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San Diego

**Setting the scene of the ecosystem services
provided by alfalfa at the rotation level and at
the territory level: towards a better use of
alfalfa**

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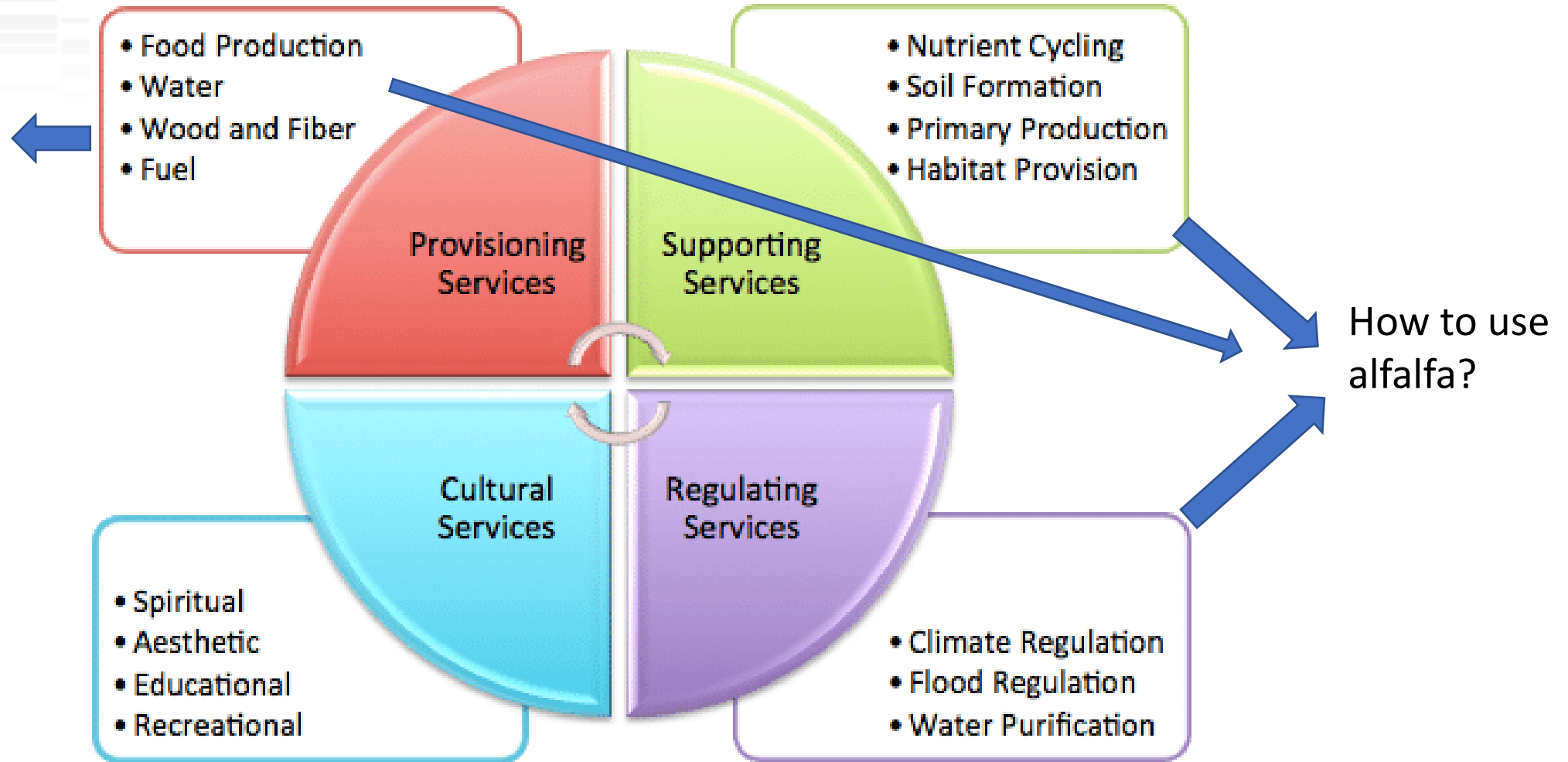
The major challenges

- Feeding the world population, in a situation of increasing population and diet transition
- Adapting to and mitigating climate change
 - How to reduce GHG emission?
 - What are the responses to increasing temperatures?
- Restoring biodiversity

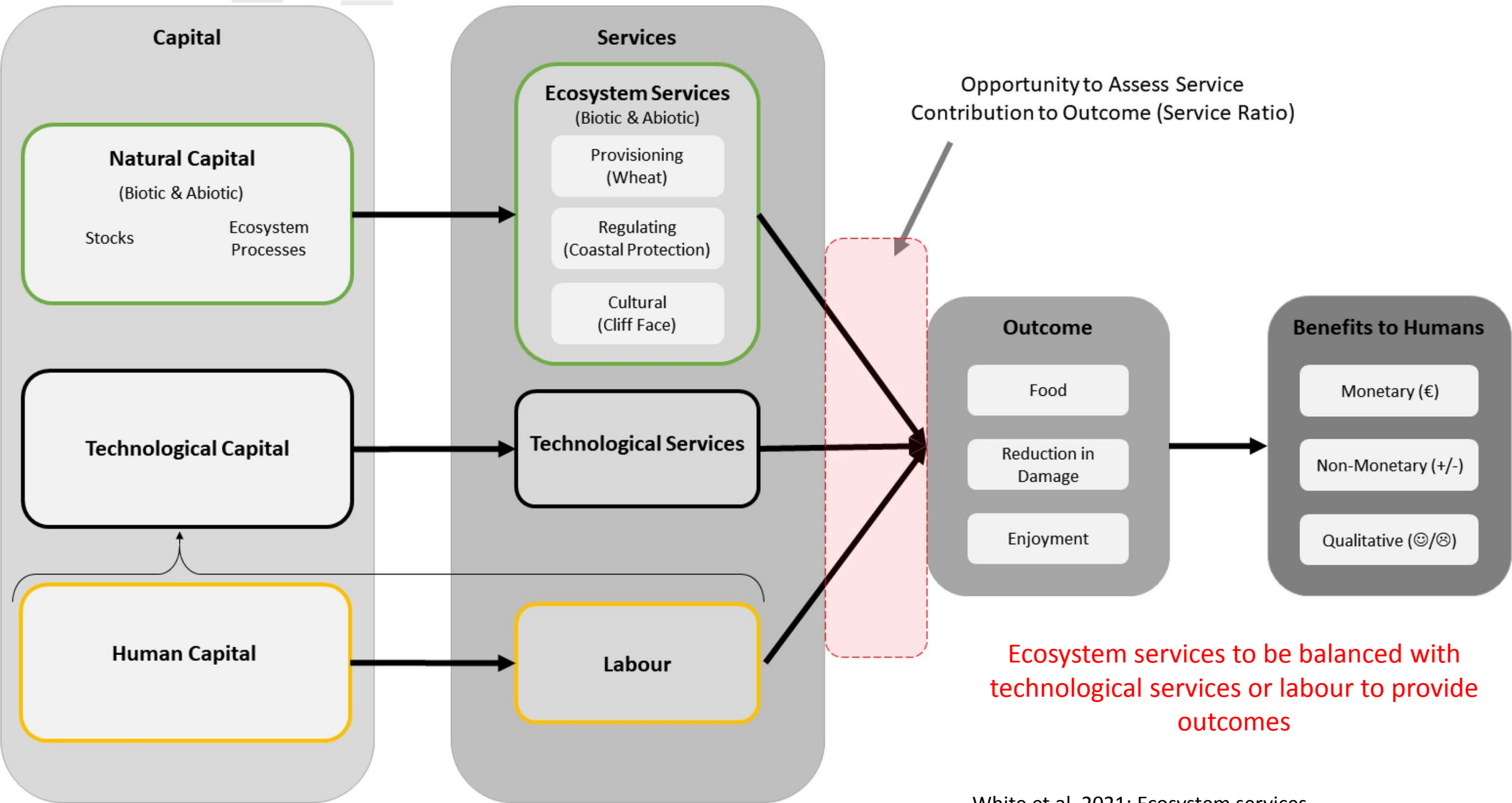
Perennial legumes and ecosystem services

Millenium Ecosystem Assessment (2005)

