Reshaping the contribution of research to agricultural innovation

From dissemination to supporting local innovation at scale

PRIFYSGOL BANGOR UNIVERSITY

Agroecology TPP

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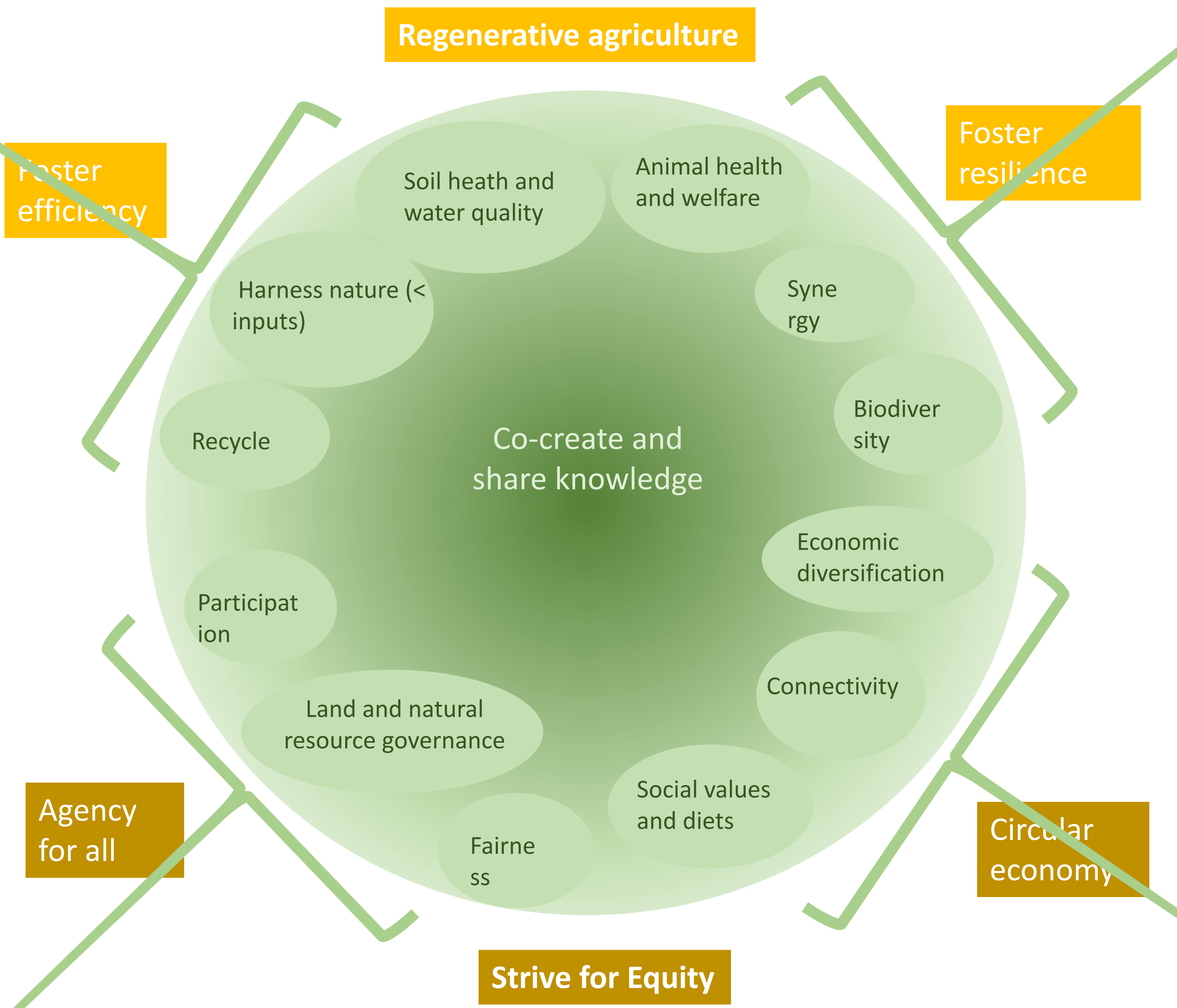
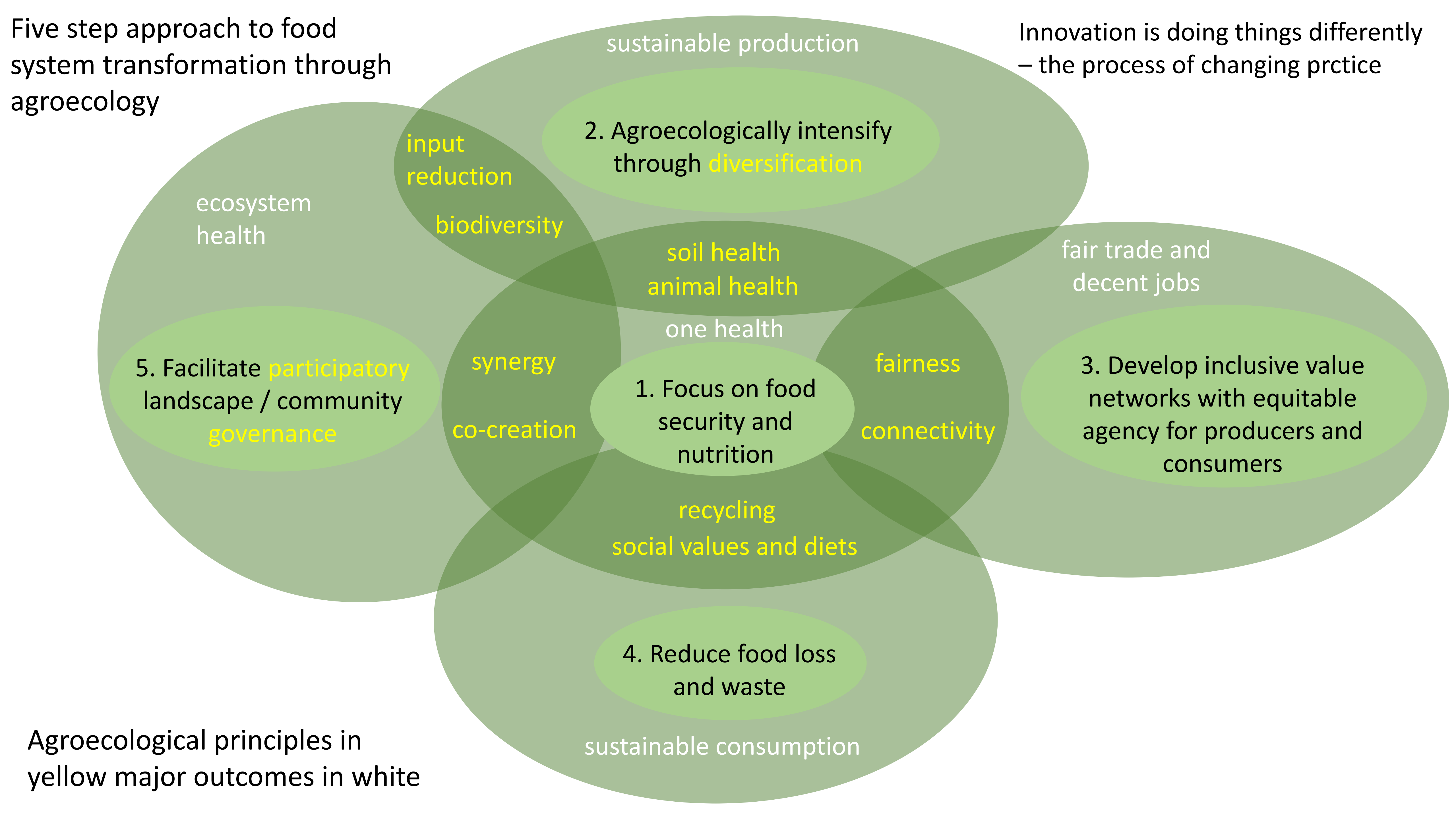
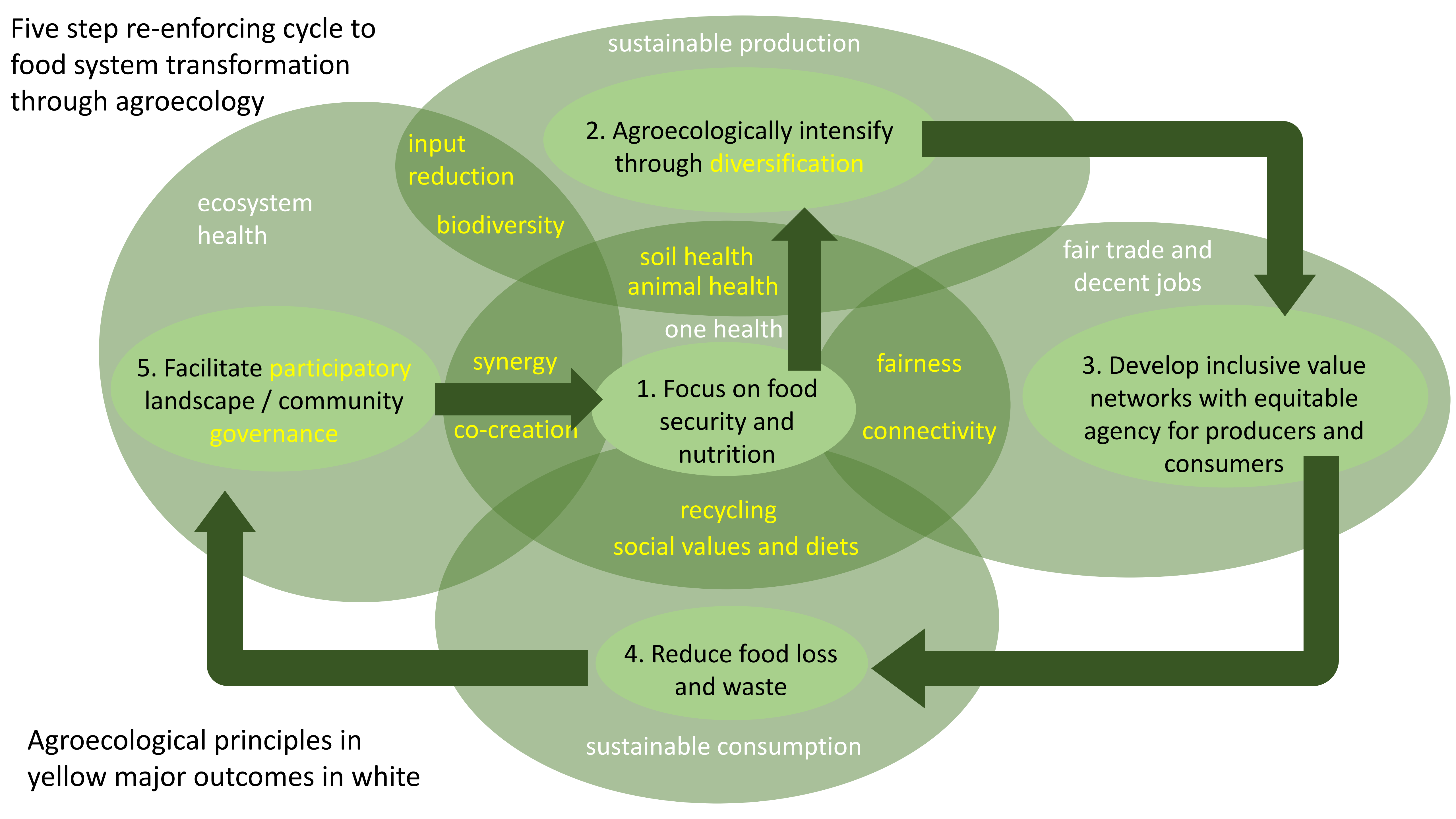
Agroecology is an integrated response to global challenges.

It involves transforming food systems through local application of the 13 CFS, HLPE (2019) agroecological principles



Wezel A, Gemmill Herren B, Bezner Kerr R, Barrios E, Gonçalves ALR and Sinclair F (2020). Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. *Agronomy for Sustainable Development* 40: 40 13pp. https://doi.org/10.1007/s13593-020-00646-z


Five step approach to food system transformation through agroecology
Innovation is doing things differently – the process of changing prctice
sustainable production
2. Agroecologically intensify through diversification
input reduction
biodiversity
ecosystem health
soil health
animal health
fair trade and decent jobs
one health
synergy
fairness
5. Facilitate participatory landscape / community governance
1. Focus on food security and nutrition
3. Develop inclusive value networks with equitable agency for producers and consumers
co-creation
connectivity
recycling
social values and diets
4. Reduce food loss and waste
sustainable consumption
Agroecological principles in yellow major outcomes in white


Five step re-enforcing cycle to food system transformation through agroecology
sustainable production
2. Agroecologically intensify through diversification
input reduction
biodiversity
ecosystem health
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animal health
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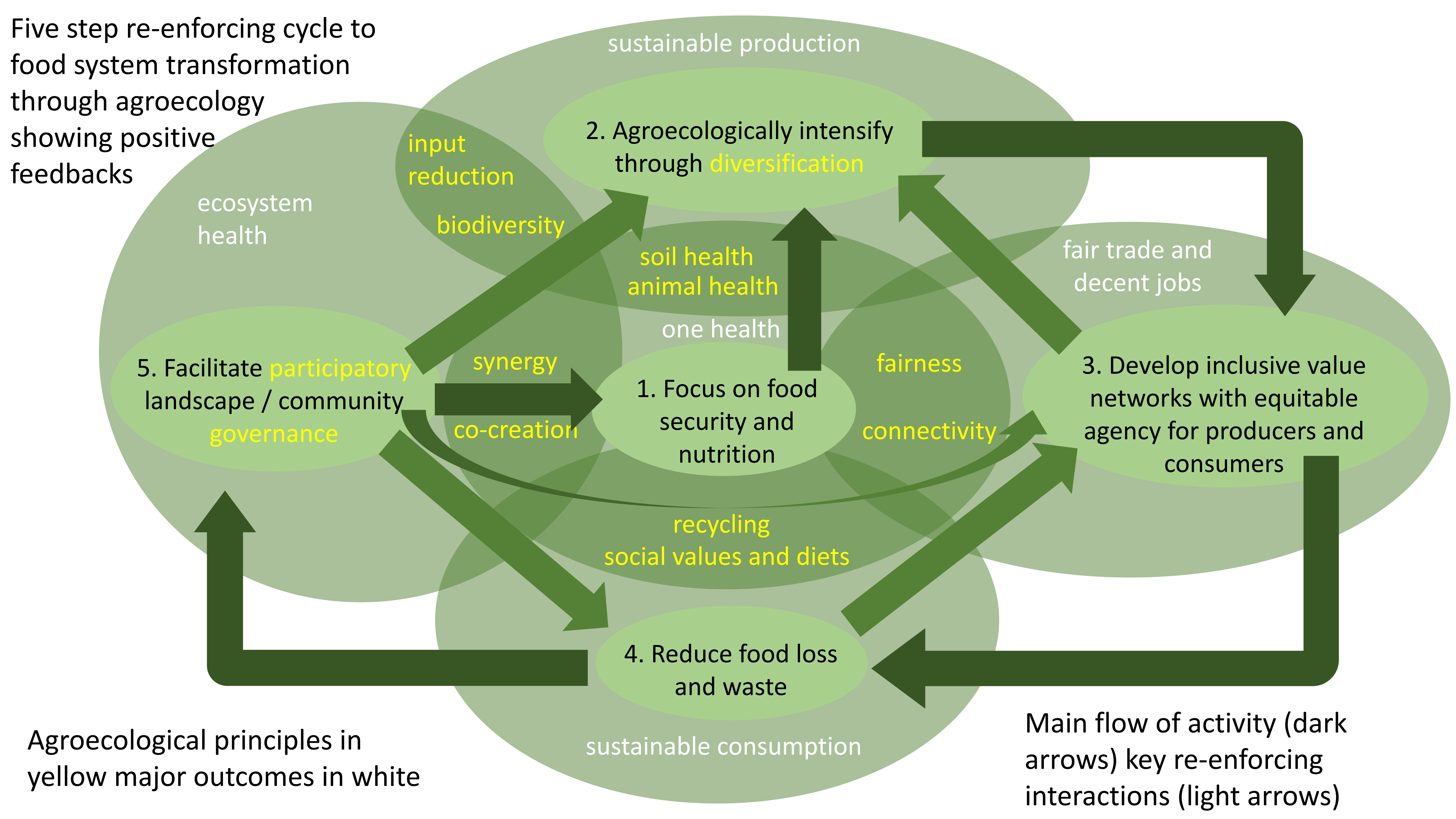
Agroecological principles in yellow major outcomes in white



