Farming without plant protection products:

Can we grow without using herbicides, fungicides and insecticides?

STOA Workshop 06/03/19

Dany Bylemans - Barbara De Coninck - Wannes Keulemans

Overview

- Introduction: evolution of plant protection products

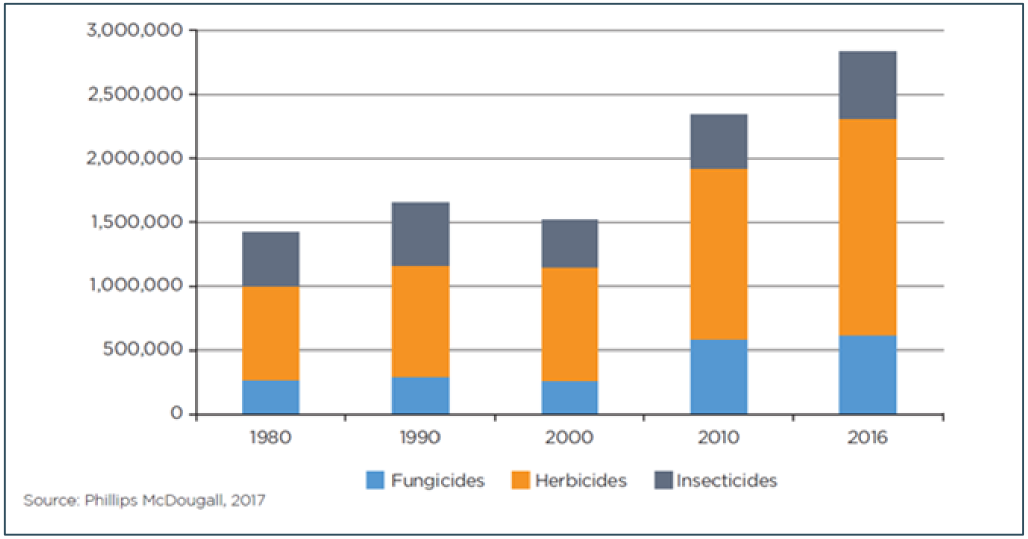
- Topics
  - PPPs and crop yield
  - PPPs and biodiversity/environment
  - PPPs and human health
  - PPPs and perception by the general public
  - PPPs and alternatives

  → Questions and answers

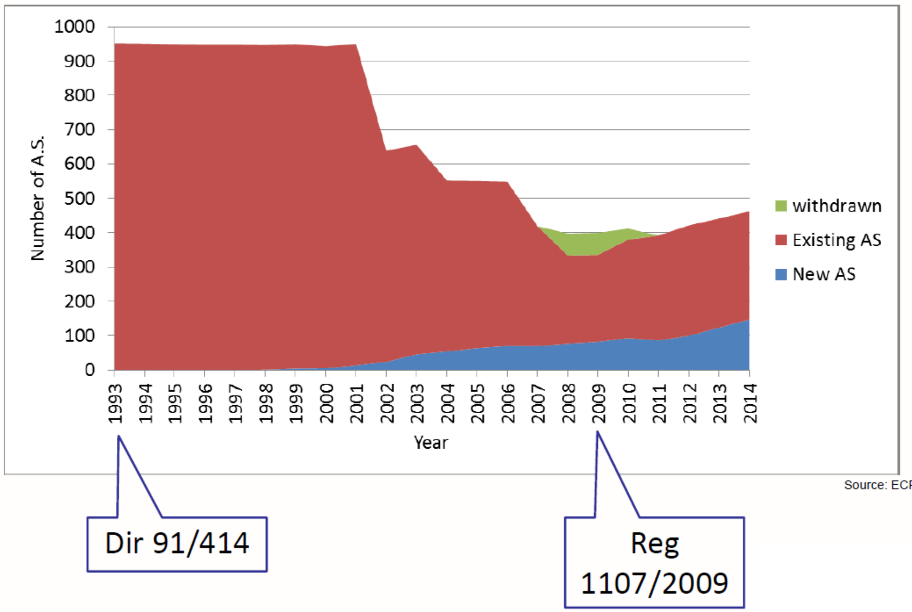
- Conclusions and debate

Plant protection products (PPPs)

- Products that protect plants or plant products from harmful organisms during production and storage
  - Insecticides, herbicides, fungicides
  - Synthetic PPPs and biopesticides (allowed in organic agriculture)



