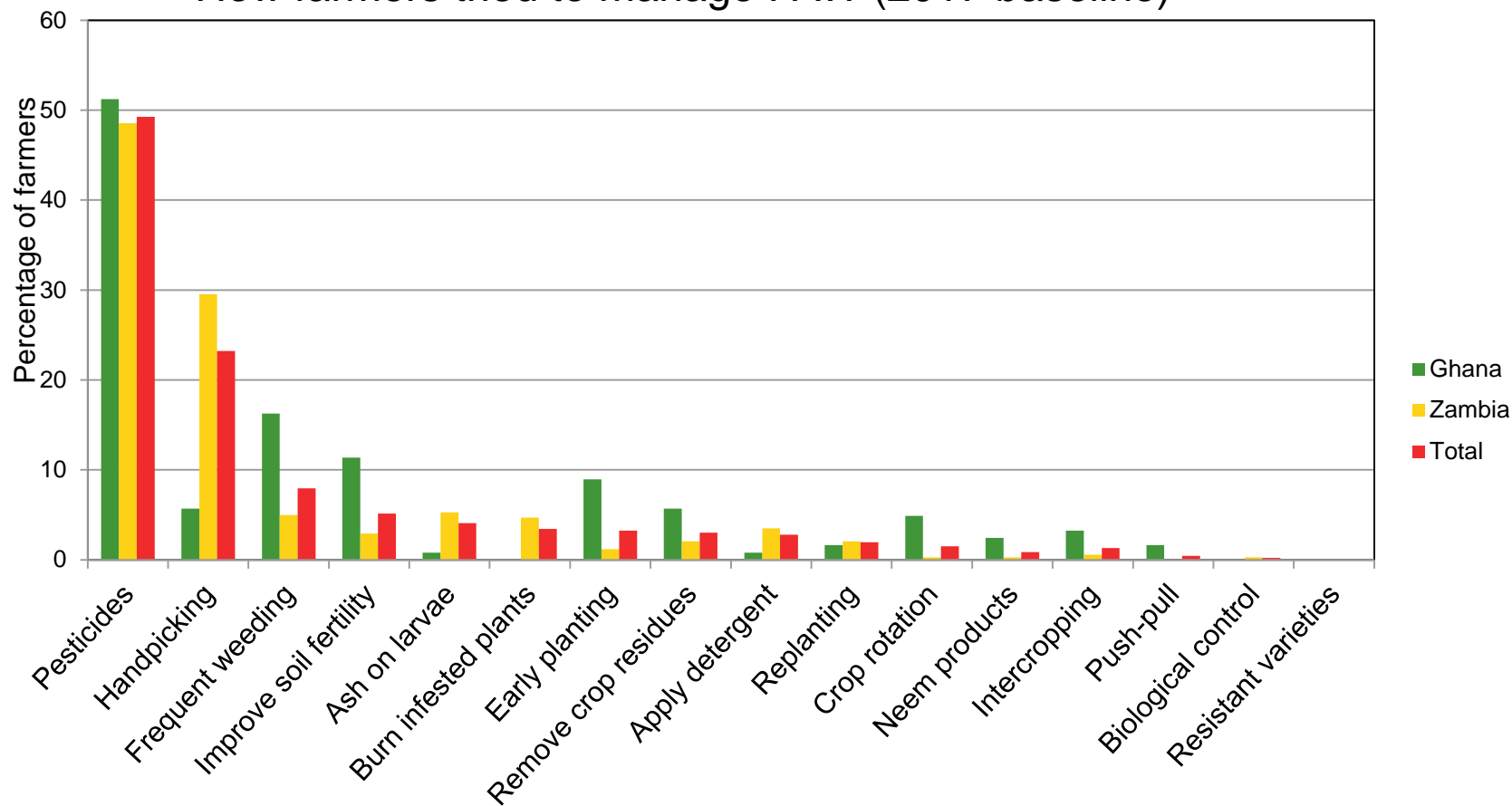


Response in Africa

- Recognised emergency: some panic
- Little or no preparedness
- National task forces
 - Ghana stakeholder meeting
- Governments distributed free pesticides
 - Usually synthetics
 - 2018 Ghana used biorationals
- All sorts of pesticides being sold and used
 - Some highly hazardous WHO Class 1
- Loss of regulatory control
 - Some temporary/emergency registrations
- Around 50% farmers using pesticides
- Farmer innovation

Understanding farmers' decisions

How farmers tried to manage FAW (2017 baseline)





Key points on management

- National coordination
- Stakeholder engagement, communication
- Maintain regulatory control
- If subsidising, subsidise lower risk approaches
- Intervention not always needed
 - Thresholds need to be determined
- Use biologicals rather than synthetic pesticides
- Encourage natural enemies
 - Can provide significant control
- Research needed



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