Our complex food system and its interactions with climate change, agriculture, land-use and biodiversity

Guest presentation for Eberswalde University for Sustainable Development (HNEE)

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Today's session

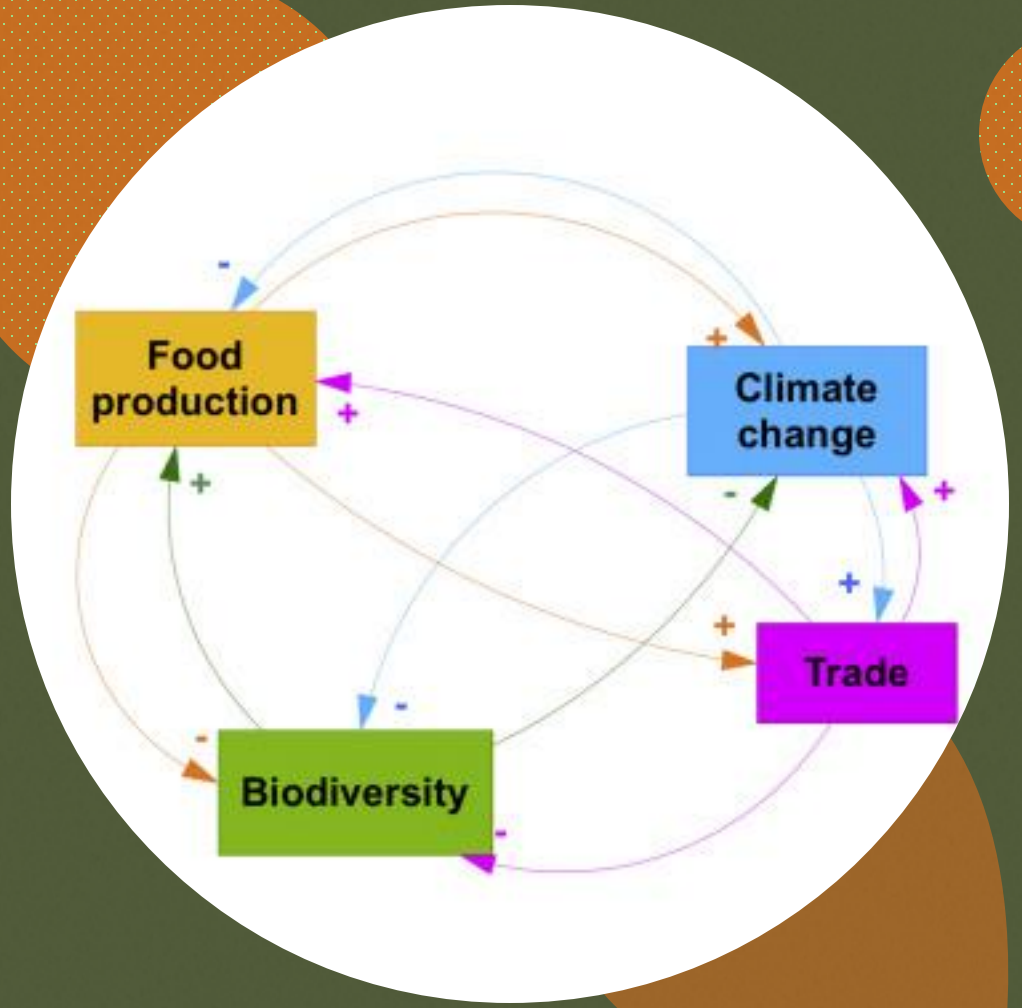
Background → Our food system → Impacts

↓

Dynamics and Interactions → Using systems thinking to approach complexity → Discussion/ exercise

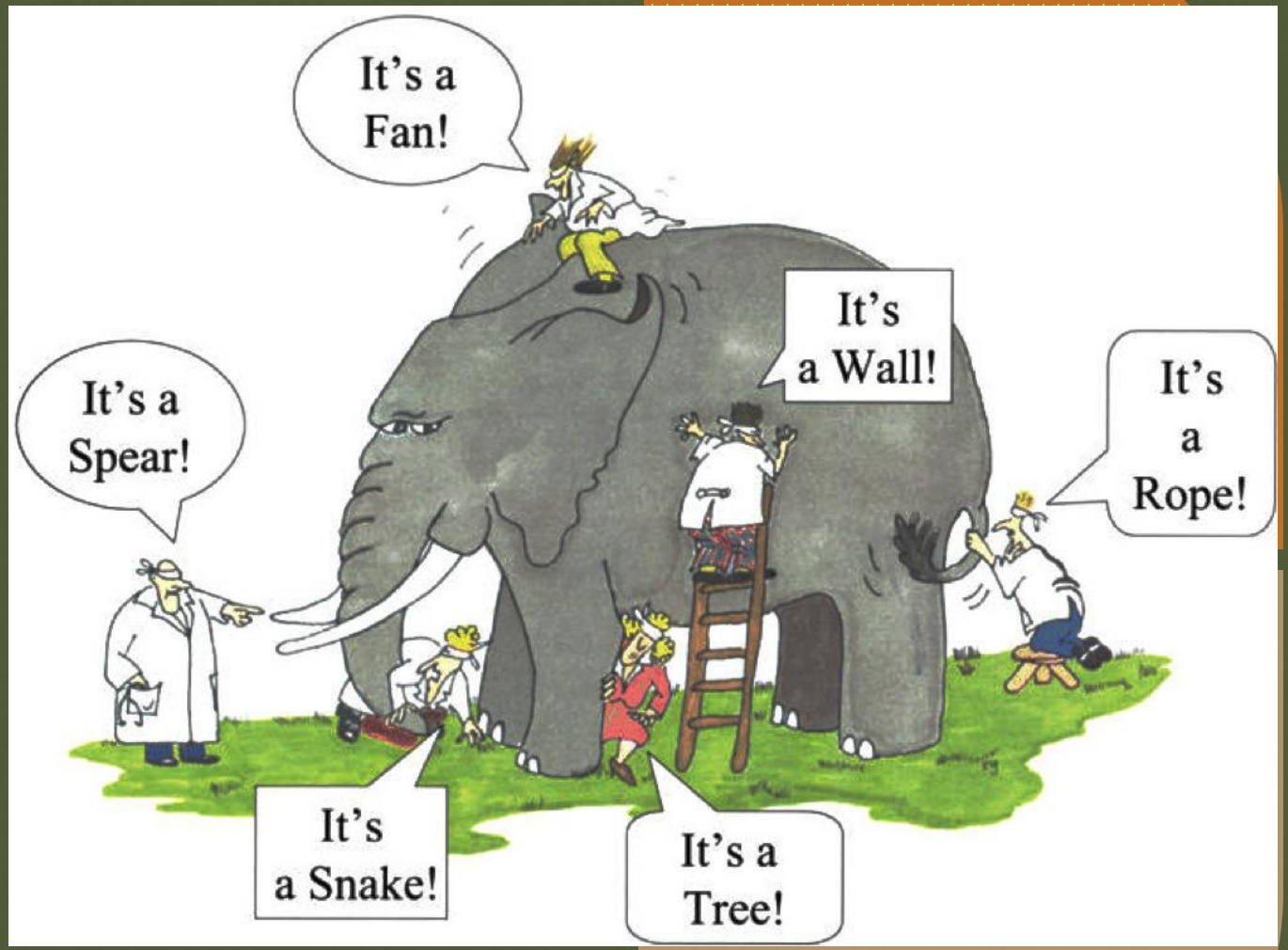
↓

Wrap-up



My background

- I am an interdisciplinary scientist focusing on climate change, food security
- Postdocs in Instituto de Ecología y Biodiversidad (Chile) and UCL, Senior Research Fellow at Manila Observatory;
- PhD in Geography at Uni of Sheffield, worked on uncertainty, bias correction, and climate projections/downscaling for crops
- Philippines: science + community + teaching + policy work
- Masters degrees from Uni Copenhagen and BOKU
- Farm and naturalist work with Audubon Society, trained biologist (UOregon)



https://www.philipchircop.com/post/25783275888/seeing-the-full-elephant-its-a-tree-its-a

CellPress

Gold Standard for the Global Goals
1 ton of CO_2 offset

One Earth

Review

A review of the interactions between biodiversity, agriculture, climate change, and international trade: research and policy priorities

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https://doi.org/10.1016/j.oneear.2020.12.008

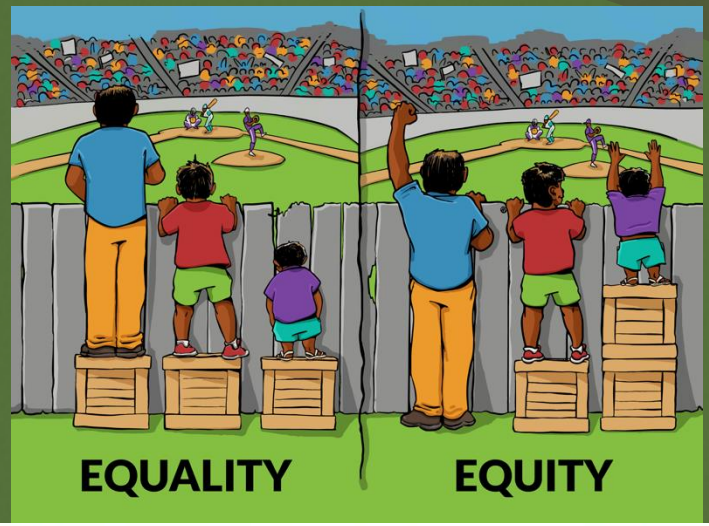
https://www.sciencedirect.com/science/article/pii/S2590332220306540

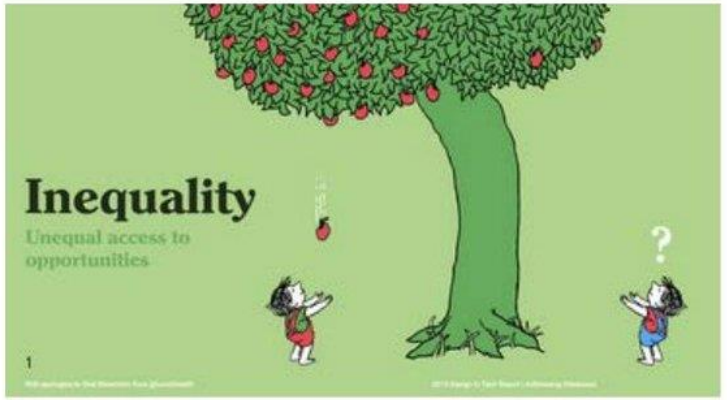
Where are we?

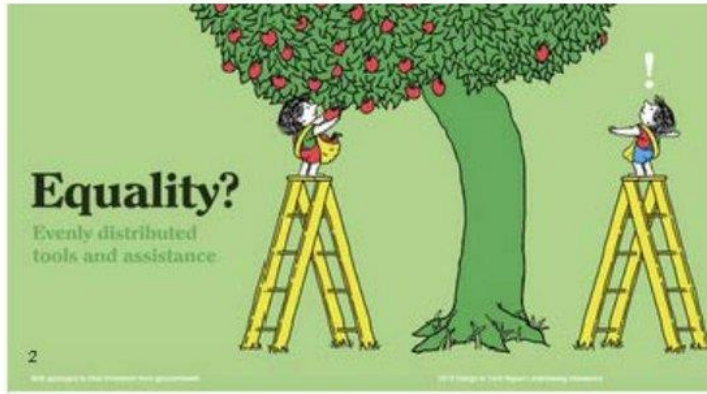
- Global population growth (10 bn, 2050)
- Demand for resources: food, feed, fuel, fibre
- Quality of life and health, equality
- Biodiversity and space for nature (Global Biodiversity Framework, 30 by 30)
- Economic output, goals, including profit and capitalism
- Coping with environmental change: climate change, hazards
- Sustainable development by 2030

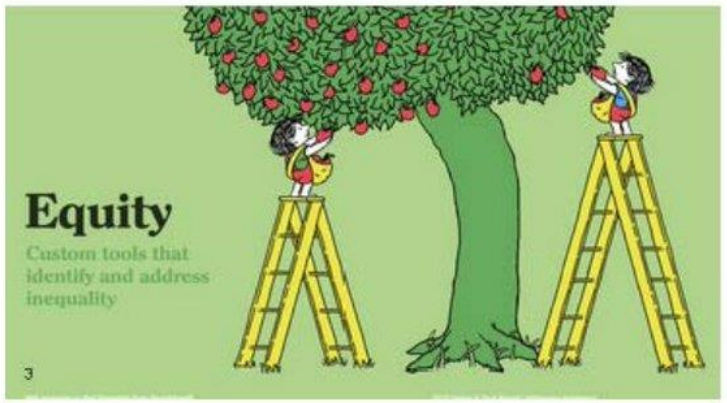
On the other side of the coin

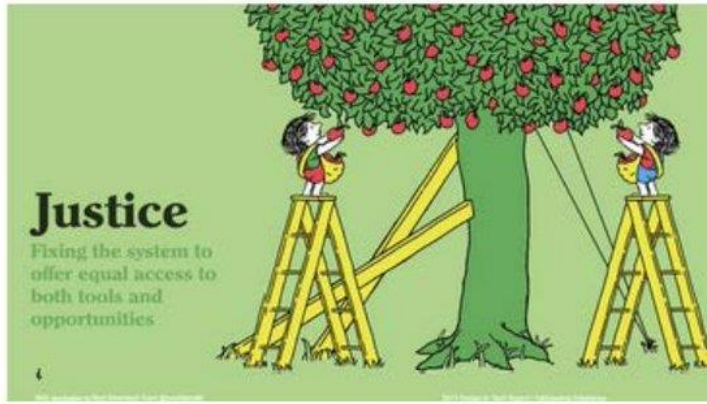
- Inequality and unequal distribution of resources, wealth, power
- Food waste and overconsumption
- Common but differentiated responsibility in climate justice/ action
- Vulnerability of communities to impacts
- Policy that exists but is ineffective or is not ambitious enough
- Underrepresented voices, especially of indigenous people, youth, women