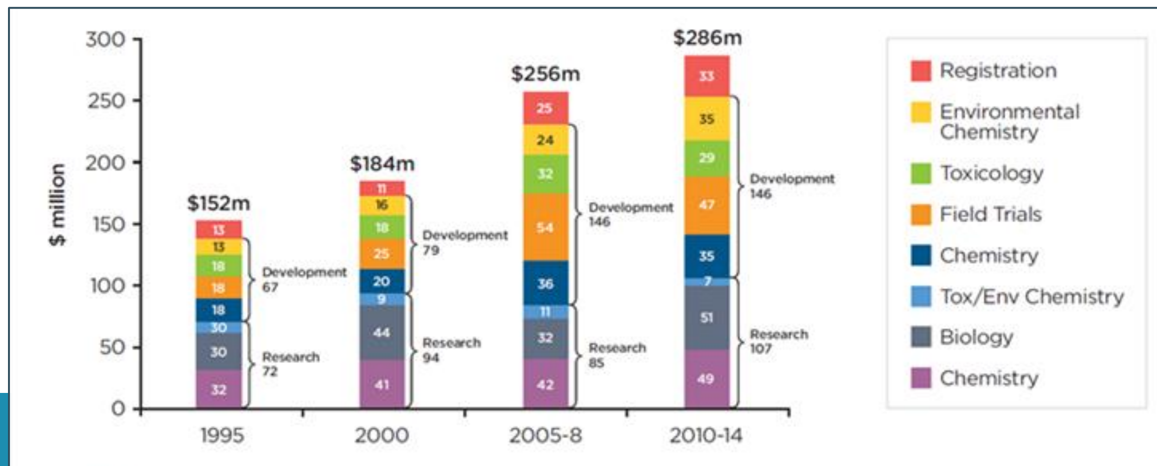
Evolution of PPPs



Source: ECPA

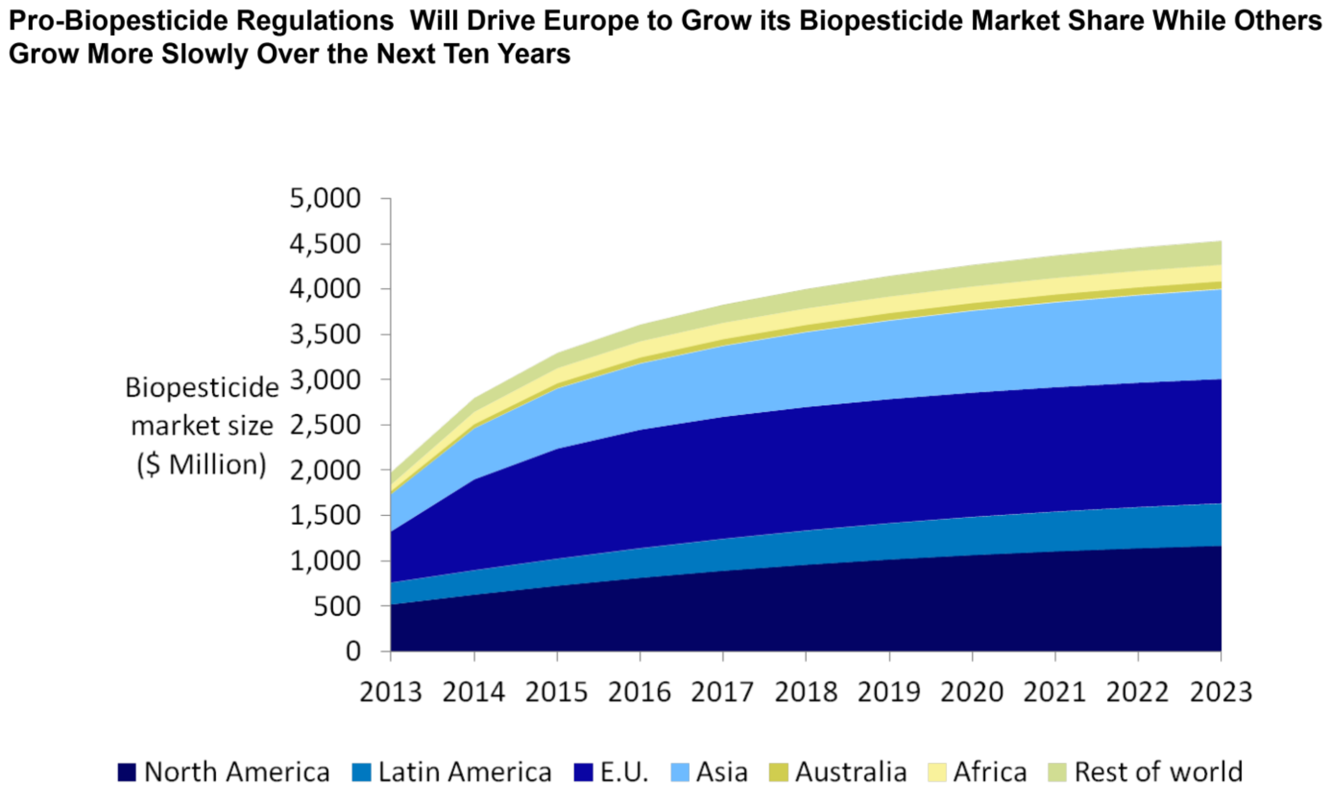
Less active substances on the market

Development costs of PPPs are increasing



Source: Phillips McDougall, 2016

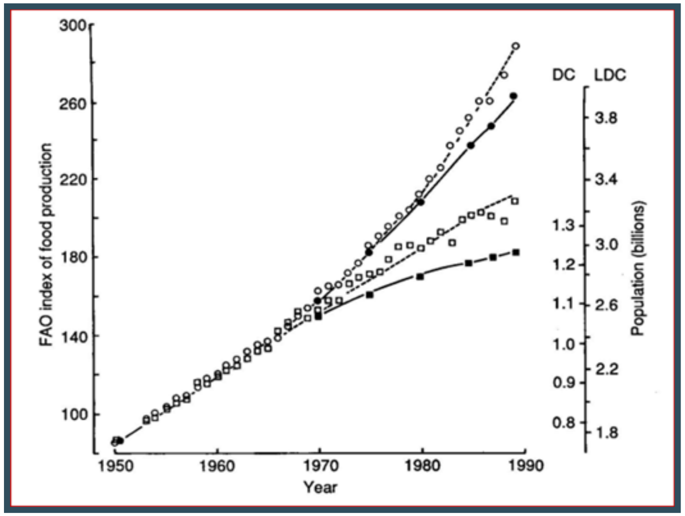
Evolution of PPPs

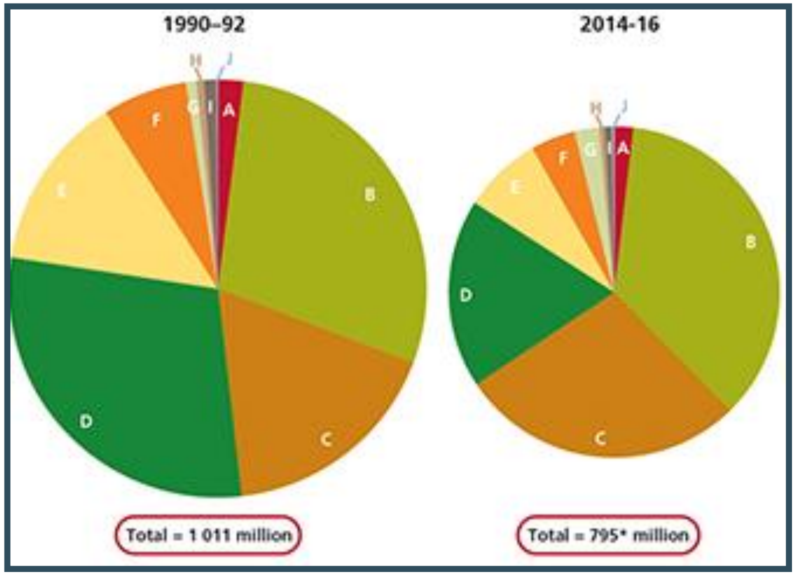


KU LEUVEN

Can we feed 11 billion people in 2100 without PPPs?

The food availability has increased more than the population growth





Drivers of increase of the yield:

- More land for crop production
- Green revolution
  - Fertilizers
  - PPPs
  - Adapted new varieties

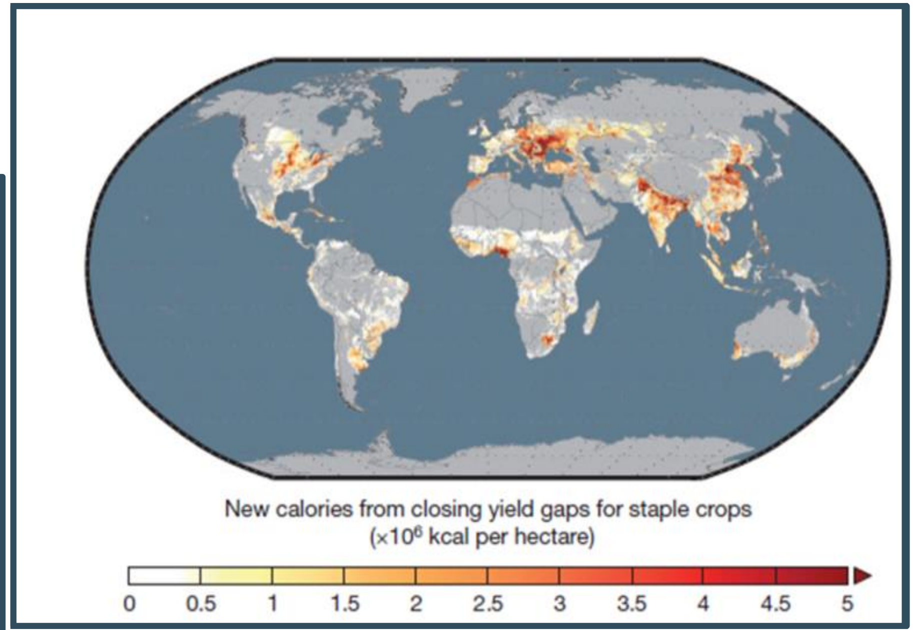
Land use change has a serious impact on sustainable planetary boundaries: we need to increase yield efficiency

