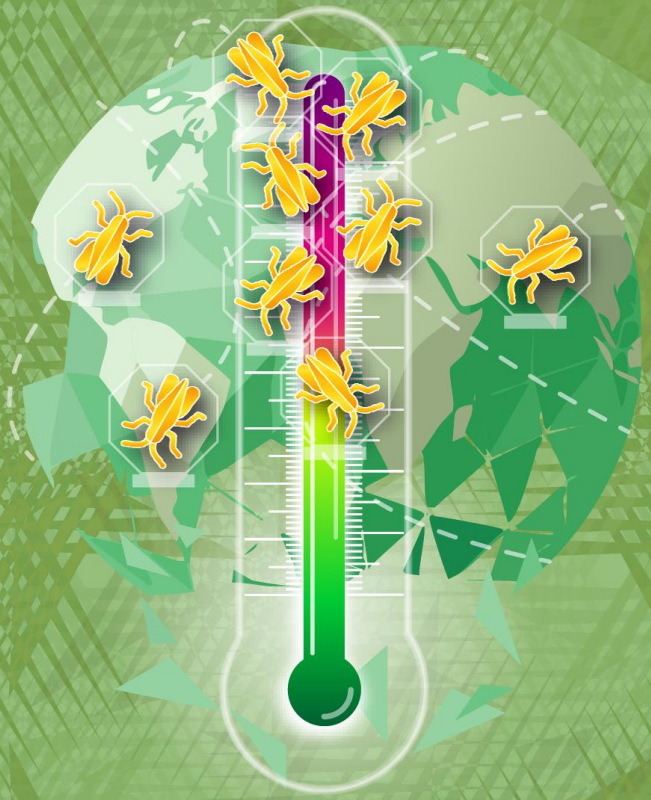
IPPC Webinar Series

Climate Change and Phytosanitary Issues

1–2 October 2025 | 14:00–16:00 CET



Nature's Climate Shield: how biological control bolsters resilience while curbing carbon emissions

Kris A.G. Wyckhuys, PhD

FAO NSP

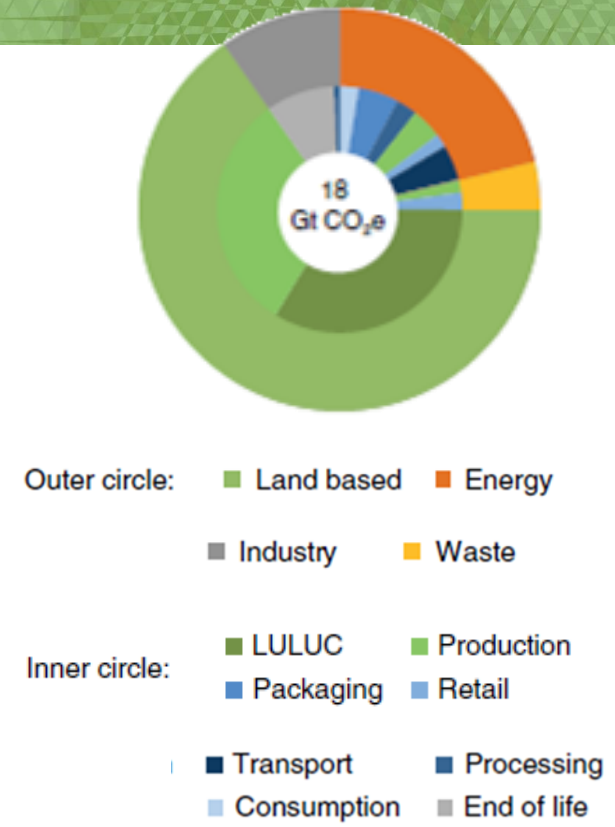
Crop pests in a warming world: an unfolding crisis

- **Multifaceted impacts** on agricultural pests, crop performance and pest control efficacy
  - Altering pest and pathogen bio-ecology
    - 2/3 of tropical pests to colonize temperate zones
  - Decaying food webs and jeopardized (direct, indirect) plant defenses
  - Accelerating pesticide resistance development
  - Increasing crop losses
    - Yield losses due to cereal pests may rise by 10-25% per degree warming
- Major implications for food security, farmer livelihoods and societal stability