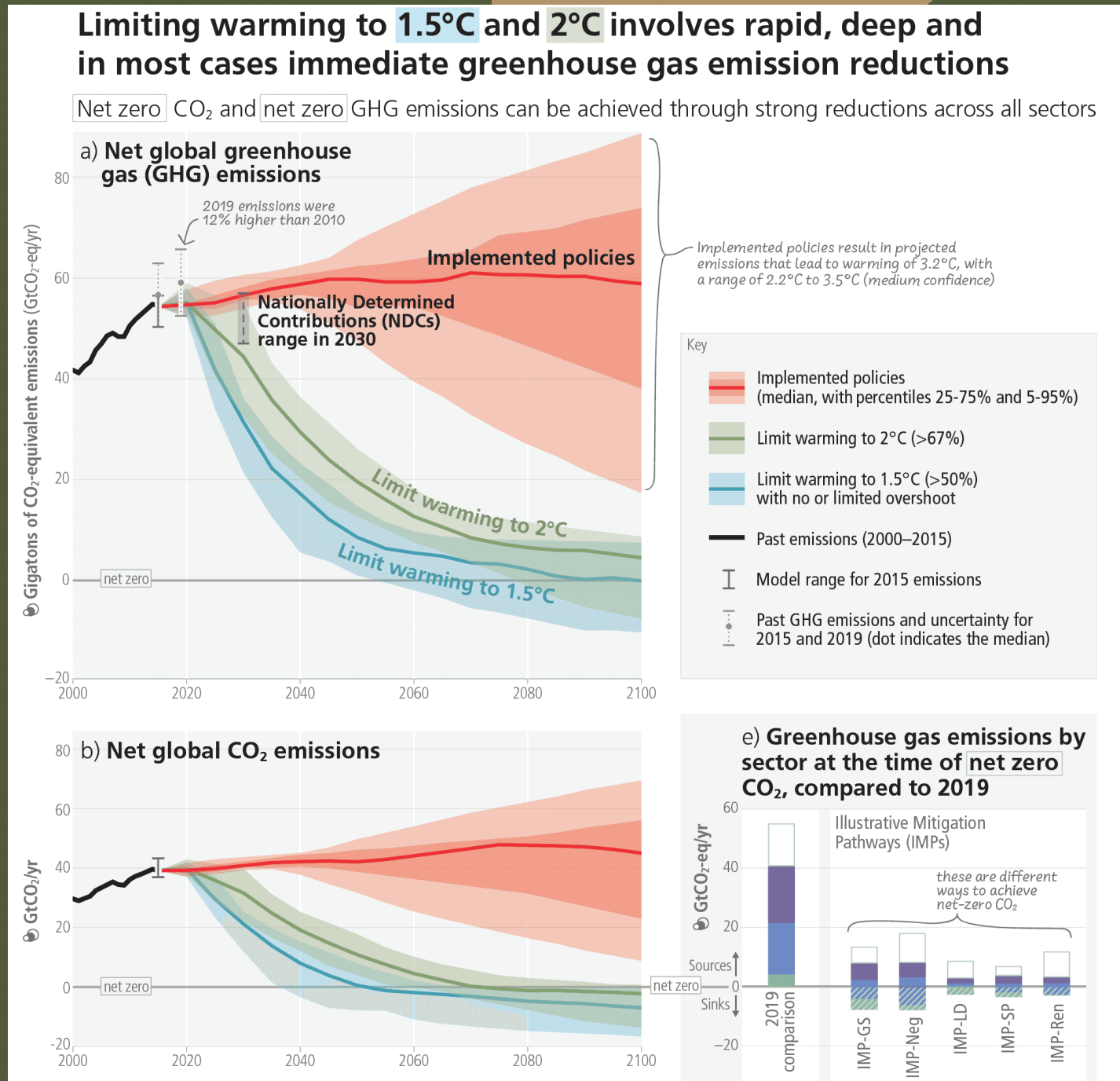




Realities of our use of land and biodiversity

- More than 2 billion people rely on wood fuel and 4 billion people rely primarily on natural medicines for their health care (IPBES)
- Indigenous Peoples manage about 25% of the earth's surface. This coincides with about 40% of protected areas (Garnett et al).
- Biodiversity has been cared for by Indigenous Peoples since time immemorial
  - peoples who are threatened by land rights/tenure, acute violence, disenfranchisement in policy processes
  - We still know little about the diverse values of nature (IPBES Values Assessment report) as we have tended to focus on "ecosystem services" – how WE benefit from nature

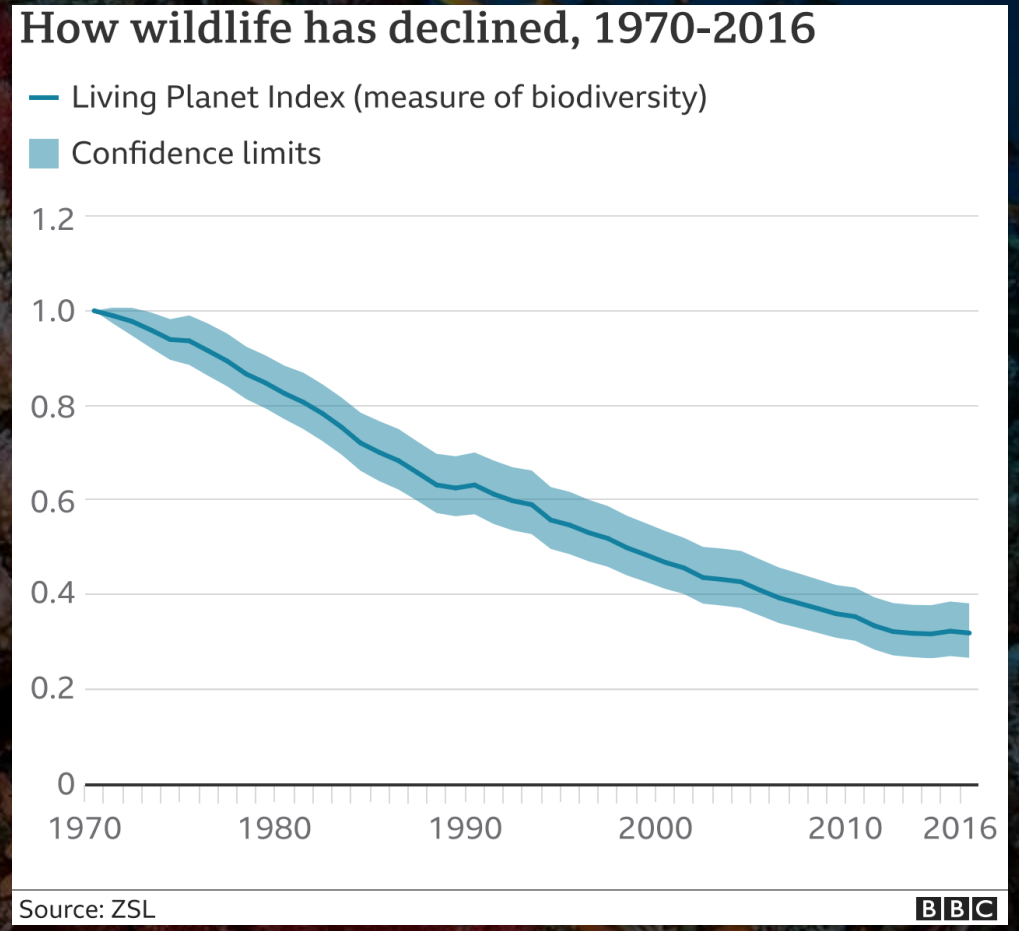
Reality of our current ambition to address climate change and the road to 2030/ 2050



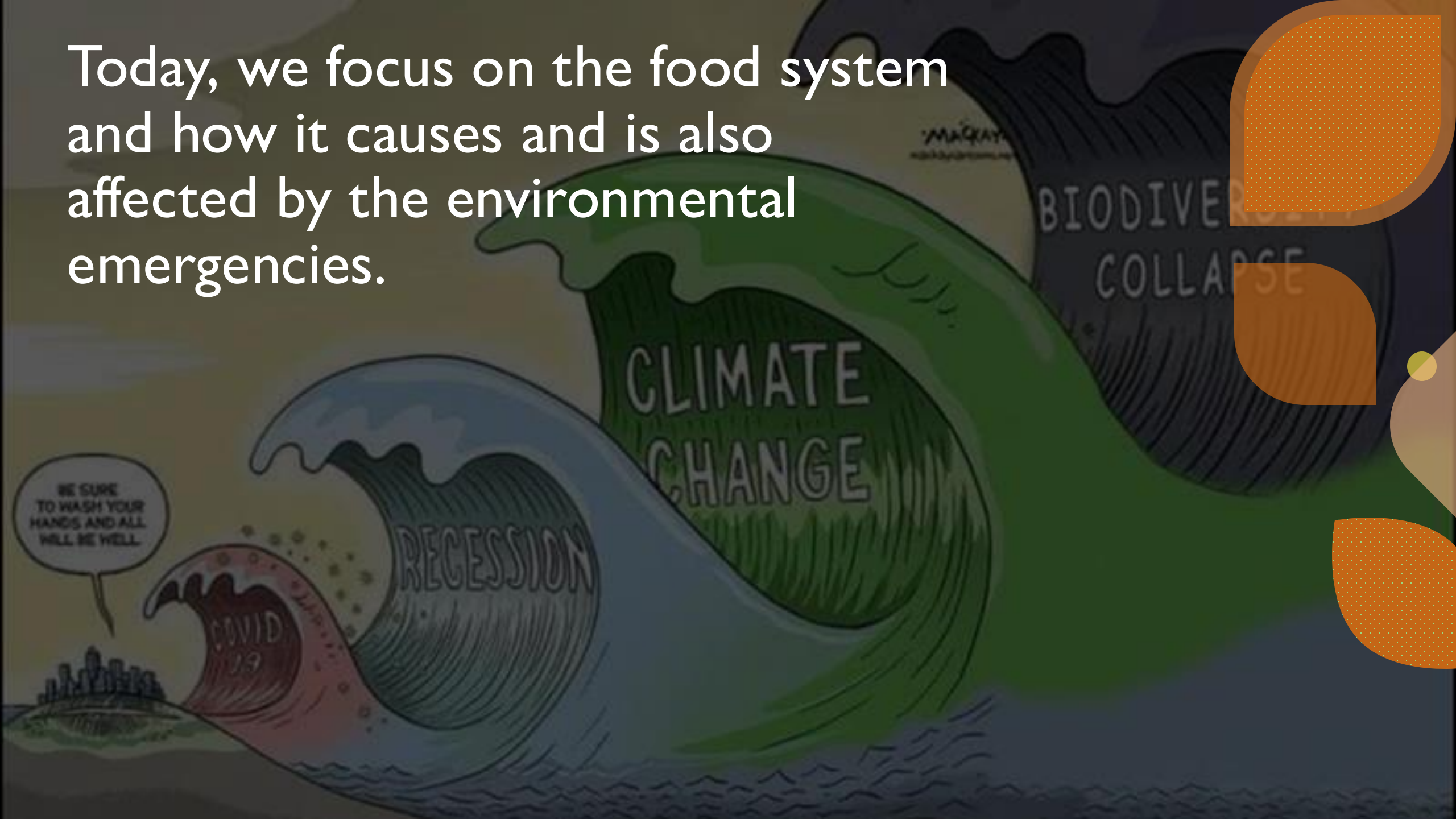
Species extinction is a major issue.

1 million species already face extinction, many within decades (IPBES)

We did not meet any of the Aichi targets for biodiversity (17% for Earth), we've upped it to 30% by 2030



Today, we focus on the food system and how it causes and is also affected by the environmental emergencies.



Our global food system is the primary driver of biodiversity loss.

(Chatham House Report, 2021)

Five main drivers of biodiversity loss

- Land-use change,
- Overexploitation of species,
- Invasive species,
- Pollution, &
- Climate change

Mace, G. M. (2010). Drivers of Biodiversity Change. In *Trade-Offs in Conservation* (pp. 349–364). Chichester, UK: Wiley-Blackwell. https://doi.org/10.1002/9781444324907.ch19

These main drivers can be connected to our food system.

- **Land use change:** cutting forests to make space for pasture or crops, degradation of ecosystems
- **Contamination/ pollution from agricultural inputs**, pesticide impacts on insect and pollinators
- **Exploitation of species** for food, medicine, human use, hunting/recreation
- **Invasive species** through trade and exchange
- **Greenhouse gases** from production, waste, transport

1. Global land use and cover change

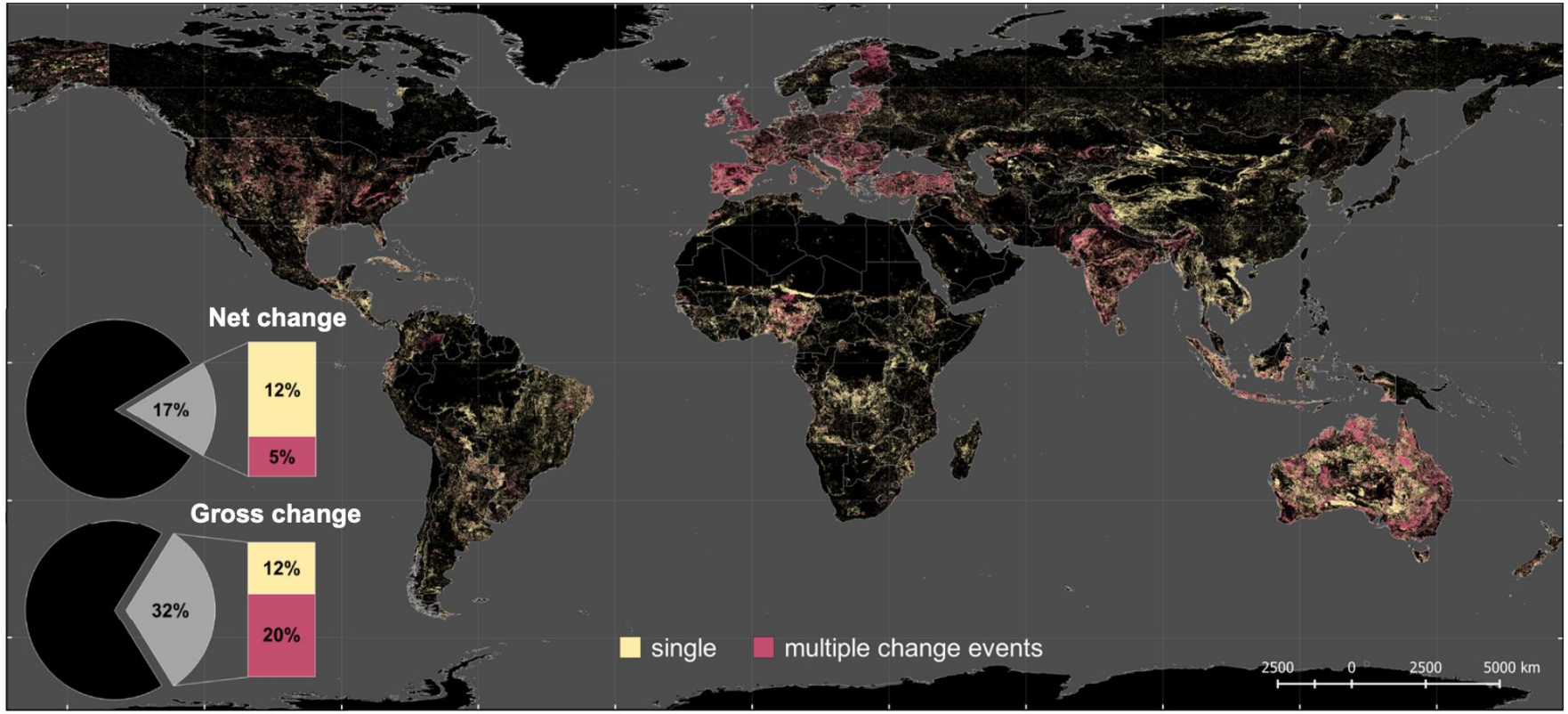


Fig. 1 Spatial extent of global land use/cover change. Share of the total land surface without (net change) and with consideration of multiple changes (gross change) between six major land use/cover categories (urban area, cropland, pasture/rangeland, forest, unmanaged grass/shrubland, non-/sparsely vegetated land) in 1960–2019. The spatial extent of land use/cover change is displayed in yellow (areas with single change events) and red (areas with multiple change events).

