Crop diversification breakthroughs

Sari Himanen
Natural Resources Institute Finland (Luke)
Finnish Organic Research Institute (FORI)

Crop protection futures in agriculture

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Crop diversification for restoring the biological regulation and resilience of our agroecosystems

From a narrow genotype pool to a wider pool of genotypes and traits
From monocultures to polycultures
Using crop management practices that maintain and increase belowground and aboveground agrobiodiversity

Increase in agroecosystem functional diversity

More multifunctional agroecosystems

Support for and utilisation of agroecosystem services such as natural biological control to reduce the need and use of chemical pesticides

supported by EU research e.g.

Crop Diversification Cluster

CORE organic

+national and regional RDI

towards

Agroecological transition

Increase in agroecosystem response diversity

More resilient agroecosystems

More resistance built in the agroecosystem targeting multiple risks, i.e. abiotic and biotic stressors

Means to diversify: effects on crop protection

- Adding crop diversity: genetic and trait diversity, legumes, spring and autumn sown crops, perennials
- Diverse crop rotations
- Different forms of intercropping
- Agroforestry
- Trap crops and companion crops, flower strips
- Undersown cover crops and catch crops
- Diverse grasslands, pastures, perennial lays, feed and forage mixtures
- Mixed farming
- Habitat and landscape management

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Globally, different means of crop diversification have a general positive effect on

- **weed reduction: 60 %** [13 to 116%]
- **disease control: 41%** [15 to 73 %]
- **insect pest reduction: 33 %** [2 to 74 %]
- **reduction of crop damages: 62 %** [37 to 93 %]
- **associated biodiversity: 24 %** [15 to 33 %]
- **agricultural crop production: 14 %** [8 to 20 %]

Diversification means have variable effects on pest and disease control

- cover crops 125 % / intercropping 66 % / agroforestry 59 %

… and on agricultural crop production

- agroforestry 35 % / intercropping 22 % / crop rotation 16 % / cover crops 6 % / variety mixtures 2 %

Source: Beillouin *et al. (*2021) Positive but variable effects of crop diversification on biodiversity and ecosystem services. *Global Change Biol* 27: 4697-4710.

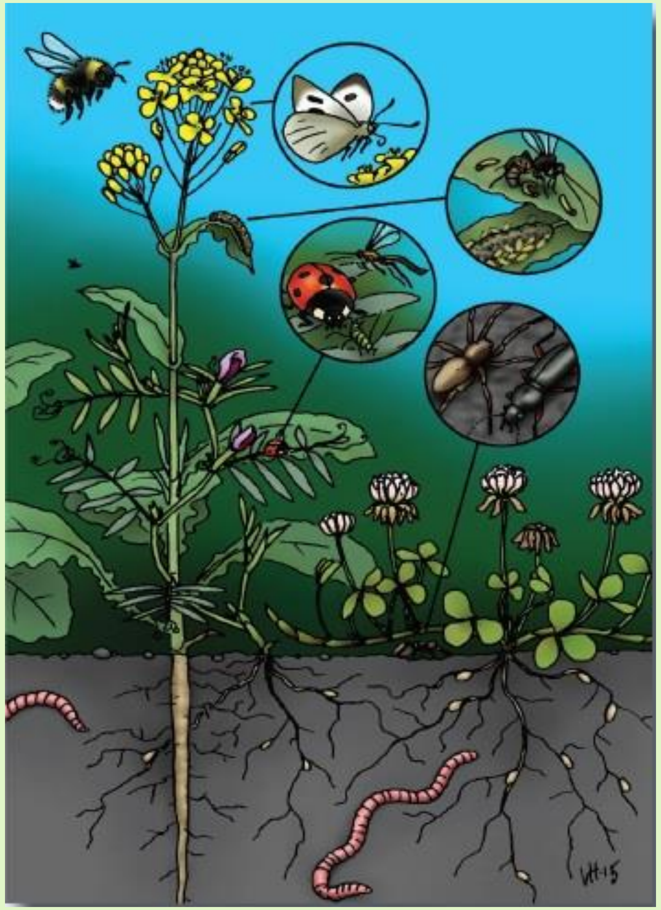
Also: Tamburini *et al.* (2020) Agricultural diversification promotes multiple ecosystem services without compromising yields. *Sci Adv* 6: eaba1715.

Intercropping for ecological intensification and pest suppression

Aboveground agrobiodiversity

Food web interactions

Belowground agrobiodiversity



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Competition
Facilitation
Associational resistance or susceptibility

Top-down regulation by natural enemies

Enhanced pest suppression

Bottom-up regulation e.g. by altered resource base

Selected references

Hahn & Cammarano (2023) Environmental context and herbivore traits mediate the strength of associational effects in a meta-analysis of crop diversity. *J Appl Ecol* 60: 875-885.

Huss *et al.* (2022) Benefits and risks of intercropping for crop resilience and pest management. *J Econ Entomol* 115: 1350-1362.