High quality forage production

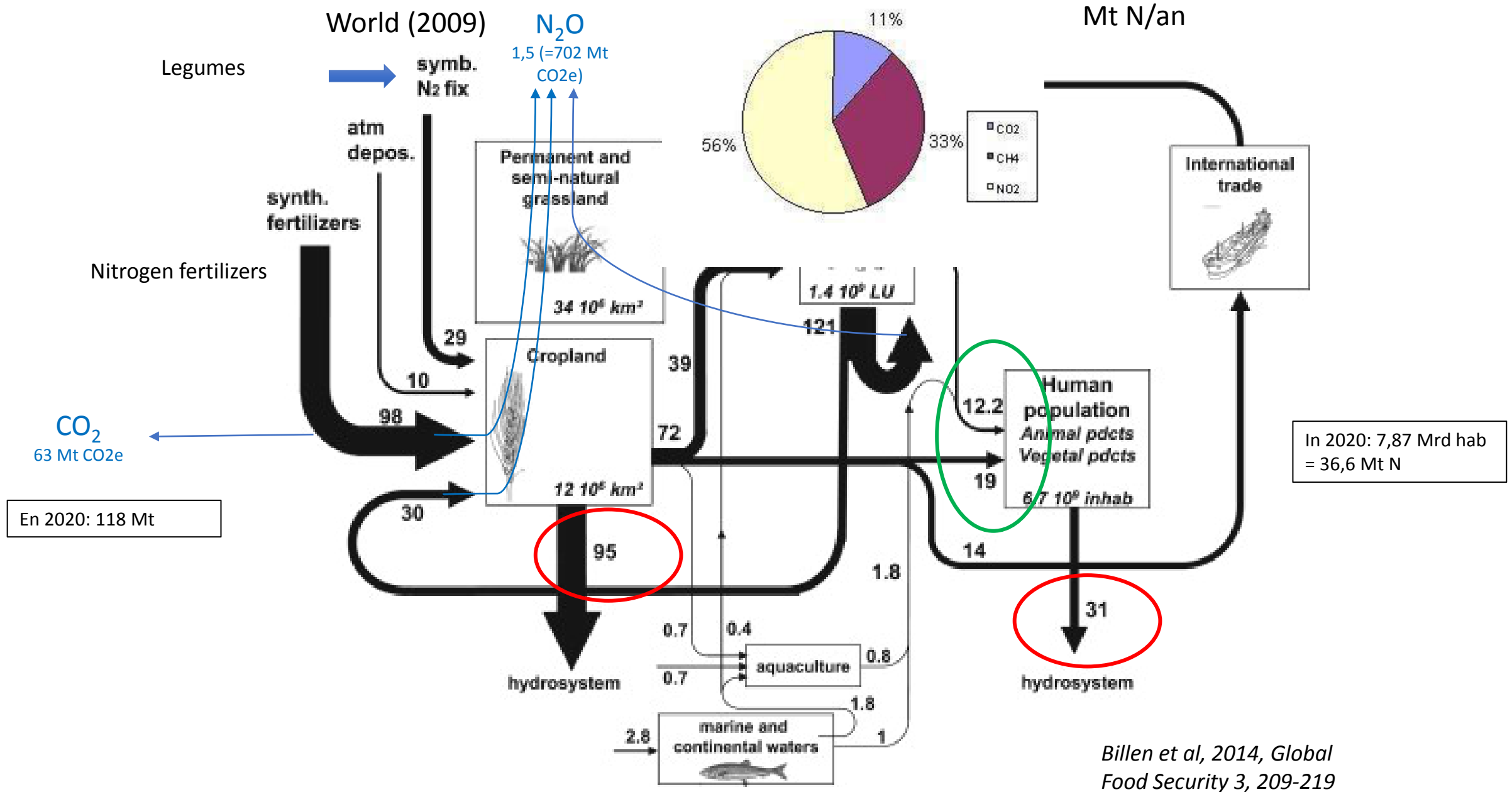


Source: Millenium Ecosystem Assessment, 2005.

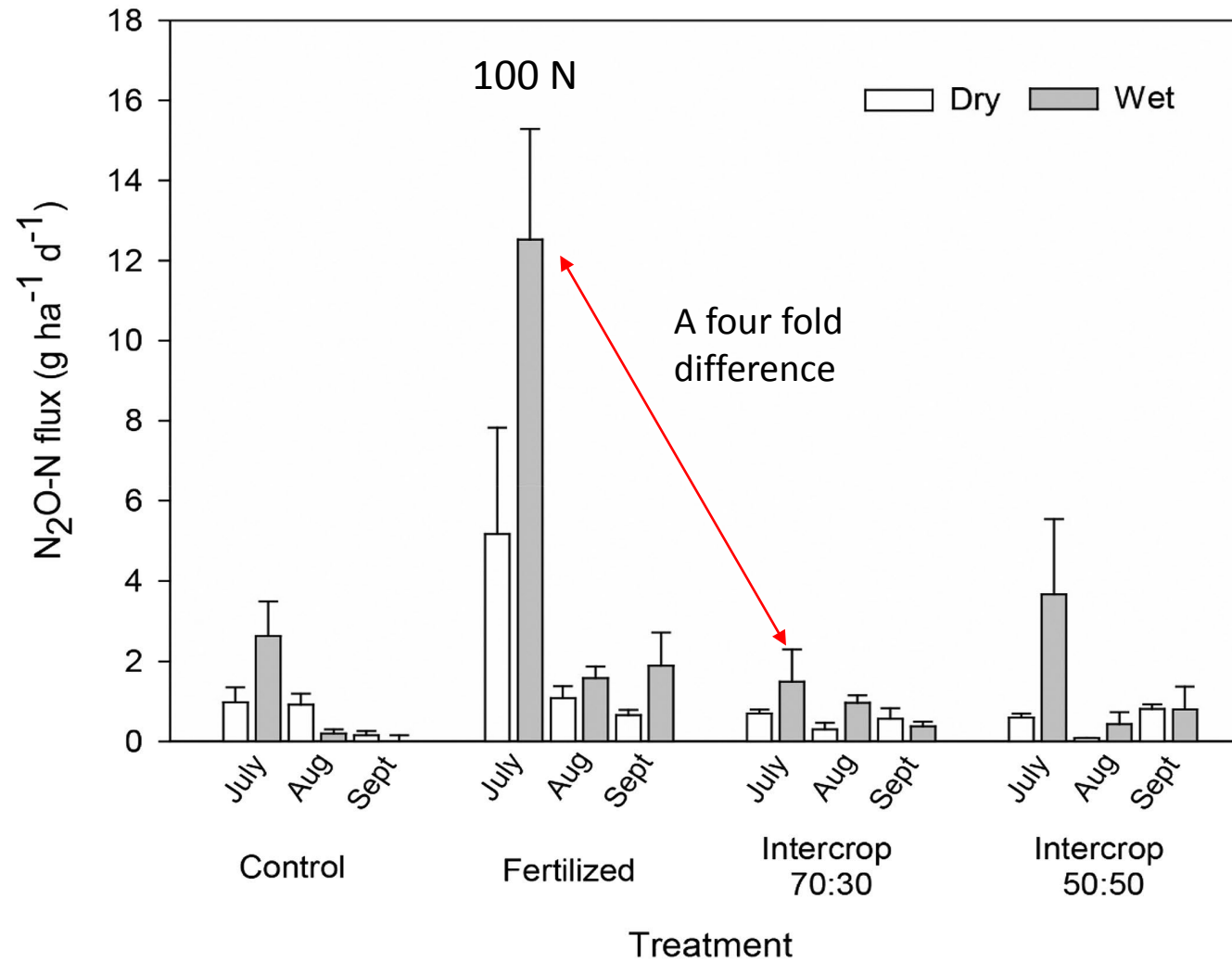


Alfalfa services

- Per se and intercropped:
 - High quality and high-protein biomass
 - Reducing the use of N fertilizers and the Green House Gas emission
 - Alfalfa and its root microbiome: the rhizobium community and the mycorrhiza community play a role in the N₂O emission
 - Massive reduction of N₂O in intercropping
 - Positive impact on biodiversity
- In rotation
 - Massive impacts
- A special attention to be paid to the alfalfa termination

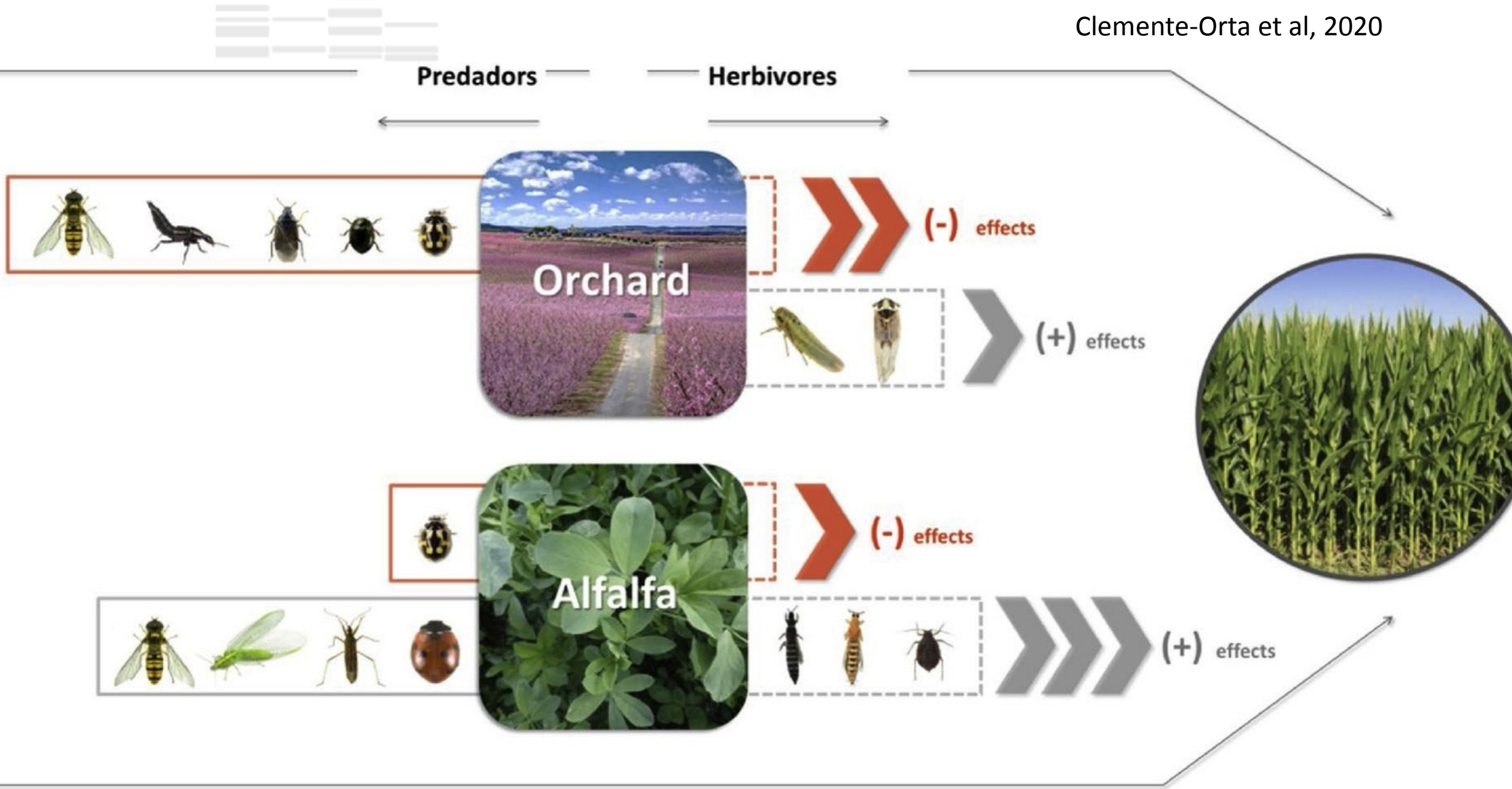


Nitrous oxide emissions associated with ammonia-oxidizing bacteria abundance in fields of switchgrass with and without intercropped alfalfa