Winkler, K., Fuchs, R., Rounsevell, M., & Herold, M. (2021). Global land use changes are four times greater than previously estimated. *Nature Communications*, *12*(1), 1–10. https://doi.org/10.1038/s41467-021-22702-2

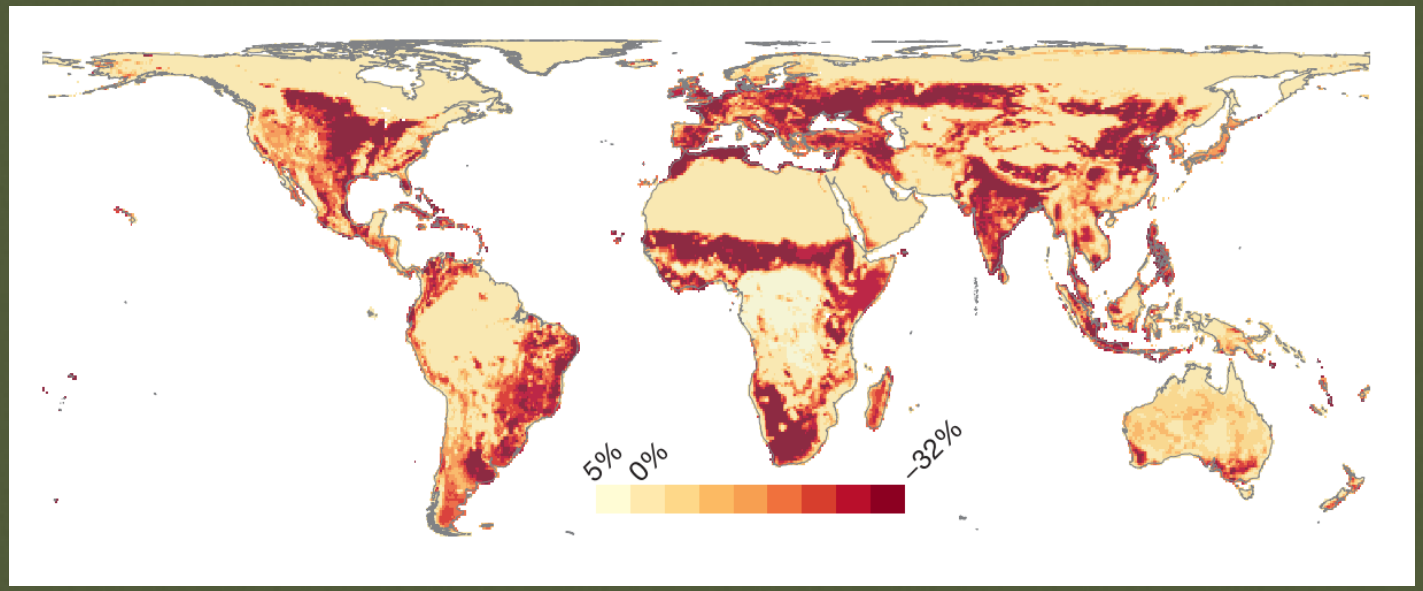
Land use change

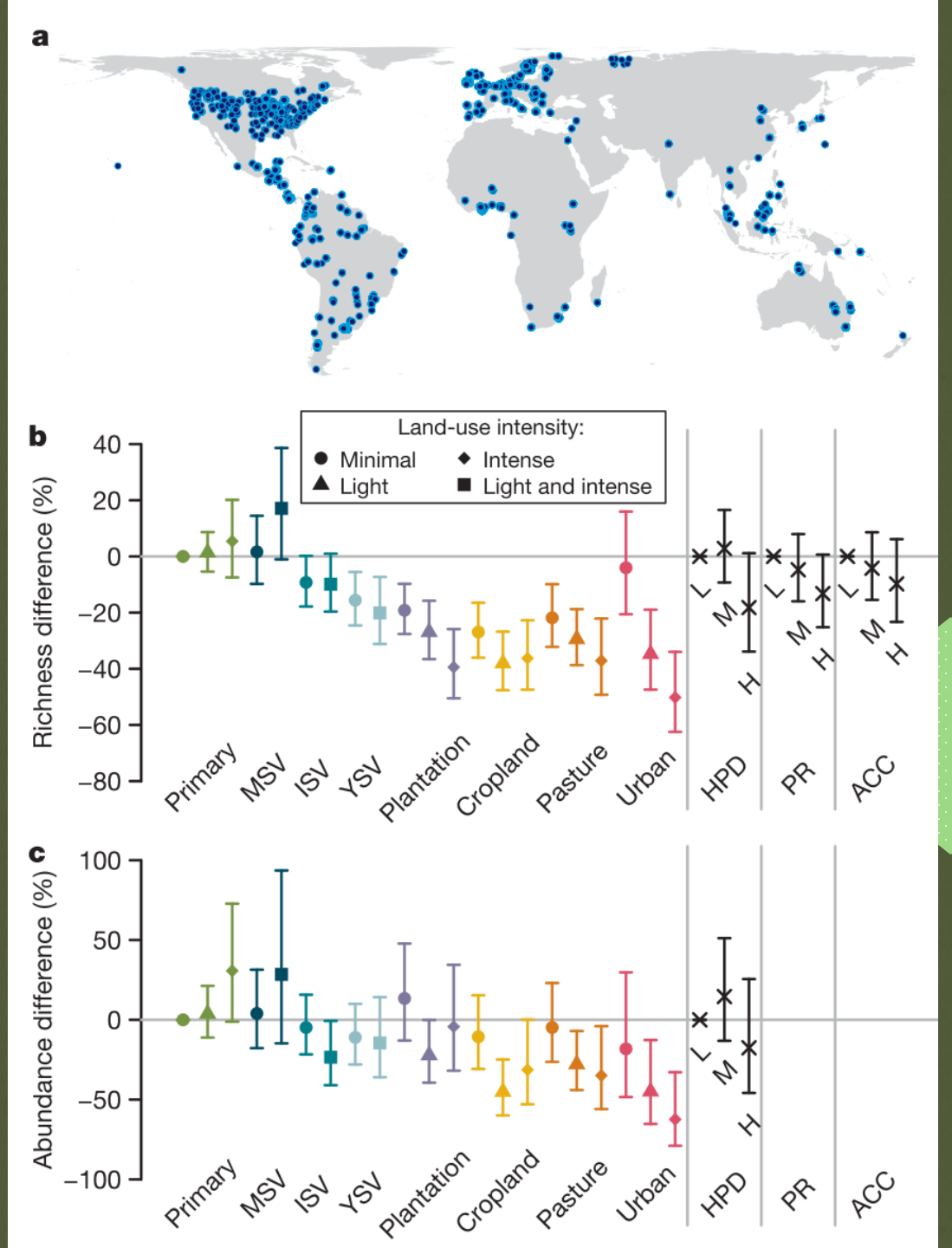
- Human use directly affects more than 70% of land
- Agriculture currently accounts for ~70% of global freshwater use
- Agriculture, Forestry and Other Land Use (AFOLU) activities accounted for around 23% of all emissions.
  - 13% of CO_2,
  - 44% of methane (CH_4), and
  - 81% of nitrous oxide (N_2O) emissions

- Seventy-five per cent of the land surface is **significantly altered**, with 32 million hectares of primary or recovering forest lost between 2010 and 2015
- Source: IPCC SRCCL

Impacts of land use on biodiversity

- Net change in local richness caused by land use and related pressures





Newbold, T., Hudson, L. N., Hill, S. L. L. L., Contu, S., Lysenko, I., Senior, R. A., … Purvis, A. (2015). Global effects of land use on local terrestrial biodiversity. *Nature*, *520*(7545), 45–50. https://doi.org/10.1038/nature14324

Pollinators under threat

- More than 75 per cent of global food crop types, including fruits and vegetables and some of the most important cash crops, such as coffee, cocoa and almonds, rely on animal pollination (IPBES)
- Intensity of land use has impacts on pollinator species richness and abundance (Millard et al 2021)

2. Species exploitation

- Species exploitation is the harvesting, logging, hunting and fishing of species for human use.
- Following land use, species exploitation has had the biggest impact in species declines.
- In marine ecosystems, direct exploitation of organisms (mainly fishing) has had the largest relative impact, followed by land-/ sea-use change (IPBES).

3. Invasive species

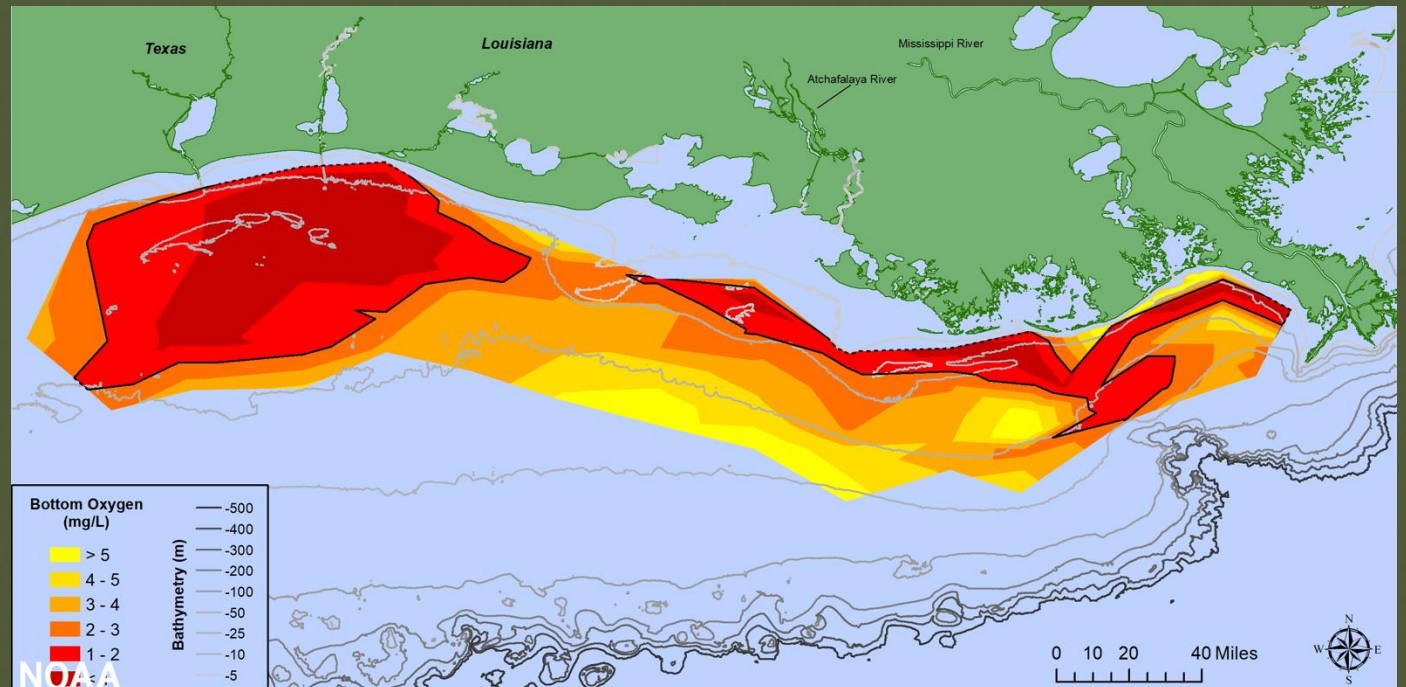
- Trade, transport, travel, and tourism are related to the rapid increase in the number and impact of invasive species
- Ports are the main entrance point of non-native species, contaminants of products (e.g. timber pathogens) or stowaways (e.g. ship hull fouling or transport with ballast water).
  - Roads, railways and canals provide pathways along which species can disperse
  - Human population density and wealth are associated with habitat degradation & invasion
  - Merchandise imports have been shown to be the most important explanatory variable

Westphal, M. I., Browne, M., MacKinnon, K., & Noble, I. (2008). The link between international trade and the global distribution of invasive alien species. *Biological Invasions*, *10*(4), 391–398. https://doi.org/10.1007/s10530-007-9138-5
Gallardo, B., Zieritz, A., & Aldridge, D. C. (2015). The Importance of the Human Footprint in Shaping the Global Distribution of Terrestrial, Freshwater and Marine Invaders. *PLOS ONE*, *10*(5), e0125801. https://doi.org/10.1371/journal.pone.0125801

The case of Chile

4. Pollution, contamination

- Agricultural inputs and practices can have a significant impact on ecosystems and species.
  - (eg Rachel Carson and Silent Spring, DDT)
- Agricultural runoff from farms and livestock operations creates oxygen-depleted areas inhospitable to animal and plant life. Here off Southern US coast in July 2021, 4 million acres (1.6 million hectares)



NOAA 2021. https://www.noaa.gov/news-release/larger-than-average-gulf-of-mexico-dead-zone-measured

Focusing on trade dynamics

Trade and biodiversity

- Consumption of internationally traded goods drives 25% of bird species losses, while 83% of total terrestrial species loss is due to domestic agricultural land use.

