

# Increasing Biodiversity in Farming Systems for Climate Resilience

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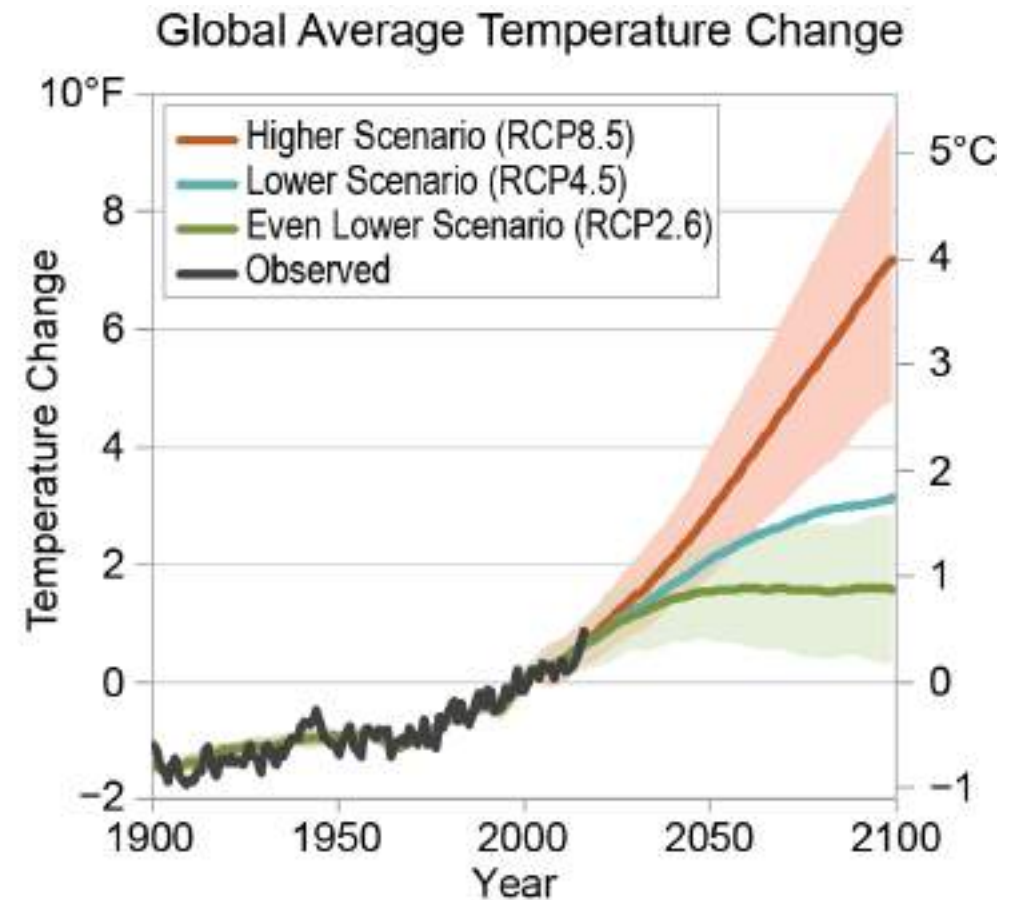
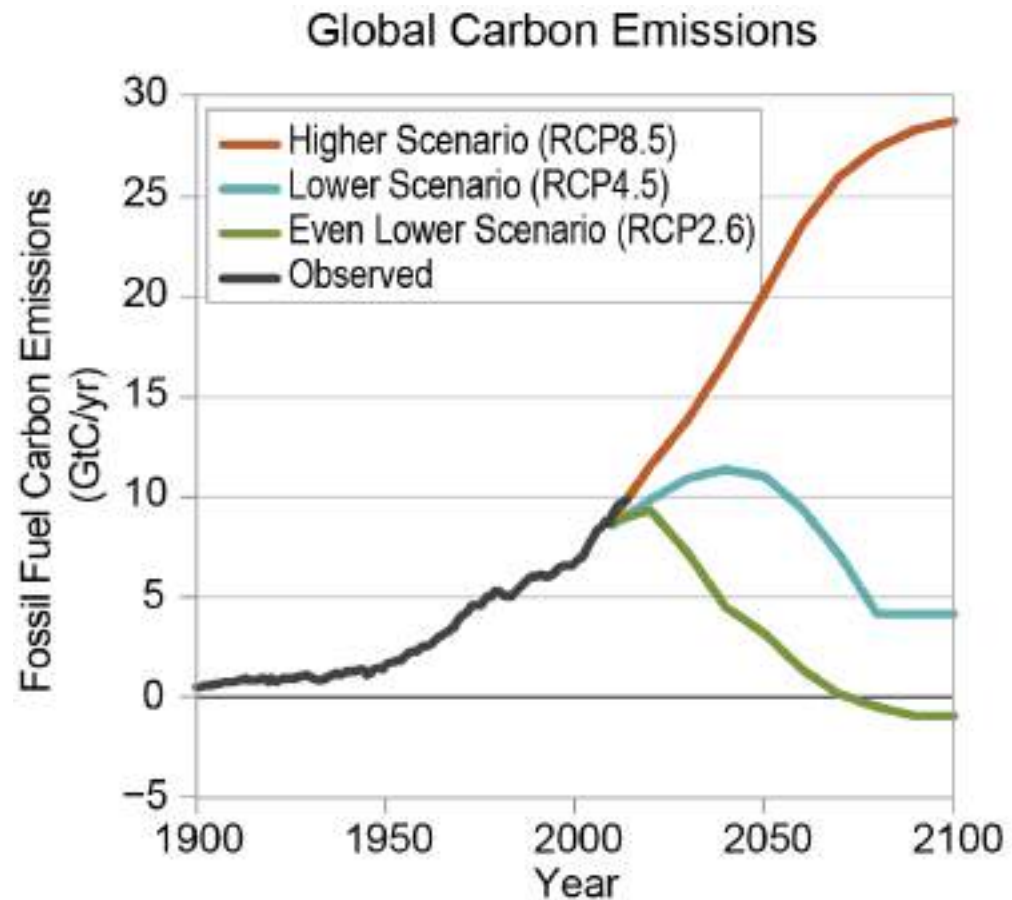
Climate Justice and Education Week