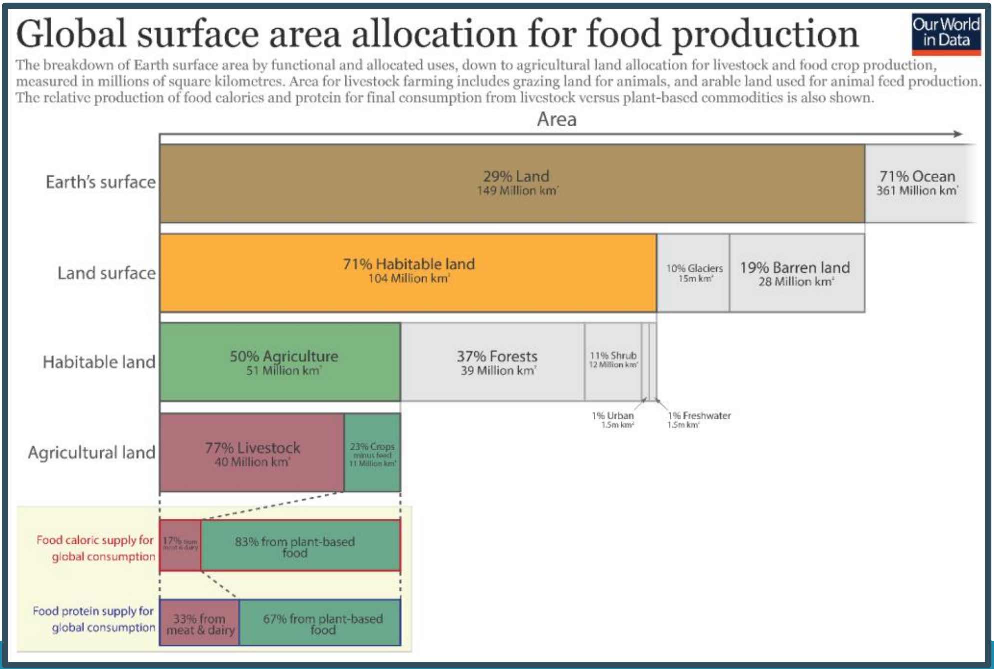
More land use is a threat to:

- Greenhouse gass emissions
- Biodiversity
- Planetary ecosystem

Close the yield gap

(green revolution bis)

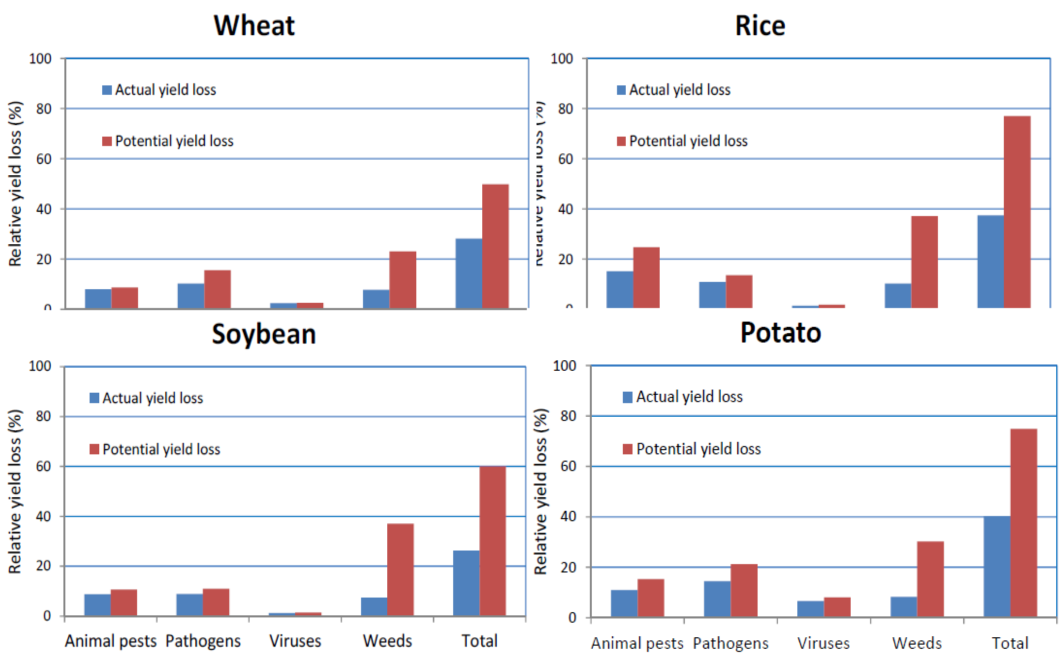




To close the yield gap plant protection is a crucial factor

Potential losses (40-80%) can be reduced by plant protection measures:

- Cultivation techniques (crop rotation, resistent varieties, weed management,…)
- PPPs



The decrease of crop loss by PPPs depends on the type of the crop and the region

Crop	% losses with PPPs*	% losses without PPPs ** (own estimation)	% potential losses ***	Yield gain by PPPs
Wheat	21% (10.1-28.1)	40%	50%	19%
Rice	30% (24.6-40.9)	62%	77%	32%
Maize	22% (19.5-41.1)	55%	69%	33%
Potato	18% (8.1-21)	60%	75%	42%
Soybean	21% (11-32.4)	48%	60%	27%

Can a reduction of the use of PPPs improve biodiversity without yield reduction?

Further reduction of PPP use is possible

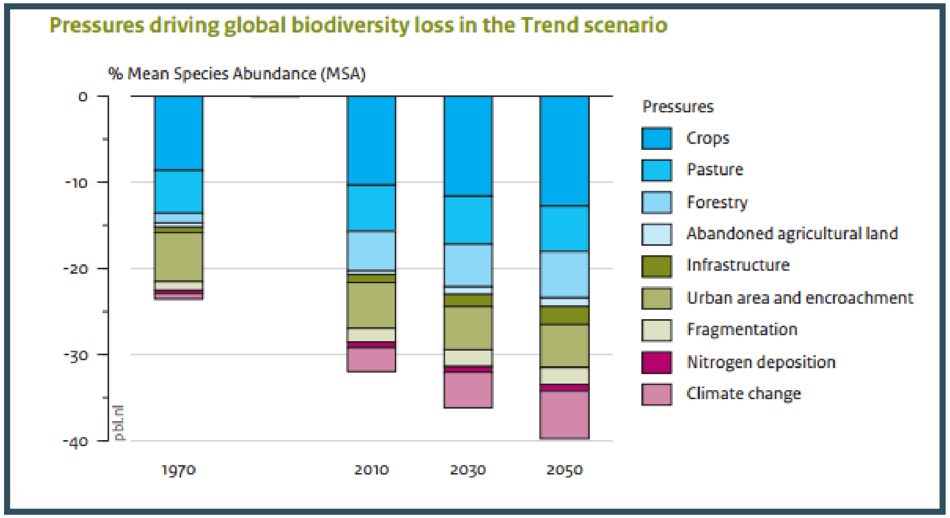
- Most extensive research: France
  - In 59% farms reduction is possible without crop losses
  - Reduction confirmed by other studies
- Reduction most applicable in cases of high use op PPPs

- Financial risk for the farmer (e.g. apple growing)
- Reduction with lower risks: IPM

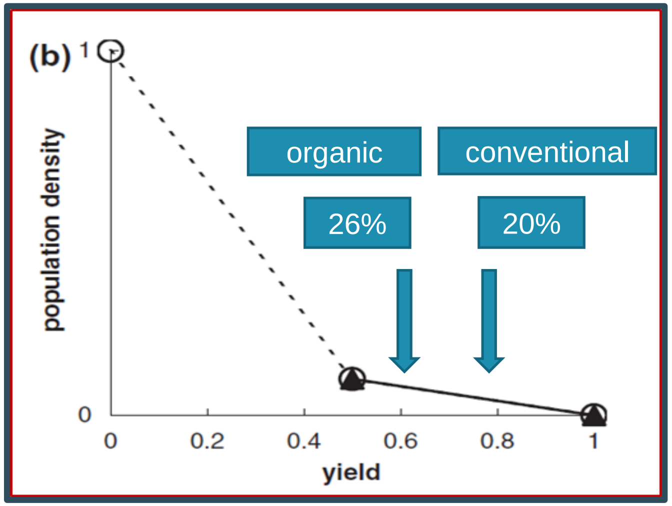
- Effect on biodiversity still unclear

Most important drivers of biodiversity loss in agriculture

1. Land use changes



- Organic: 15-30% more biodiversity at field level
- Yield reduction in organic farming: 20-25%
- Land use change organic: 74% loss per extra ha