- Chaudhary, A., & Kastner, T. (2016). Land use biodiversity impacts embodied in international food trade. *Global Environmental Change*, *38*, 195–204. https://doi.org/10.1016/j.gloenvcha.2016.03.013
- Marques, A., Martins, I. S., Kastner, T., Plutzar, C., Theurl, M. C., Eisenmenger, N., … Pereira, H. M. (2019). Increasing impacts of land use on biodiversity and carbon sequestration driven by population and economic growth. *Nature Ecology & Evolution*, *3*(4), 628–637. https://doi.org/10.1038/s41559-019-0824-3

Spatial decoupling of production and consumption

- Subsistence needs that used to be met by local resources are now being supplied by other regions via increased trade flows.
- This has made it easier for **biodiversity losses to be outsourced** outside of where consumers can readily perceive these impacts.
- As a result, developed regions often import from developing, typically highly biodiverse, regions.
- This international trade can contribute to increased pressure on habitats with a high potential for land conversion, such as tropical forests, which has major consequences for biodiversity.

Beef, soy, palm oil, wood

- Between 2000 and 2011 the production of beef, soybeans, palm oil, and wood products in seven countries (Argentina, Bolivia, Brazil, Paraguay, Indonesia, Malaysia, and Papua New Guinea) was responsible for 40% of total tropical deforestation and resulting carbon losses

- Henders, S., Persson, U. M., & Kastner, T. (2015). Trading forests: Land-use change and carbon emissions embodied in production and exports of forest-risk commodities. *Environmental Research Letters*, *10*(12). https://doi.org/10.1088/1748-9326/10/12/125012

Great resource

- https://supplychains.trase.earth/explore

- Trase.earth

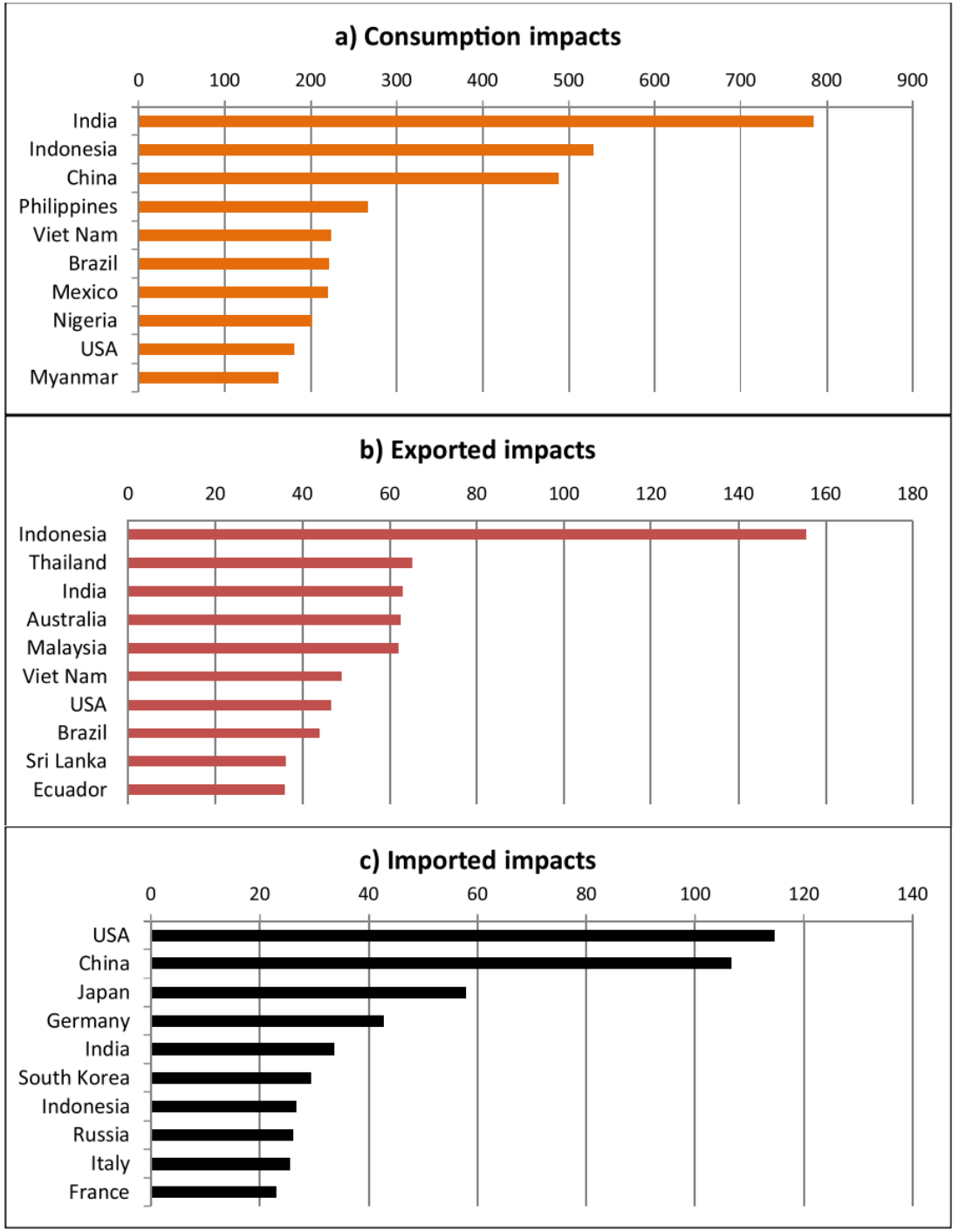
Other tools and measurements of biodiversity impacts

A lot of these are in the domain of what is called “industrial ecology”.

- Life Cycle Analysis
- Input-Output analysis
- Human Appropriated Net Primary Production
- Embedded biodiversity impacts on species, e.g. through SARs
- Combinations of these methods

- Top ranking countries for biodiversity impacts due to consumption (A), exports (B) and imports (C).

- Chaudhary, A., & Kastner, T. (2016). Land use biodiversity impacts embodied in international food trade. *Global Environmental Change*, *38*, 195–204. https://doi.org/10.1016/j.gloenvcha.2016.03.013



However, is all trade bad?

- Nearly 1 billion people consume internationally traded products to cover their daily nutrition
- While international demand drives more than half of the biodiversity impacts due to loss of suitable habitat from soybean production in the Brazilian Cerrado, the domestic market is responsible for the greatest share of impacts of any country (Green et al, 2019)
- It is not **trade itself** that is driving these changes.
  - It is the **changes in demand (from us!)**
  - Enabled by trade liberalization and agreements

Should we only “eat local” for biodiversity?

- It is unlikely that more localized food systems will be advantageous for biodiversity, since certain products are suited to production in certain locations, thereby reducing the need for additional inputs

Climate change will affect all the components of this food system.

- Agricultural productivity
- Extremes and major food loss events (tropical cyclones/ droughts)
- Biodiversity and the ecosystem services it provides towards agriculture
- Species themselves: range, distribution
- Other interactions with species: pests, diseases
- Ecosystems, their services, their resilience to change
- Human systems Farmer well-being and livelihood, conflict, migration

How will these events…

- Affect local biodiversity?
- Affect agricultural production in itself?
- Affect trade? Food prices?

What is the role of policy?

- Globally agreed goals and targets
- Climate change mitigation and nature-based solutions
- Forest and biodiversity conservation/ protection
- Trade agreements
- Regulation of agricultural production, inputs and land use
- Support and finance for adaptation and communities.
- National / international economic goals and objectives.

Example: Soya and the China, US, Brazil telecoupling

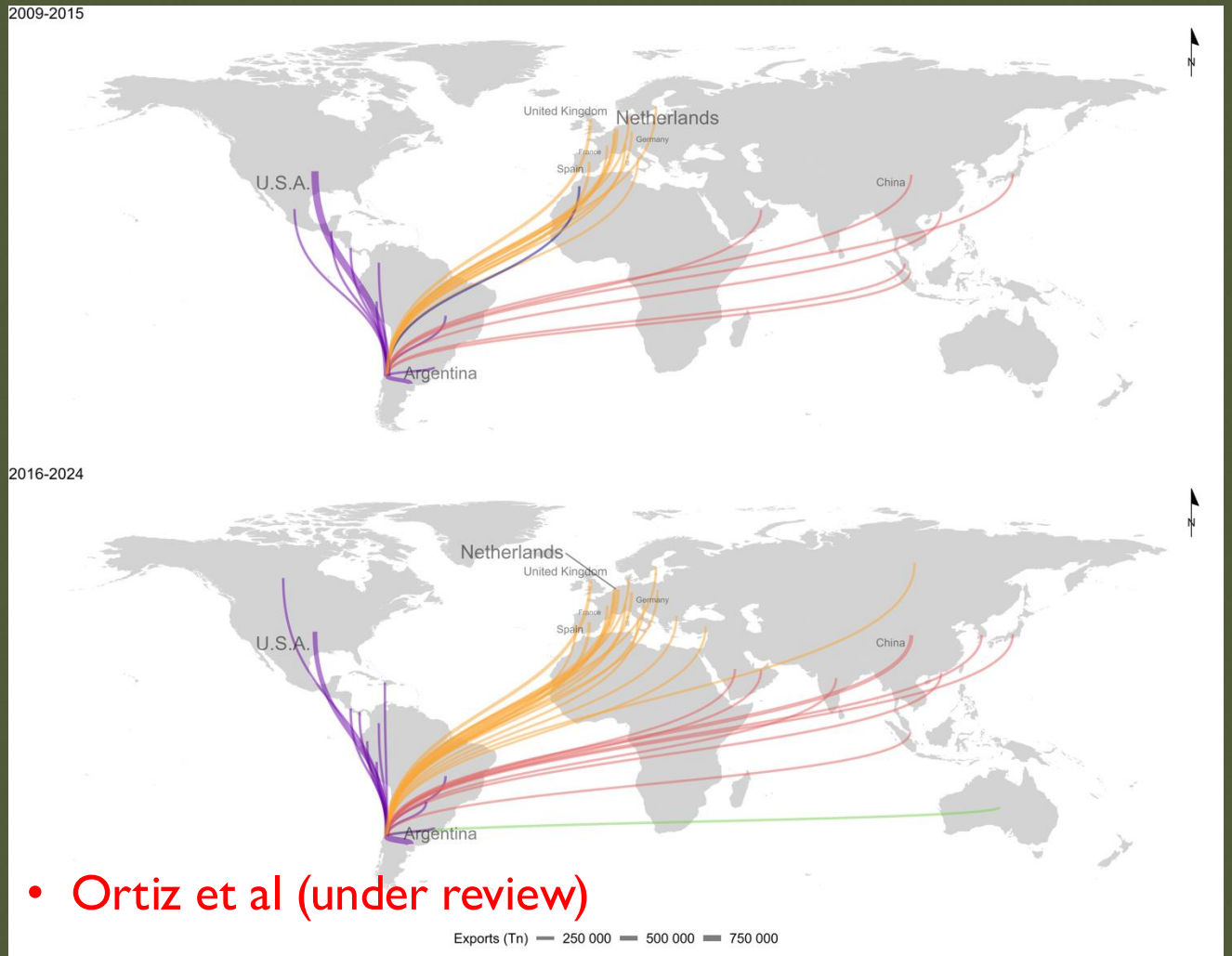
China used to be the largest soybean producer and exporter, but has become the largest soybean importer.

Due to the advanced agricultural technology and management in main exporting countries, imported soybeans are much cheaper than domestic ones in China

To become a World Trade Organization (WTO) member, China reduced the tariff on imported soybeans from 130 to 3% in 1995. This allowed the trade from countries like Brazil to sell soy very cheaply.

Sun, J., Tong, Y., & Liu, J. (2017). Telecoupled land-use changes in distant countries. *Journal of Integrative Agriculture*, *16*(2), 368–376. https://doi.org/10.1016/S2095-3119(16)61528-9

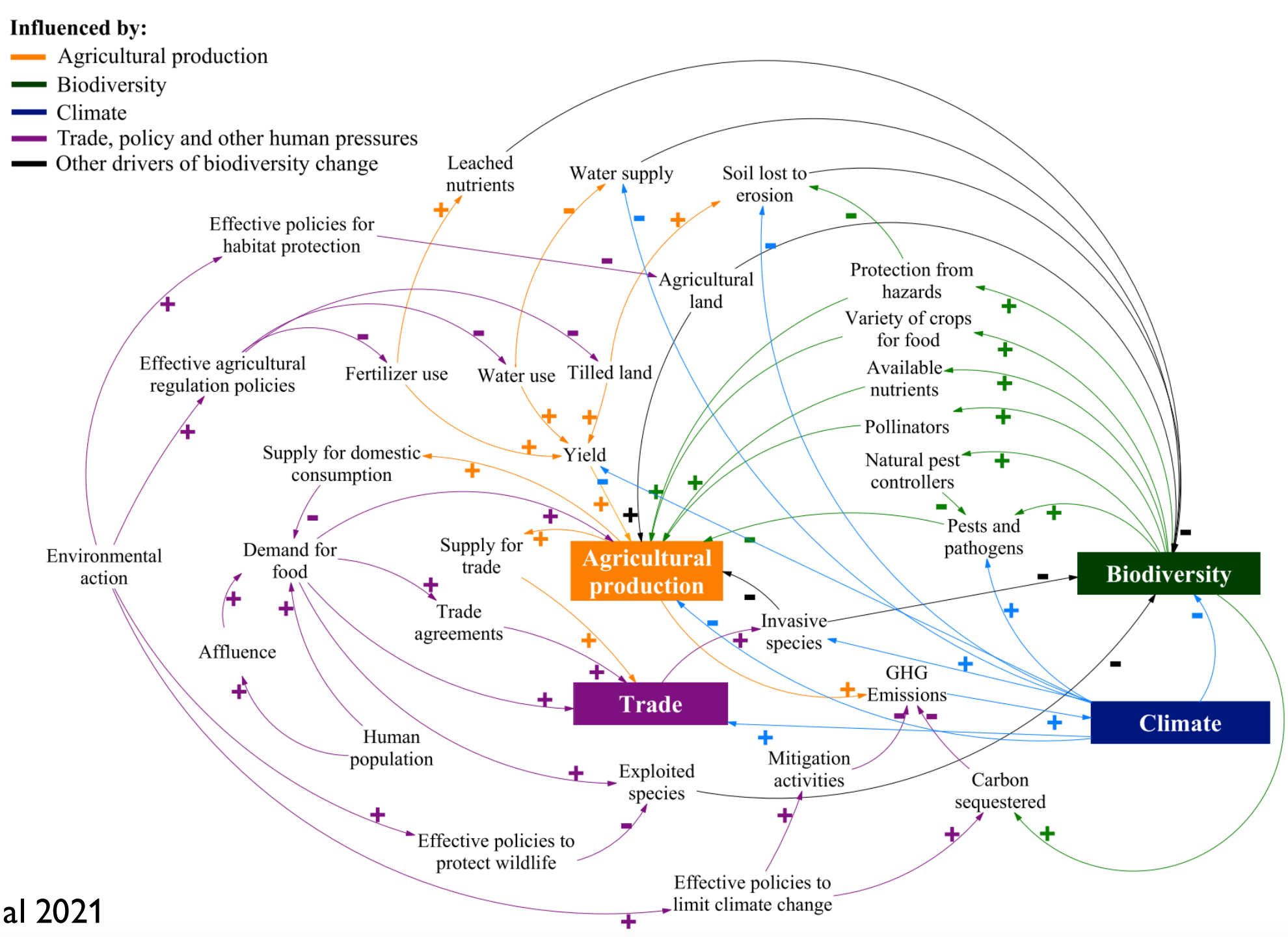
The case of avocado in Chile



- Ortiz et al (under review)