Five step re-enforcing cycle to food system transformation through agroecology showing positive feedbacks
sustainable production
2. Agroecologically intensify through diversification
input reduction
biodiversity
ecosystem health
soil health
animal health
one health
fair trade and decent jobs
5. Facilitate participatory landscape / community governance
synergy
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1. Focus on food security and nutrition
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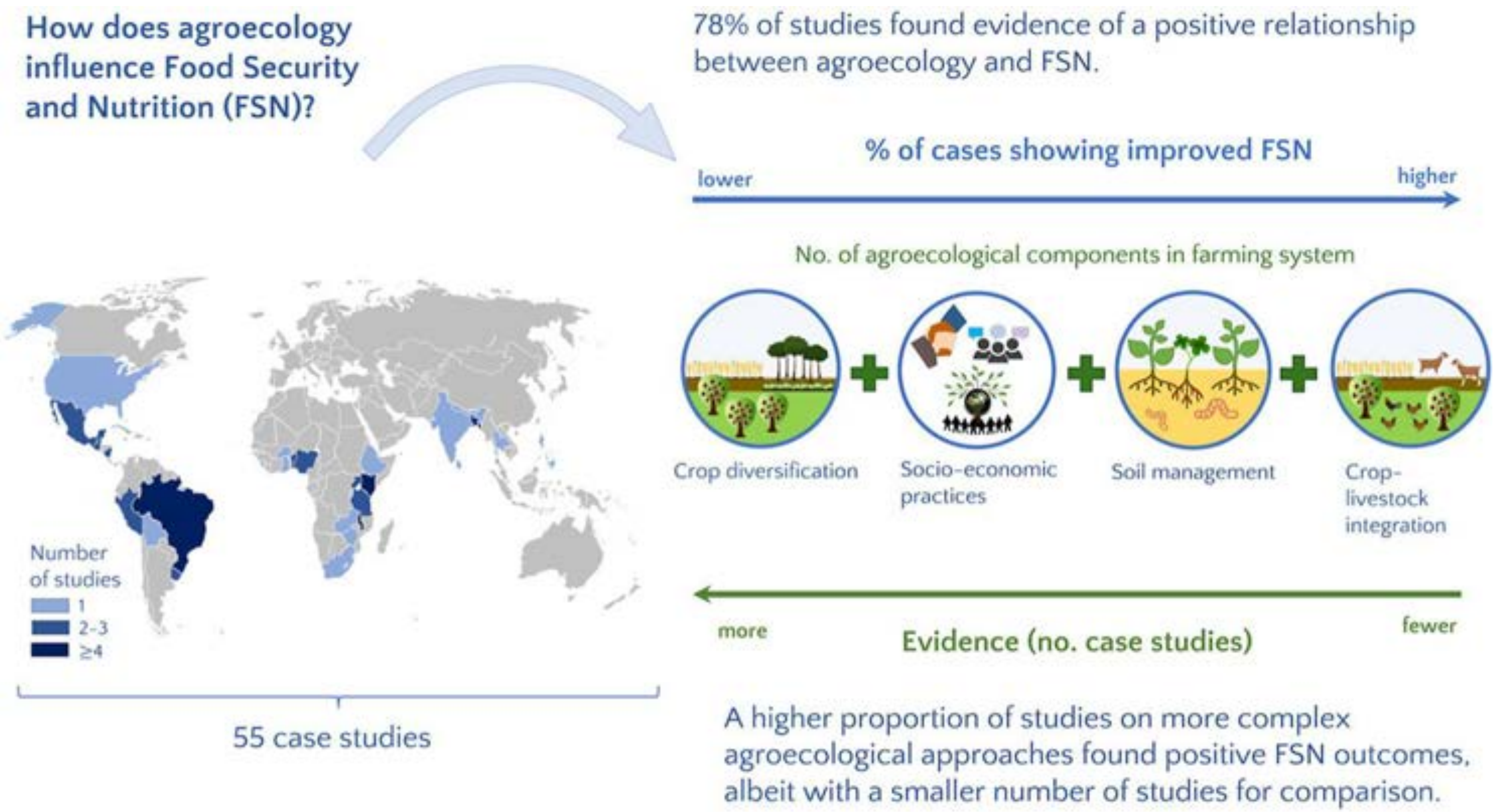
connectivity
3. Develop inclusive value networks with equitable agency for producers and consumers
recycling
social values and diets
4. Reduce food loss and waste
sustainable consumption
Agroecological principles in yellow major outcomes in white
Main flow of activity (dark arrows) key re-enforcing interactions (light arrows)

Step 1: Focus on food security and nutrition



Bezner Kerr et al., 2021. Can agroecology improve food security and nutrition? A review. *Global food security* 29: 100540

Fertiliser Security for Food Security in Southeast Asia: Going Local and Circular

FULCRUM

ELYSSA KAUR LUDHER

Southeast Asia is highly dependent on a volatile global supply of synthetic fertilisers.

https://fulcrum.sg/fertiliser-security-for-food-security-in-southeast-asia-going-local-and-circular/#:~:text=The%20Russia%2DUkraine%20war%20that,respectively%20(see%20Figure%201).

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This blog post is part of a special series on the global and regional food security implications of high food and fertilizer pri... Ukraine war. The blog series is edited by Johan Swinnen, Managing Director, Systems Transformation, CGIAR, and Director...

IFPRI Blog : Issue Post

High fertilizer prices contribute to rising global food security concerns

APRIL 25, 2022

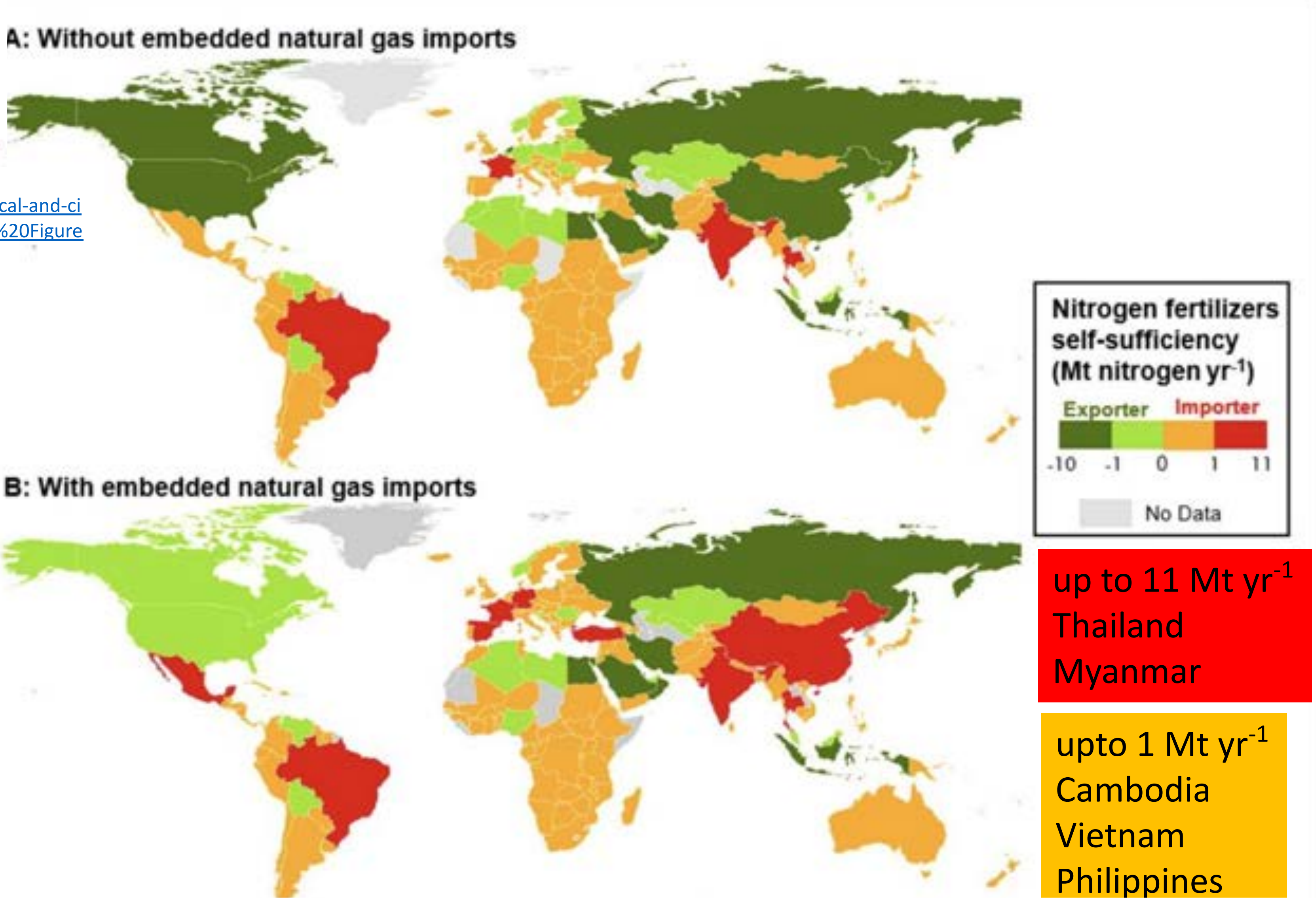
BY CHARLOTTE HEBEBRAND AND DAVID LABORDE

OPEN ACCESS | CC-BY-4.0

Like people, plants need a multitude of nutrients to thrive. These are categorized into micro... as zinc and iron; secondary macronutrients; such as calcium and magnesium; and three prin... macronutrients: nitrogen (N), phosphorus (P), and potassium (K). Mineral fertilizers provide... plant accessible nutrients, while organic minerals importantly also provide carbon, which c... healthy soils. While efforts to reduce nutrient losses to the environment must be continued... it bears emphasizing that fertilizers play a crucial role in agricultural productivity.

1.78 billion people are fed from food reliant on imports of fertilizers or natural gas used to produce them

Global N fertilizer self-sufficiency with and without embedded fossil fuel imports



up to 11 Mt yr^{-1}
Thailand
Myanmar

upto 1 Mt yr^{-1}
Cambodia
Vietnam
Philippines

Rosa & Gabrielli 2022 Environ.Res.Lett.18(2023)014008 https://doi.org/10.1088/1748-9326/aca815

Transitioning to biological N fixation means supporting farmer innovation

Industrial

Empower smallholder farmers

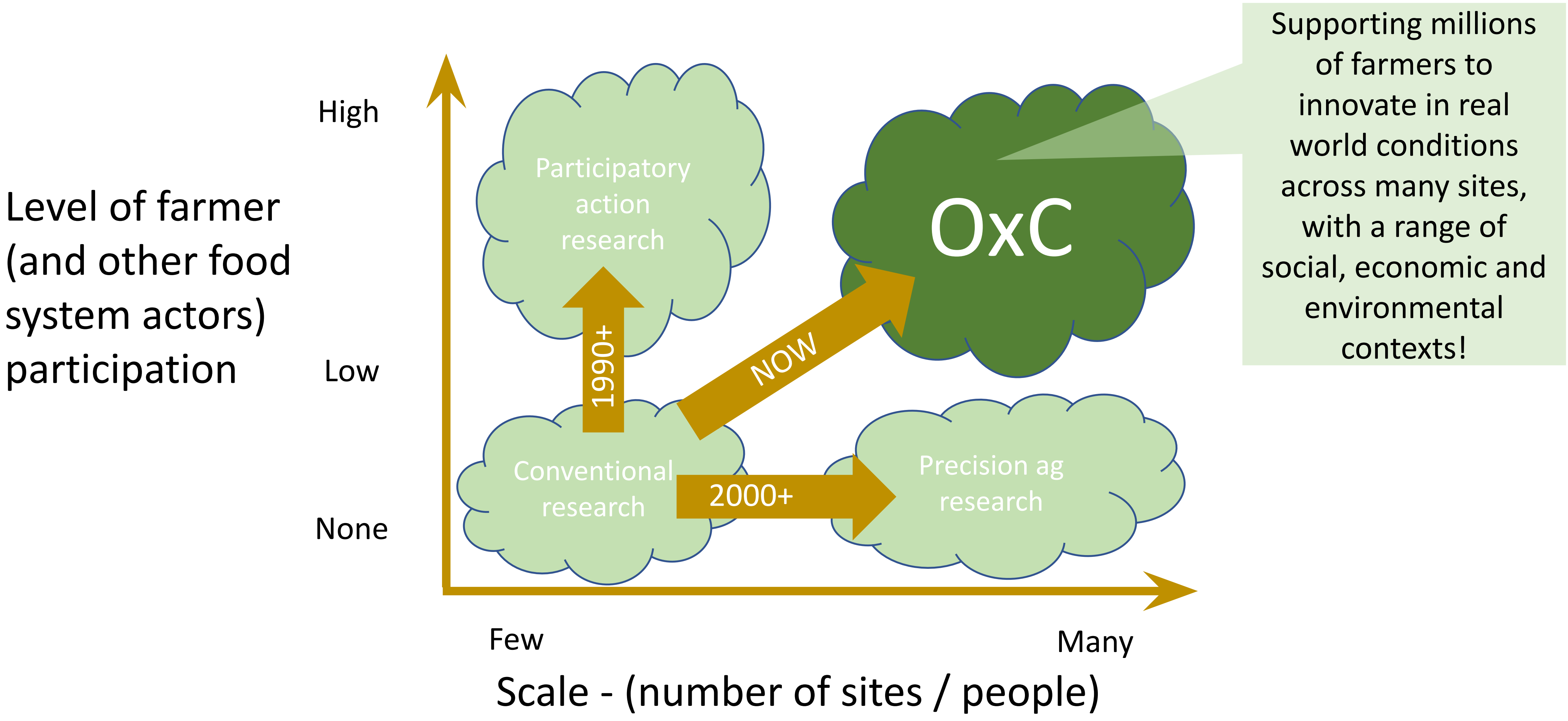
Biological

Citizen science

Centrally owned and produced, derived from fossil fuel use - high green house gas emissions, distribution costs and challenges, cost and risk to farmers (and governments where subsidized), non-resilient at farm and often national levels, high losses (leakage / pollution) BUT **SIMPLE**