Bebber, 2015; Deutsch et al., 2018; Redhead et al., 2020; Ma et al., 2021

Anthropogenic global warming: a planetary emergency

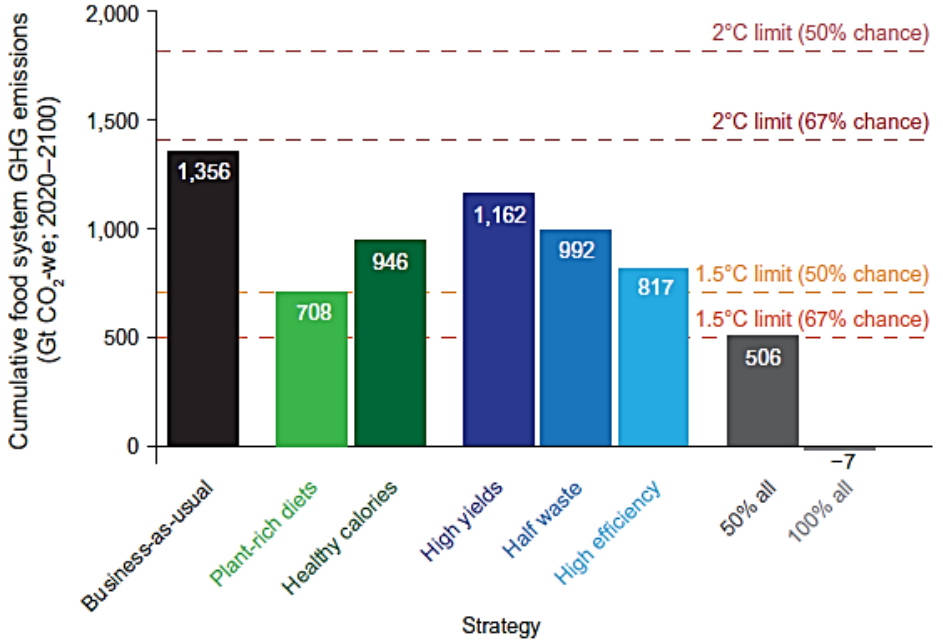
- Global food system annually generates greenhouse gas (GHG) emissions worth 18 Gt CO_2e or 4.9 Gt carbon equivalent (CE)
  - ~ 30% global GHG emissions
  - Rapidly rising esp. in developing countries
- 'On-farm' production responsible for 39% emissions
- Cropland emissions primarily ascribed to
  - CH_4 from rice cultivation,
  - CO_2, N_2O, and CH_4 from peatland draining,
  - N_2O from N fertilizer application
- Curbing carbon emissions: a pressing imperative



Carlson et al., 2016; Crippa et al., 2021

Decarbonizing the global food system

- Food system change can lower emissions
  - Transition to plant-rich diets could attain ~ 50% GHG reduction
- Yet, cultivating crops is still (too) energy-intensive
  - 15-50% GHG in wheat production due to (synthetic) fertilizers and pesticides
- Synthetic pesticides: blind-spot in carbon accounting
  - Carbon footprint unquantified
  - Under-recognized as a driver of environmental change, human health hazards and biodiversity loss



Poore & Nemecek, 2018; Clark et al., 2020

Pesticide volumes

- Extract FAOSTAT data for insecticides, fungicides and bactericides, and herbicides (including seed treatment)
- Average values over 2016-2018

Carbon conversion

- Compute carbon equivalents for pesticide production, transportation, storage and transfer as per Lal (2004)
- Add 0.4 kg CE/kg active ingredient (a.i.) for pesticide formulation

Application energy use

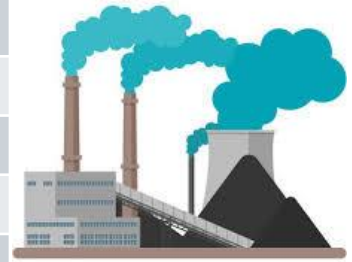
- Incorporate 39.2% energy expenditure for field spraying / equipment manufacturing (Audsley et al., 2009)
- Use 511 MJ/kg a.i. of production energy for seed treatment

Wyckhuys et al., 2022. Nature Food

Country	Carbon emissions (Mt CE)		Passenger vehicles driven ('000s)	Barrels of oil consumed ('000s)
	Average	Range		
G7				
Canada	0.703	0.222-1.351	561	5,973
France	0.534	0.178-1.023	426	4,534
Germany	0.335	0.107-0.605	267	2,846
Italy	0.354	0.127-0.649	282	3,006
Japan	0.379	0.123-0.686	302	3,220
United Kingdom	0.131	0.045-0.251	105	1,115
USA	3.033	0.948-5.689	2,419	25,751
BRICS				
Brazil	3.004	0.952-5.650	2,395	25,500
Russia	0.558	0.182-1.056	445	4,739
India	0.295	0.093-0.511	235	2,505
China	2.145	0.684-3.894	1,710	18,207
South Africa	0.189	0.061-0.349	151	1,607
World	19.936	6.393-37.233	15,897	169,239