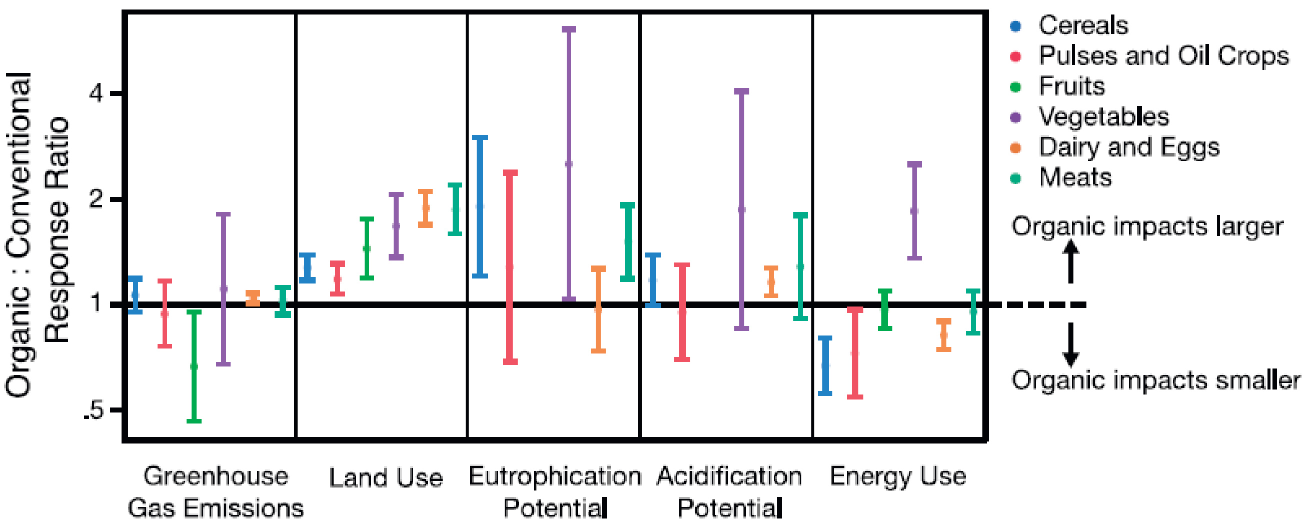


Most important drivers of biodiversity loss in agriculture

2. Fertilizers

3. Acidification

4. PPPs (not all biodiversity is positive for crop production)



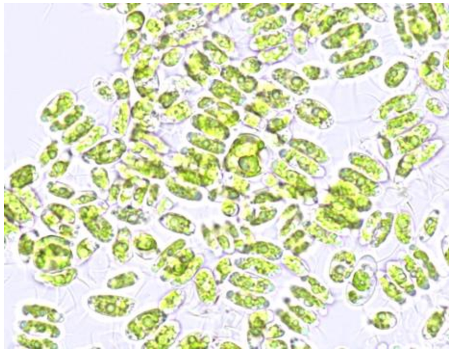
KU LEUVEN

Are PPPs by definition bad for human health or for the environment?

Yes, they are…
…as they mostly kill living organisms

Insecticides → effect on the water flea, *Daphnia magna*

Herbicides → effect on algae



But … no ‘by definition’ difference in toxicity between natural/chemical PPPs

Insecticide	IPM?	Organic?	Toxicity Human*	Toxicity Environment**
Pyrethrum	yes	yes	1030	1.2
Deltamethrin	no	no	135	3.5
Parathion	no	no	2	2.5
Pymetrozin	yes	no	>3000	87
Abamectin	depending on crop	yes	10	0.34
Flufenoxuron	yes	No	> 3000	0.04

Lower = more toxic as based on

*Acute oral LD50 (ppm)

** Daphnia magna EC50 (ppb)

Why is risk evaluation of PPPs so badly perceived by the general public?

Consumer perception versus scientific opinion

Public Ranking	Food scientist ranking
Food additives	Microbial contamination
PPP residues	Nutritional imbalance
Naturally occuring toxicants	Environmental contaminants
Environmental contaminants	Naturally occuring toxicants
Nutritional imbalance	PPP residues
Microbial contamination	Food additives

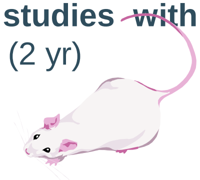
Ban on PPPs → increase food prices
→ lower income classes would consume less F&V
→ nutritional imbalance would become worse

KU LEUVEN

Risk assessment by life-long (chronic) exposure of consumers to PPPs

Toxicology

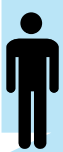
Feeding studies with animals (2 yr)



NOEC or NOAEC

Safety factor 100 to 1000

Extrapolation to human (diet)



Acceptable Daily Intake ADI

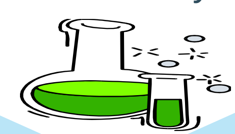
Ex. : 11,3 mg/kg body weightl/day

Good Agricultural Practice (GAP)

GLP trials (2 years)

Use parameters

Residue analysis



Analyzed residue

Ex. : 0,5 mg/kg fresh produce

Legal MRL in food

1 mg/kg

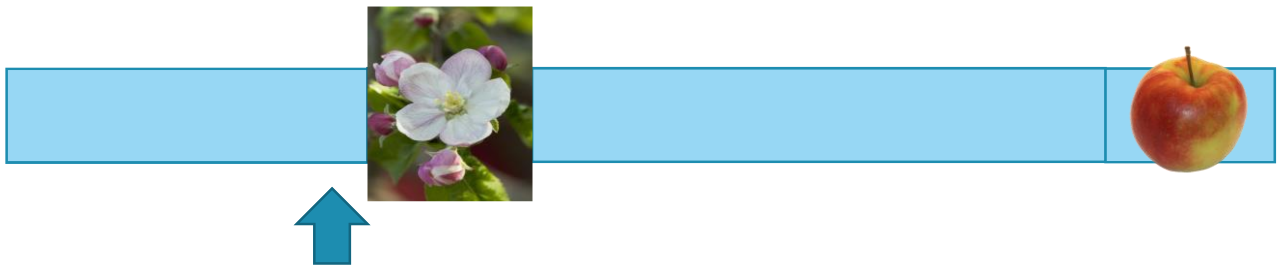
But … (i) other safety factors in our daily life are much smaller than in PPP risk assessments