Distributed ownership by millions of farmers, derived from solar energy, lower cost and risk to farmers, more resilient at farm and often national levels, less leakage / pollution BUT **COMPLEX and KNOWLEDGE INTENSIVE – REQUIRES SYSTEM CHANGE – SUPPORT for LOCAL INNOVATION** (co-creation and sharing of knowledge)

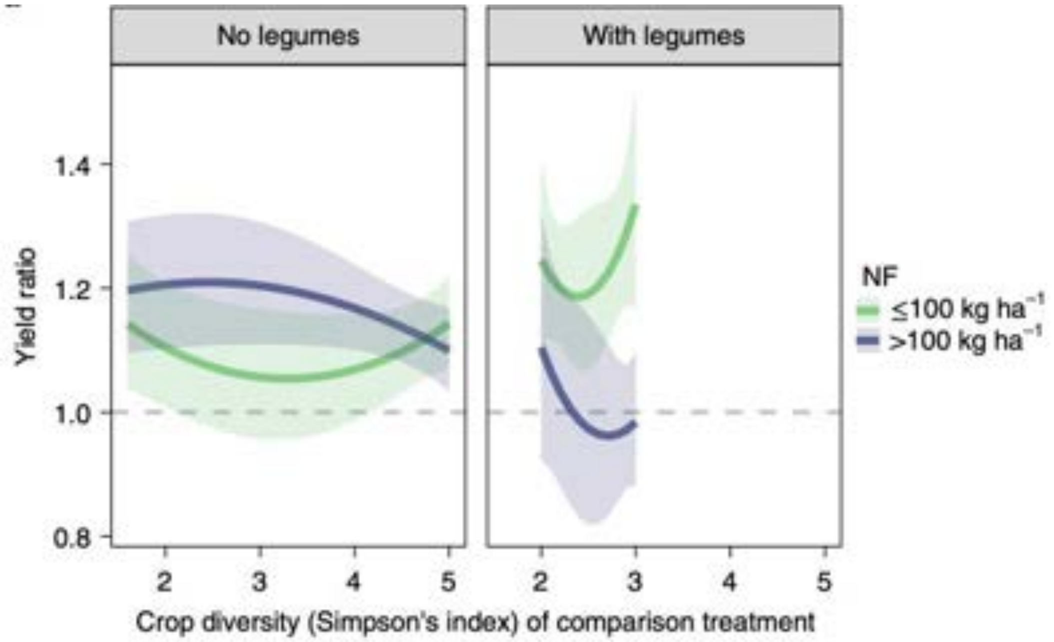
Options by context (OxC)



Sinclair, F and Coe R, 2019. The options by context approach: a paradigm shift in agronomy. *Experimental Agriculture* 55 (S1): 1–13.

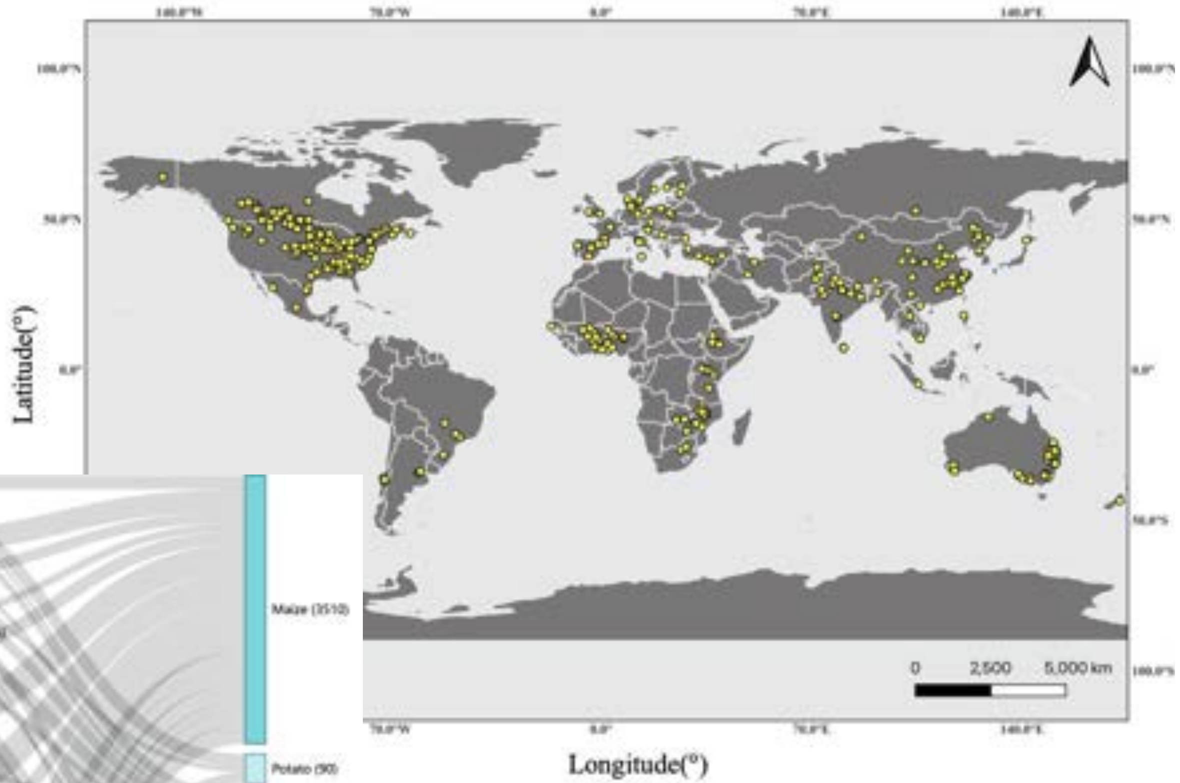
Step 2 - Diversity and productivity go hand in hand

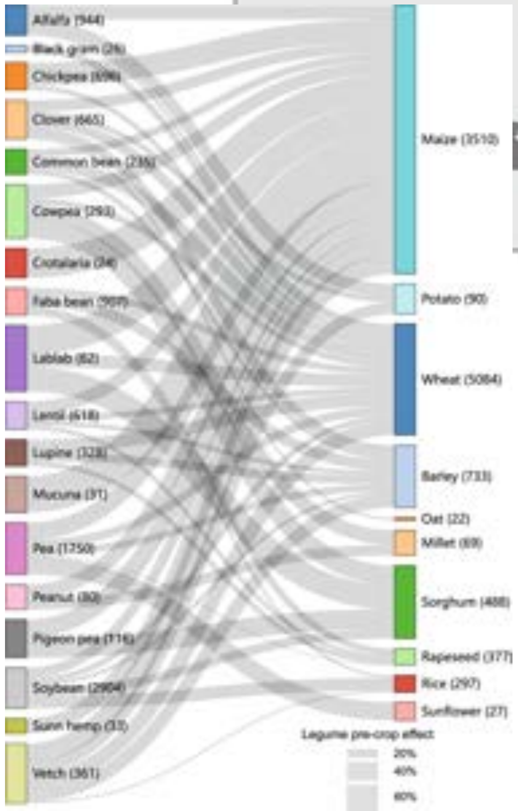
Crop diversification with legumes substitutes for nitrogen fertiliser on monocultures



Metanalysis of 30 long-term trials (each with at least 9 years data) (>25,000 data points).

MacLaren, C et al., 2022. Long-term evidence for ecological intensification as a pathway to sustainable agriculture. *Nature Sustainability*. https://www.nature.com/articles/s41893-022-00911-x

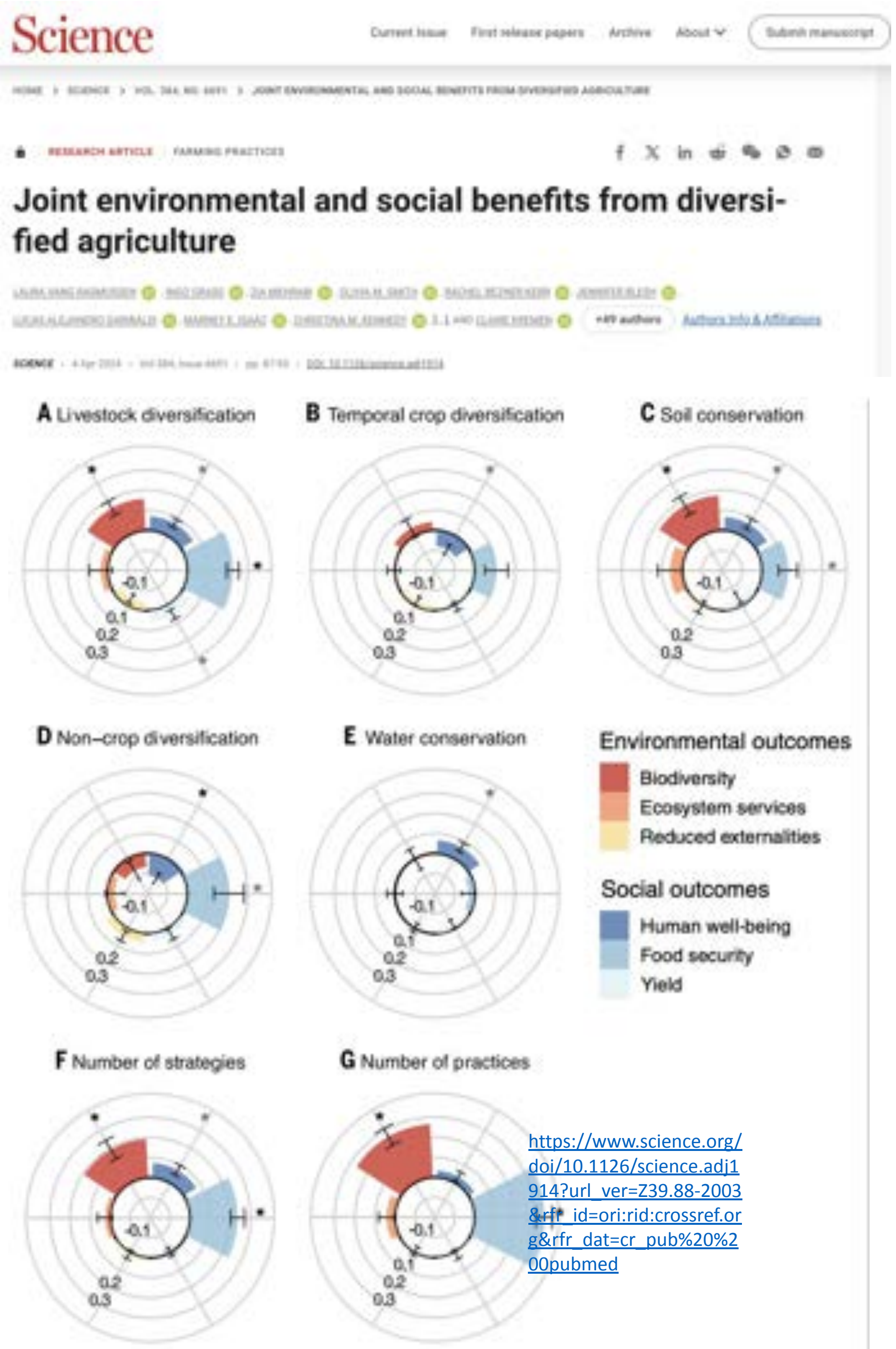




Global metanalysis of 11,768 yield observations from 462 field experiments comparing legume-based and non-legume cropping systems show that legumes enhanced main crop yield by 20% but effect declines as N fertilizer application increases

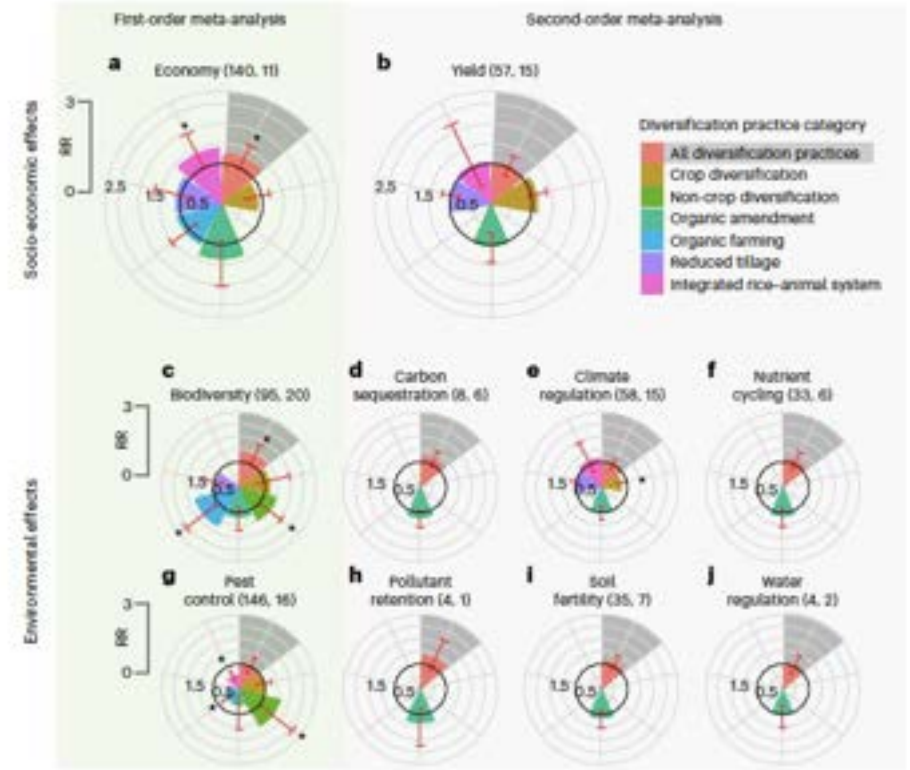
Zhao, J., Chen, J., Beillouin, D. *et al.* [Global systematic review with meta-analysis reveals yield advantage of legume-based rotations and its drivers]. *Nature*

FARM



https://www.science.org/doi/10.1126/science.adj1914?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%20%200pubmed