# Overview of the presentation: The challenge and the response...

- Review current predictions for climate change
  - Extreme climate events will increase
- Opportunities to create resilient farming systems
  - Diversification
    - *Functional diversity*
    - *Response diversity*
  - Enhancing ecosystem services



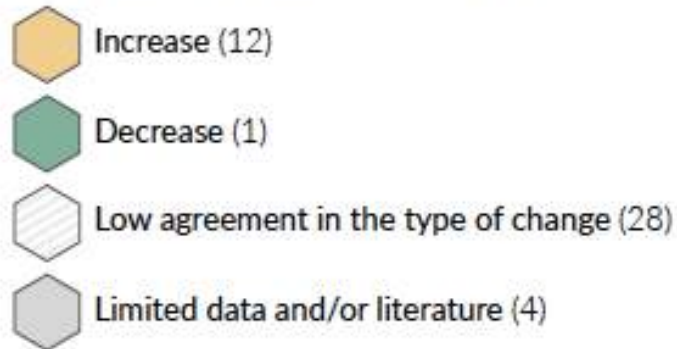
Projections for future climate currently track the “business as usual” scenario (RCP8.5). (Figure 2.2 in USGCRP, 2018, 4<sup>th</sup> National Climate Assessment)



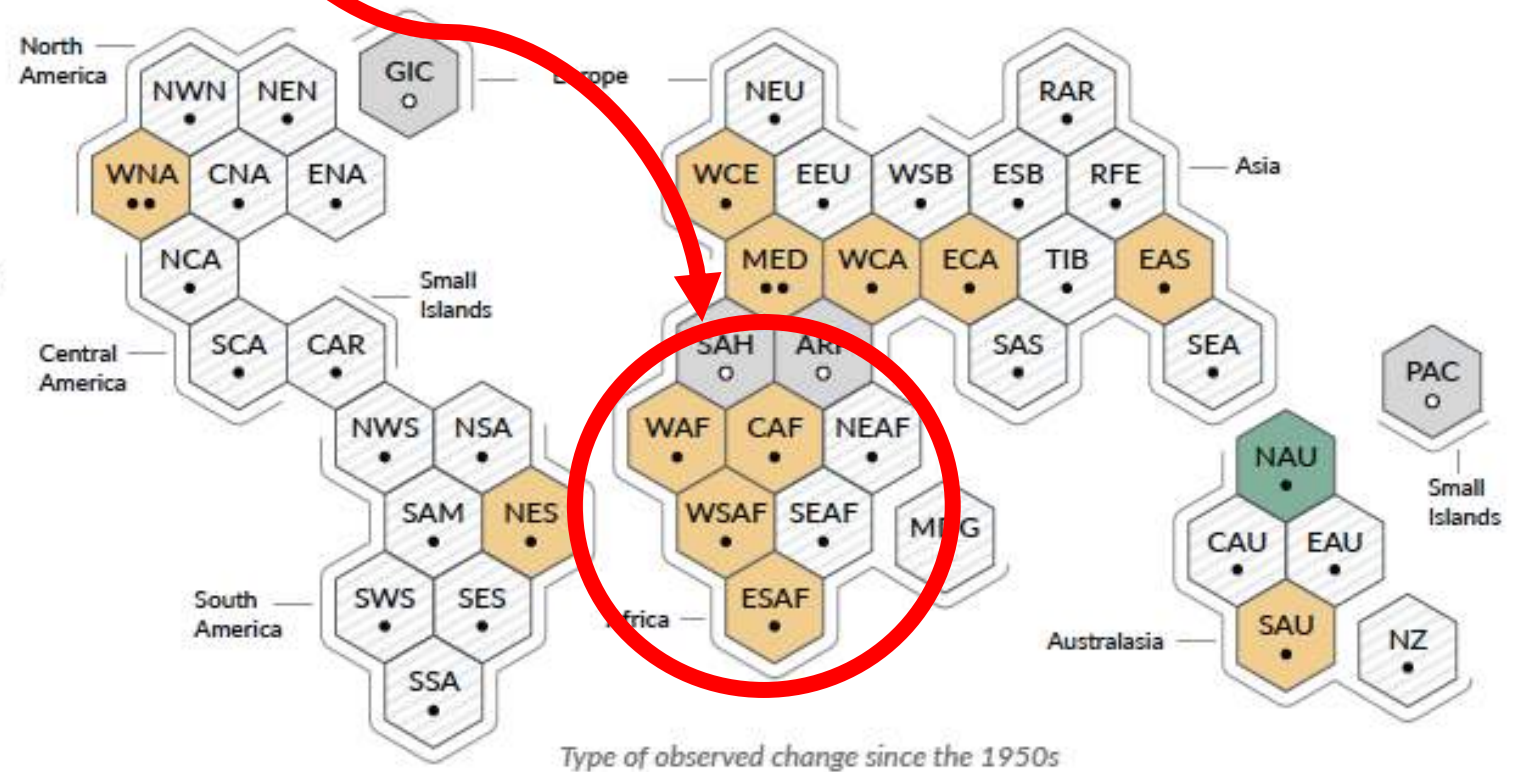
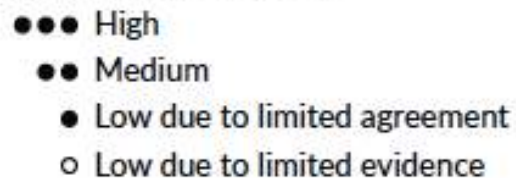
Climate is already changing: Most of Africa is showing *an increase in agricultural drought* (IPCC AR6 Summary for Policymakers, 2021).