Current advice to keep a distance between cars @ 120 km/h

As a safety factor of 100 would be applied

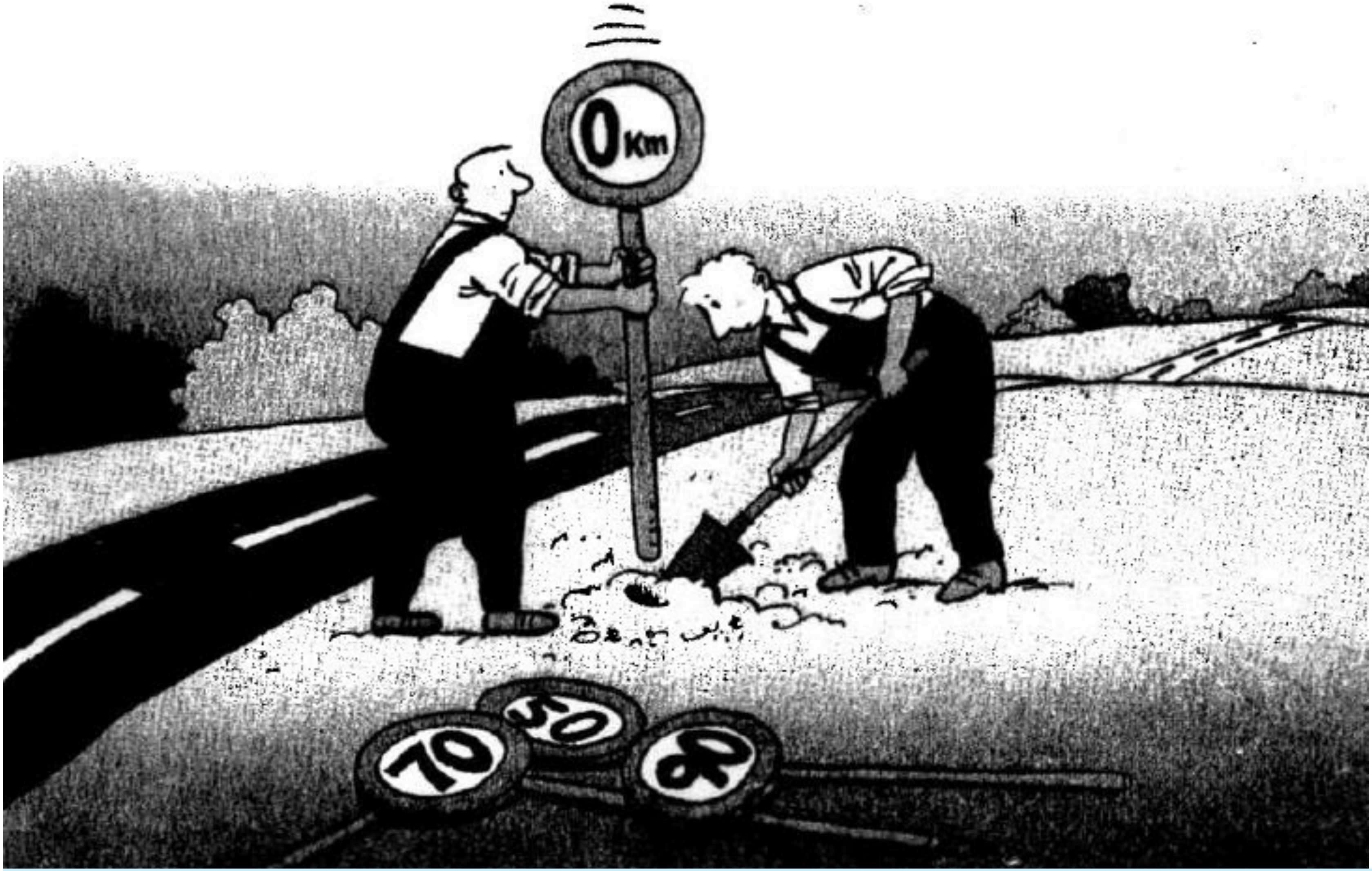
But … (ii) EU applies the ALARA principle !

ALARA = As Low As Reasonably Achievable



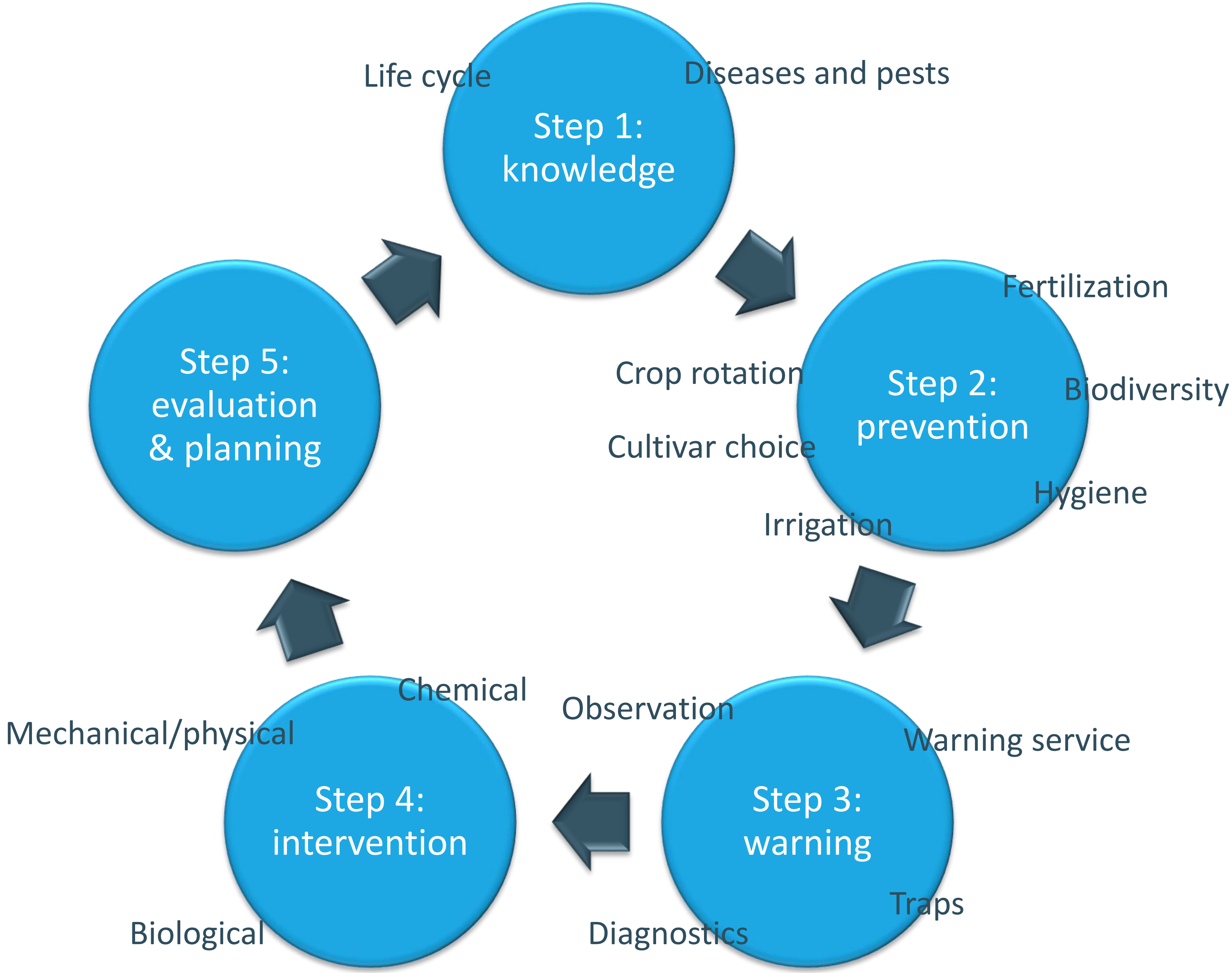
	Toxicology	GAP
Scientific data	20 mg/kg	0,1 mg/kg

But … US MRL = 20 mg/kg
EU MRL = 0,1 mg/kg



Zero risk doesn’t exist.
Neither does it exist in food production or PPP use.
Risk is part of life. The question is: which risk level do we accept?