FIELD

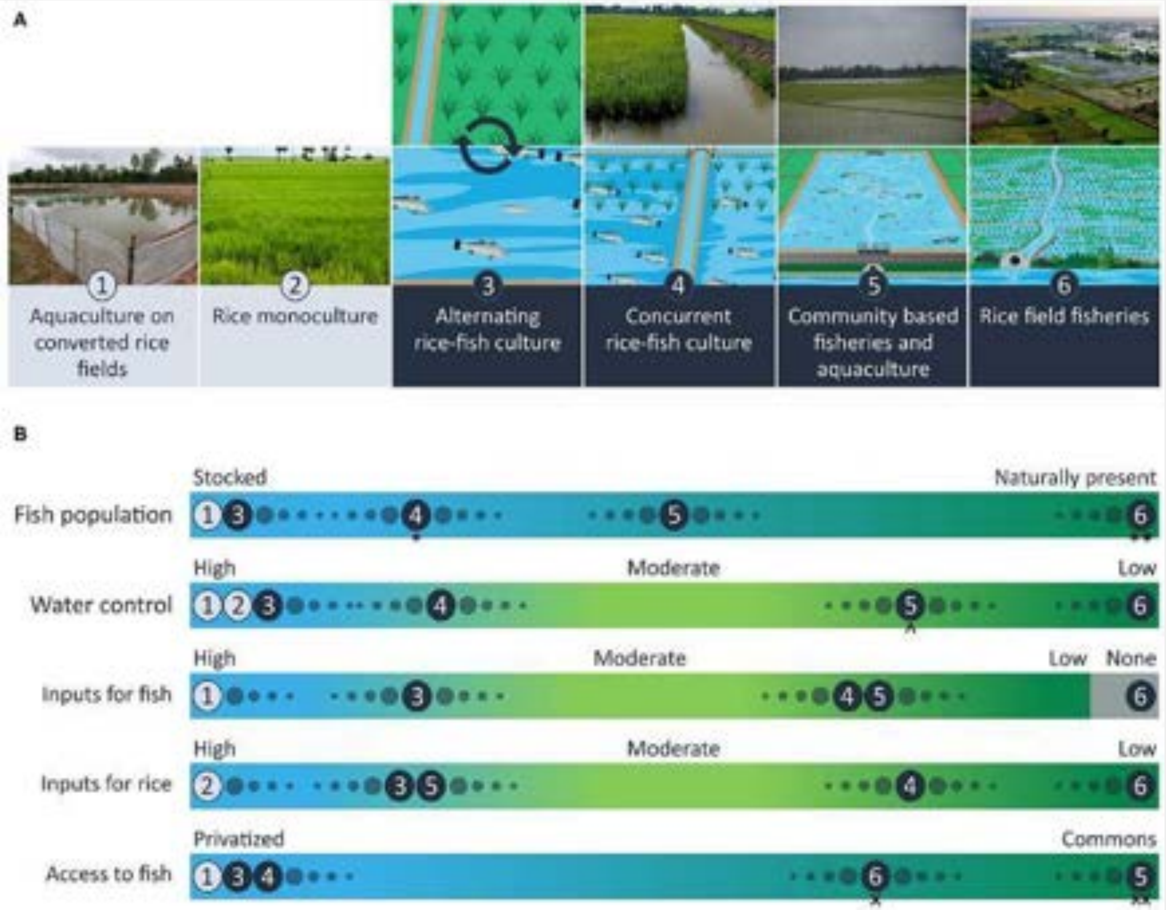


Agricultural diversification in rice production increased biodiversity 40%, improved economy by 26% and reduced crop damage by 31% **promoteing win–win scenarios between yield and other ecosystem services in 81% of cases**

He, X., Batáry, P., Zou, Y. *et al.* Agricultural diversification promotes sustainable and resilient global rice production. *Nature Food* **4**, 788–796 (2023). https://doi.org/10.1038/s43016-023-00836-4

Lots of rich examples at different scales (from field to food system) showing value of integrated systems

6TH INTERNATIONAL RICE CONGRESS



Freed S, et al., 2020. Maintaining diversity of integrated rice and fish production confers adaptability of food systems to global change. *Frontiers in Sustainable Food Systems* 4(2020).

Diversified rice production systems:

- higher annual net income because of lower production costs for agrochemicals and high yields of rice and fish.
- low use of pesticides and fertilizers create less impacts on the environment, allows for higher biodiversity, stimulating a more efficient circulation of nutrients and natural control mechanisms of rice pests.
- socially less pesticides, a diversified production of crops and increased income improved farmers' health and wellbeing.

Berg et al., 2023. An ecological economic comparison between integrated rice-fish farming and rice monocultures with low and high dikes in the Mekong Delta, Vietnam. Ambio https://doi.org/10.1007/s13280-023-01864-x

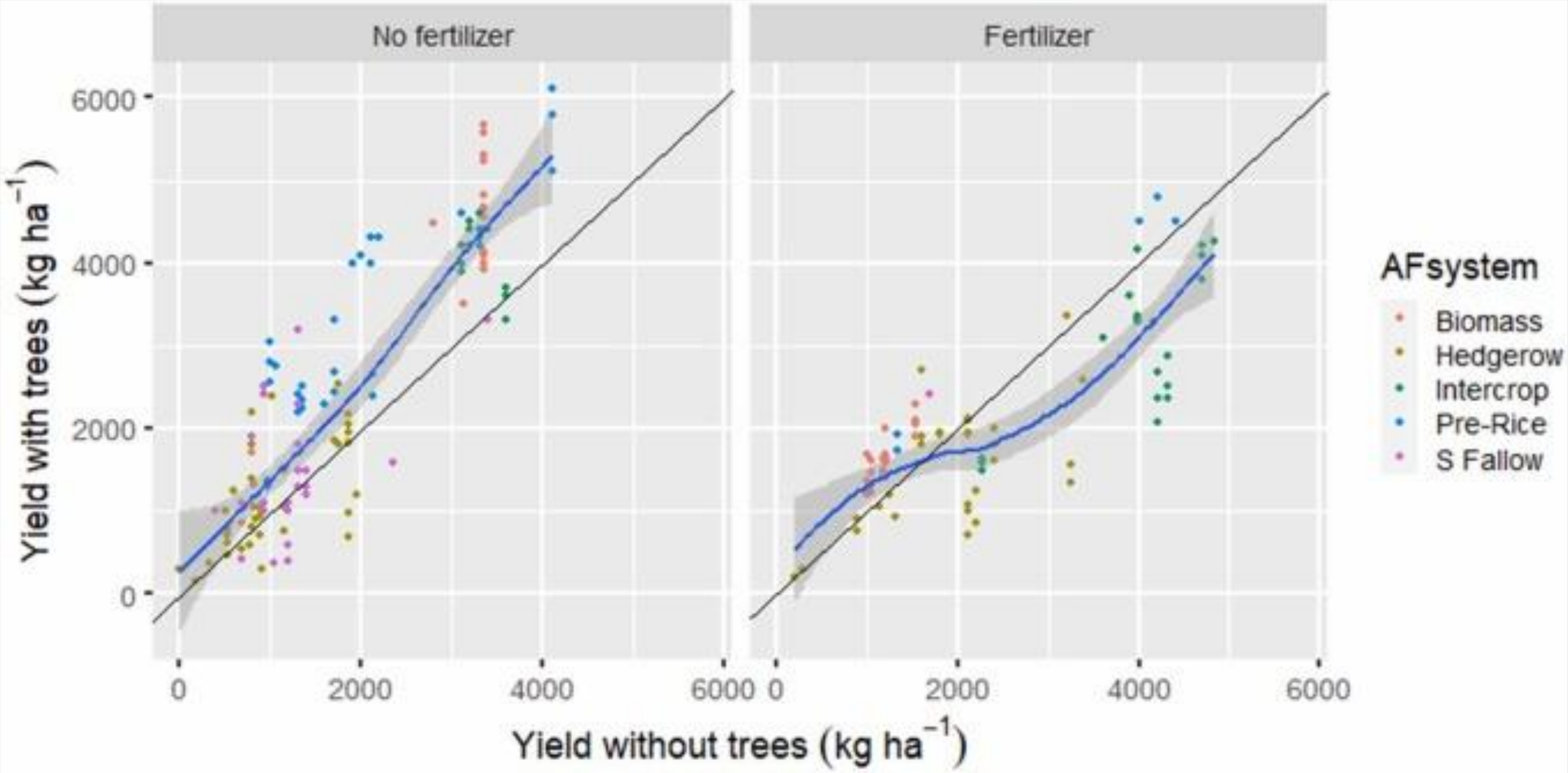
IRRI CGIAR CIFOR World Agroforestry

https://www.worldagroforestry.org/blog/2020/11/16/agroecology-whets-global-appetite-rice-and-fish

Global analysis of impacts of integrating trees with rice production

https://glfx.globallandscapesforum.org/topics/21467/news/695616

6TH INTERNATIONAL RICE CONGRESS



IRRI CGIAR CIFOR World Agroforestry

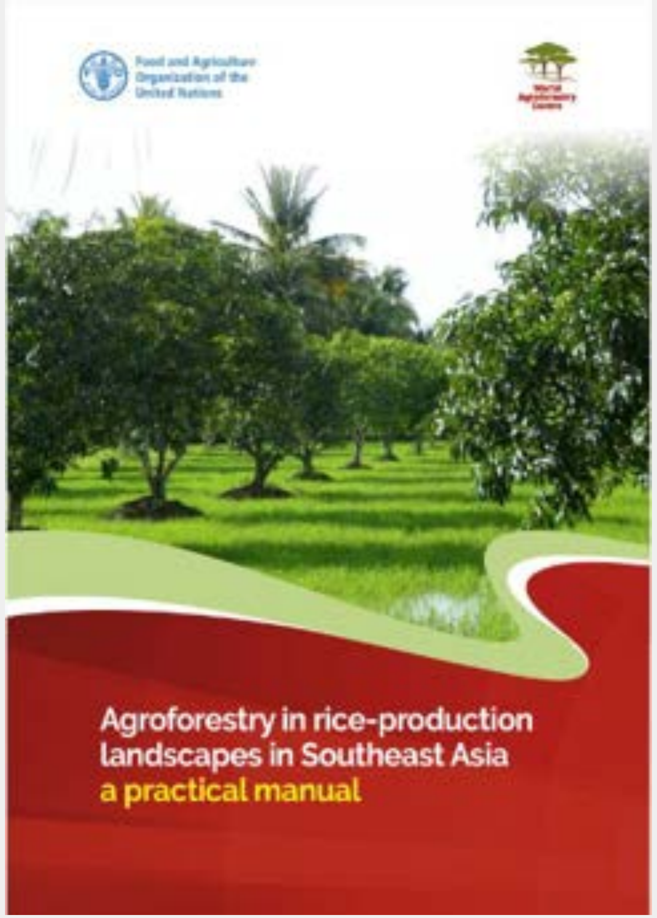
Rodenburg, J., Mollee, E., Coe, R. and Sinclair, F (2022). Global analysis of yield benefits and risks from integrating trees with rice and implications for agroforestry research in Africa. *Field Crops Research* 281: 108504. https://doi.org/10.1016/j.fcr.2022.108504

Rice agroforestry in practice

6TH INTERNATIONAL RICE CONGRESS

According to Rodenburg et al. (2022):

- Based on a review of 87 publications, 204 woody perennial species were used in various rice agroforestry practices worldwide.
- 6 types of rice agroforestry practices: (1) hedgerow alley-cropping, (2) short-term (0.5–4 years) improved fallows, (3) pre-rice green manuring, (4) biomass transfer, (5) systematically arranged rice–tree intercropping and (6) irregularly dispersed trees in fields.
- Main benefits of integrating trees with rice: (1) fertiliser is provided through biological nitrogen fixation or organic inputs, (2) pests, diseases and weeds are controlled through vegetation structure, rotation, mulching or the use of biopesticides, (3) higher resilience to climate threats (e.g., heat, strong wind).



Wangpakapattanawong P, Finlayson R, Öborn I, Roshetko JM, Sinclair F, Shono K, Borelli S, Hillbrand A, Conigliaro M. 2017. [Agroforestry in rice-production landscapes in Southeast Asia: a practical manual](). Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific, Bangkok, Thailand

https://worldagroforestry.org/blog/2017/04/26/helping-rice-farmers-grow-trees-adapting-climate-change

IRRI CGIAR CIFOR World Agroforestry

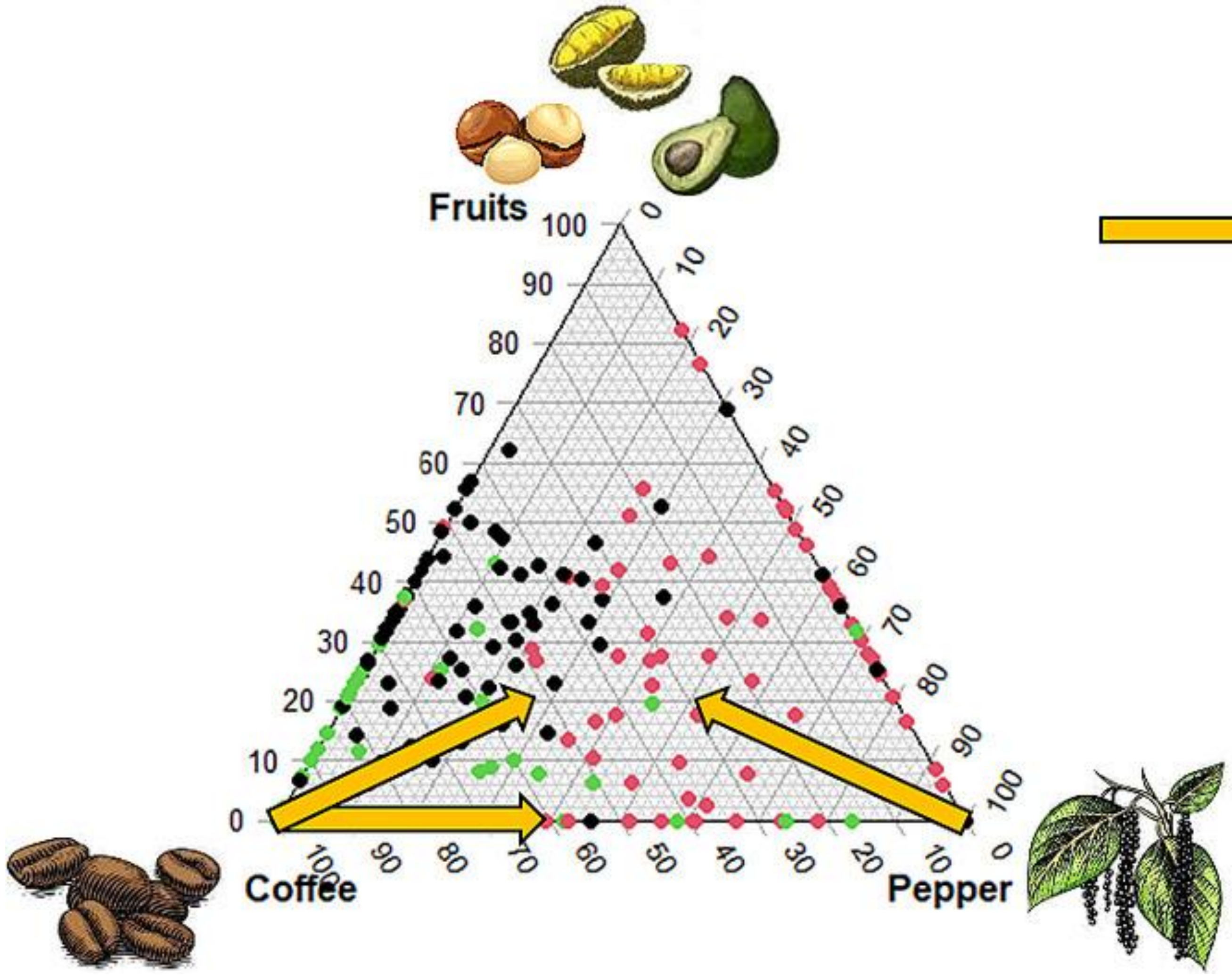
From traditional ‘sonor’ farming system to climate smart agro-silvo-fishery. South Sumatra

https://www.worldagroforestry.org/blog/2022/07/18/more-rice-and-no-fire-degraded-peatland-indonesia

Quick and easy: BUT wide range of environmental, social, economic, and political impacts

No burning: growing rice with various timber, fruit and fish species [MORE FOOD, BIOMASS, NO FIRE]

Cahya M, Suwignyo RA, Sodikin E, Baral H. 2022. Increasing rice productivity in degraded peatlands using improved planting methods and rice varieties. BIOVALENTIA: Biological Research Journal 8(1):69–82.