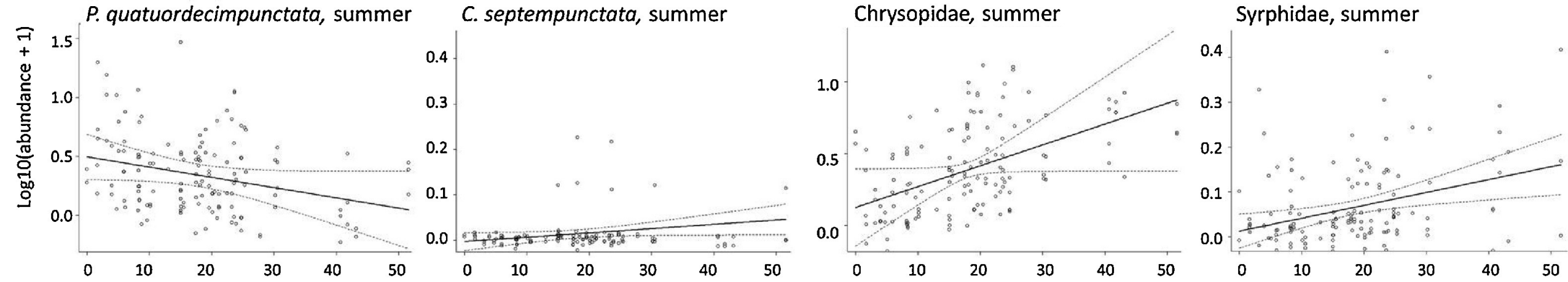


Alfalfa and biodiversity

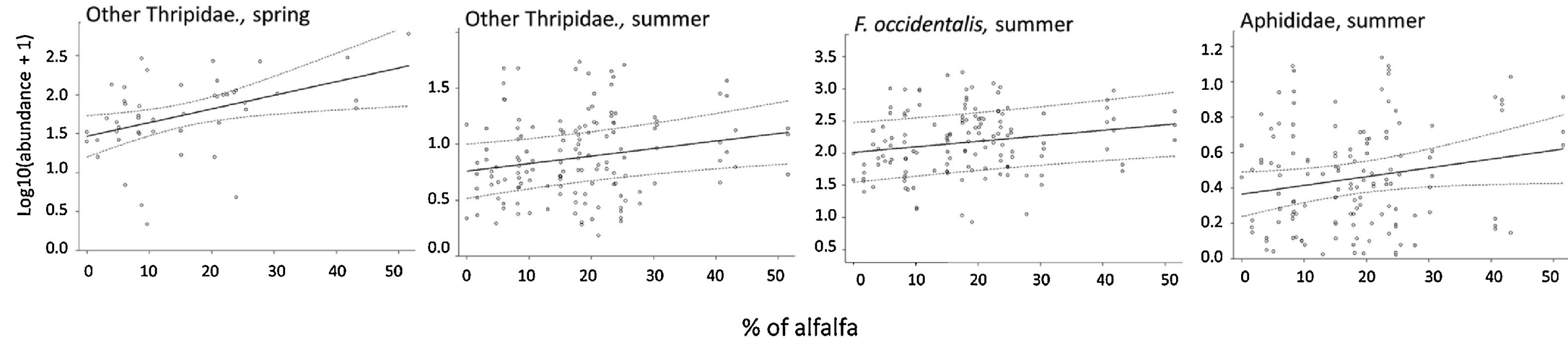
- It has been shown that alfalfa has very strong biocontrol effect on the neighbouring crops
 - Alfalfa >> Orchards