Iverson *et al.* (2014) Do polycultures promote win-wins or trade-offs in agricultural ecosystem services? A meta-analysis. *J Appl Ecol* 51: 1593-1602

Strip intercropping

- Spatiotemporal diversification at field plot level
- Potentiates independent crop management of strips

Potential for insect pest suppression:
Herbivore abundance and density reduced
More diverse predator communities or a higher predator-prey ratio
More research needed e.g. on design and management, impact on different agroecosystem services

Turnip rape-Faba bean strip intercropping, Jokioinen, Finland

Selected references
Alarcón-Segura *et al.* (2022) Strip intercropping of wheat and oilseed rape enhances biodiversity and biological pest control in a conventionally managed farm scenario. *J Appl Ecol* 59: 1513-1523.
Cuperus *et al.* (2023) Effects of field-level strip and mixed cropping on aerial arthropod and arable floral communities. *Agric Ecosyst Env* 354: 108568.
Järvinen *et al.* (2023) Intercropping shifts the balance between generalist arthropod predators and oilseed pests towards natural pest control. *Agric Ecosyst Env* 348: 108415.

Diversification through habitat management and flower strips

- Provide more continuous shelter, nectar, pollen, insect prey and host, overwintering sites supporting conservation biological control
- Flower strips enhanced pest control services by ca. 16 % in adjacent fields (Albrecht et al. 2021)

Practically feasible for farmers. Tailoring of seed mixtures and positioning of the ecological infrastructure important to increase impacts on pest suppression and crop yields, in addition to the positive agrobiodiversity value.





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Selected references

Albrecht *et al.* (2021) The effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield: a quantitative synthesis. *Ecol Lett* 23: 1488-1498.

Gurr *et al.* (2017) Habitat management to suppress pest populations: Progress and prospects. *Annu Rev Entomol* 62: 91-109.

Landscape management for restoring biological regulation

- Re-design of agricultural landscapes (mosaics of crop area, semi-natural habitats, forest-field edges, buffer zones, flower and grass strips etc.) towards multifunctionality and agroecosystem services
- Modelling approaches integrating landscape and in-field diversification for specific crop-pest-natural enemy associations
- Supported by biodiversity monitoring

Landscape largely determines the potential for insect pest suppression by natural biological regulation. Research on diversification actions from field to landscape level are important for potentiating a positive spill-over of beneficials between fields and surrounding habitats.

Selected references

Bonato *et al*. (2023) Applying generic landscape-scale models of natural pest control to real data: Associations between crops, pests and biocontrol agents make the difference. *Agric Ecosyst Env* 342: 108215.

Lichtenberg *et al*. (2017) A global synthesis of the effects of diversified farming systems on arthropod diversity within fields and across agricultural landscapes. *Global Change Biol* 23: 4946-4957.

Martin *et al*. (2019) The interplay of landscape composition and configuration: new pathways to manage functional biodiversity and agroecosystem services across Europe. *Ecol Lett* 22: 1083-1094.

Organic farming as a pioneer of crop diversification

- Organic farming systems embed preventive pest management through e.g.
  - Diversified crop rotations with legumes
  - Use of organic fertilizers, amendments and soil improvers
  - Avoidance of synthetic pesticides and mineral fertilizers, use of mechanical and biological control
  - Available resistant and tolerant varieties adapted to local conditions and low-input systems
- Diverse genotypes and management practices are also important for increasing organic yields

Organic farming, fostering agrobiodiversity, can benefit from more interdisciplinary research on diversification, covering the whole organic value chains. This is essential also for the Farm to Fork target of 25 % of total EU farmland area under organic farming by 2030.

Selected references
Chopin *et al.* (2023) The reflection of principles and values in worldwide organic agricultural research viewed through a crop diversification lens. A bibliometric review. *Agr Sust Dev* 43: 23.
EU action plan for the development of organic production.
Ponisio *et al.* (2015) Diversification practices reduce organic to conventional yield gap. *Proc R Soc B* 282: 20141396.

On-farm innovations and co-designed solutions: putting science into practice

- Through on-farm research, practical feasibility considerations, sociotechnological lock-ins, barriers and incentives for diversification, are revealed
- Farmers desire science-based guidelines for diversification

Combining scientific and practical know-how in agroecological co-design of pest-buffered systems can integrate different options for and multiple means of diversification. This can also help movement towards a more systemic approach.

Selected references
Carrillo-Reche *et al.* (2023) Finding guidelines for cabbage intercropping systems design as a first step in a meta-analysis relay for vegetables. *Agric Ecosyst Env* 354: 108564.
Himanen *et al.* (2016) Engaging farmers in climate change adaptation planning: Assessing intercropping as a means to support farm adaptive capacity. *Agriculture* 6: 34.

Diversification is key for the resilience of our agrifood systems

- *In future crop protection*, in-field and landscape diversification are both key for **preventive pest management** supporting movement towards chemical pesticide-free agriculture

- *In agroecosystems*, diversification is key for **functionally diverse food webs** integrating soil health, plant health, environmental health and human health

- *In agrifood systems*, **restoring and making use of agrobiodiversity** is key for enhancing food system resilience from farm to fork

Thank you!

Contact: sari.himanen@luke.fi