Ongoing transition from monoculture to mixed cropping systems resulting in :

- ↗ Planting density (+33-71%)
- ↗ Gross margin (+30-158%)
- ↗ Economic resilience

Rigal Clément, Duong Tuan, Vo Cuong, Bon Le Van, Hoang quôc Trung, Chau Thi Minh Long, **Transitioning from Monoculture to Mixed Cropping Systems: The Case of Coffee, Pepper, and Fruit Trees in Vietnam**, *Ecological Economics*, Volume 214, 2023.

Nguyen, M.P.; Vaast, P.; Pagella, T.; Sinclair, F. (2020). Local Knowledge about Ecosystem Services Provided by Trees in Coffee Agroforestry Practices in Northwest Vietnam. *Land*, 9 (12): 486. https://doi.org/10.3390/land9120486

Farmers apply surplus nutrients even on mixed systems and …. the higher the prices of their products the more they appply

$\frac{Nu\_pro}{Nu\_fer}$

	Agroforestry systems	Year	$Nu_{\_fer}$			$Nu_{\_pro}$			PNB		
			N	P	K	N	P	K	N	P	K
1	Macadamia-coffee-soybeans	2013	140	95	102	6 (±1.8)	0.5 (±0.1)	0.7 (±0.2)	0.04	0.01	0.01
		2014	93	41	93	12 (±1.8)	0.9 (±0.1)	1.4 (±0.2)	0.1	0.02	0.02
		2015	100	24	78	8 (±0.6)	0.6 (±0.04)	8.5 (±0.7)	0.1	0.03	0.1
		2016	100	24	78	9 (±0.4)	0.6 (±0.03)	9.8 (±0.4)	0.1	0.03	0.1
		2017	100	24	78	17 (±3.2)	1.2 (±0.2)	18 (±3.4)	0.2	0.1	0.2
		2018	100	24	78	18 (±5.2)	1.4 (±0.4)	19 (±5.4)	0.2	0.1	0.2

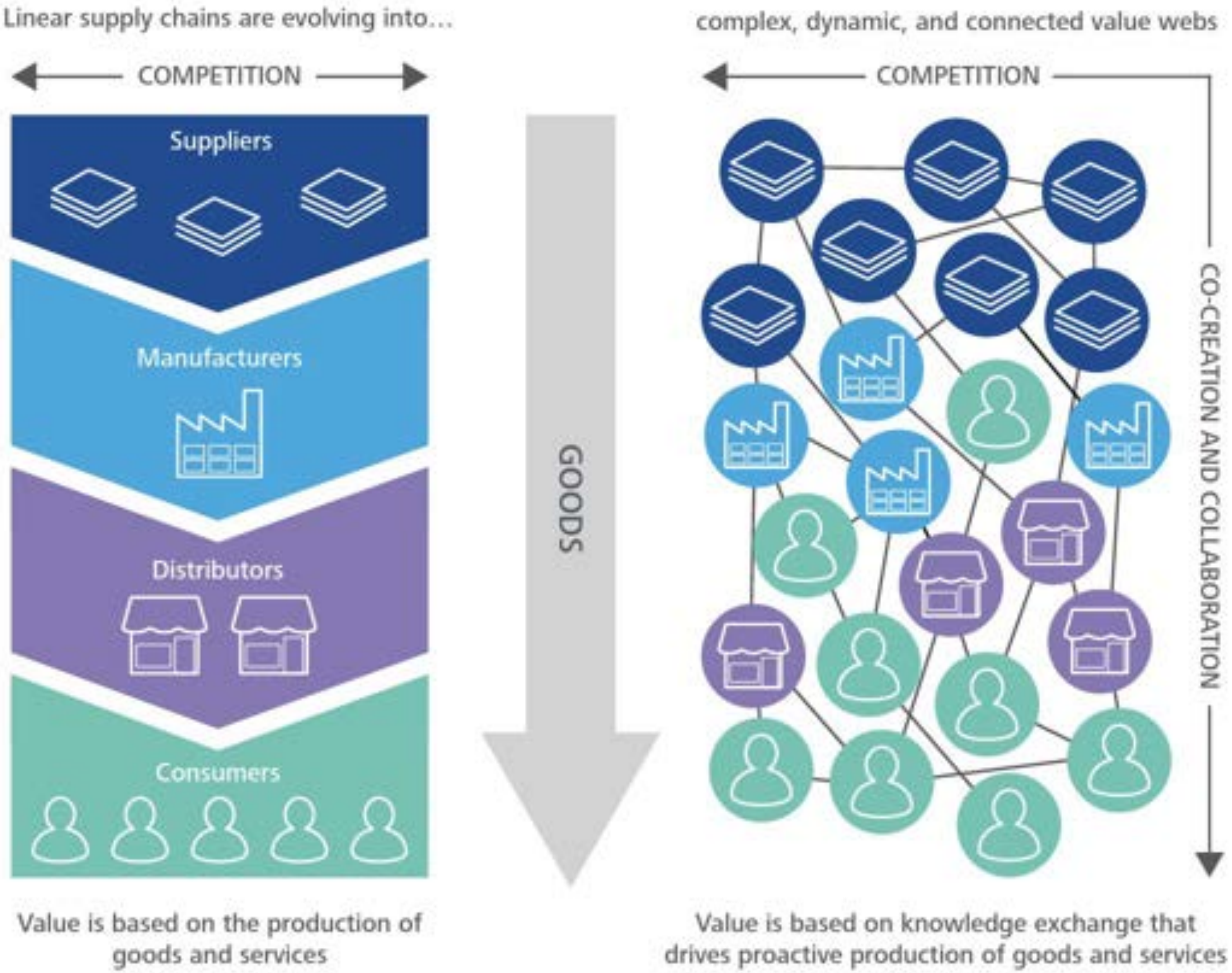
La Nguyen et al., in prep. **Evaluation of agroforestry options NW Vietnam and their alternatives in relation to economic benefits and nutrient efficiency. ICRAF Vietnam Office.**

Not all agroforestry is consistent with agroecological principles and not all agroecology involves trees BUT trees can enance agroecological transitions

Isaac, ME, Sinclair, F, Laroche, G, Olivier, A and Thapa, A (2024) The ties that bind: how trees can enhance agroecological transitions. Agroforestry Systems 98, 2369–2383.

Step 3: Develop inclusive value networks with equitable agency for producers and consumers

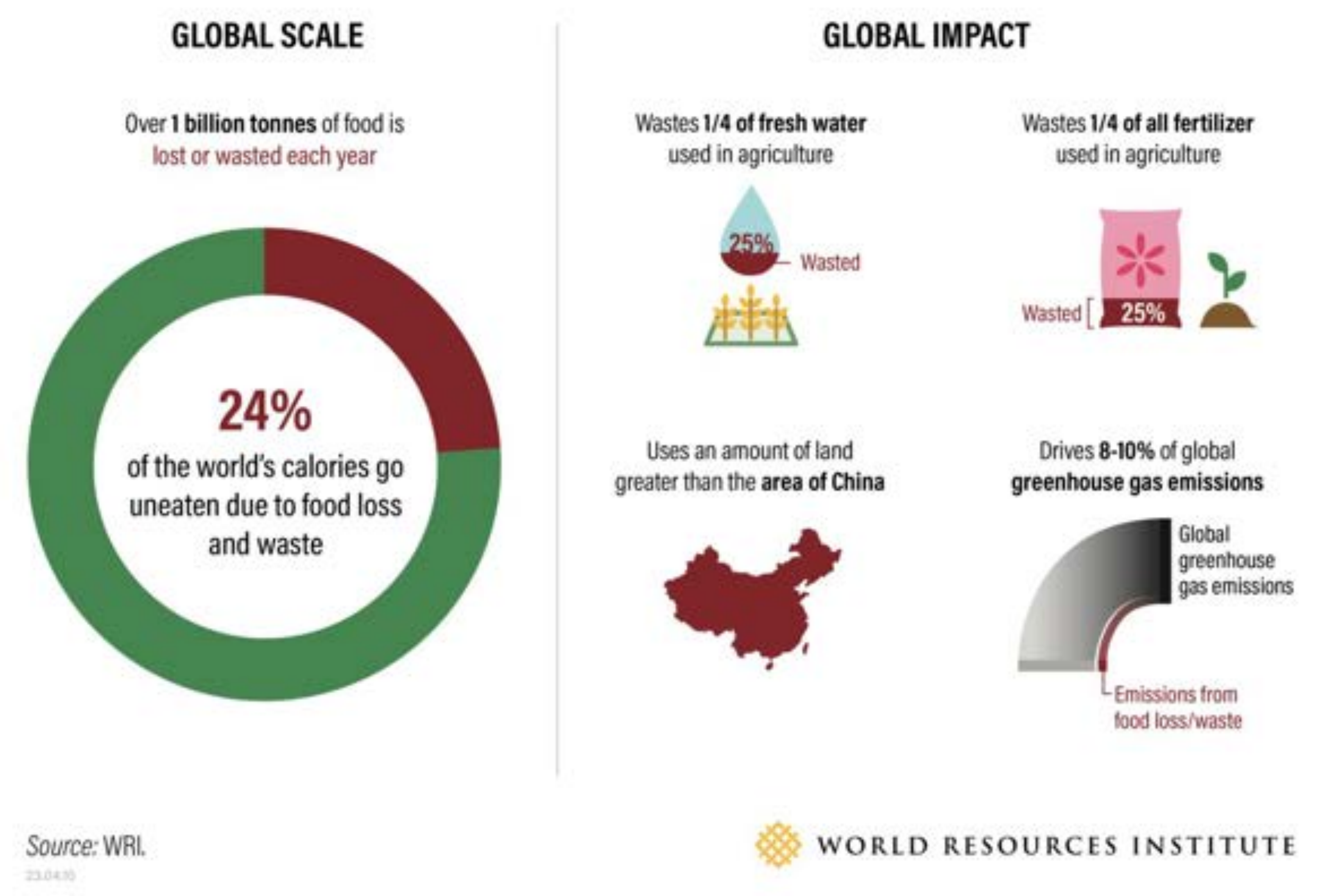
Value chains evolve into **value networks**



Kelly E and Marchese K (2015). Supply chains and value webs. Deloite University Press.

https://www2.deloitte.com/content/dam/Deloitte/za/Documents/strategy/za_Supply_chains_and_value_webs.pdf

Step 4: Reduce food loss and waste



Reducing food loss and waste **before consumption** is vital alongside recycling waste **after consumption –** food regulations apply

Note: we can biologically fix N but need to return P and K to soil

Changing attitudes to food and how it is produced, processed and consumed is the cutting edge

Globally, **30% of food is lost or wasted**. Around **13% of food produced is lost between harvest and retail**, while an estimated **17% is wasted** in households, in the food service and in retail all together (FAO).

Recycling and more circular economies

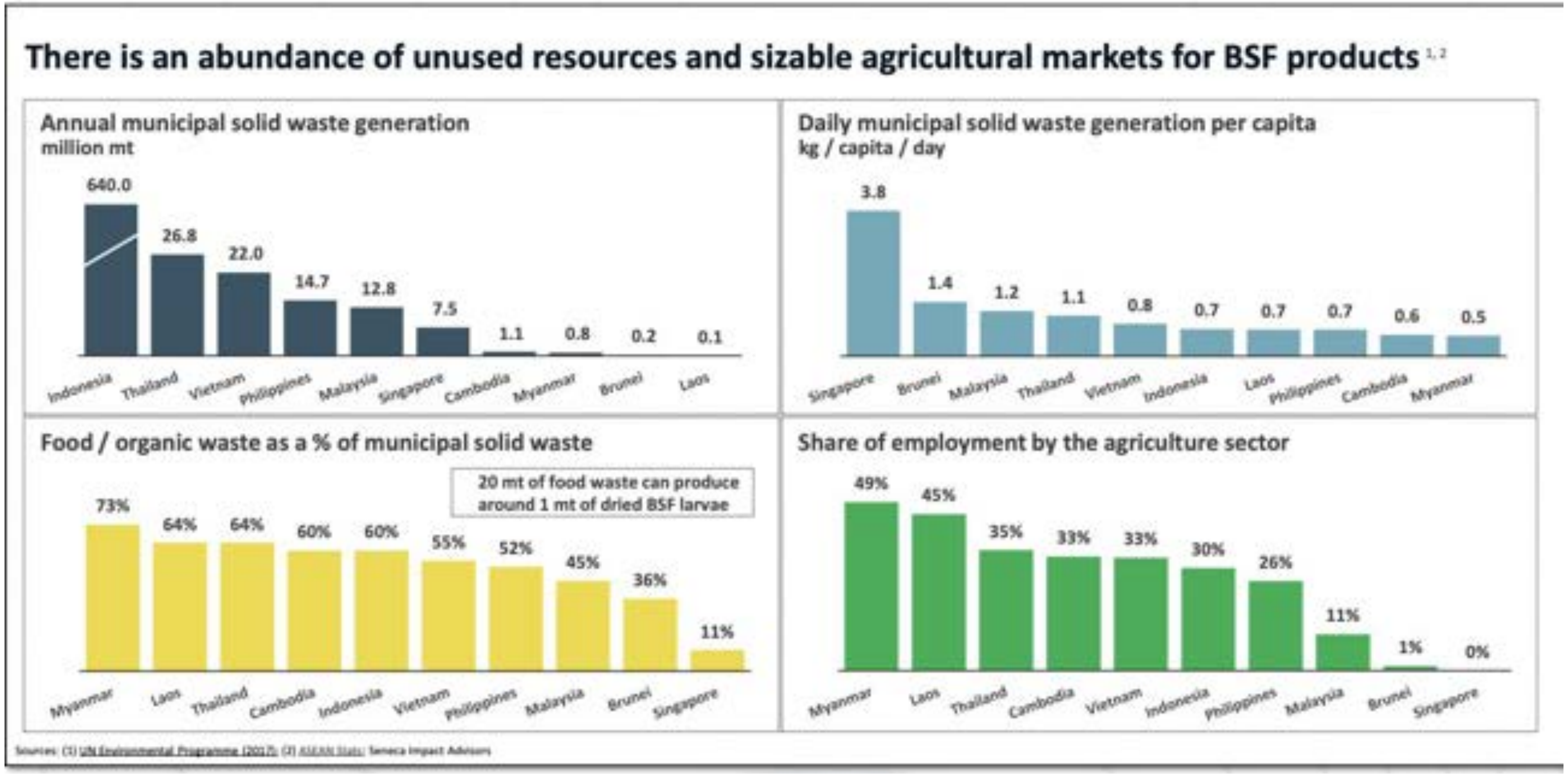
feeds back to value networks through encouraging business development to recycle waste

Black soldier fly larvae can efficiently convert organic waste, including food scraps and manure, into high-quality protein and fertilizer. The cultivation of BSF significantly reduces waste disposal impacts, **creates jobs**, enhances food security through animal feed production and organic fertilizer availability. **The global commercial market for BSF products is expected to grow from $200 million in 2022 to $1.5 billion in 2030**