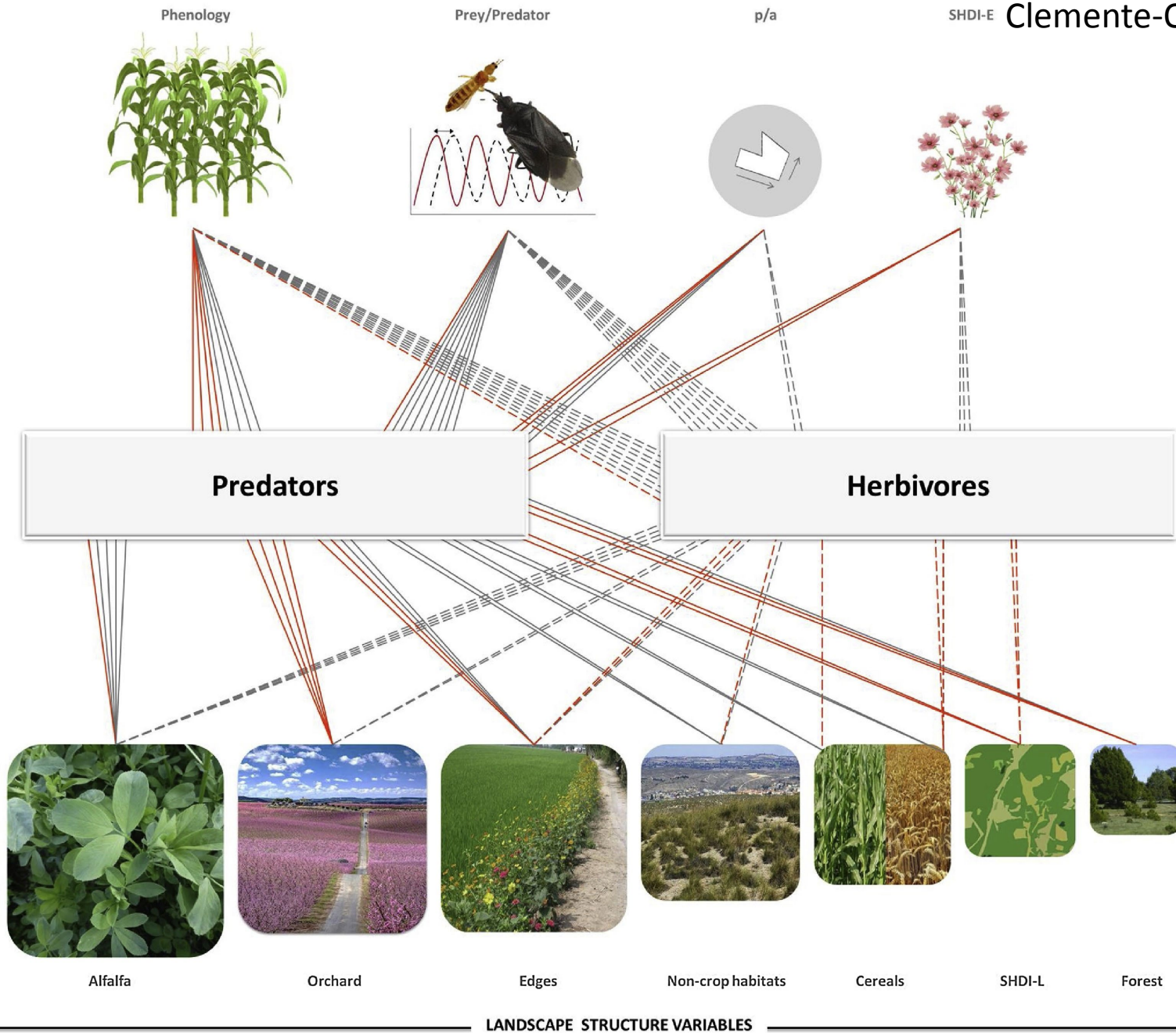
Predators



Herbivores



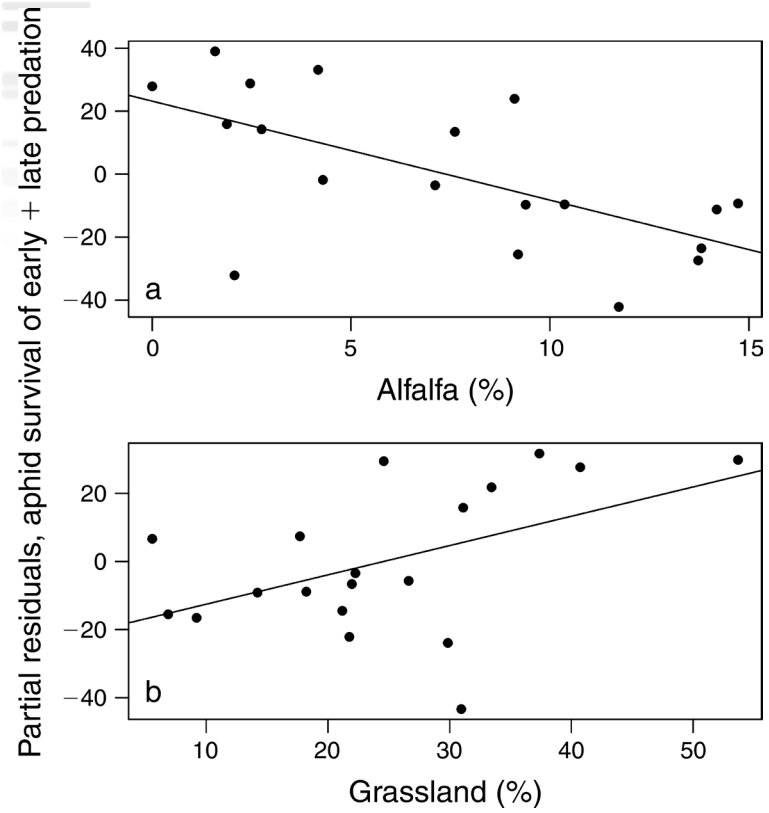
% of alfalfa



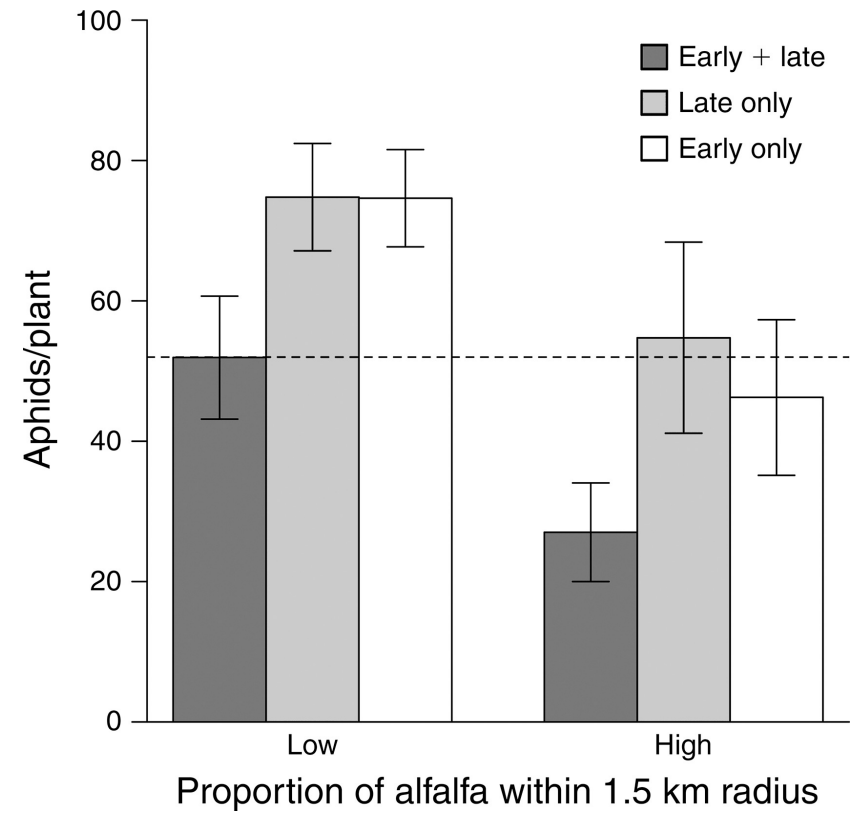
Alfalfa and biodiversity

- It has been shown that alfalfa has very strong biocontrol effect on the neighbouring crops (Clemente-Orta et al, 2020)
 - Alfalfa >> Orchards
- Alfalfa increases both early and late predation of aphids (in cotton crops in Australia) (Costamagna et al, 2015)

Landscape-scale pest suppression is mediated by timing of predator arrival



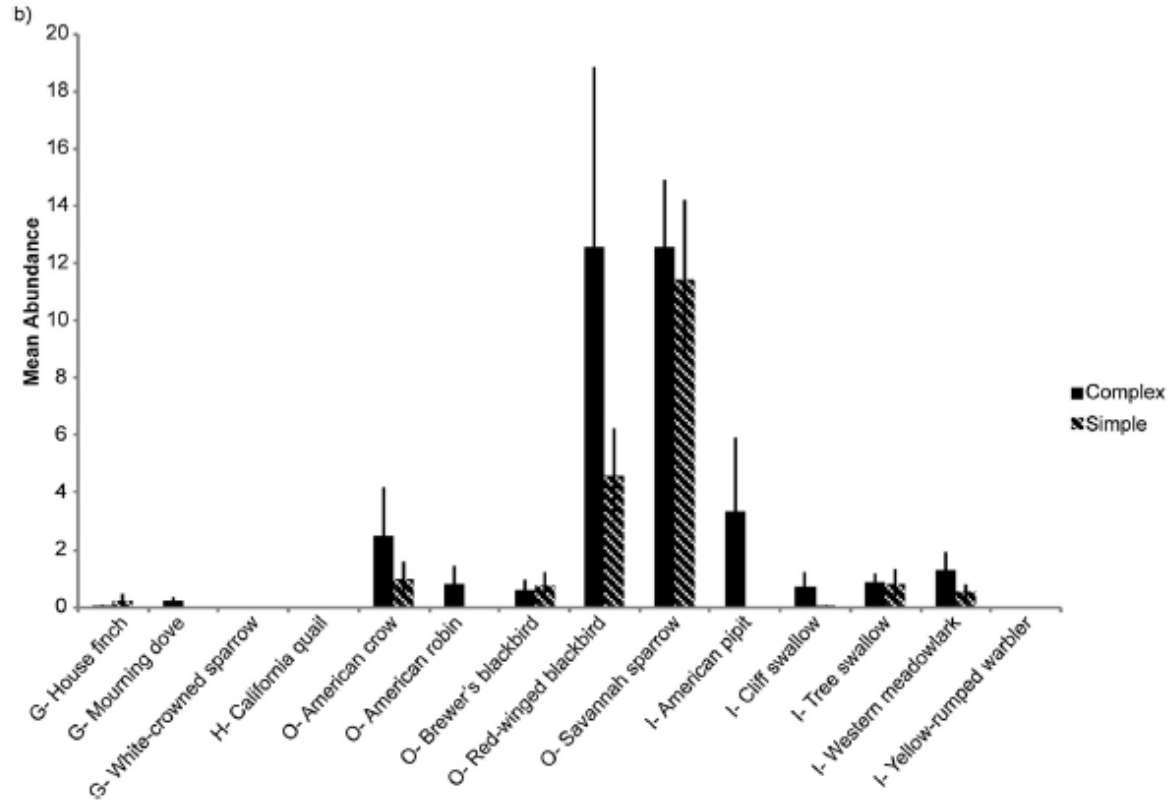
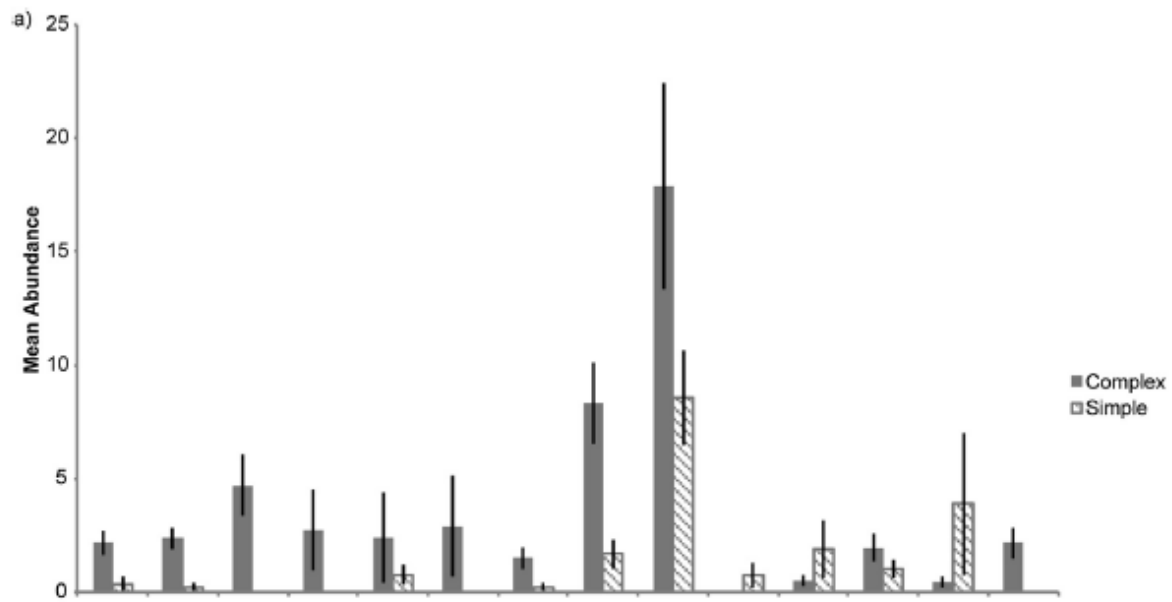
Costamagna et al, 2015. Ecological applications



Alfalfa and biodiversity

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 - Alfalfa >> Orchards
- Alfalfa increases both early and late predation of aphids (in cotton crops in Australia) (Costamagna et al, 2015)
- Complex interactions exist with the neighbouring habitats (Kross et al, 2016)
 - With rich edge habitats, more efficient avian conservation and more bird foraging to control pests

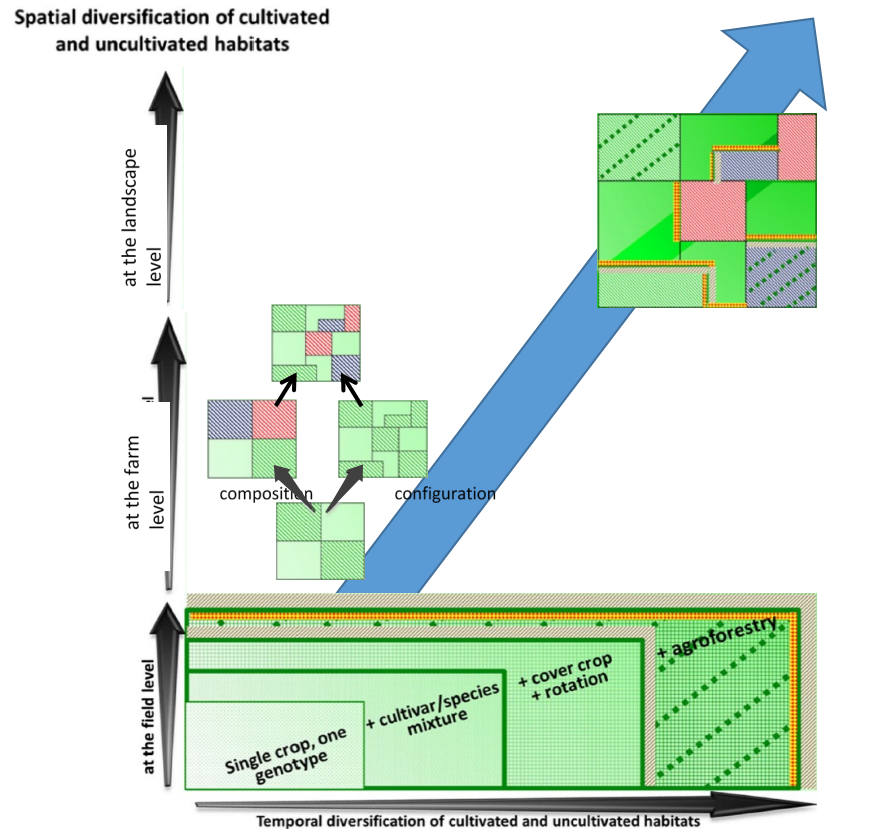
Avian abundance in alfalfa field is related to the surrounding habits and especially the edge habits