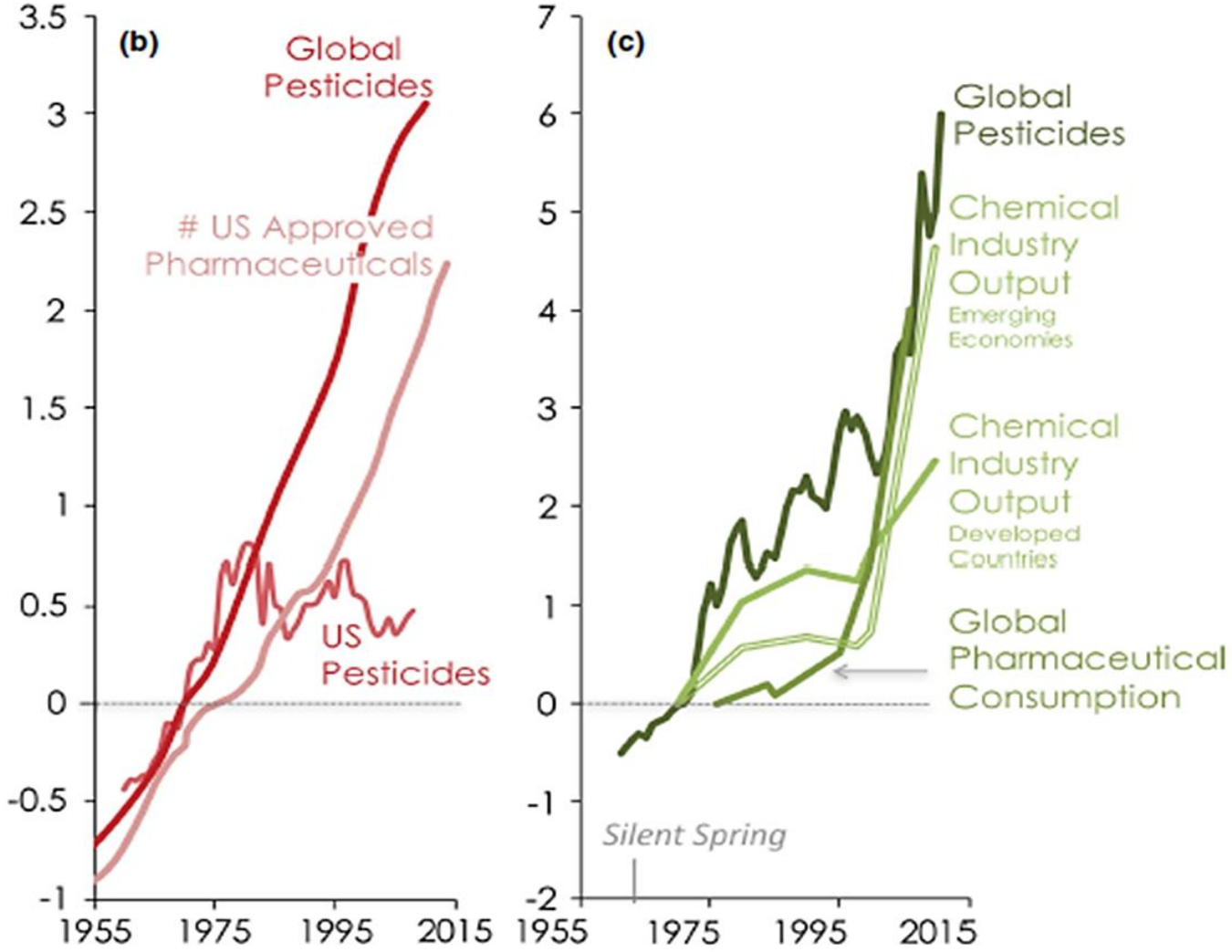
16 million/yr

170 million/yr



18.4 per yr

Wyckhuys et al., 2022. Nature Food



Time to turn the tide

Pesticide usage intensity does not cease to rise

- Continuous growth post-1950s
  - 2010-20: pesticide use grew by 20% globally and 153% in low-income countries