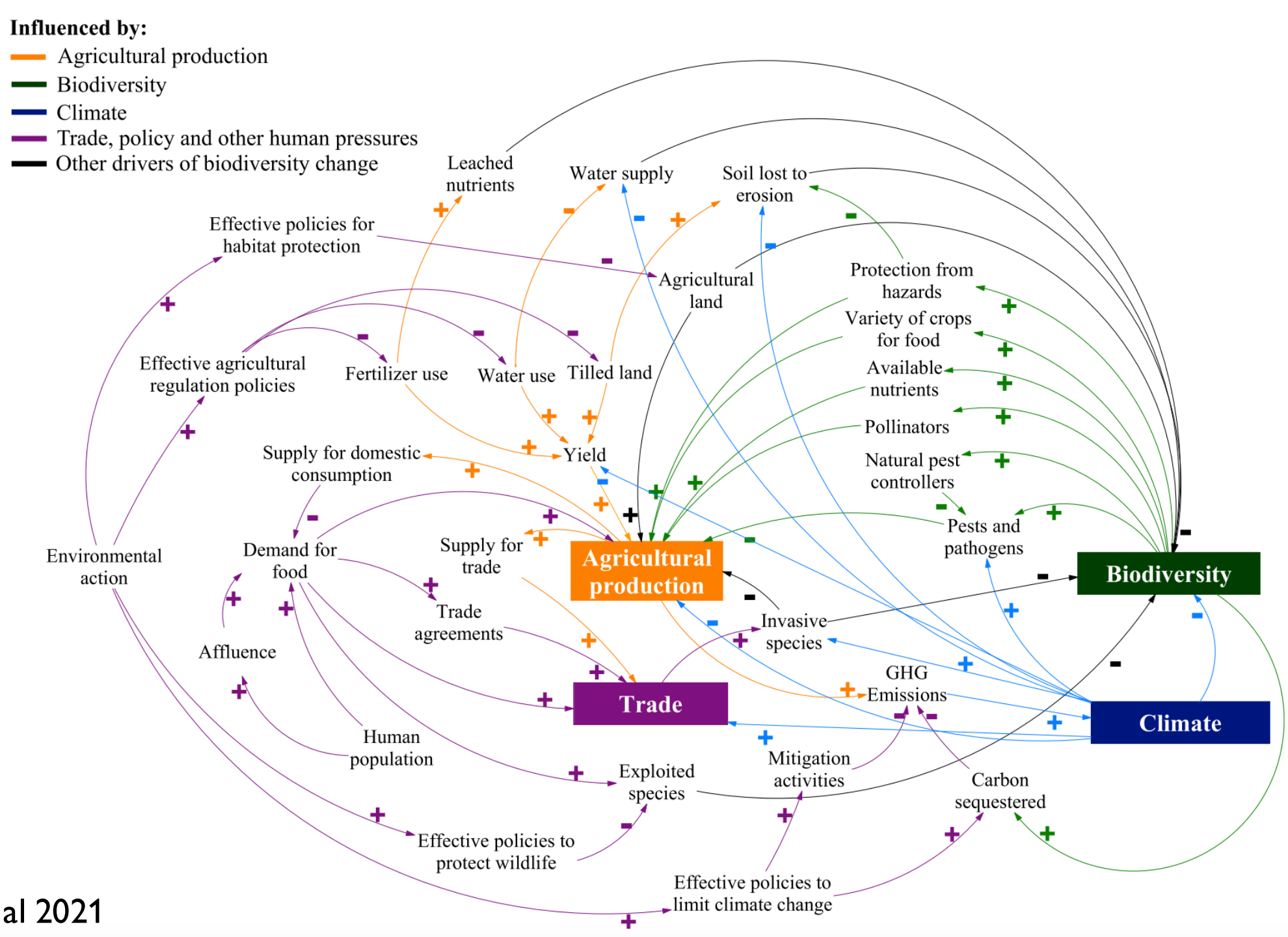
Our complex food system

- Agricultural production
- Biodiversity and the ecosystem services it provides for agriculture
- People and communities → Demand, production, policy, trade
- Climate and climate change



- Ortiz et al 2021

Break for questions and small pause



- Ortiz et al 2021

Systems thinking

Simply put, looking at the bigger picture(s)

Sometimes looking at the whole system tells us things that we wouldn't learn by only looking at smaller parts.

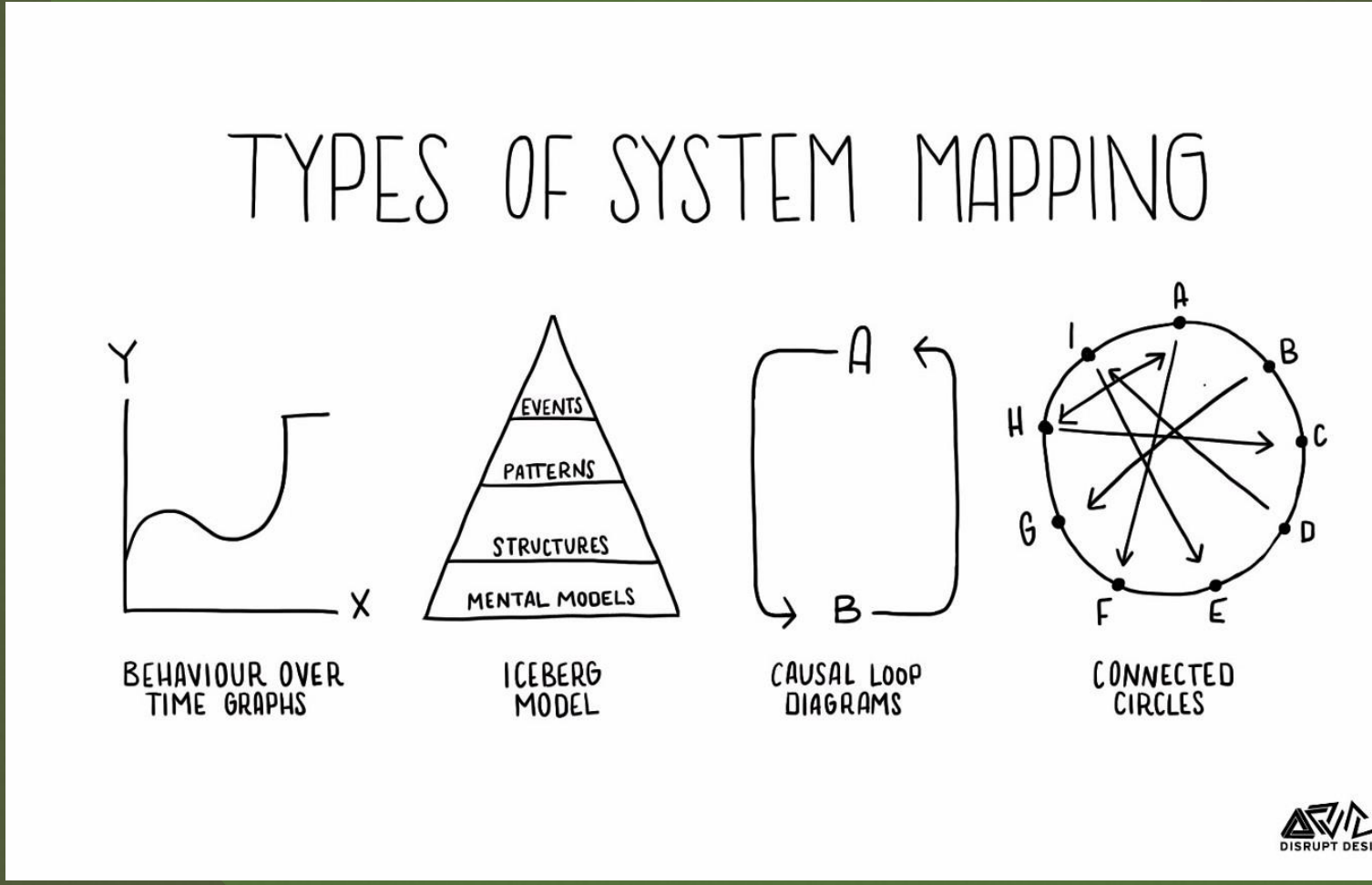
Understanding how things affect others within a system.

Recognizing that our global systems are very complex and that they interact with each other.

Systems thinking

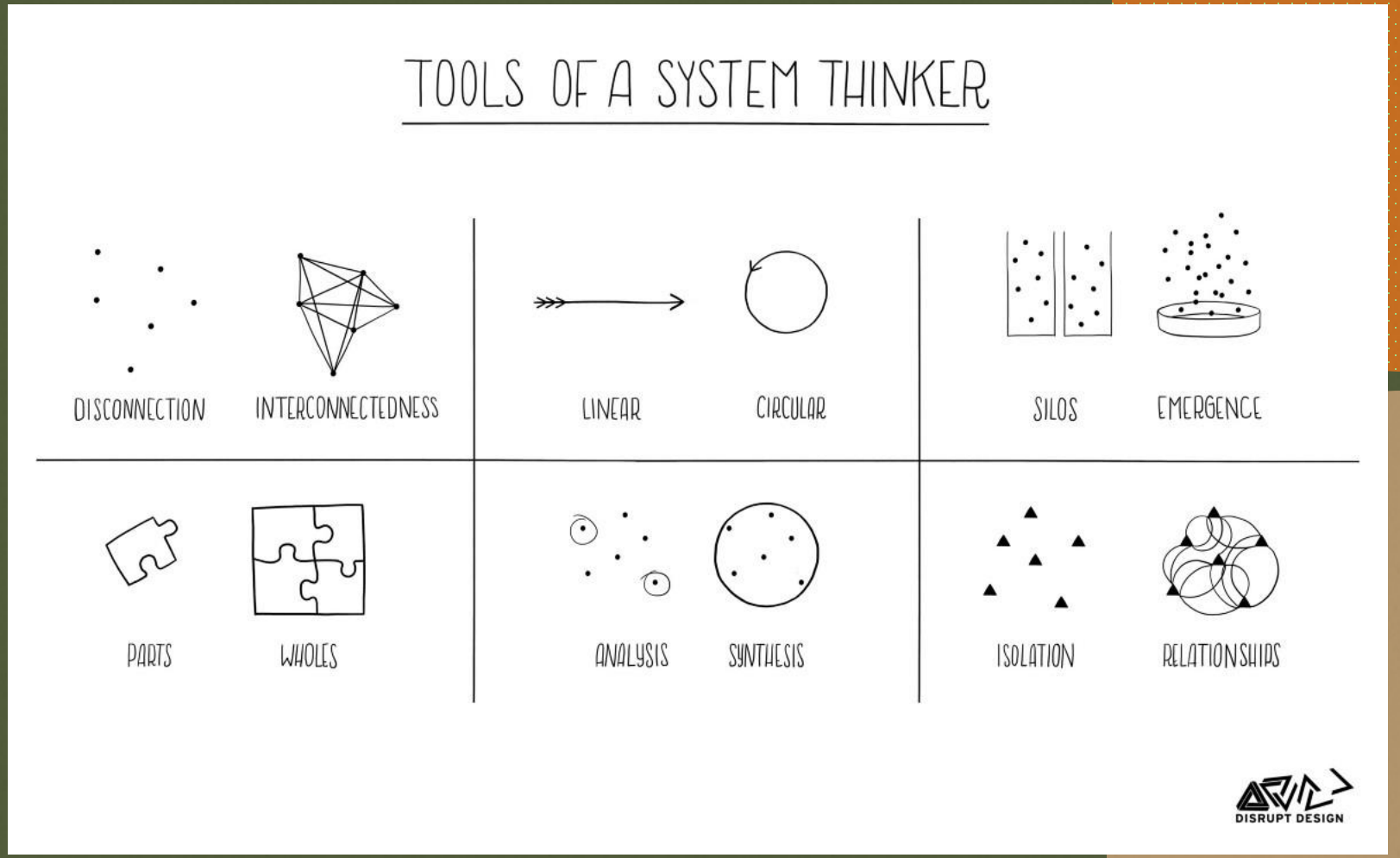
- The term ‘systems thinking’ refers to approaches that emphasize the **interdependence of components of dynamic systems and their interactions with other systems, including societal and environmental systems.**

- Helpful accessible reference (and images):
- https://medium.com/disruptive-design/tools-for-systems-thinkers-the-6-fundamental-concepts-of-systems-thinking-379cdac3dc6a



Mahaffy, P. G., Matlin, S. A., Holme, T. A., & MacKellar, J. (2019). Systems thinking for education about the molecular basis of sustainability. *Nature Sustainability*, *2*(5), 362–370. https://doi.org/10.1038/s41893-019-0285-3

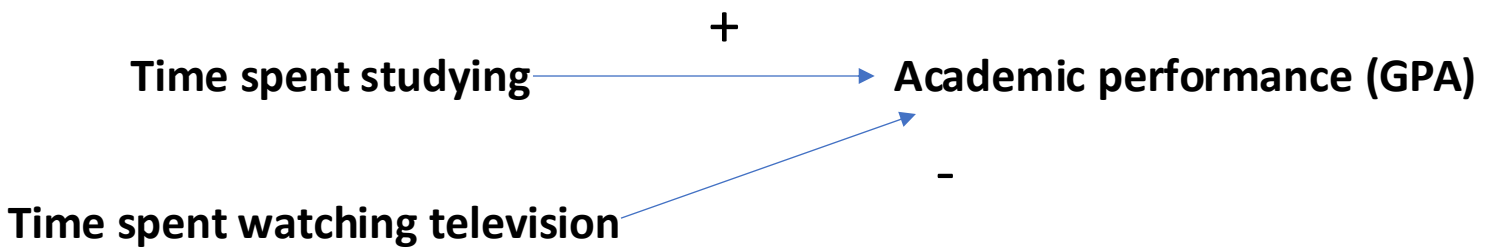
Systems thinking



How can we represent these connections?