Kross et al, 2016. Agriculture, Ecosystems and Environment

The collective scientific expertise on the natural regulations obtained from increasing functional diversity (Inrae, Oct 2022)

Increasing field and landscape diversities leads to more natural regulations of weeds, pests and diseases

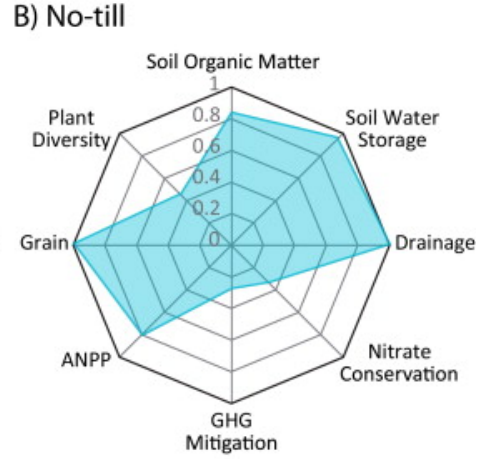
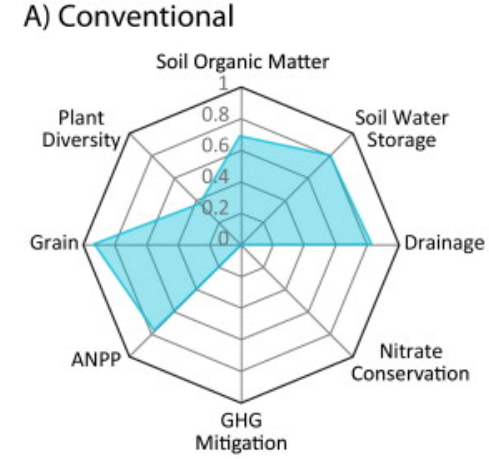


No field margin (f.m.) Simple f.m. (grass strip) Complex f.m. (grass strip + hedge) Complex f.m. + specific habitat

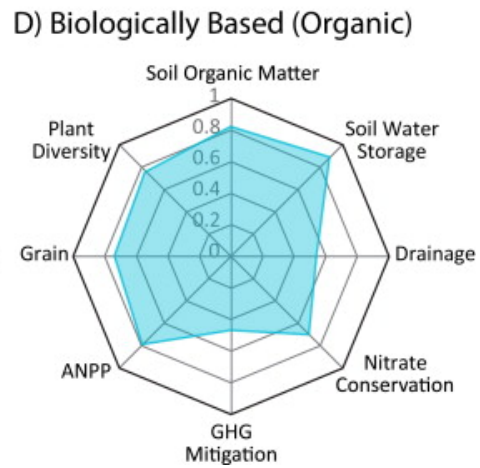
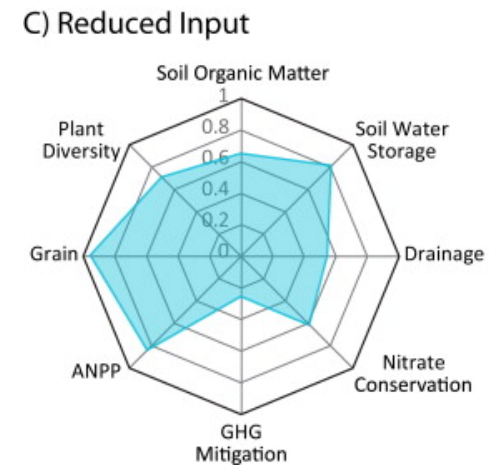
	Adventices	Insectes aériens	Insectes telluriques	Maladies vectorisées	Pathogènes aériens	Pathogènes telluriques	Nématodes	Autres bioagresseurs	
Mélanges variétaux	* Effet attendu positif	**	?	* Effet faible	*** Amplitude très variable	* Effet faible	?	?	?
Cultures associées	***	*** Effet fort	*	?	*** Effet fort	* Amplitude variable	?	?	?
Agroforesterie	** Effet assez fort	*** Amplitude variable	?	?	** Effet plus faible que pour les insectes	?	*	striga : * gastéropodes : *	Effet lié à l'absence de travail du sol
↗ diversité rotations	*** Effet fort lié au travail du sol	* Effet à l'échelle du paysage	* Effet potentiellement fort	?	* Efficace lorsque l'inoculum est local	* Effet potentiellement fort	** Effet potentiellement très fort	?	?
↘ part d'une culture dans le paysage	?	* Effet attendu positif	?	* Effet attendu positif		?	?	rats taupiers : *	
↗ diversité de l'assolement	0*	* Effet attendu positif	?	* Effet attendu positif		?	?	araignées : 0*	chauves-souris : * oiseaux : *
↘ taille des parcelles	* Effet attendu positif	* Effet faible	?	* Effet attendu peu clair			* Effet attendu peu clair	?	?
↗ distance d'isolement entre cultures	* Effet attendu variable	* Effet faible	* Effet attendu positif	* Effet attendu positif			* Effet attendu positif	?	?
↗ diversité des ESN dans le paysage	* Effet attendu positif	** Effet faible	?	* Effet attendu positif			?	Acariens : * Effet attendu positif	

NB : La non-additivité des effets synthétisés dans ce tableau interdit toute lecture transversale entre lignes mais aussi entre colonnes. Cette règle est d'autant plus fondamentale que l'analyse des effets multiples de chaque modalité de diversification sur des cortèges de bioagresseurs, ainsi que des effets combinés de plusieurs modalités de diversification constitue un champ de recherche à développer.

Multi-criteria assessment of alfalfa services

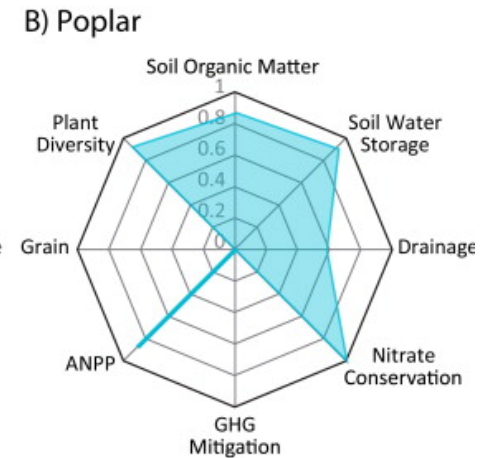
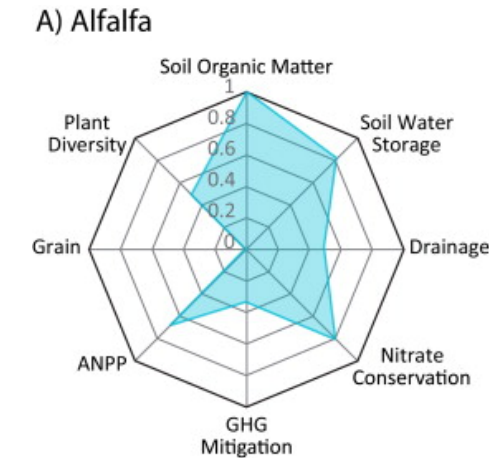


Ecosystem service indicators for conventional, no-till, reduced input, and biologically based (USDA certified organic) systems of the KBS LTER site. Values are relative to maximum values for each service observed in the study. 100% GHG mitigation was achieved by an early successional community



Alfalfa:

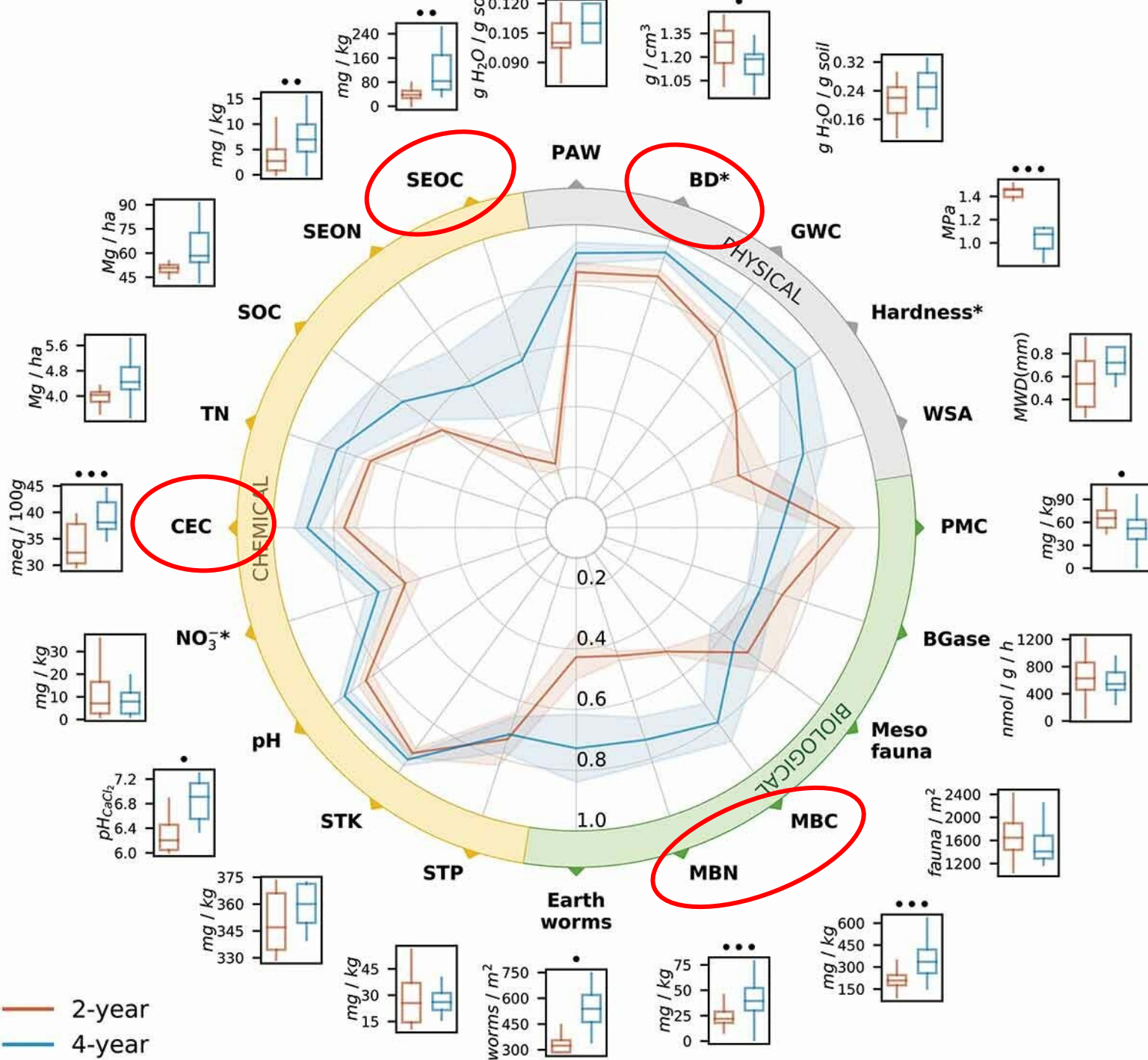
- High soil organic matter
- High soil water storage
- High nitrate conservation



Alfalfa in rotation

- Benefits for biodiversity
- Massive benefits for the soil
 - Reduction in soil resistance to root growth: - 8%
 - Increase in cation exchange capacity: + 16%
 - Increase in salt-extractable soil carbon: +157%
 - Increase in soil microbial biomass: + 62%

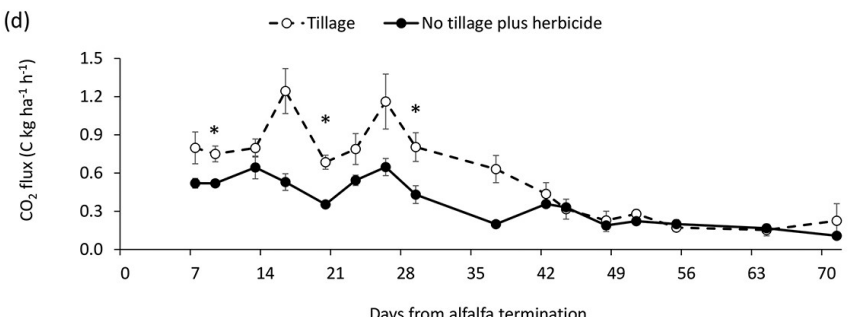
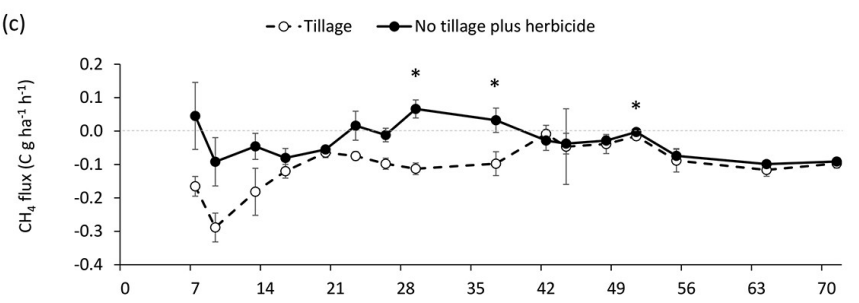
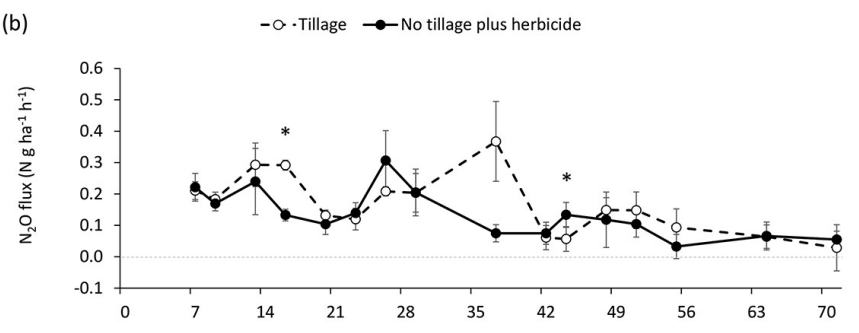
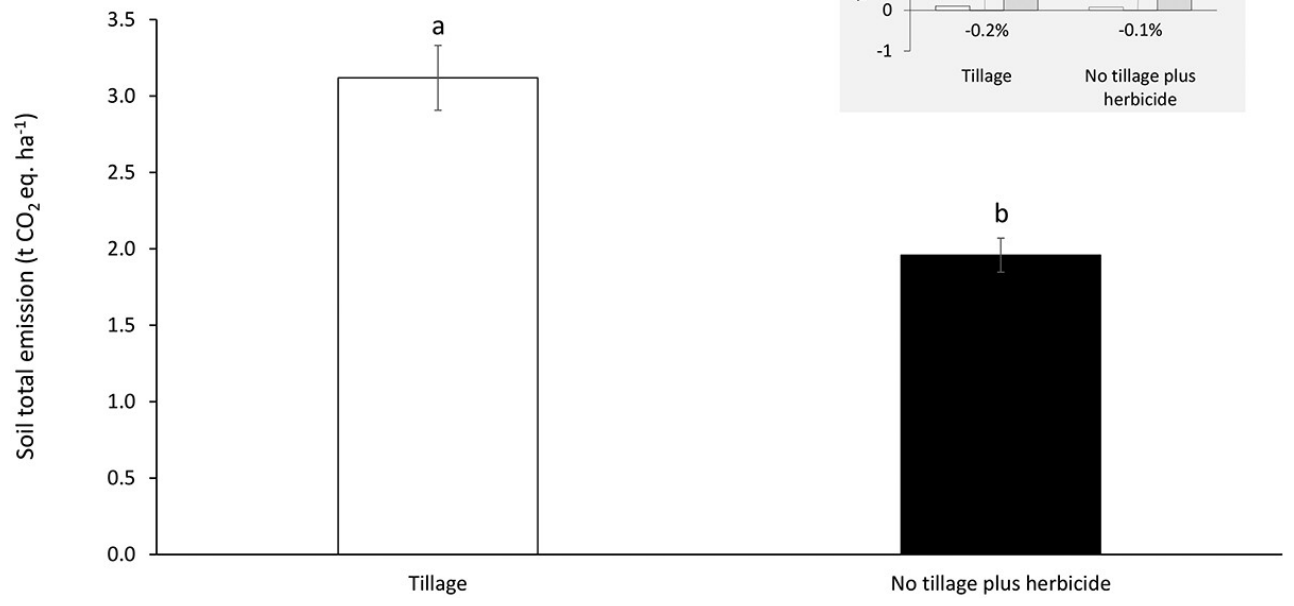
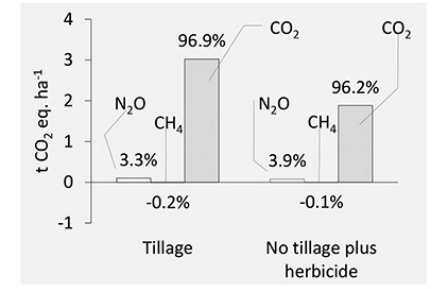
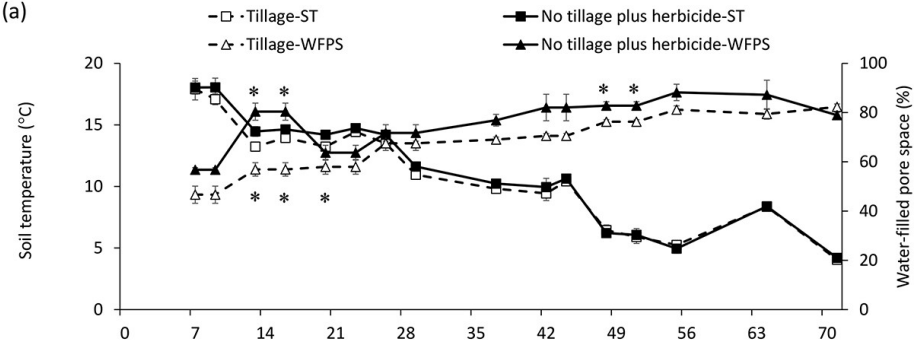
A two years rotation vs diversified 4 year cropping systems:



The strongest and most salient improvements in soil health from the diversified, 4-year cropping system included: 8% reduction in soil resistance to root growth (BD) ($p = .006$), 16% increase in cation exchange capacity (CEC) ($p = .001$), 157% increase in salt-extractable soil carbon (SEOC) ($p = .024$), and 62% increase in soil microbial biomass (MB) ($p = .017$).

Some benefits may be lost at alfalfa termination

- How to destroy alfalfa crops?
 - Tillage vs no-till + herbicide ?