Two-pronged remediative action

- **Imperative #1:** replace chemicals with biodiversity-based alternatives
- **Imperative #2:** build biodiverse, pest-resilient cropping systems

Focus on pesticide-intensive crops & scale 'best-bet' solutions

Bernhardt et al., 2019; Shattuck et al., 2024

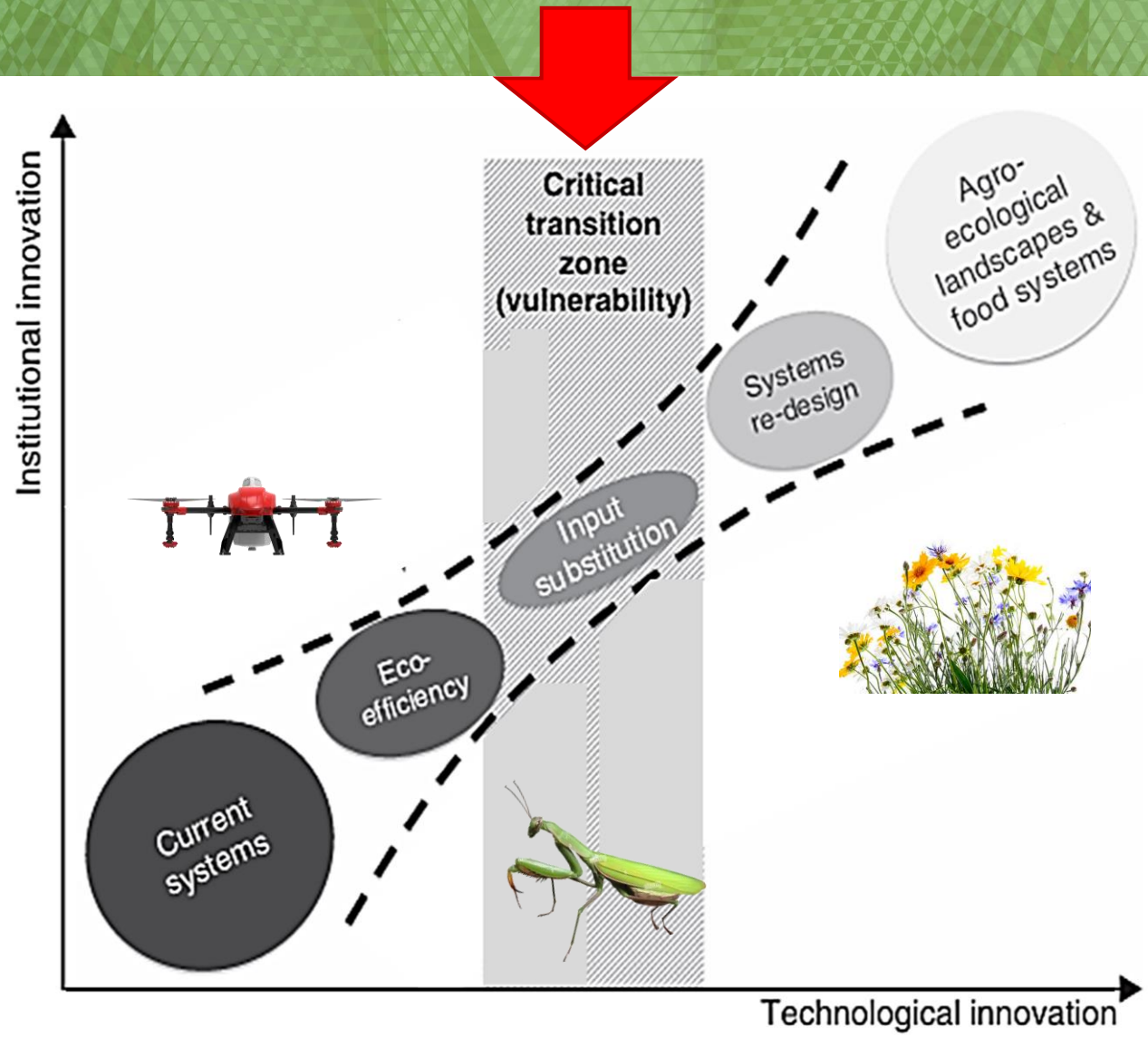
Step-by-step towards pest-resilient systems