One of the main tools of systems thinking is a **causal loop diagram.**

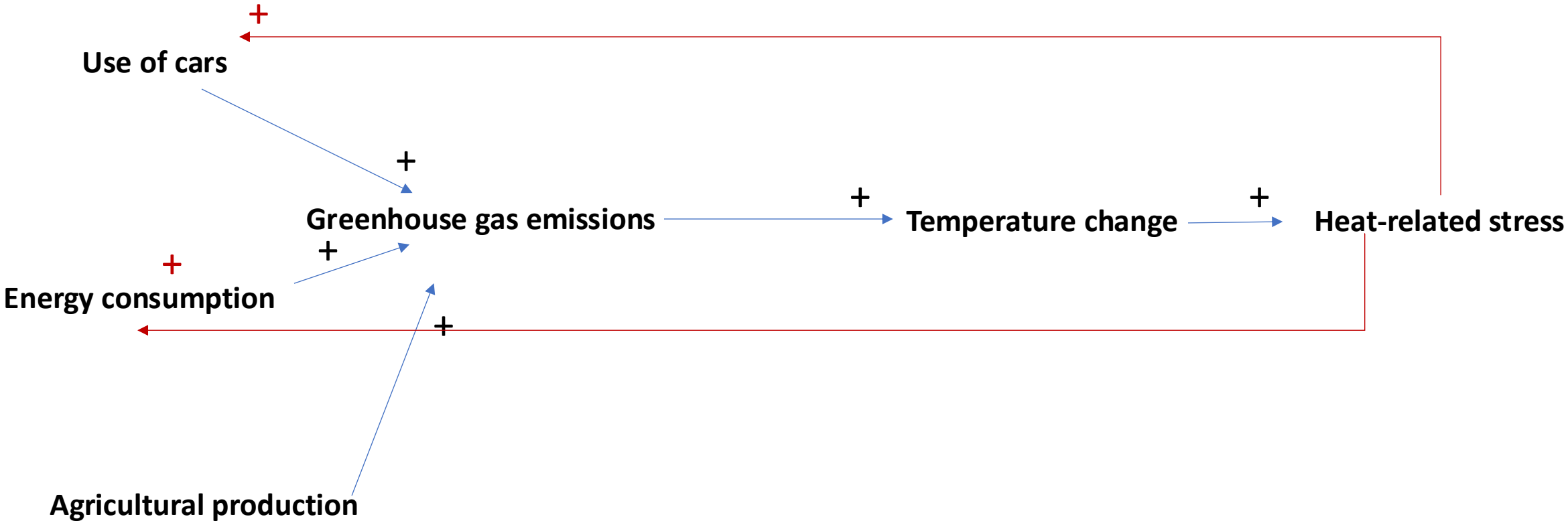
It is also sometimes called an **influence diagram.**



Reference:

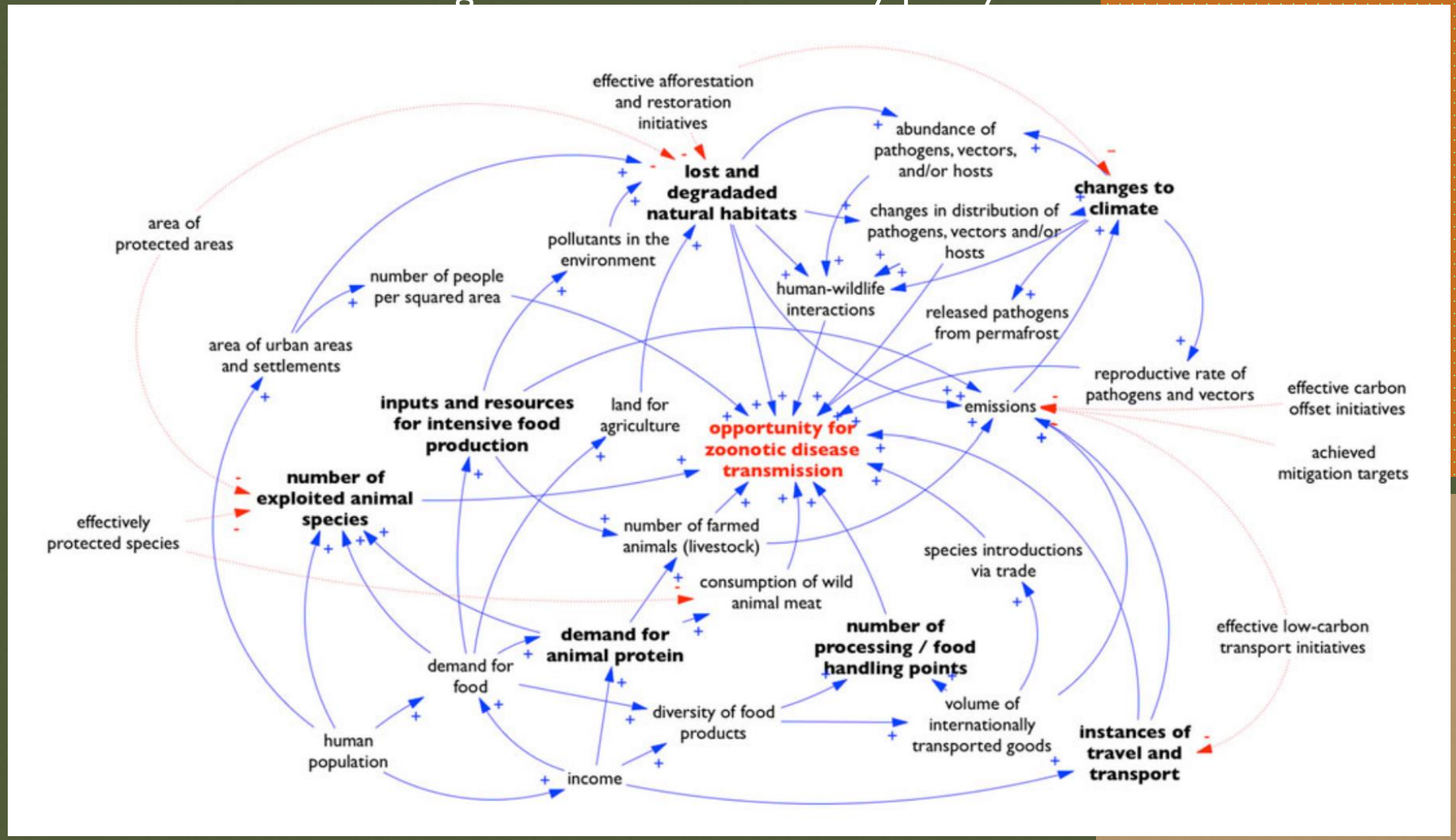
Ng, S. F., Zakaria, R., Lai, S. M., & Confessore, G. J. (2016). A study of time use and academic achievement among secondary-school students in the state of Kelantan, Malaysia. *International Journal of Adolescence and Youth*, *21*(4), 433–448. https://doi.org/10.1080/02673843.2013.862733

Another example



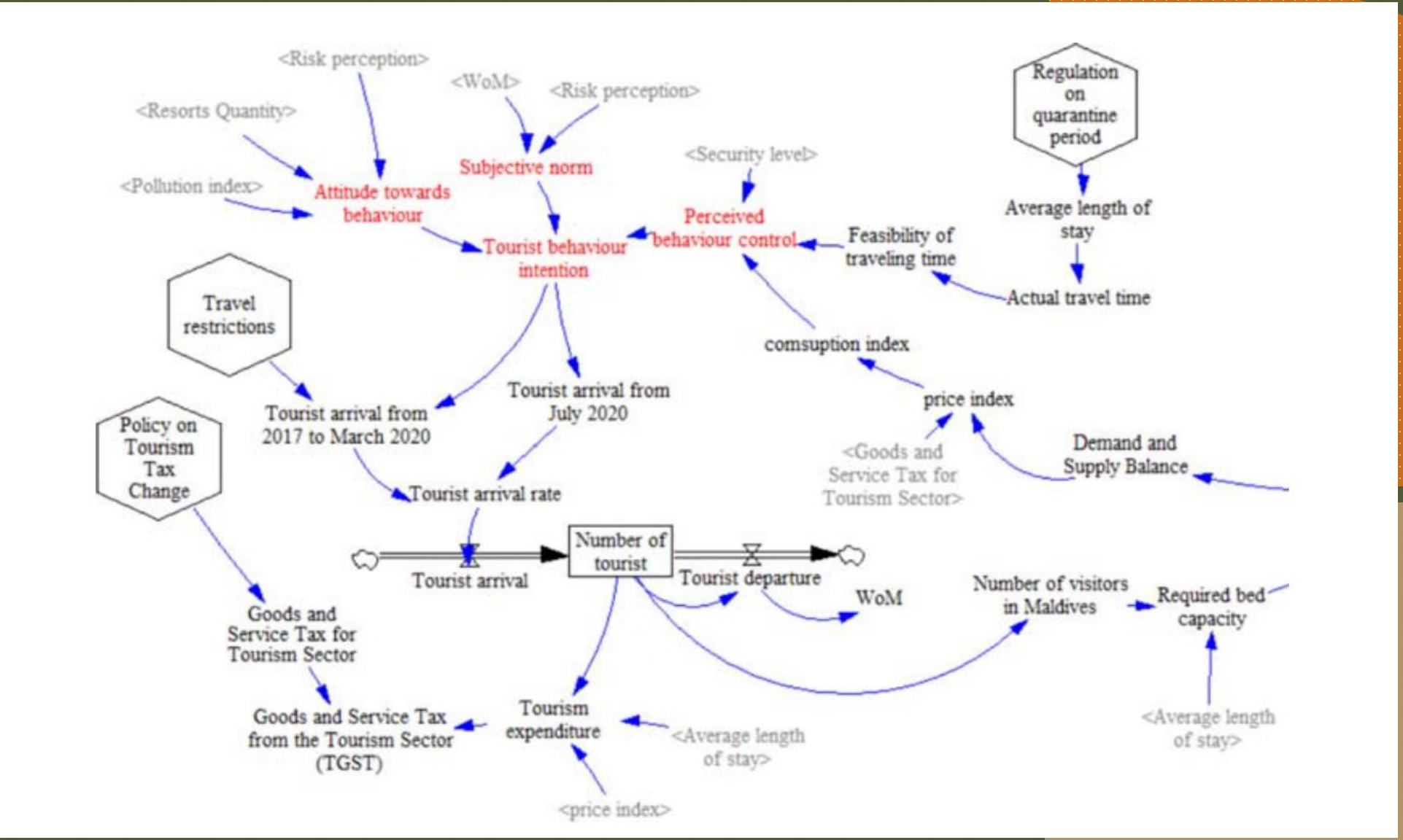
Other applications of systems thinking

- Zoonotic disease transmission and global climate/biodiversity policy:



Ortiz, A. M. D., de Leon, A. M., Torres, J. N. V., Guiao, C. T. T., & La Viña, A. G. M. (2021). Implications of COVID-19 on progress in the UN Conventions on biodiversity and climate change. *Global Sustainability*, *4*, e11. https://doi.org/10.1017/sus.2021.8

Tourism in SIDS amidst COVID



Gu, Y., Onggo, B. S., Kunc, M. H., & Bayer, S. (2021). Small Island Developing States (SIDS) COVID-19 post-pandemic tourism recovery: A system dynamics approach. *Current Issues in Tourism*, *0*(0), 1–28. https://doi.org/10.1080/13683500.2021.1924636