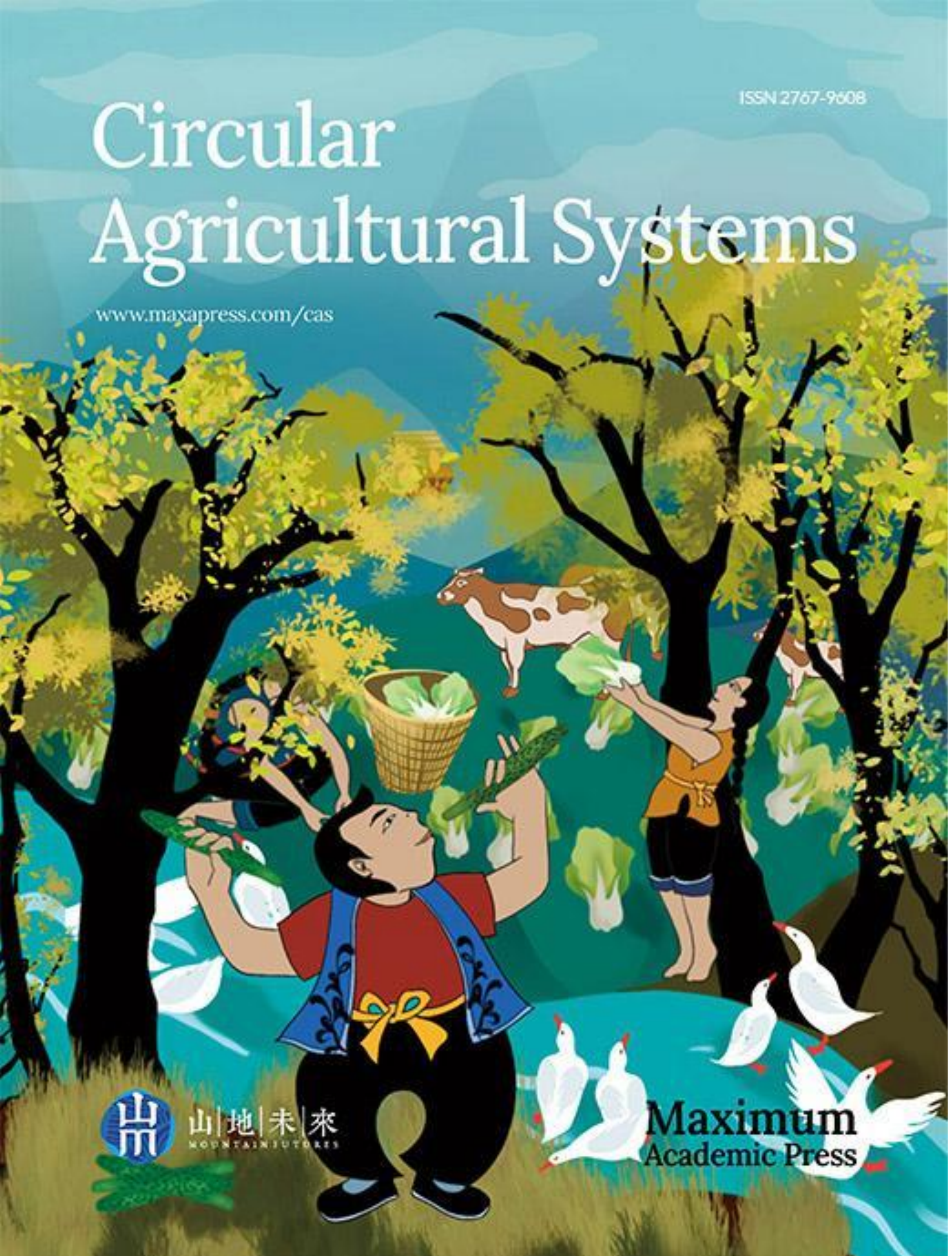
The Black Soldier Fly in Southeast Asia: From Food Waste to Bankable Opportunities

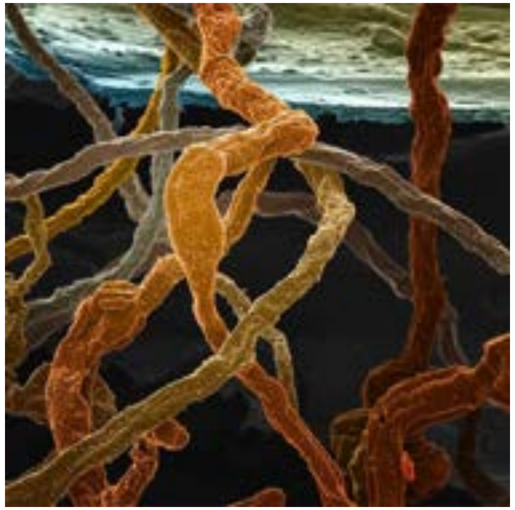
Waste in food production and consumption is as pressing a concern for developed countries as it is for emerging markets. In this report, we examine the dire consequences of food waste on climate and nature and demonstrate how the black solider fly (BSF) could be a viable bioconversion solution in Southeast Asia.

The global commercial market for BSF products is expected to grow from $200 million in 2022 to $1.5 billion in 2030. In their various



https://senecaimpact.earth/wp-content/uploads/2023/12/The-Black-Soldier-Fly-in-Southeast-Asia-From-Food-Waste-to-Bankable-Opportunities.pdf

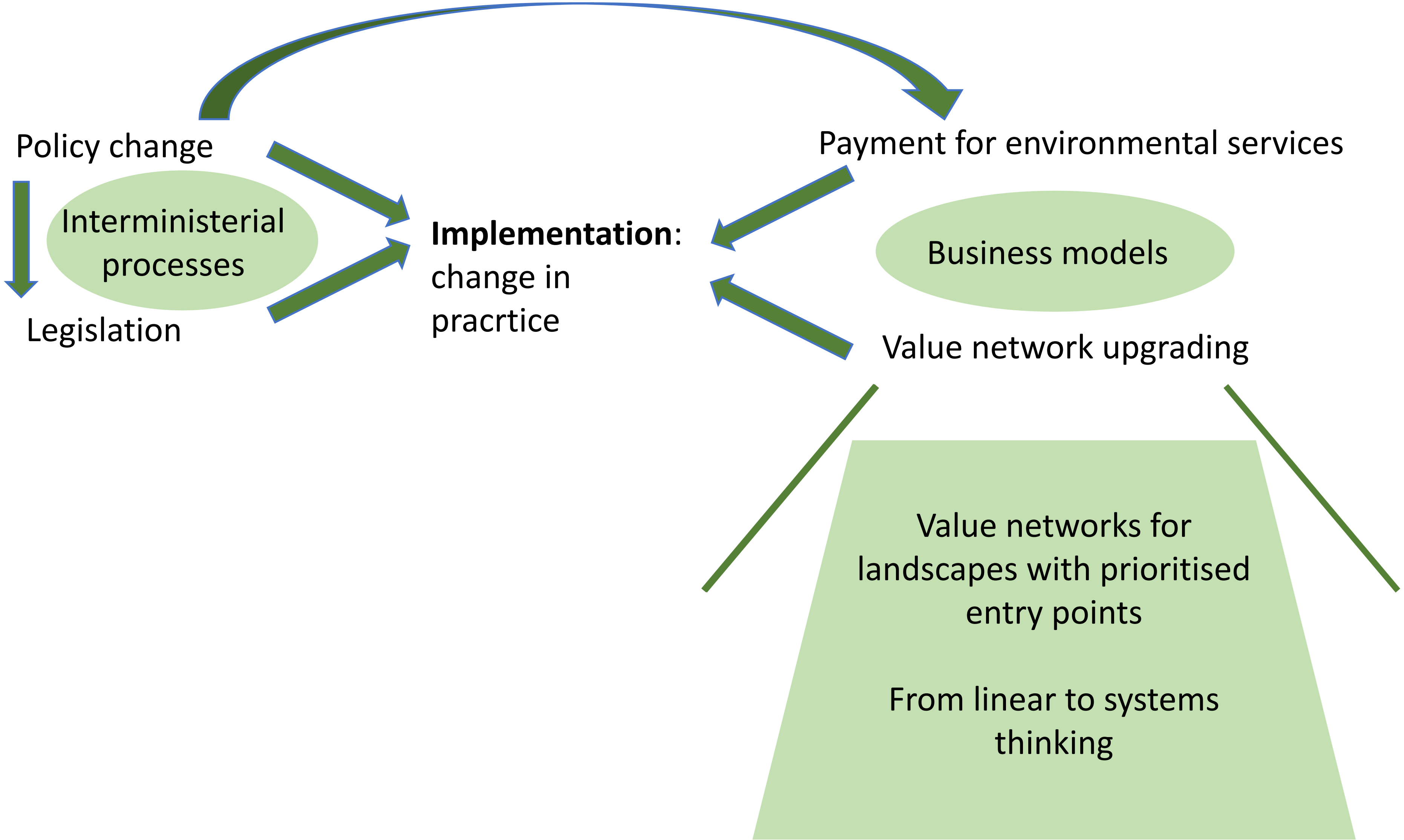




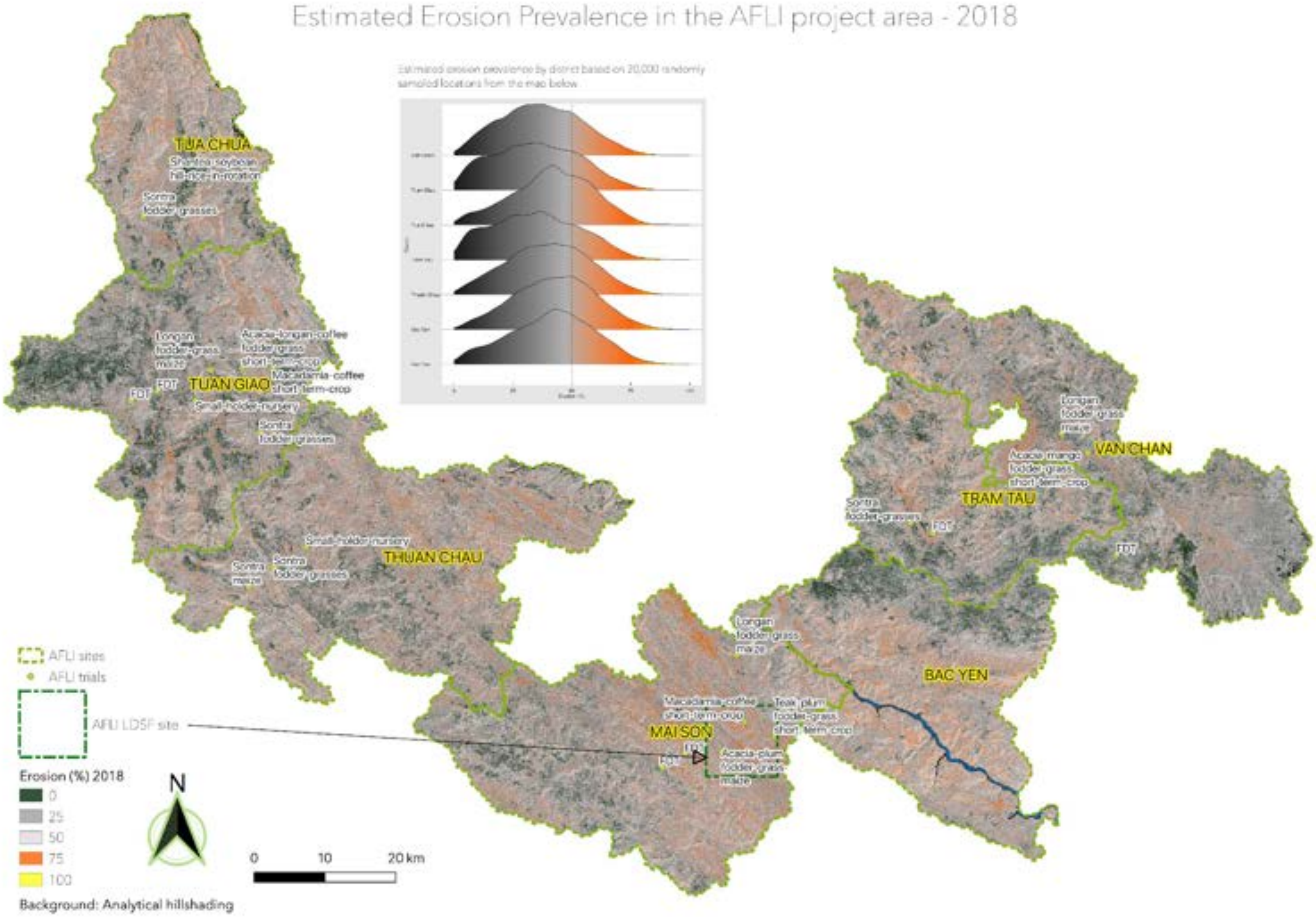
The fungus *Trichoderma reesei*, rapidly converts biomass to fuels. The fungus is known for its profuse production of biomass-degrading enzymes, which enhance the conversion process.

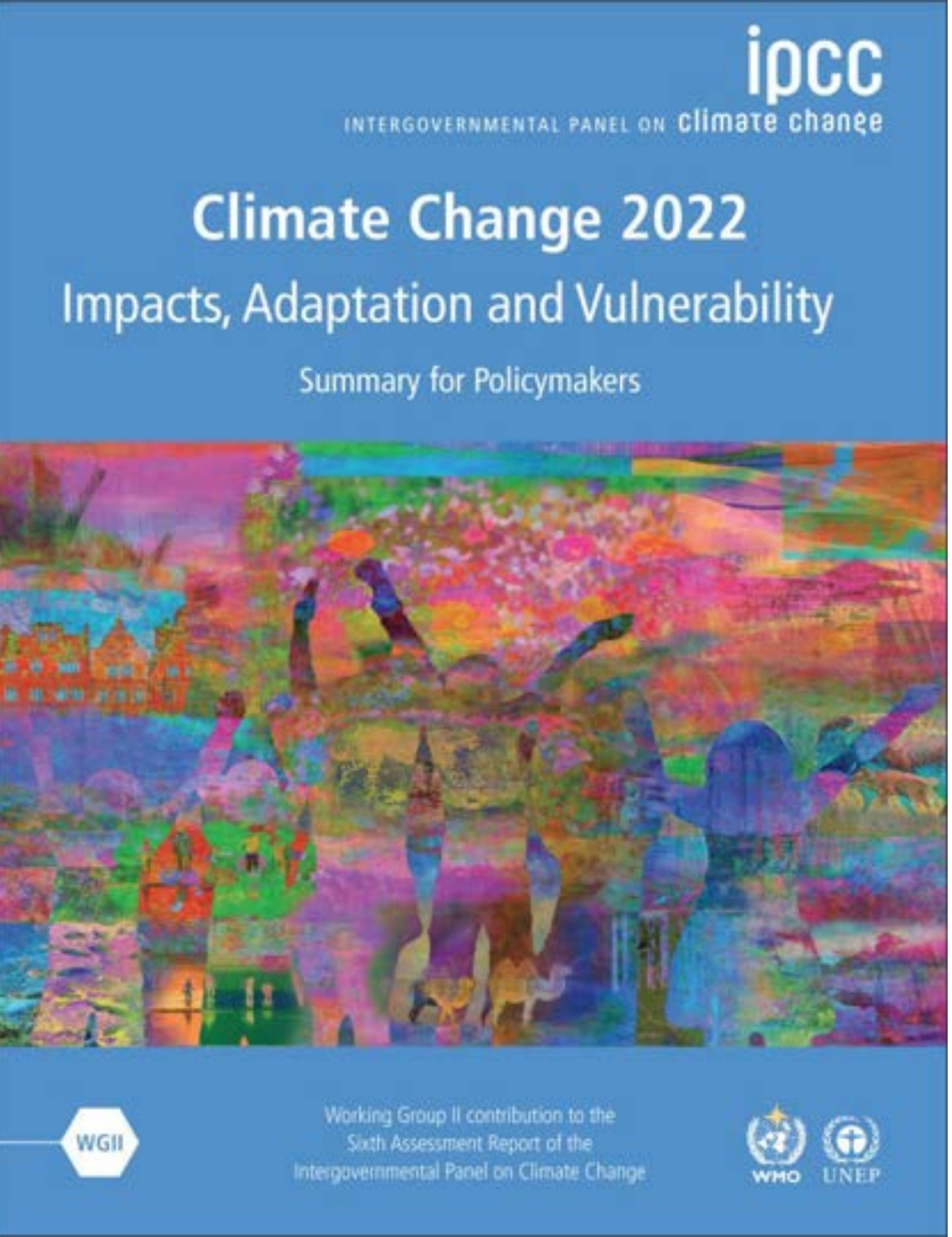
Filamentous fungi (mold) reduce solid waste (feaces) while converting it into a consumable, high protein food product.