#1. Enhance efficiency of synthetic pesticides – without compromising resilience

#2. Systematically substitute chemicals with non-chemical alternatives

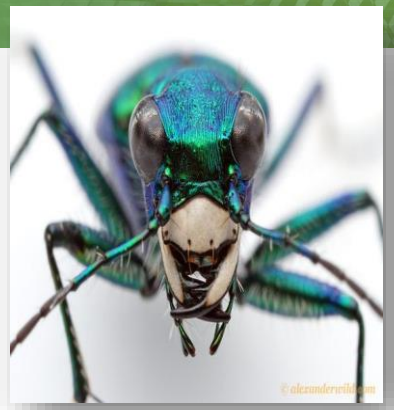
- Reclaim core ecosystem services, remove chemical toxics

#3. Pursue a 'wholesale' redesign of farming systems



Tittonell, 2014

Powerful allies for a low-carbon future





Biological control is valued at **US$ 191 billion/year** globally (Pimentel et al., 1997), including **$20.7 billion/year** natural control of native insects in the USA alone (Losey and Vaughan, 2006).

The little things that run the world (EO Wilson)

Biological control - a ‘best bet’ crop protection solution since 300 AD

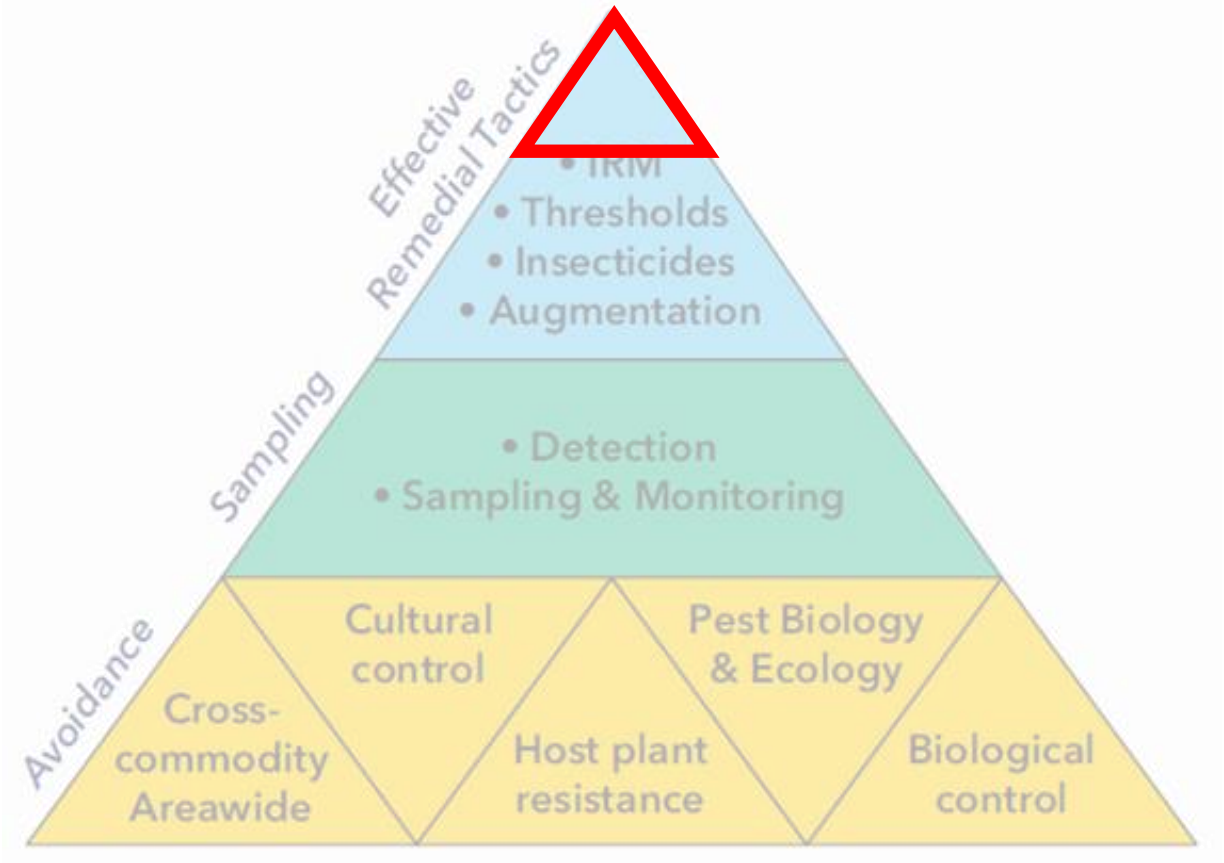
1. Active conservation of resident farm biota
- Naturally-occurring predators alone increase crop yields by 25%
- Raises farm-level revenue by hundreds of USD per ha