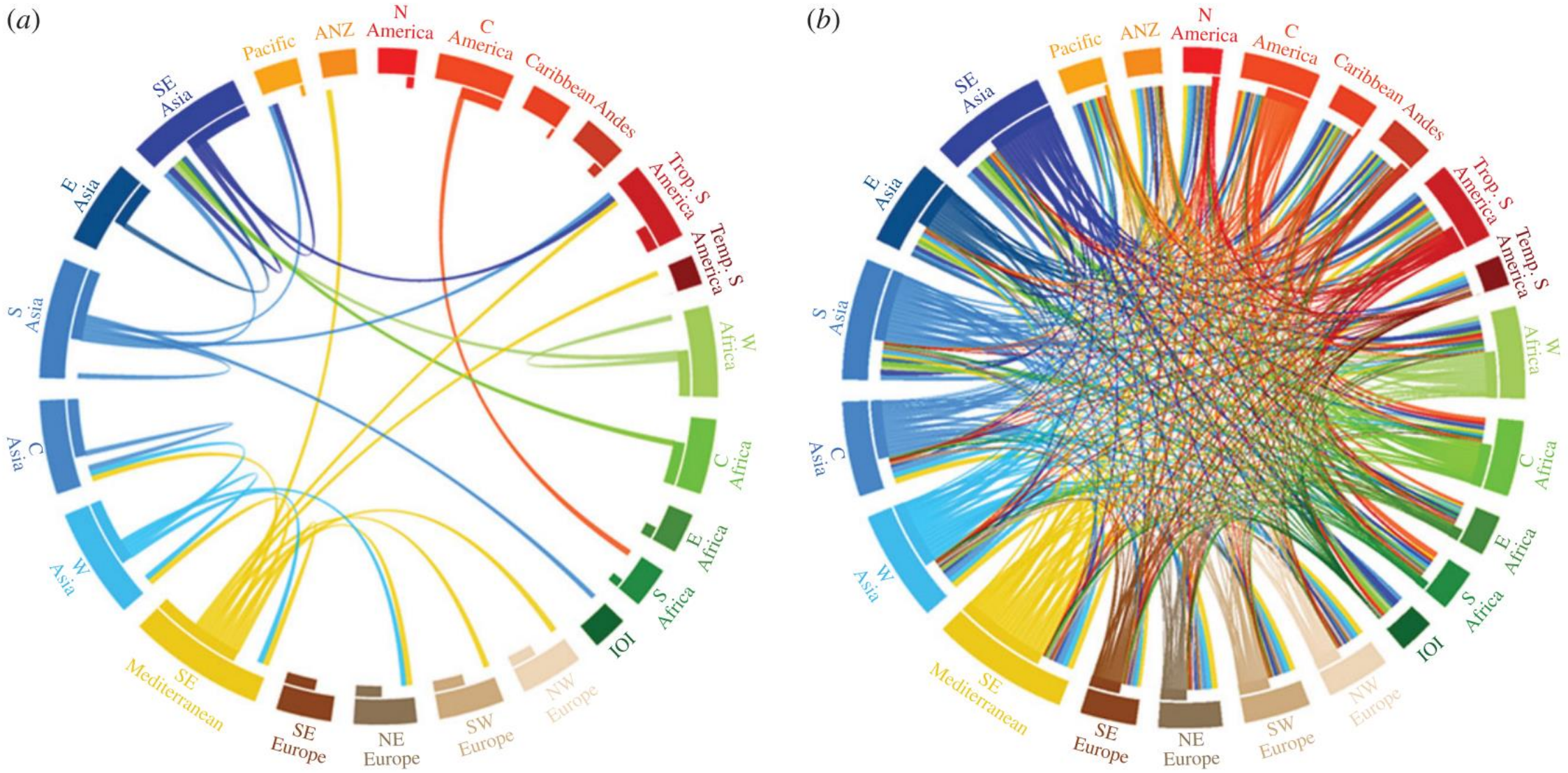


Figure 2. Circular plots linking the primary regions of diversity of food crops with their current importance in the context of calories (kcal capita^{-1} d^{-1}) in regional

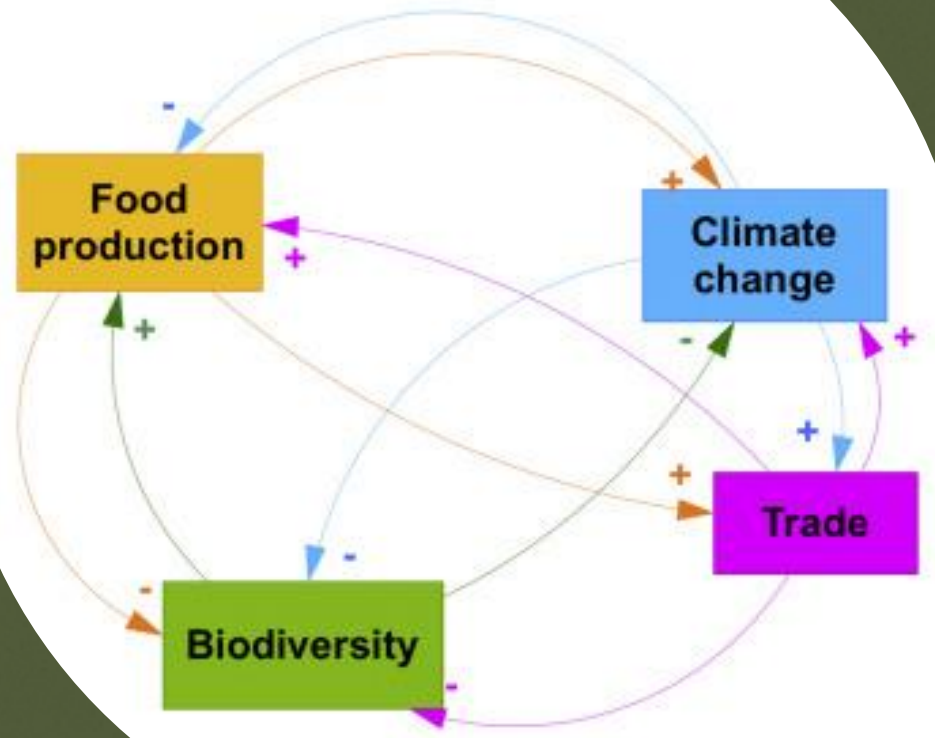
Khoury, C. K., Achicanoy, H. A., Bjorkman, A. D., Navarro-Racines, C., Guarino, L., Flores-Palacios, X., … Struik, P. C. (2016). Origins of food crops connect countries worldwide. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1832), 1–9. https://doi.org/10.1098/rspb.2016.0792

Limitations of systems thinking

- By simplifying, are we losing complexity?
- Not as commonplace as we would like to think
- Other processes involved are not systemic in nature (funding, programs, policy)
- Usefulness vs utility in quantitative analyses, policy-making

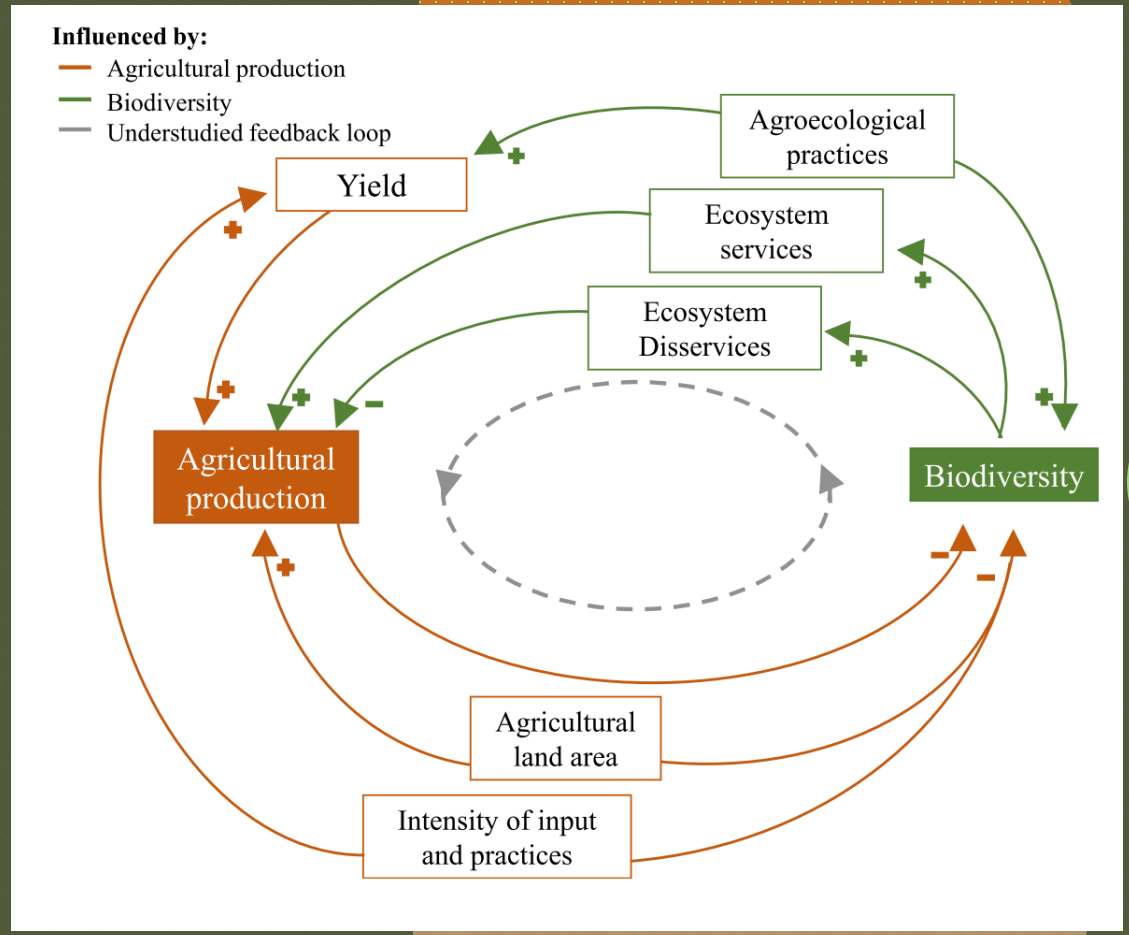
What parts of the system are well understood and not?

Research and policy priorities



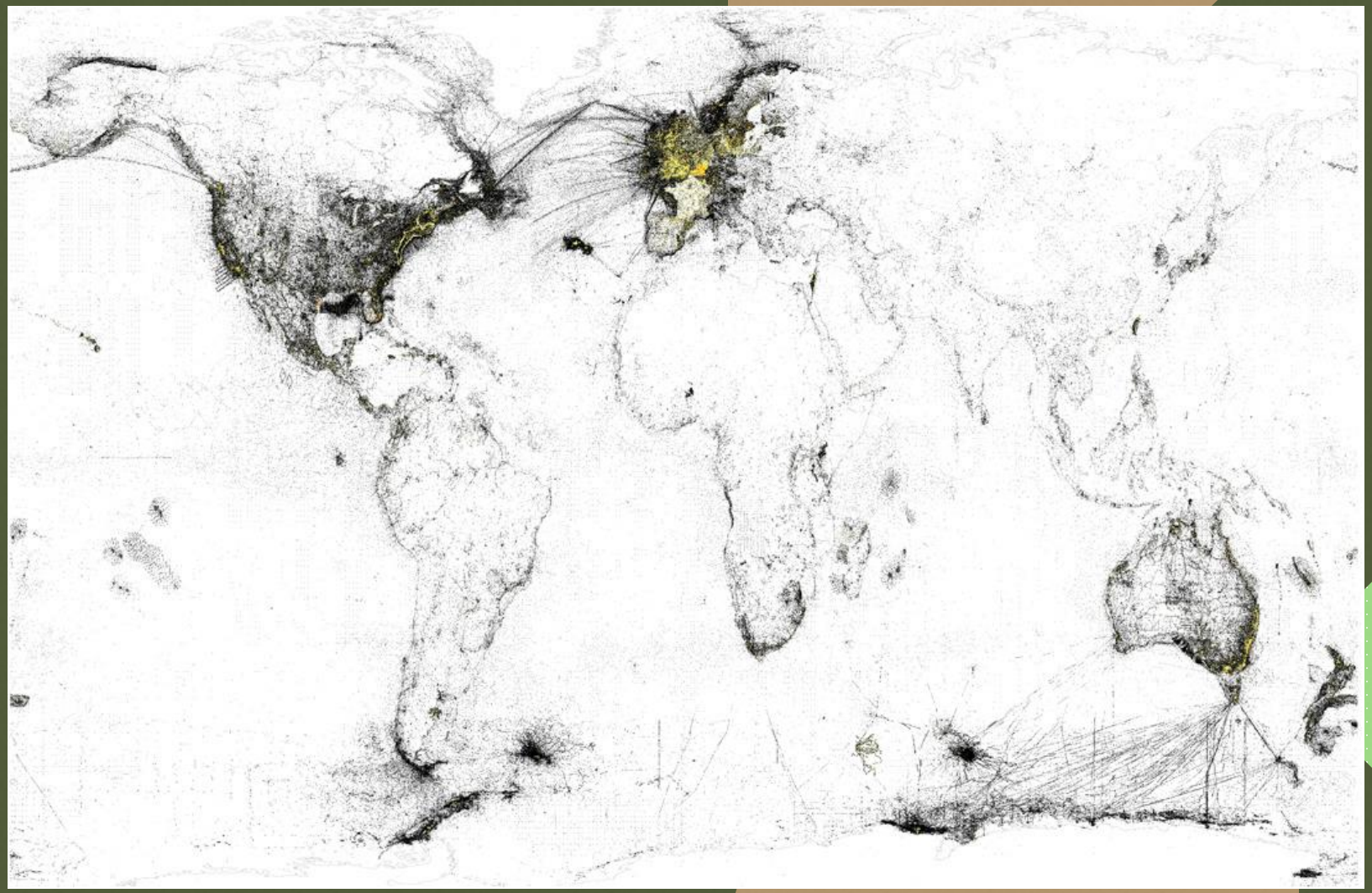
RP1

- better inclusion of biodiversity in large-scale studies



RP2

- improving data availability, access, and coverage



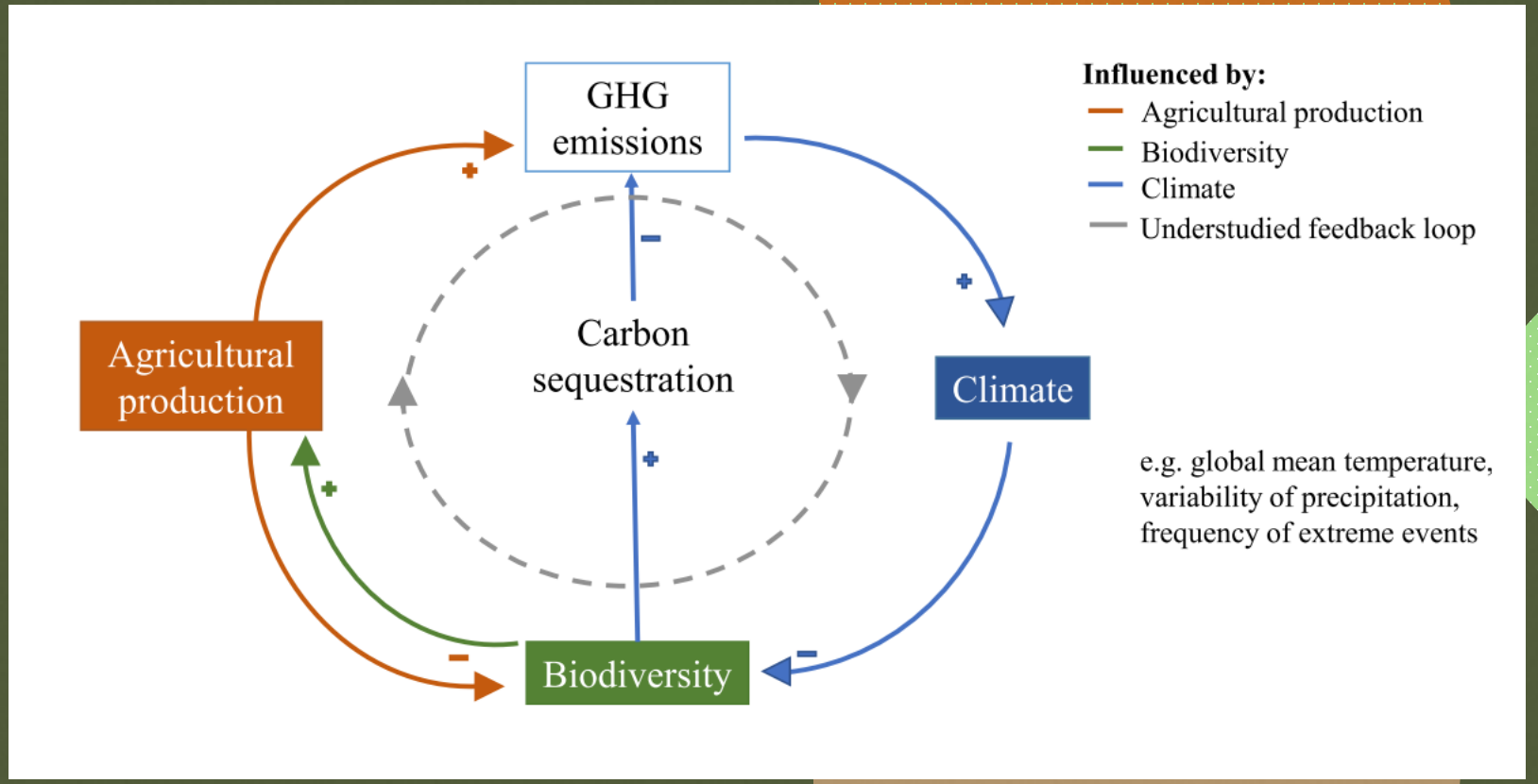
"Societal preferences, rather than research activity, strongly correlate with taxonomic bias, which lead us to assert that scientists should advertise less charismatic species and develop societal initiatives (e.g. citizen science) that specifically target neglected organisms"