Does IPM always lead to less PPP use?



Step 1: knowledge
Life cycle
Diseases and pests
Step 2: prevention
Fertilization
Crop rotation
Biodiversity
Cultivar choice
Hygiene
Irrigation
Step 3: warning
Observation
Warning service
Traps
Diagnostics
Step 4: intervention
Chemical
Mechanical/physical
Biological
Step 5: evaluation & planning

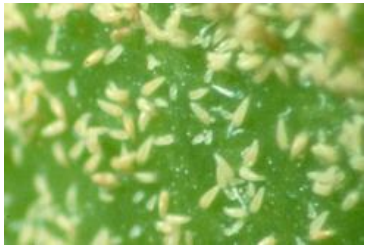
KU LEUVEN

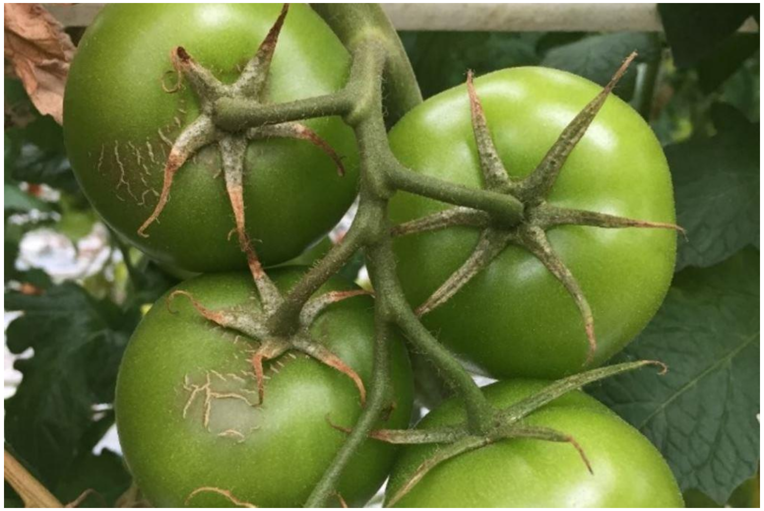
Sometimes, it does….

But… (i) invase species may trigger PPP use

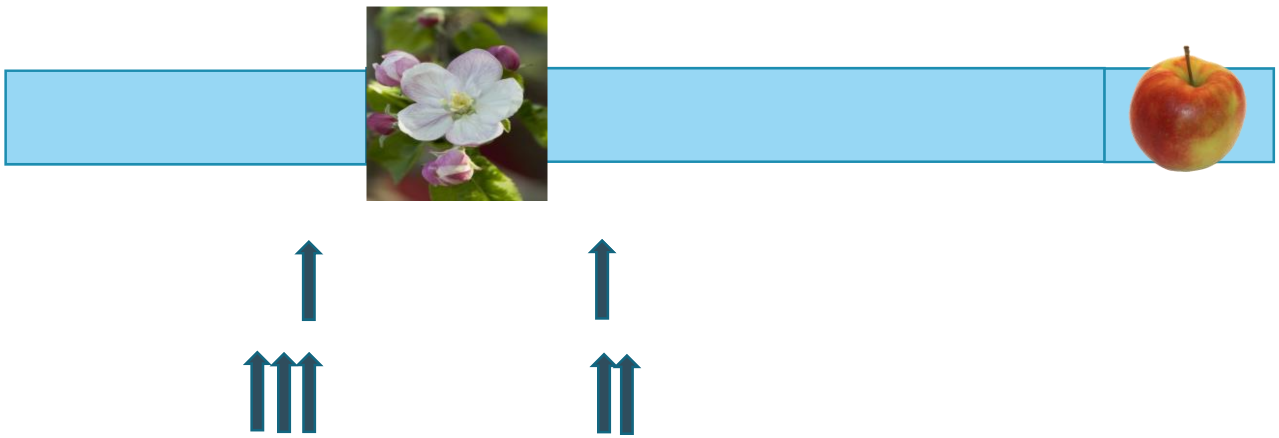
← tomato leafminer (*Tuta absoluta)*

tomato russet mite (*Aculops lycopersici)* →





But… (ii) PPPs become more specific (= less broad spectrum)



50s-80s

90s-now

Aphids
Weevils
Caterpillars

Capsids
Scales

… saving predatory mites, coccinellids, parasitic wasps, earwigs, ….