2. Field release of laboratory-grown biota
- More than 360 beneficial organisms used on >30 million ha
- Product development 1:10 success rate (1:140,000 for pesticides)

3. Translocation of non-native organisms
- Restores ecological balance of invaded agro-ecosystems
- Deployed on ~10% of global terrestrial surface

Key to pest-suppressive, climate-resilient food systems

IPM: FAO's compass for sustainable crop protection



Pesticides as a **measure of last resort**

not as unguided 'blanket' measures e.g., soil drenches, seed treatment

Biological control & agro-ecology as the **first line of defense**

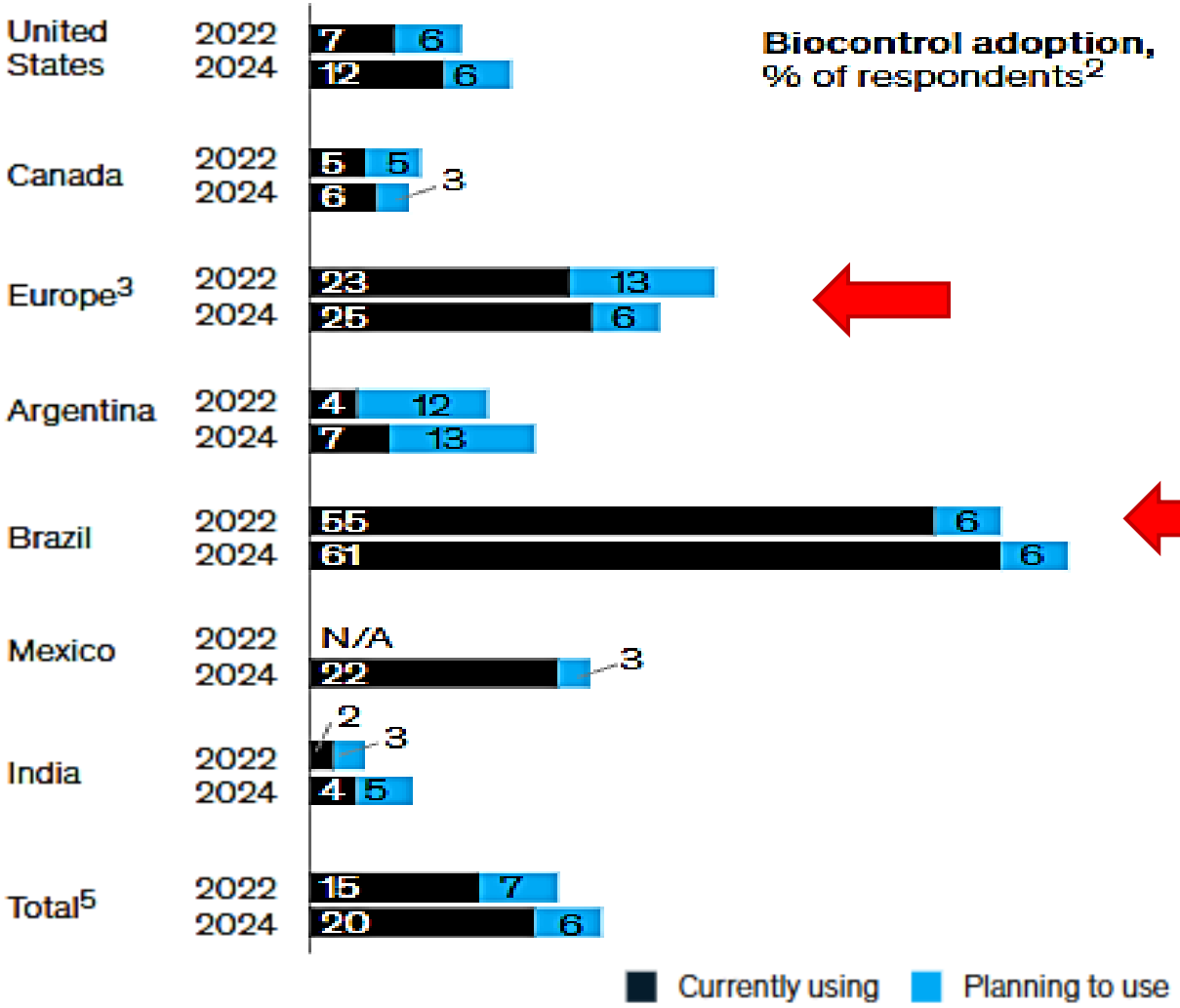
Augmentation biological control

> 212 species of beneficial insects and mites commercially available

> 42 species of beneficial fungi, bacteria, viruses or nematodes available for pest/weed/disease control