Troudet, J., Grandcolas, P., Blin, A., Vignes-Lebbe, R., & Legendre, F. (2017). Taxonomic bias in biodiversity data and societal preferences. *Scientific Reports*, *7*(1), 1–14. https://doi.org/10.1038/s41598-017-09084-6

Hughes, A. C., Orr, M. C., Ma, K., Costello, M. J., Waller, J., Provoost, P., … Qiao, H. (2021). Sampling biases shape our view of the natural world. *Ecography*, *44*(9), 1259–1269. https://doi.org/10.1111/ecog.05926

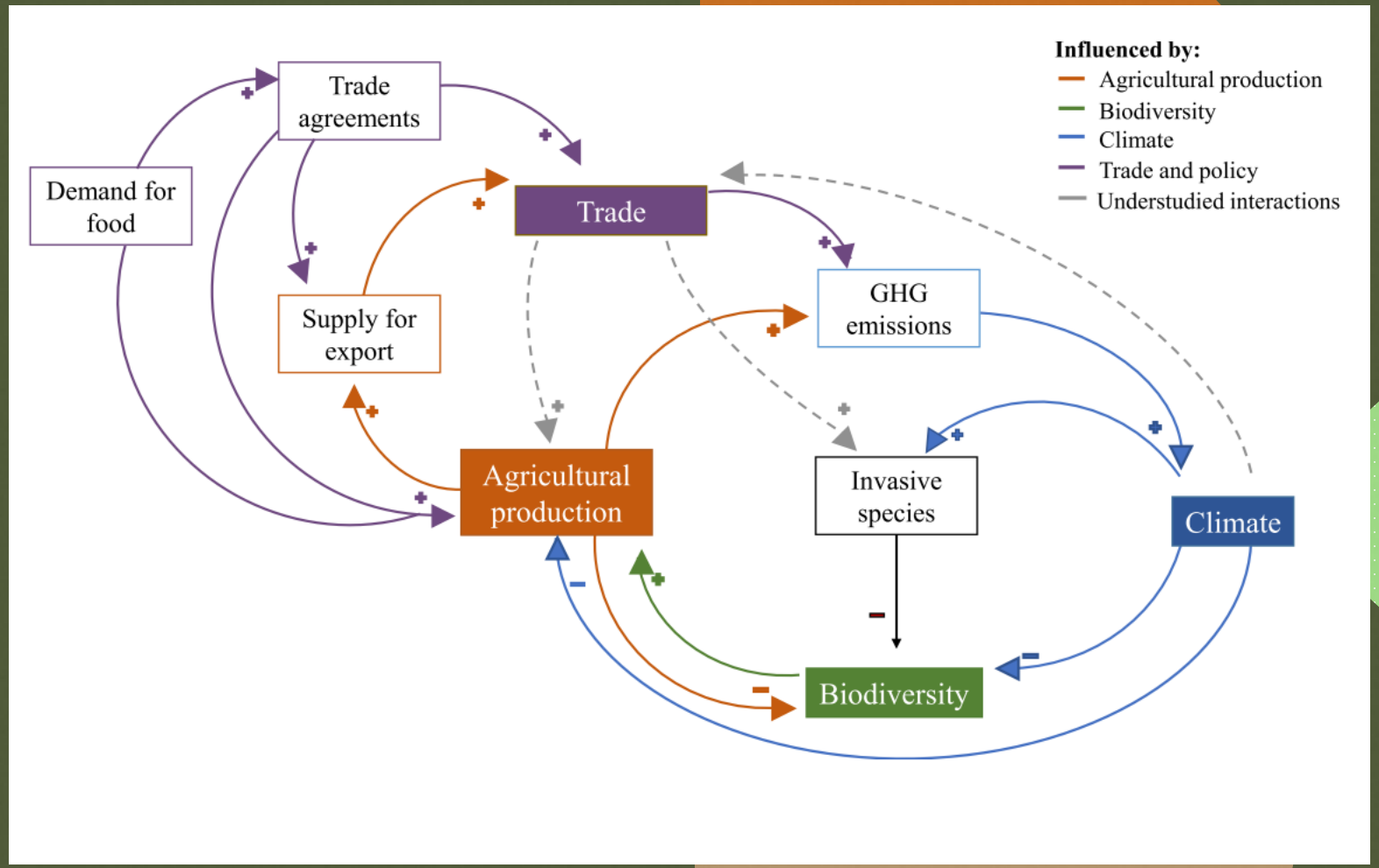
RP3

- interactions with climate change and resulting feedback



RP4

- trade as a facilitator of biodiversity and climate-change impacts

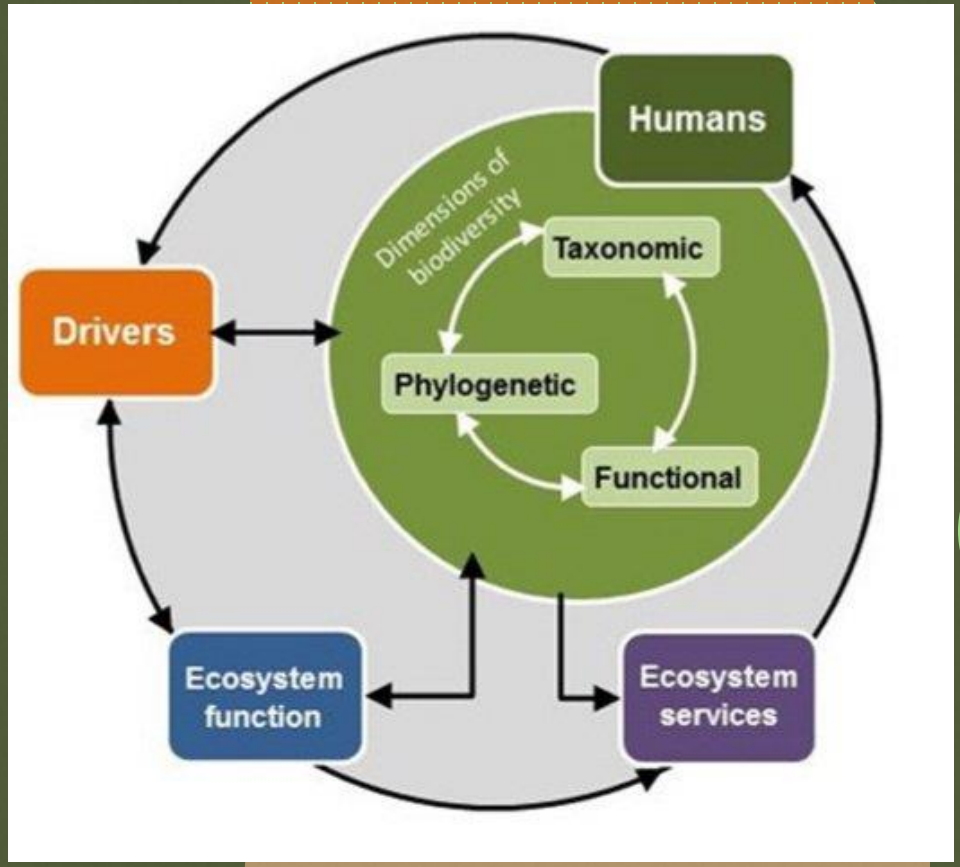


RP5

- additional measures of biodiversity in impact analyses

- not just abundance, richness – function, etc. as well

- Heydari 2020



RP6

- encourage and enable multidisciplinary approaches

Policy priorities

- Policy priority 1: increased recognition of international trade in biodiversity targets, goals, and policy
- Policy priority 2: increased communication of the impacts of food on biodiversity

Questions

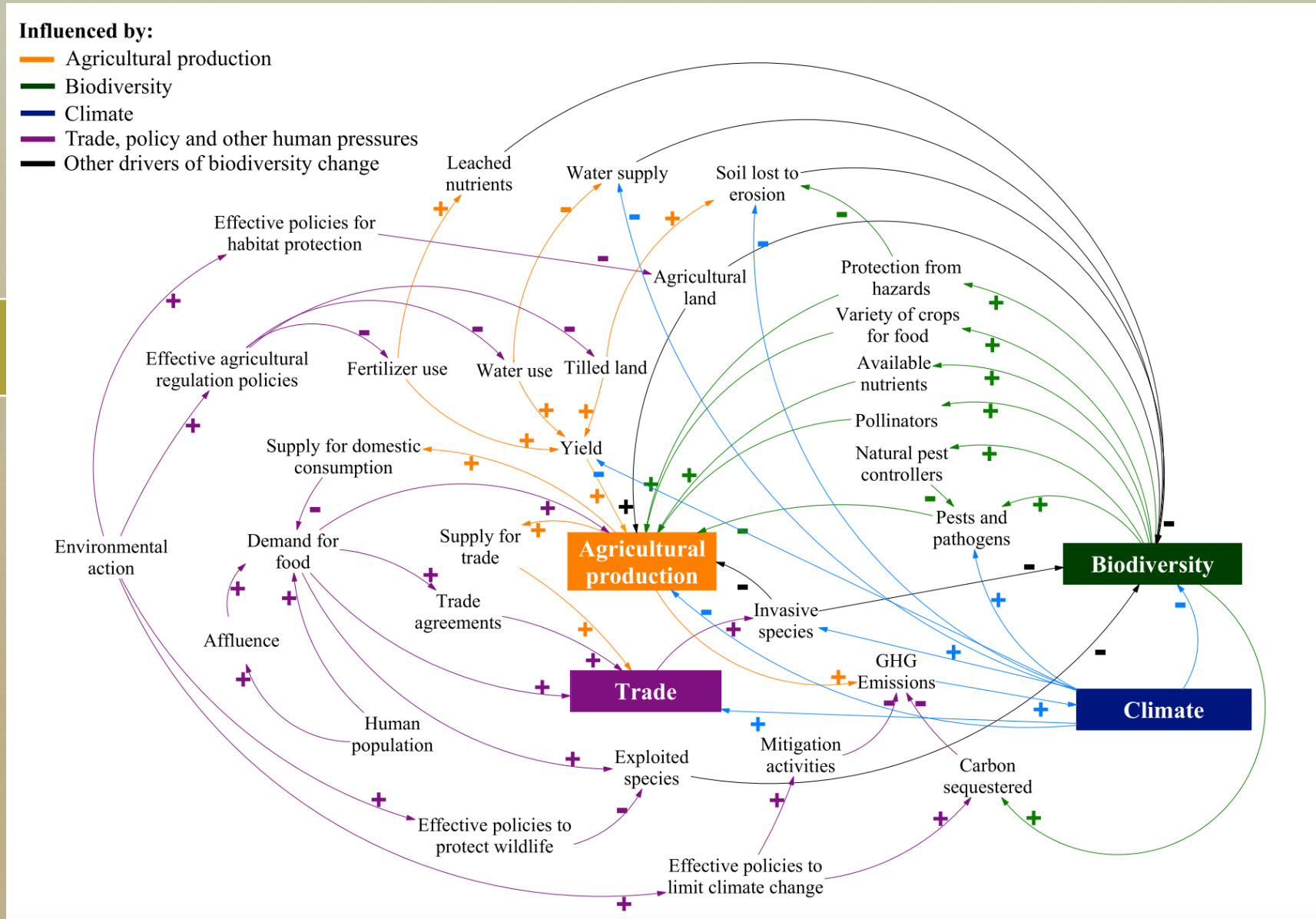
Discussion: Limitations of our review

- Little emphasis on social-cultural factors.
- Food system a social-ecological system (eg. Work of Elinor Ostrom).

Discussion

Choose one

- Where does gender come into the food system?
- Where do indigenous peoples participate in the food system?
- How does the youth come into the system?
- How do nature-based solutions and carbon offsetting programs affect the food system?



Solutions

GLOBAL DIETARY PATTERNS
NEED TO MOVE TOWARDS MORE PLANT-HEAVY DIETS

MORE LAND NEEDS TO BE PROTECTED AND SET ASIDE FOR NATURE.

WE NEED TO FARM IN A MORE NATURE-FRIENDLY, BIODIVERSITY-SUPPORTING WAY, LIMITING THE USE OF INPUTS.

(CHATHAM HOUSE REPORT, 2021)

Solutions

(1) incentives and capacity-building;

(2) cross-sectoral cooperation;

(3) pre-emptive action;

(4) decision-making in the context of resilience and uncertainty; and

(5) environmental law and implementation.

(IPBES)

Ultimately, we need action to make and meet goals for protecting nature, and thus protect ourselves.

Thank you!