Step 5: Facilitate participatory landscape / community governance across sectors and scales



Monitoring of ecosystem services through time and the effectiveness of interventions using satelite image analysis – adaptive management





Future Adaptation Options and their Feasibility - SPM.C.2.2

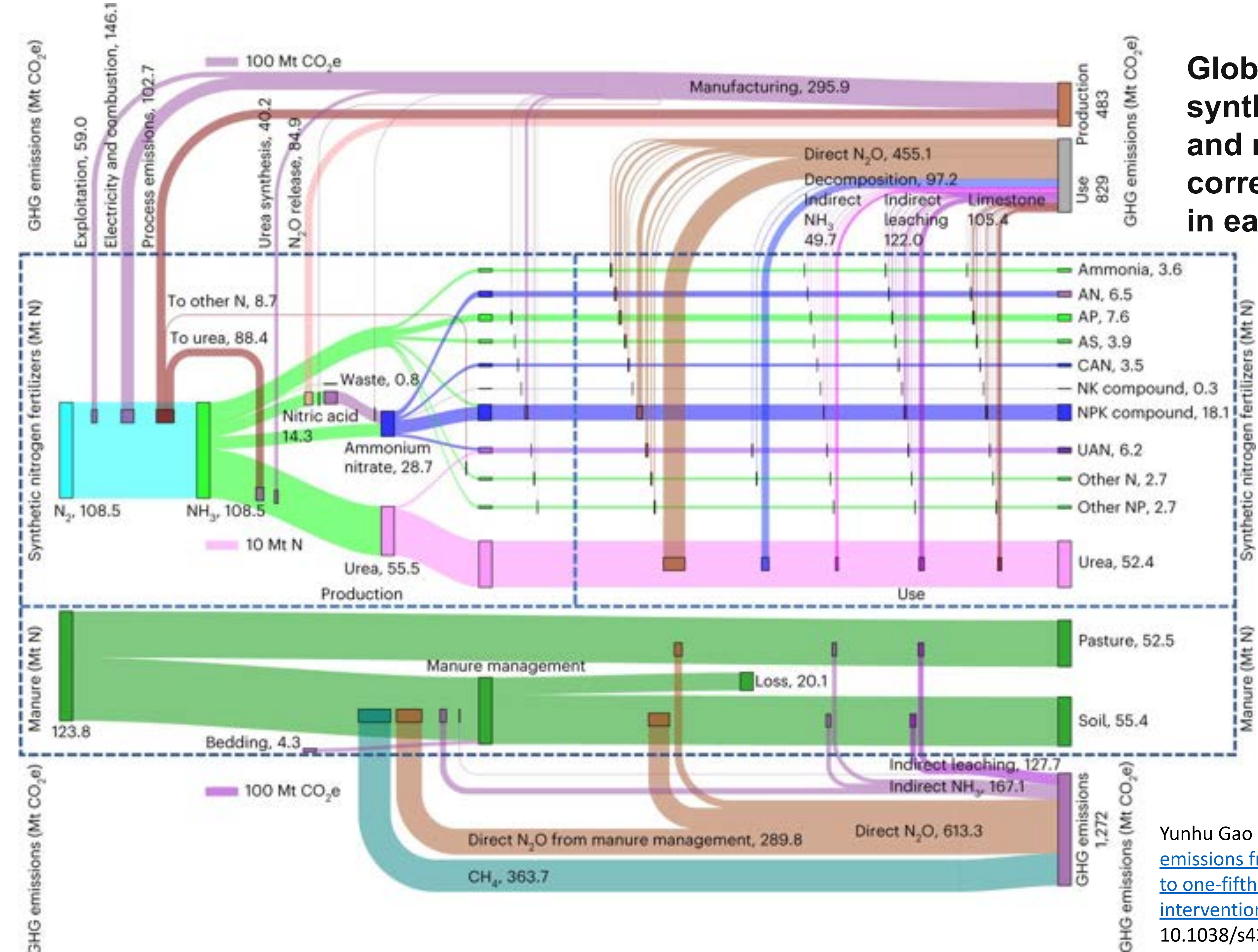
Agroecological principles and practices and other approaches that work with natural processes **support food security, nutrition, health and well-being, livelihoods and biodiversity, sustainability and ecosystem services** (high confidence).

These services include pest control, pollination, buffering of temperature extremes, and carbon sequestration and storage (high confidence).

Their potential effectiveness varies by socio-economic context, ecosystem zone, species combinations and institutional support (medium confidence).

Integrated, multi-sectoral solutions that address social inequities and differentiate responses based on climate risk and local situation will enhance food security and nutrition (high confidence).

https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_SummaryForPolicymakers.pdf



Global mass flow of synthesized nitrogen fertilizers and manure and corresponding GHG emissions in each life-cycle stage in 2019

Synthetic N fertiliser accounts for as much GHG emissions as the aviation industry, and represents 6.2% - 7.5% of all emissions from food systems that are about a third of global emissions

Yunhu Gao and André Cabrera Serrenho. '[Greenhouse gas emissions from nitrogen fertilisers could be reduced by up to one-fifth of current levels by 2050 with combined interventions.](#)' *Nature Food* (2023). DOI: 10.1038/s43016-023-00698-w https://www.cbd.int/gbf/targets/10

Kunming-Montreal
GLOBAL BIODIVERSITY FRAMEWORK

Target 10

Enhance Biodiversity and Sustainability in Agriculture, Aquaculture, Fisheries, and Forestry

Ensure that areas under agriculture, aquaculture, fisheries and forestry are managed sustainably, in particular through the sustainable use of biodiversity, including through a substantial increase of the application of biodiversity friendly practices, such as sustainable intensification, agroecological and other innovative approaches contributing to the resilience and long-term efficiency and productivity of these production systems and to food security, conserving and restoring biodiversity and maintaining nature's contributions to people, including ecosystem functions and services .

Following are the guidance notes prepared by the Secretariat for Target 10

A. Why is this target important?

Nitrogen pollution harms the environment and human health

Climate change and the ozone layer

- Nitrous oxide is 300 times more potent than methane and carbon dioxide.
- It is the biggest human-made threat to the ozone layer
- With an atmospheric lifetime of 200 years, it poses a long-term threat

Biodiversity and ecosystems

- N pollution is the third biggest driver of biodiversity loss on the planet after habitat destruction and greenhouse gas emissions
- It causes inadvertent fertilization of nitrogen tolerant species that outcompete more sensitive wild plants and fungi
- Nitrogen pollution creates “dead zones” in the ocean and causes toxic algal blooms in marine ecosystems.

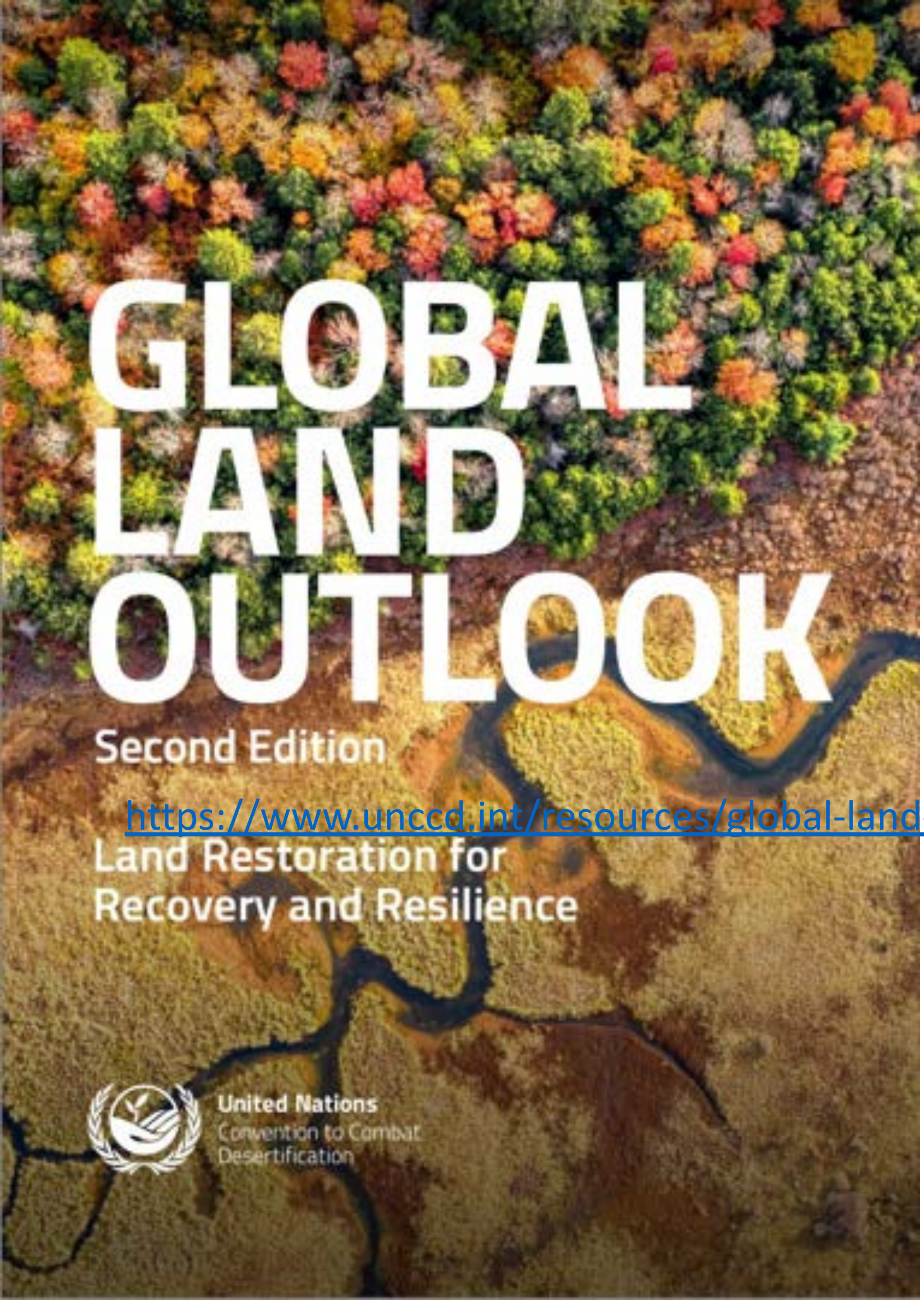
Air

- Nitrogen oxides lead to smog and ground-level ozone
- 77% of people breathe dangerous annual average concentrations of nitrogen dioxide
- Agricultural ammonia emissions combined with pollution from vehicle exhausts create extremely dangerous particulates in the air, which can exacerbate respiratory diseases

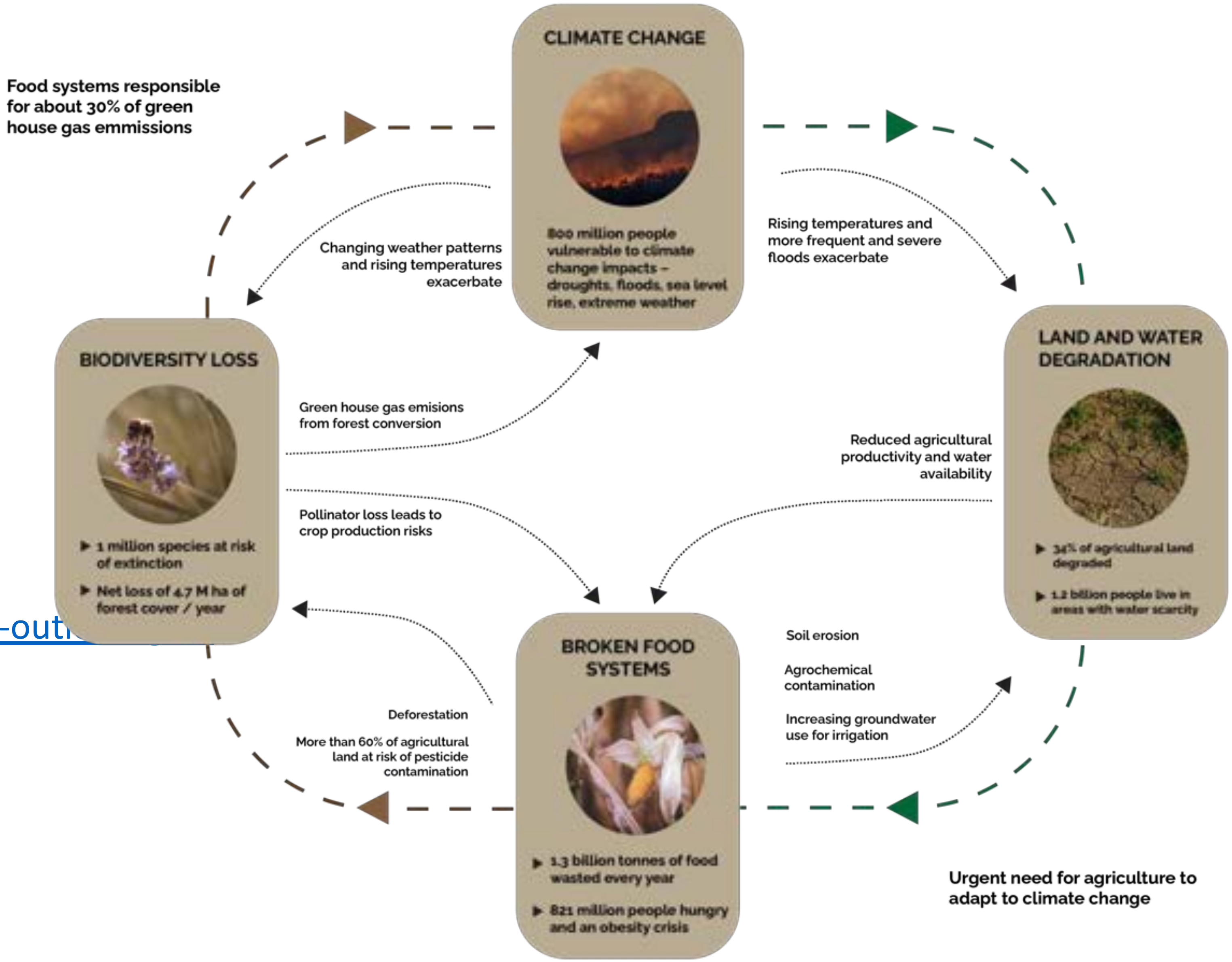
Crops do not take up all the N supplied as fertiliser. Each year, 200 million tonnes of reactive nitrogen is lost to the environment, leaching into soil, rivers and lakes and emitted to the air