Market growth 10-15% (as compared to ~5% for chemical pesticides)

Biocontrol adoption, % of respondents[2]



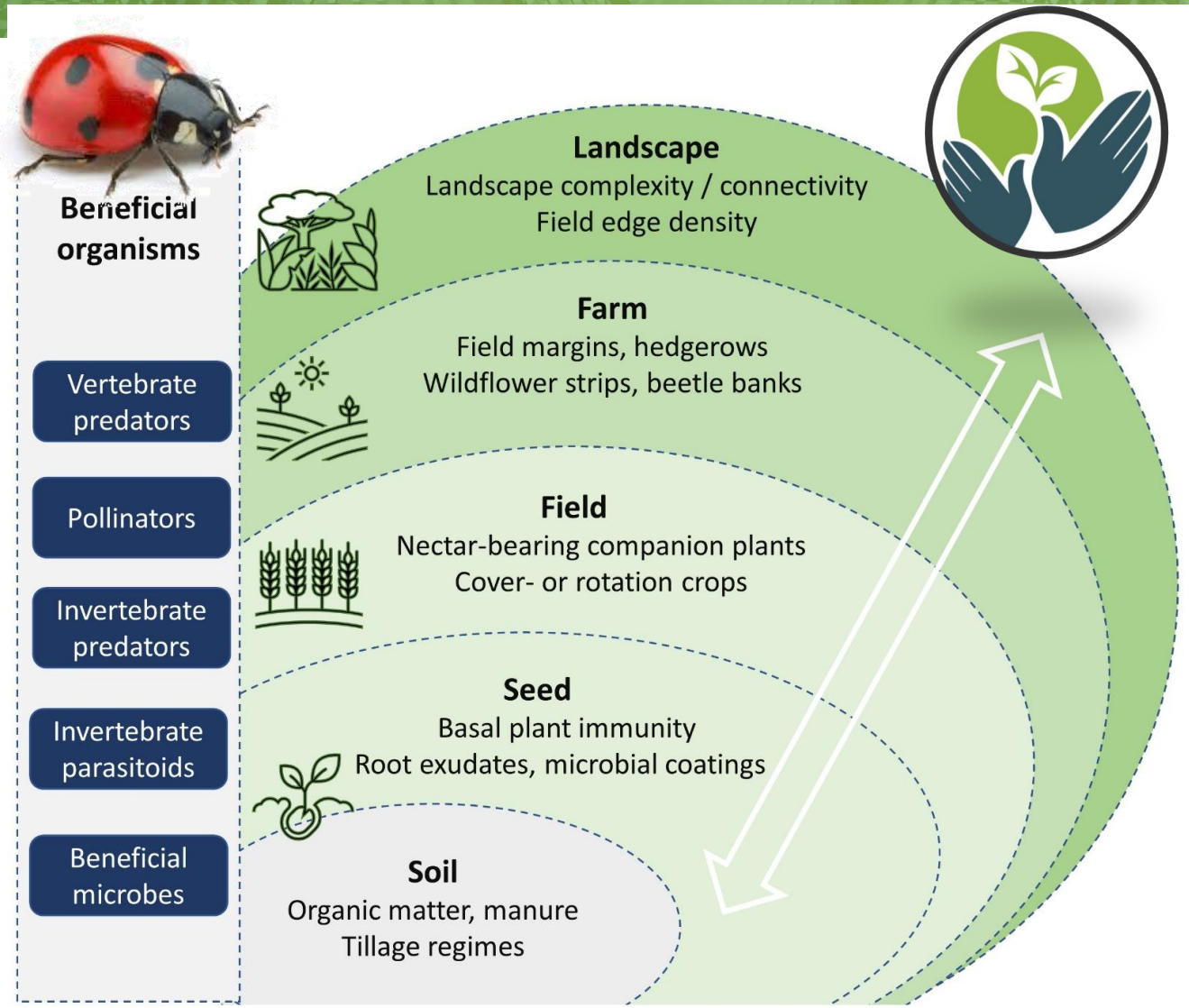
Restoring balance in invaded agroecosystems