But… (iii) PPPs become shorter-lived

Shorter-lived = less residual effect

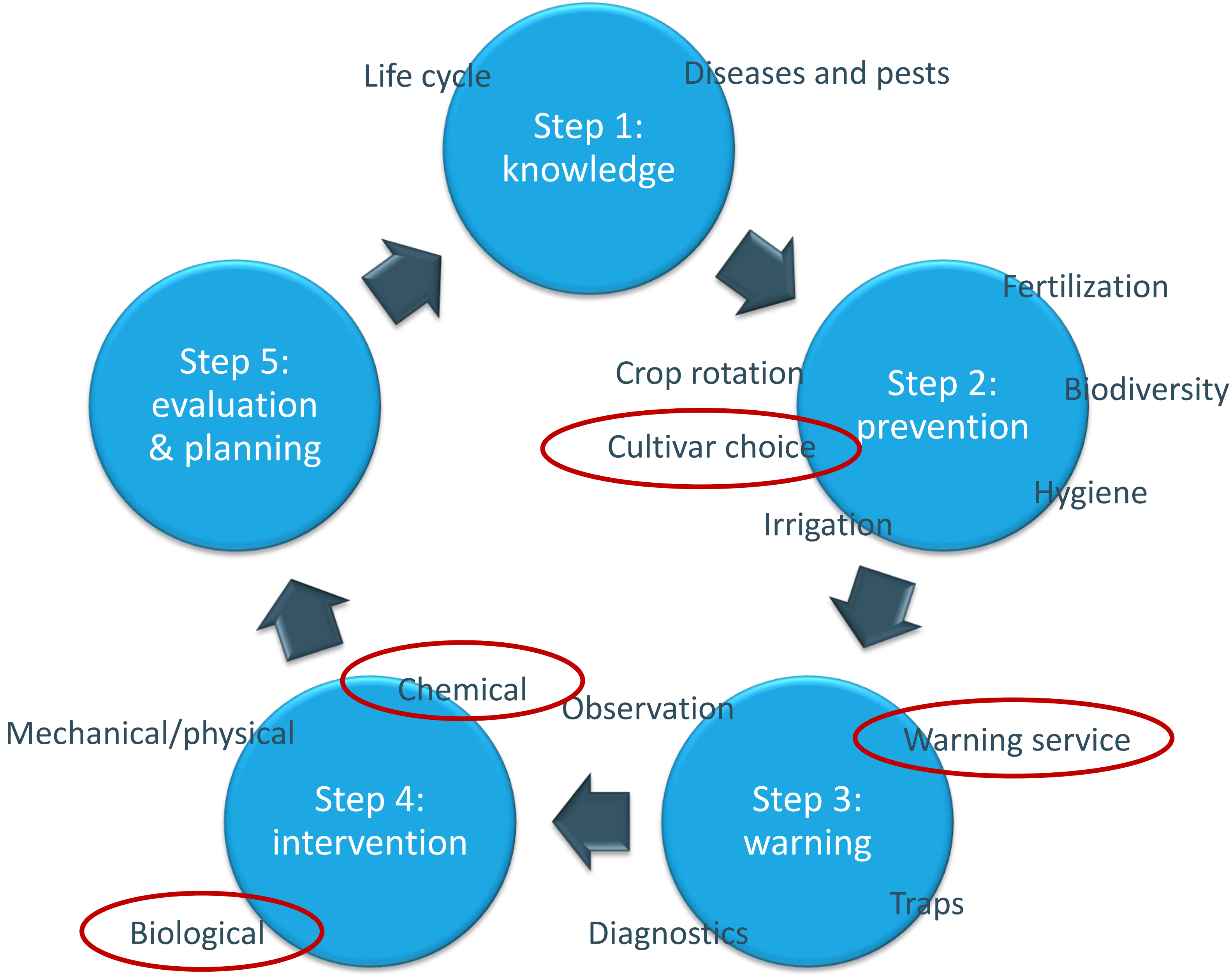
☺ Environmental fate

☹ Agronomic efficiency

Multiple treatments

KU LEUVEN

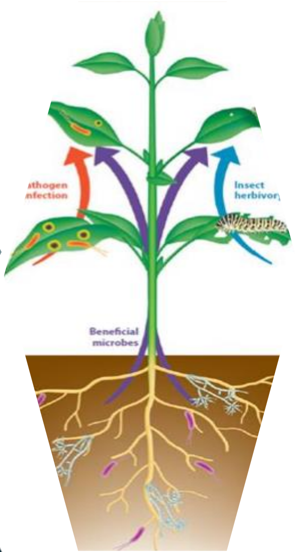
What are the most promising trends to further reduce PPP use?



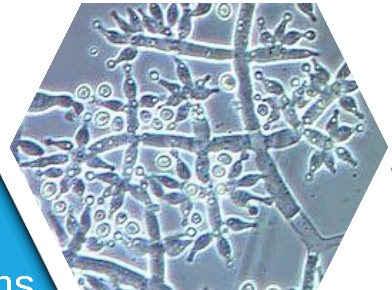
Life cycle
Diseases and pests
Step 1:
knowledge
Fertilization
Crop rotation
Step 2:
prevention
Biodiversity
Cultivar choice
Hygiene
Irrigation
Step 5:
evaluation
& planning
Chemical
Observation
Warning service
Mechanical/physical
Step 4:
intervention
Step 3:
warning
Traps
Biological
Diagnostics