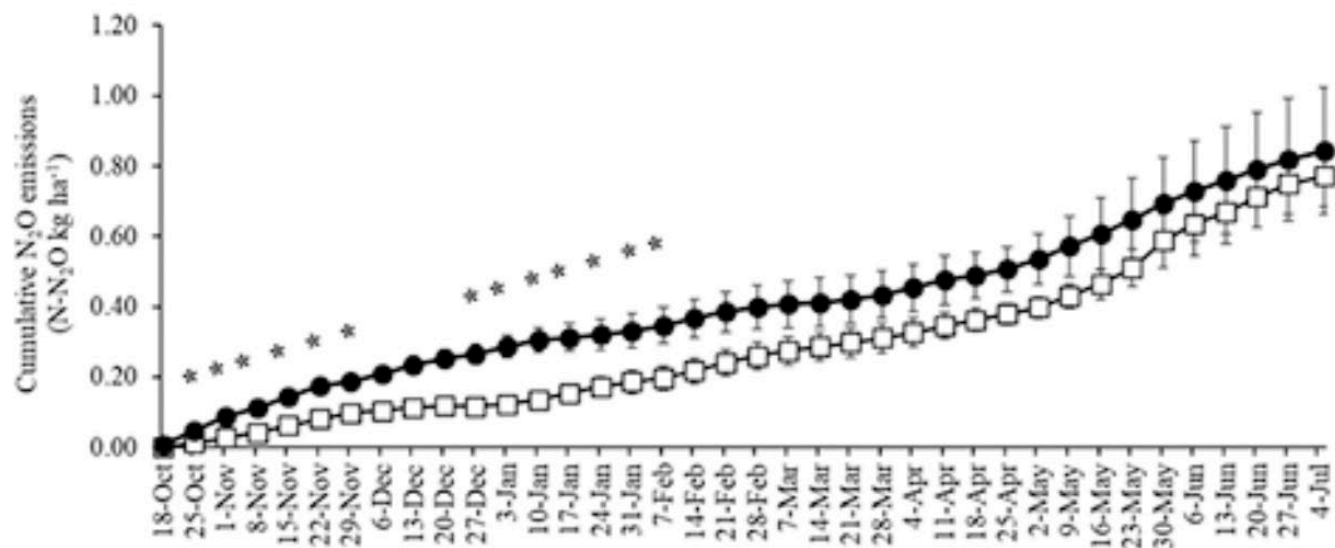


In the first 70 days after destruction

- CO₂ is the main source of GHG emission (up to 3t of CO₂ eq./ha)
- No tillage is better

Some benefits may be lost at alfalfa termination

- How to destroy alfalfa crops?
 - Tillage vs no-till + herbicide ?
- Alfalfa termination and GHG emissions
 - Alfalfa – wheat vs continuous alfalfa

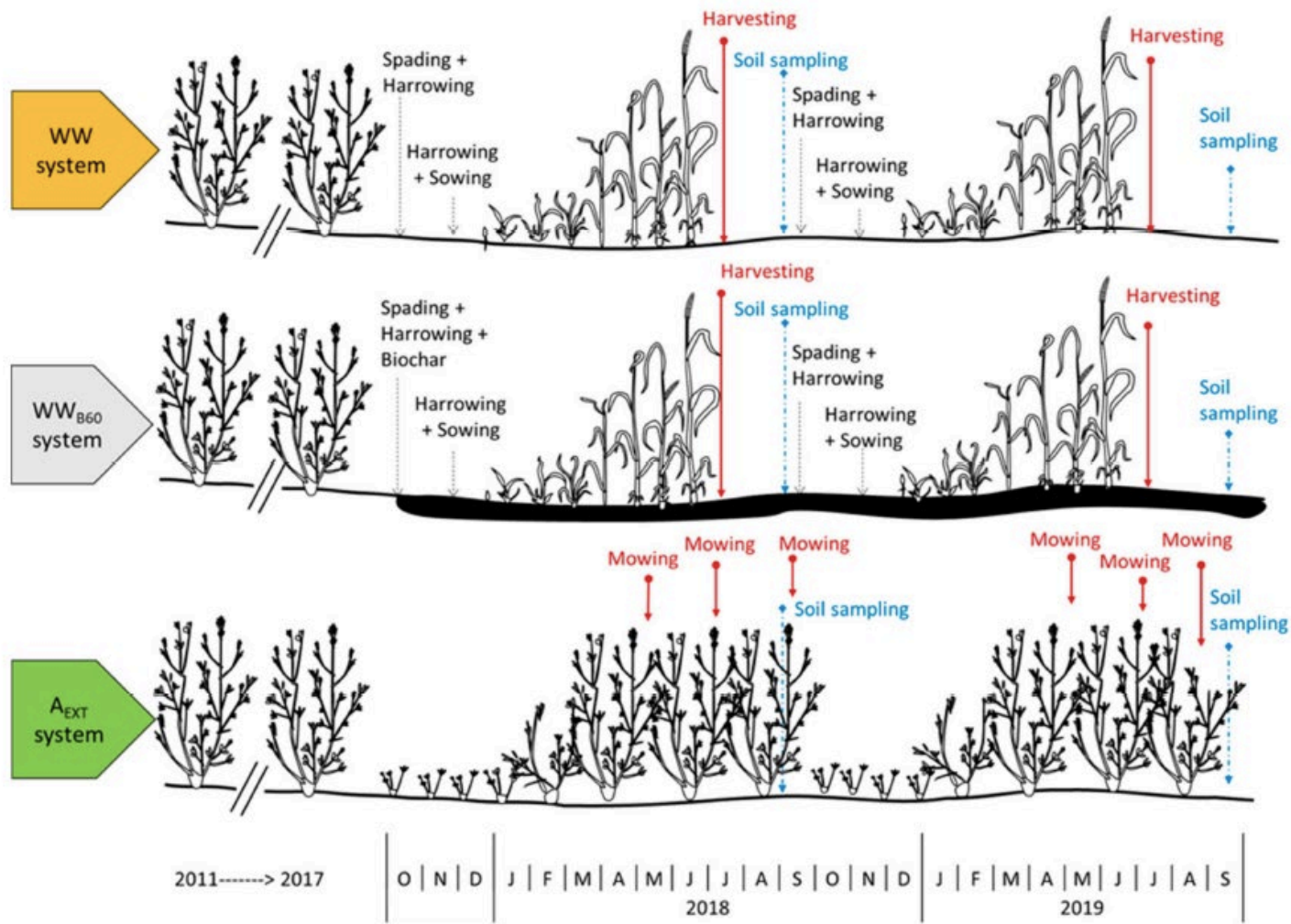


In the wheat crop (⚙) following an autumn termination of alfalfa, there is no significantly more GHG than in a continuous alfalfa (□)

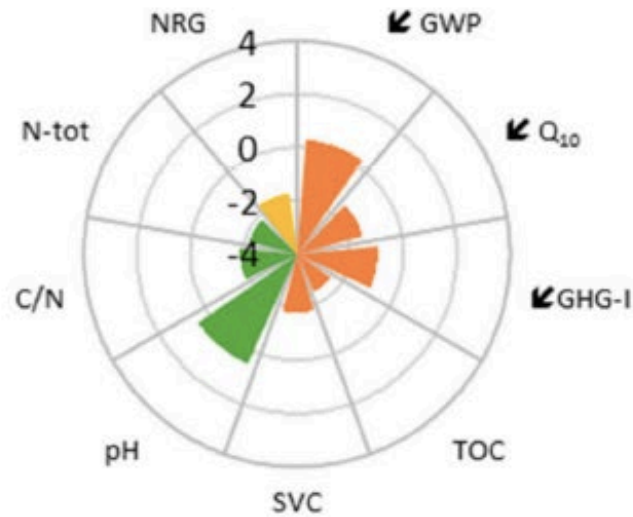
Trozzo et al, 2020, Italian Journal of Agronomy

Some benefits may be lost at alfalfa termination

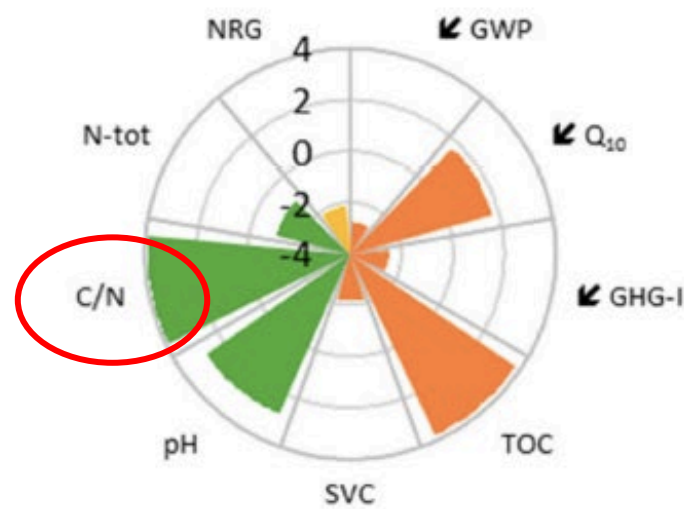
- How to destroy alfalfa crops?
 - Tillage vs. no-till + herbicide ?
- Alfalfa termination and GHG emissions
 - Alfalfa – wheat vs. continuous alfalfa
- Following an alfalfa, addition of Biochar may be beneficial for providing supporting services (C/N ratio)



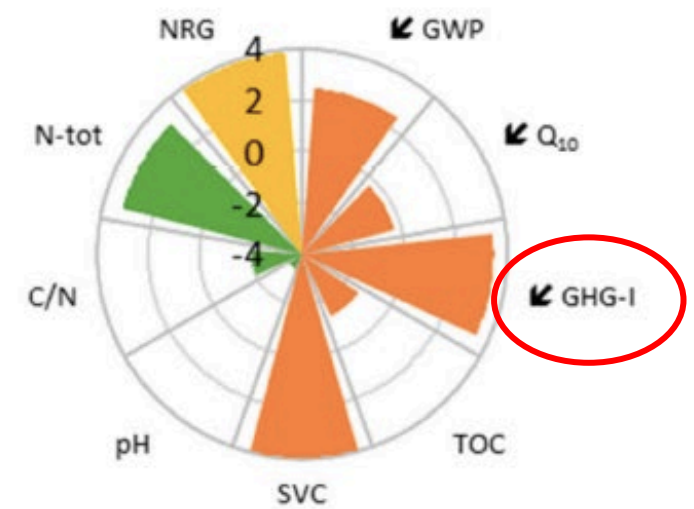
WW system



WW_{B60} system



A_{EXT} system



Regulating services

GWP = global warming potential
Q₁₀ = temperature sensitivity to soil respiration
GHG-I = soil greenhouse gas intensity
TOC = soil total organic carbon
SVC = soil vegetation cover