- **Biological control: durable, self-sustaining, environmentally sound solution for invasive pest mitigation**
- In the Asia-Pacific, biological control generates dividends of US$ 14.6–19.5 billion/year
  - Reconstituted yields of critical food & livelihood security crops e.g., coconut, banana, breadfruit
  - Non-chemical pest control at continental scales
- **Its economic benefits amply surpass those of Green Revolution rice germplasm**
- In tropical Africa, biological control quickest way to control invasive biota, with highest return on investment

Neuenschwander et al., 2023
Wyckhuys et al., 2022. Nature E&E

Building resilience through agro-ecology and technology integration

- Pest prevention e.g., crop sanitation, manuring, cultural control
- Legume integration, field and landscape diversification
- Microbial coatings / inoculants
- Crop varietal mixtures, resistance inducers and defense priming
- Precision agriculture, robotic weeders



Wyckhuys et al., 2022, 2023

FAO as a steadfast supporter

- **IPM Farmer Field Schools FFS (1990s)**
  - Cut pesticide use up to 82-92% in Vietnam or Bangladesh rice; 78% in India cotton; 50-70% in Vietnam tea or cabbage
  - Enhanced crop yields by 13%
  - Raised farmers' revenue by 19%
- From 1992 to 1997, FAO-led FFS training programs cut insecticide use by 50% (without yield loss) on 2 million rice farms in the Mekong Delta
- In the US Midwest, IPM reduces pesticide use by 95% while enhancing pollination by 129% and yield by 26%

Waddinton report on IPM FFS, 2014; Pecenka et al., 2021
Bottrell & Schoenly, 2012; Escalada et al., 1999; Thorburn, 2015; Van den Berg & jiggins, 2007

FAO as a steadfast supporter

- **Global Action against FAW (2019-24)**
- FAO's coordinated response against the invasive fall armyworm, *Spodoptera frugiperda*
- Established a globe-spanning plant health research, extension, and policy support network
  - Reduced FAW yield losses to 3-5% in multiple countries
  - Cut farmers' pesticide expenditure by 30-50% in Kenya, Burkina Faso and Zambia
  - Increased farmer income by up to US$ 666 per hectare
- Training on biopesticide registration in the Caribbean and Africa
- Established laboratory capacity for production of natural enemies

Xia & Wyckhuys, 2024

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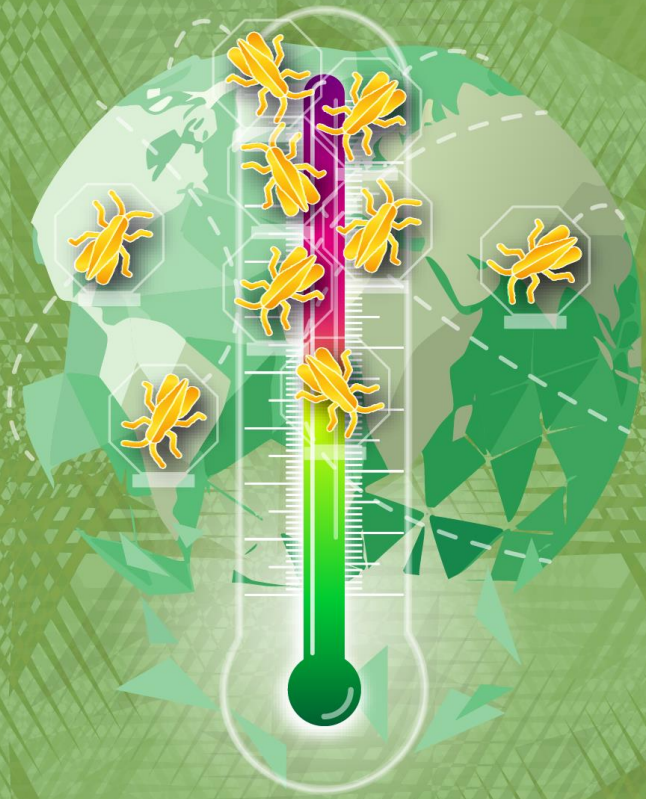

Thank you