KU LEUVEN

Biological intervention



Micro-organisms



Products derived from micro-organisms

Pheromones

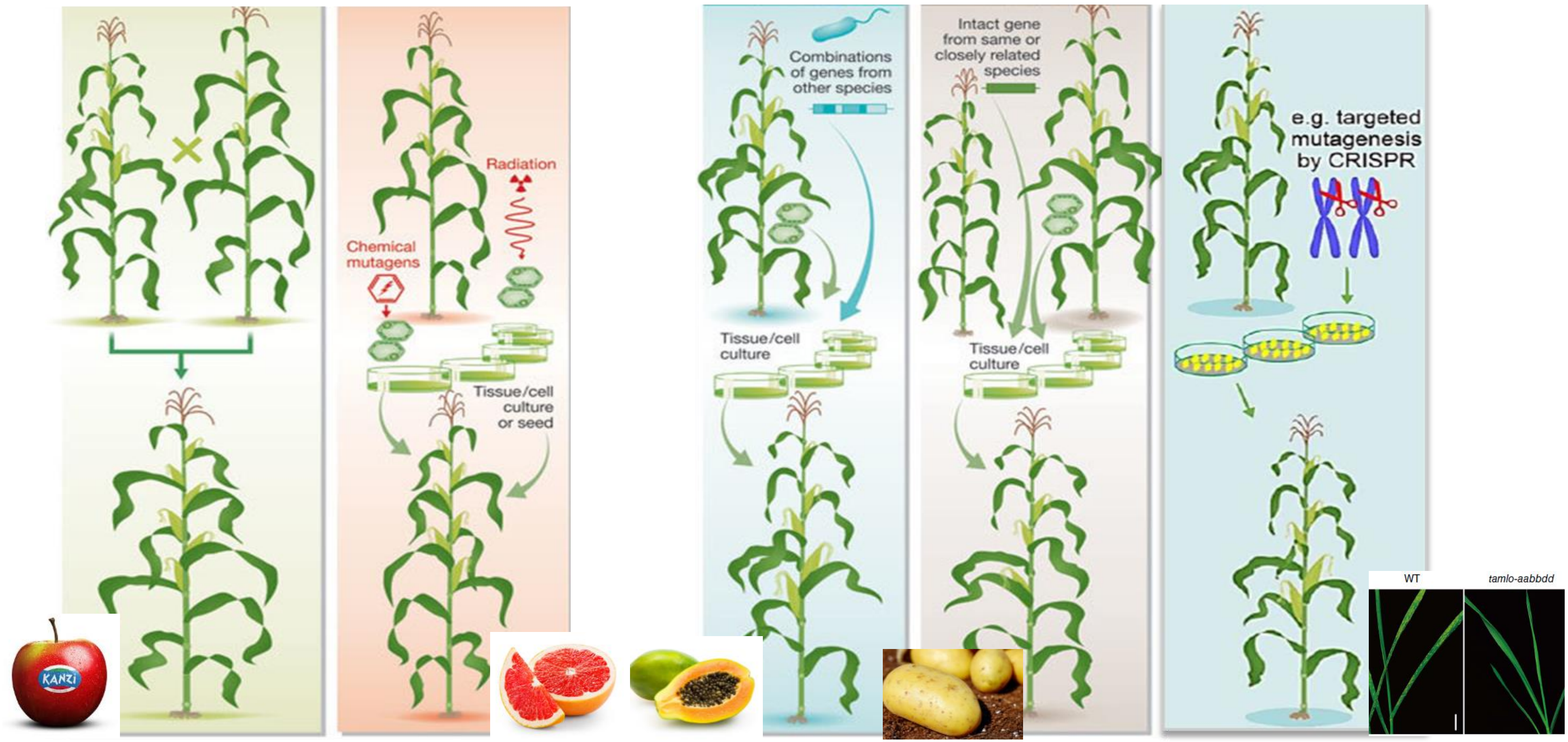
Natural ennemies

Products derived from plants/animals

Resistant cultivars

GMO

Conventional Mutagenesis Transgenesis Cisgenesis Genome editing



Time consuming Regulatory complexity

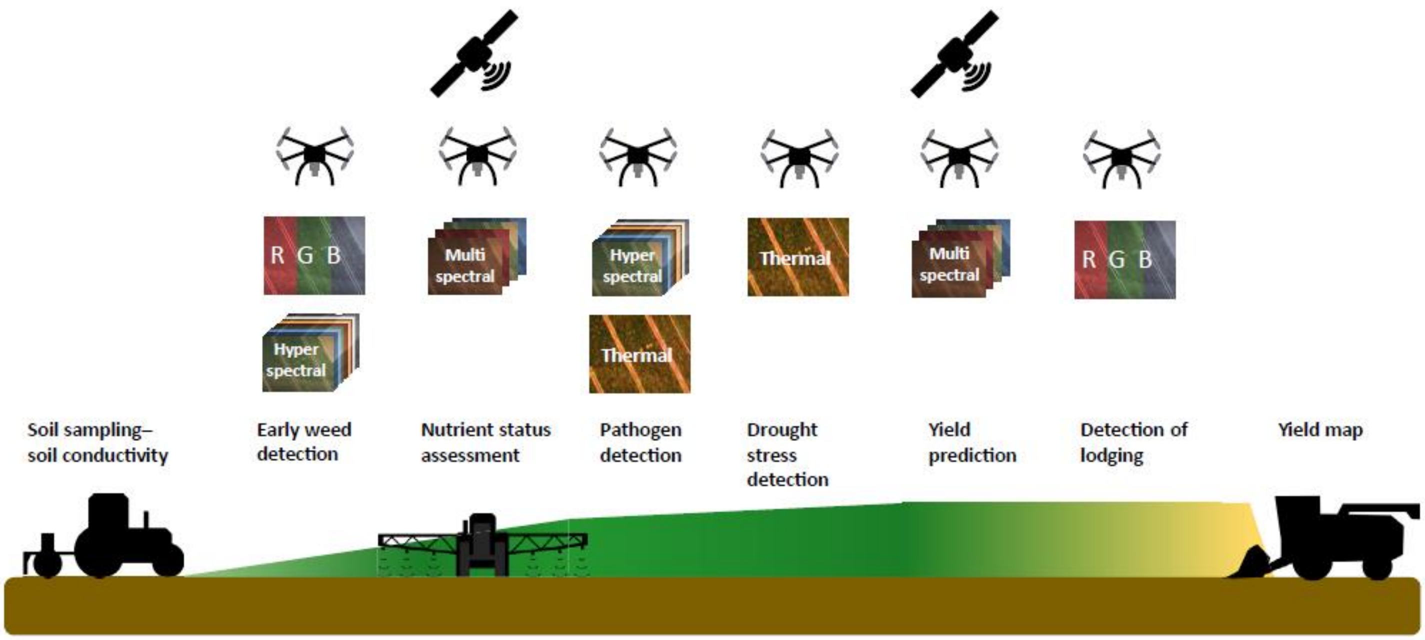
Narrow genetic diversity Expensive screens Precise

KU LEUVEN

Smart farming

- Decision support systems
- Remote sensing with lightweight and powerful hyperspectral cameras combined with unmanned aerial vehicles (UAVs)

The Role of Unmanned Aerial Vehicles (UAVs) for Assessing Field and Crop Status Spatially.



Trends in Plant Science

Conclusions

- PPPs are amongst the best studied compounds in the world.

- Agriculture without any PPPs will compromise food security. However, further reduction of the use of PPPs is possible.

- On the other hand, modern crop protection can lead to more or more frequent use of PPPs. The concern is on the potential risk of a PPP rather than on the use.

- The use of PPPs leads to affordable food prices, in particular important to offer lower income classes access to healthy fruits and vegetables.

- At the global scale conventional agriculture (IPM) has less negative impacts on environment and biodiversity than other production systems.

- To reduce PPPs we need to adopt and further develop novel technologies including resistant varieties, highly effective biopesticides and smart farming.

References

- Slide 3:
  - https://croplife-r9qnrxt3qxgjra4.netdna-ssl.com/wp-content/uploads/2018/11/Phillips-McDougall-Evolution-of-the-Crop-Protection-Industry-since-1960-FINAL.pdf
- Slide 4:
  - ECPA
  - https://croplife-r9qnrxt3qxgjra4.netdna-ssl.com/wp-content/uploads/2018/11/Phillips-McDougall-Evolution-of-the-Crop-Protection-Industry-since-1960-FINAL.pdf
- Slide 5
  - http://www.luxresearchinc.com/sites/default/files/EL%20Analysts%2098%20agriculture%20Lux.pdf
- Slide 7
  - FAOstat and UN websites
- Slide 8
  - Our world in data: https://ourworldindata.org/
  - Foley JA, Ramankutty N, Brauman KA, *et al.* 2011. Solutions for a cultivated planet. Nature 478, 337–342.
- Slide 9
  - https://inra-dam-front-resources-cdn.brainsonic.com/ressources/afile/416601-2607f-resource-crop-losses-conference-keynote-willocquet.pdf
  - OERKE E-C. 2006. Crop losses to pests. The Journal of Agricultural Science 144, 31.
- Slide 10
  - *: Savary *et al.*, 2019; **: estimated at 80% of the potential losses; ***: Oerke, 2006
    - Savary S, Willocquet L, Pethybridge SJ, Esker P, McRoberts N, Nelson A. 2019. The global burden of pathogens and pests on major food crops. Nature Ecology & Evolution, 1.
    - OERKE E-C. 2006. Crop losses to pests. The Journal of Agricultural Science 144, 31.

References

- Slide 13:
  - Netherlands Environmental Assessment Agency: https://www.pbl.nl/en/
- Slide 14:
  - Clark M, Tilman D. 2017. Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. Environmental Research Letters 12, 64016.
- Slide 16:
  - Daphnia: Dieter Ebert, Basel, Switzerland - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=47132022
  - Algae: https://www.energy.gov/sites/prod/files/2017/05/f34/algae_ogden_135111.pdf
- Slide 17
  - http://registerofquestions.efsa.europa.eu/roqFrontend/wicket/bookmarkable/eu.europa.efsa.raw.gui.pages.substance.SubstanceSearchPage?2
- Slide 19
  - Adapted from **Whitford F.** 1993. Pesticide Facts and Perception. Journal of extension **31** (1): 9-11
- Slide 21
  - Adapted from Bayer (2016). Kennis kweken. Vragen en antwoorden over moderne landbouw. Information booklet.
- Slide 23
  - Mens (2001). Voedselveiligheid, een complex verhaal. 16 p.
- Slide 26
  - Tomato: https://wholesomebabyfood.momtastic.com/tomatoesbabyfoodrecipes.htm
  - Upper left: https://www.biconet.com/biocontrol/cucumeris.html
  - Upper right: https://undergrow.es/Encarsia-Formosa-against-White-Fly
  - Lower left: http://bioplanet.it/nl/phytoseiulus-persimilis-6/
  - Lower right: http://ephytia.inra.fr/fr/D/3962

KU LEUVEN

References

- Slide 27:
  - Upper left: https://www.direct2farmer.com/Tuta-absoluta
  - Upper right: https://nl.wikipedia.org/wiki/Tomaatmineermot
  - Lower left: http://www.omafra.gov.on.ca/french/crops/facts/14-014.htm
  - Lower right: https://www.pcgroenteteelt.be/nl-nl/Projecten/Vlaamse_Overheid/Vlaio/BALTO/ArtMID/4076/ArticleID/2167/Gezocht-Natuurlijke-vijanden-voor-tomatengalmijt
- Slide 29
  - http://vtip.be/sites/default/files/useruploads/3%20Onkruidbestrijding%20ma%C3%AFs.pdf
- Slide 32
  - Adapted from https://www.pcgroenteteelt.be/DesktopModules/EasyDNNNews/DocumentDownload.ashx?portalid=0&moduleid=742&articleid=1863&documentid=2189. page 9
- Slide 33
  - Adapted from Podevin et al. (2012) Transgenic or not? No simple answer! New biotechnology-based plant breeding techniques and the regulatory landscape. EMBO reports Vol13.
  - Apple: https://www.kanziapple.com/nl-be/
  - Pink grapefruit: http://www.georgeperry.co.uk/Pink-Grapefruit.html
  - Papaya: https://www.ahealthylife.nl/de-voedingswaarde-van-papaja/
  - Potato: https://agronomag.com/new-gmo-potatoes-obtain-approval-human-consumption-2017/
  - Wheat: Wang et al. (2014) Simultaneous editing of three homoeoalleles in hexaploid bread wheat confers heritable resistance to powdery mildew. Nature Biotechnology Vol32
- Slide 34
  - Maes and Steppe (2019) Perspectives for Remote Sensing with Unmanned Aerial Vehicles in Precision Agriculture. Trends in Plant Science Vol24