Source: Facts about Nitrogen Pollution, UNEP

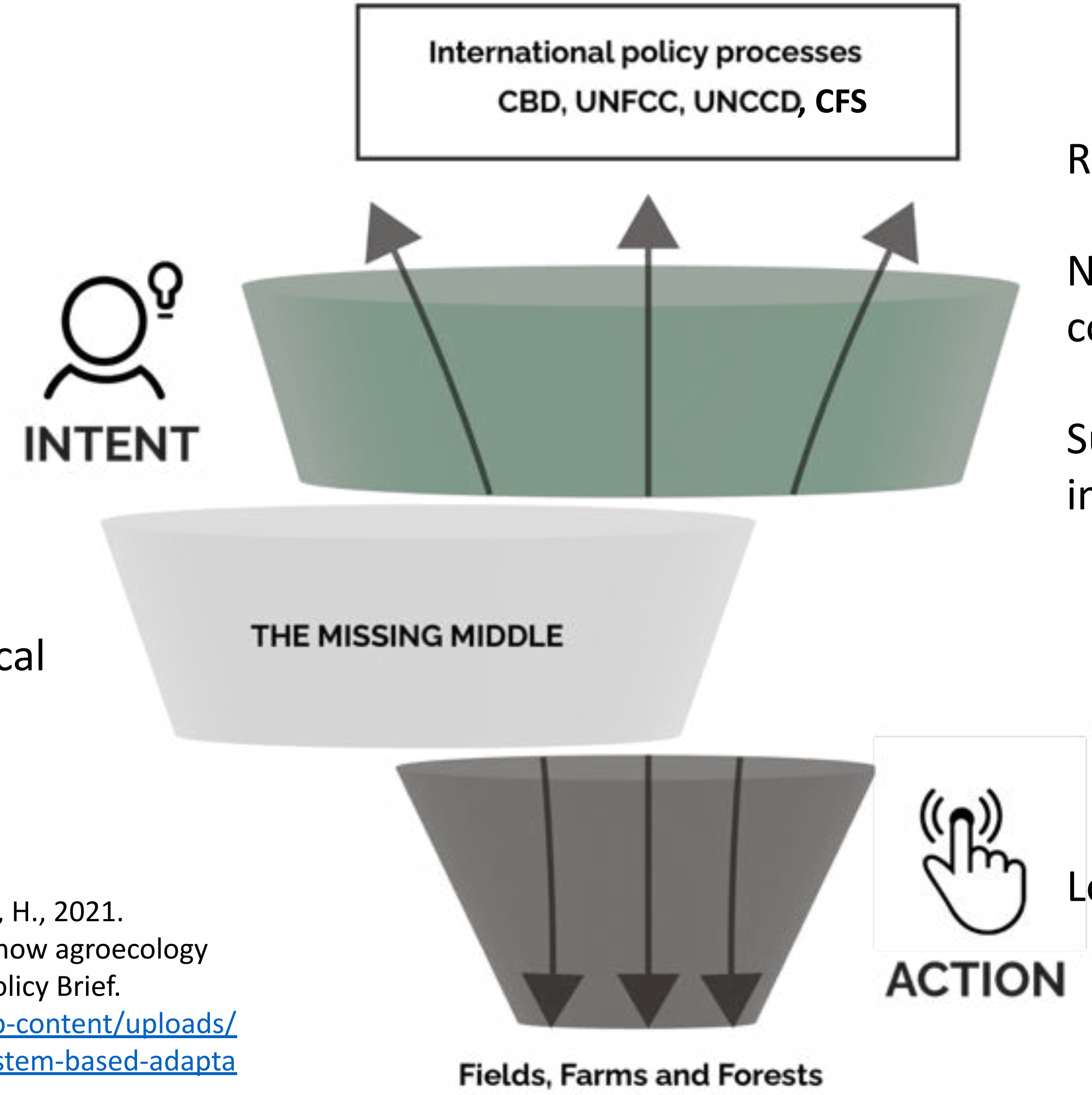
Plastics coating fertiliser for slow release, persist in soil, and now getting into human food chain causing health problems including erectile dysfunction



https://www.unccd.int/resources/global-land-outl



The **missing middle**: a generic implementation challenge in food system transformation



Regional processes

National commitments

NAPs, NDCs, Food system transformation pathways

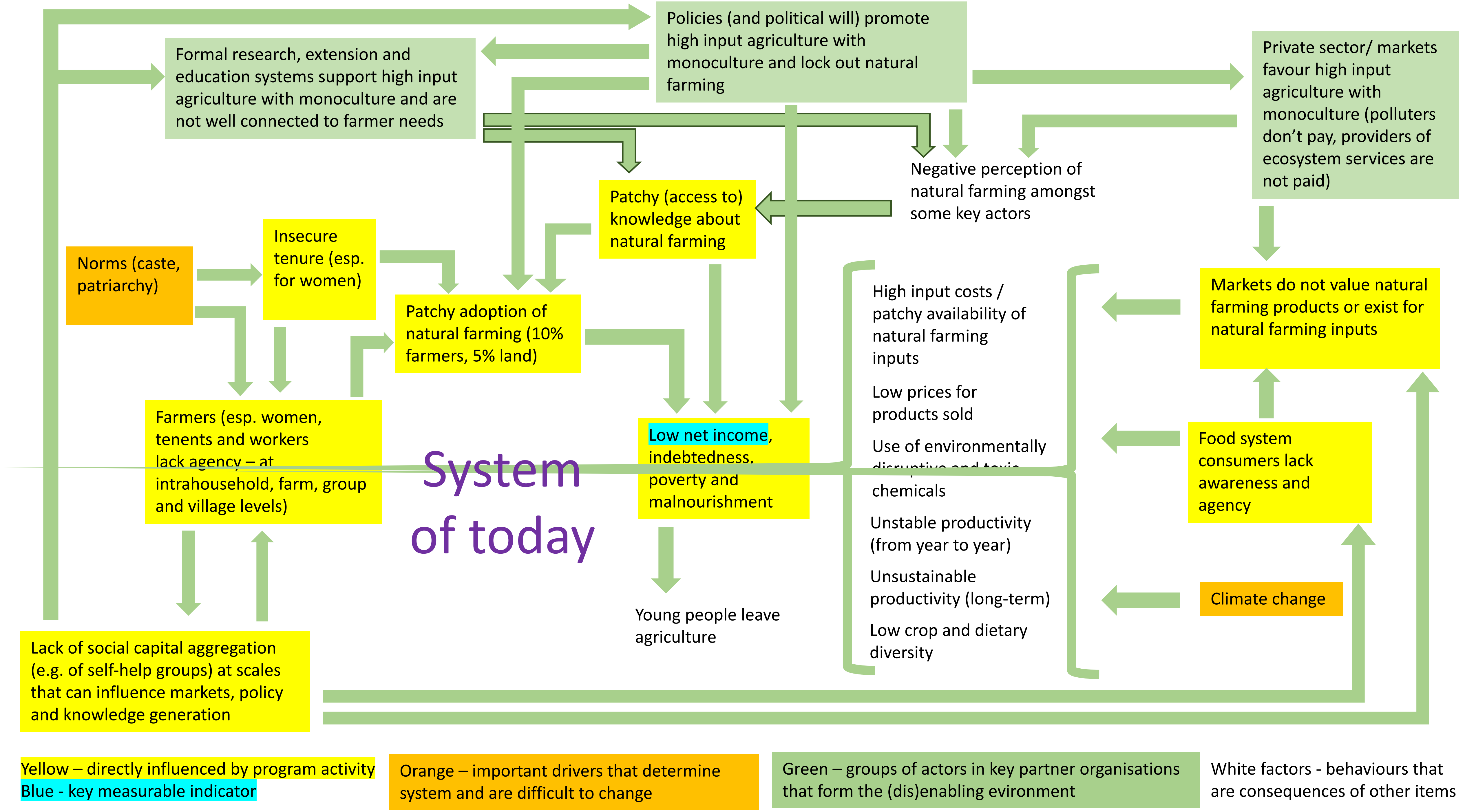
Sub-national implementation

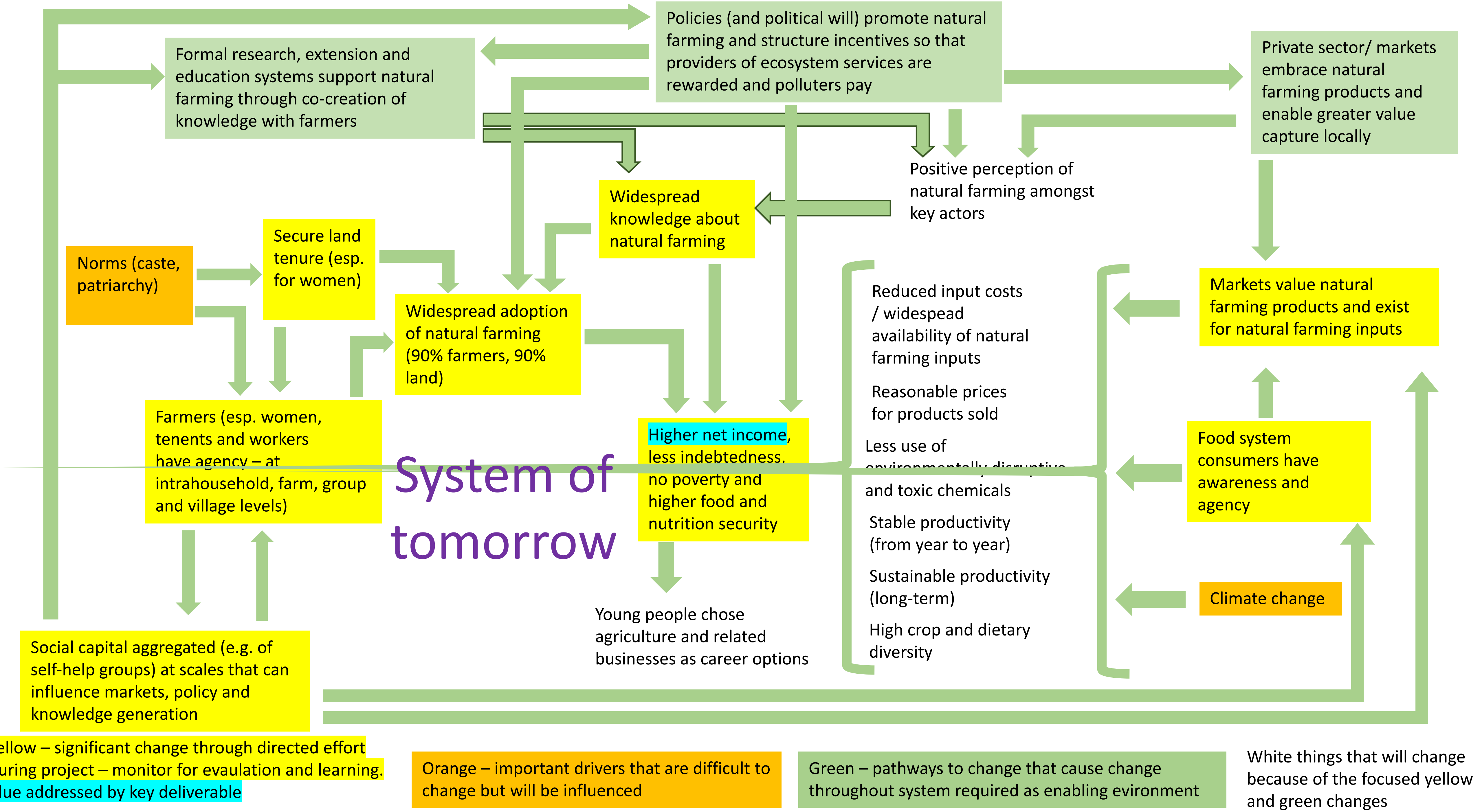
Local action

Cross–sectoral integration

Policy implementation at local landscape (territorial) scale

Weigelt, J, Sinclair F., Mikulcak, F and Lossak, H., 2021. Ecosystem-based adaptation in agriculture: how agroecology can contribute to tackling climate change. Policy Brief. https://www.globallandscapesforum.org/wp-content/uploads/2021/11/6-White-Paper_GLF-Climate-Ecosystem-based-adaptation-in-agriculture_En.pdf


Policies (and political will) promote high input agriculture with monoculture and lock out natural farming
Formal research, extension and education systems support high input agriculture with monoculture and are not well connected to farmer needs
Private sector/ markets favour high input agriculture with monoculture (polluters don't pay, providers of ecosystem services are not paid)
Negative perception of natural farming amongst some key actors
Patchy (access to) knowledge about natural farming
Norms (caste, patriarchy)
Insecure tenure (esp. for women)
Patchy adoption of natural farming (10% farmers, 5% land)
Farmers (esp. women, tenants and workers lack agency – at intrahousehold, farm, group and village levels)
System of today
Low net income, indebtedness, poverty and malnourishment
Young people leave agriculture
High input costs / patchy availability of natural farming inputs
Low prices for products sold
Use of environmentally
chemicals
Unstable productivity (from year to year)
Unsustainable productivity (long-term)
Low crop and dietary diversity
Markets do not value natural farming products or exist for natural farming inputs
Food system consumers lack awareness and agency
Climate change
Lack of social capital aggregation (e.g. of self-help groups) at scales that can influence markets, policy and knowledge generation
Yellow – directly influenced by program activity
Blue - key measurable indicator
Orange – important drivers that determine system and are difficult to change
Green – groups of actors in key partner organisations that form the (dis)enabling evironment
White factors - behaviours that are consequences of other items



Policies (and political will) promote natural farming and structure incentives so that providers of ecosystem services are rewarded and polluters pay
Formal research, extension and education systems support natural farming through co-creation of knowledge with farmers
Private sector/ markets embrace natural farming products and enable greater value capture locally
Positive perception of natural farming amongst key actors
Widespread knowledge about natural farming
Norms (caste, patriarchy)
Secure land tenure (esp. for women)
Widespread adoption of natural farming (90% farmers, 90% land)
Farmers (esp. women, tenents and workers have agency – at intrahousehold, farm, group and village levels)
System of tomorrow
Higher net income, less indebtedness, no poverty and higher food and nutrition security
Reduced input costs / widespread availability of natural farming inputs
Reasonable prices for products sold
Less use of
and toxic chemicals
Stable productivity (from year to year)
Sustainable productivity (long-term)
High crop and dietary diversity
Markets value natural farming products and exist for natural farming inputs
Food system consumers have awareness and agency
Climate change
Young people chose agriculture and related businesses as career options
Social capital aggregated (e.g. of self-help groups) at scales that can influence markets, policy and knowledge generation
ellow – significant change through directed effort
uring project – monitor for evaulation and learning.
lue addressed by key deliverable
Orange – important drivers that are difficult to change but will be influenced
Green – pathways to change that cause change throughout system required as enabling evironment
White things that will change because of the focused yellow and green changes

Transformative Partnership Platform on agroecological approaches to building resilience of livelihoods and landscapes

https://www.agroecologytpp.org/