Supporting services

pH = soil pH
N-tot = soil total nitrogen
C/N = soil carbon–nitrogen ratio

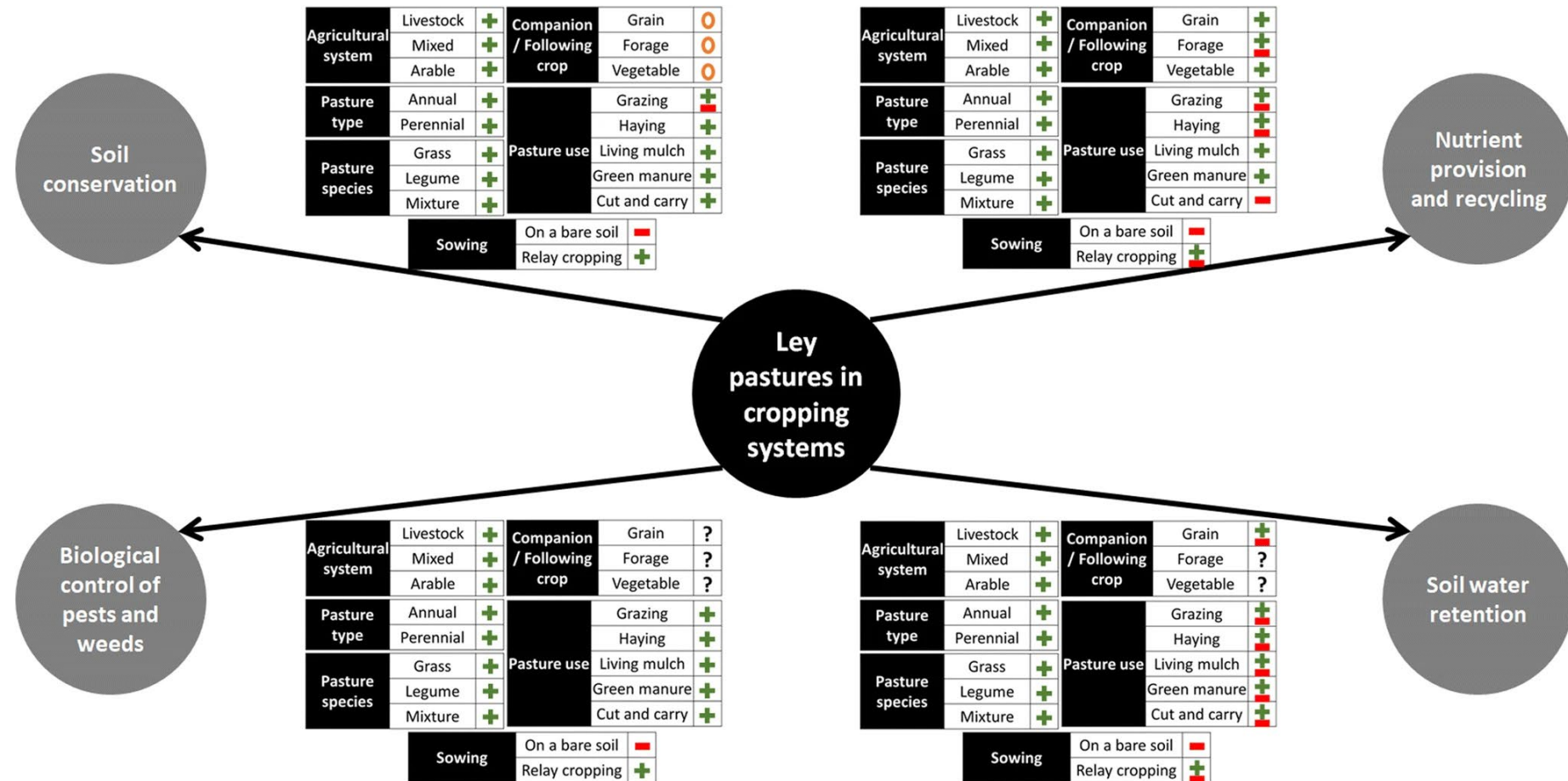
Provisioning services

NRG = crop energy output

↙ = indicators of ecosystem disservices. For each of these ecosystem disservices indicator (GWP, Q₁₀ and GHG-I), the graph shows the contribution of each management option to the reduction of the ecosystem disservices (i.e., the higher the value of the GWP, the lesser CO₂ equivalent emitted)

Conclusions

- Benefits from alfalfa in rotations are massive but also depend upon management

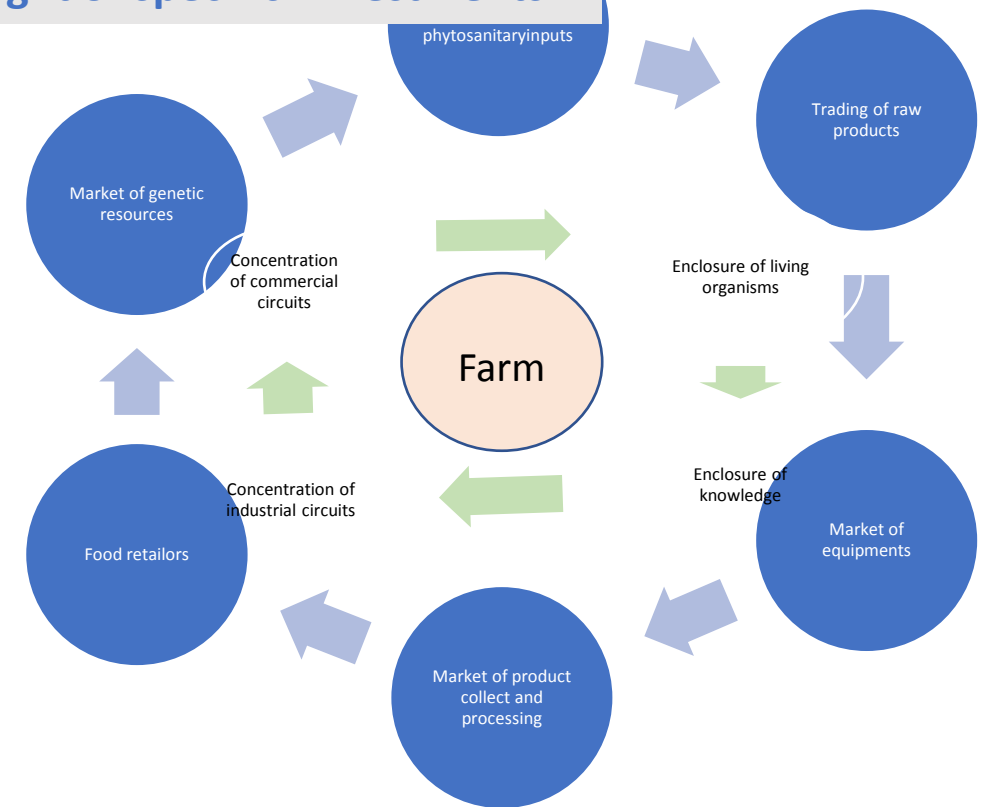
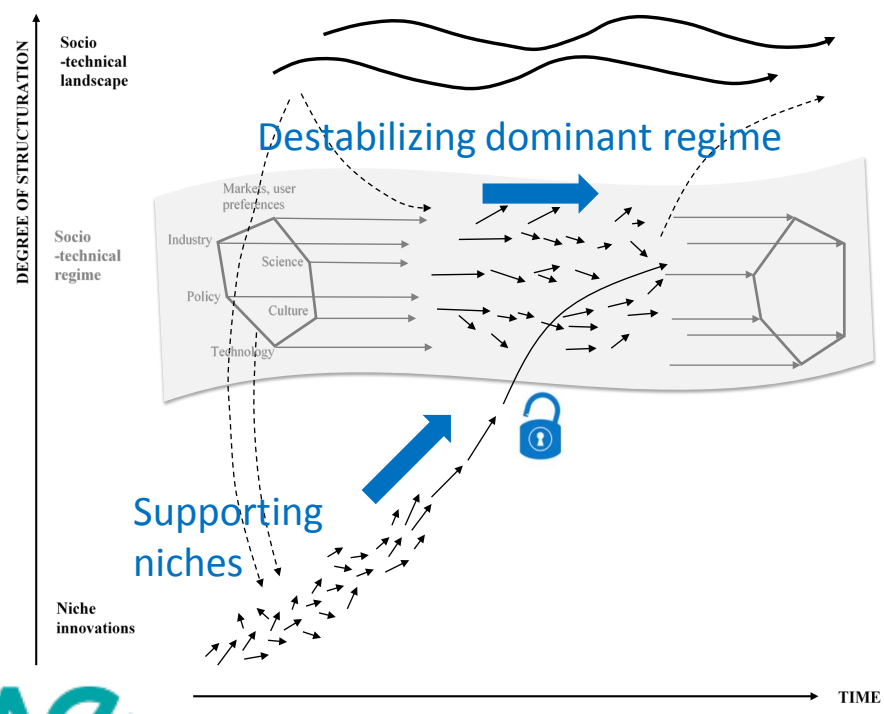


Conclusions

- Benefits from alfalfa in rotations are massive but also depend upon management
- Adoption of innovative practices and systems must consider the locked-in systems in which farmers are involved

Two major issues to foster transition

- The enclosure patterns
- The **weight of specific investments**



Thank you for your attention ...