(c) Synthesis of assessment of observed change in agricultural and ecological drought and confidence in human contribution to the observed changes in the world's regions

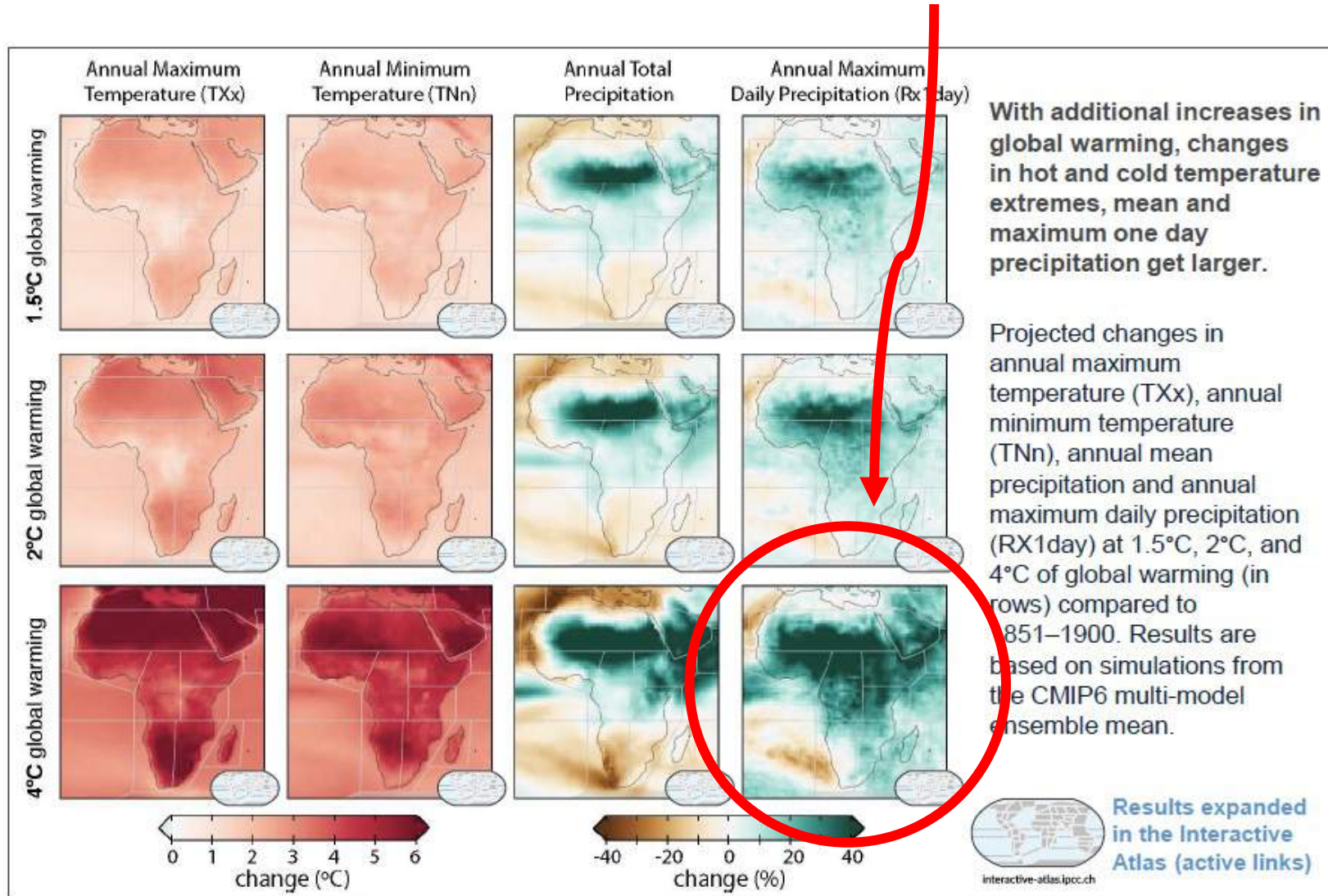
Type of observed change in agricultural and ecological drought



Confidence in human contribution to the observed change



# At the same time, models tell us to expect an increase in extreme rainfall events (IPCC AR6 Summary for Policymakers, 2021).



Crop yields have already declined by 10-15% in West Africa due to climate change according to an analysis by Sultan et al. (2019).

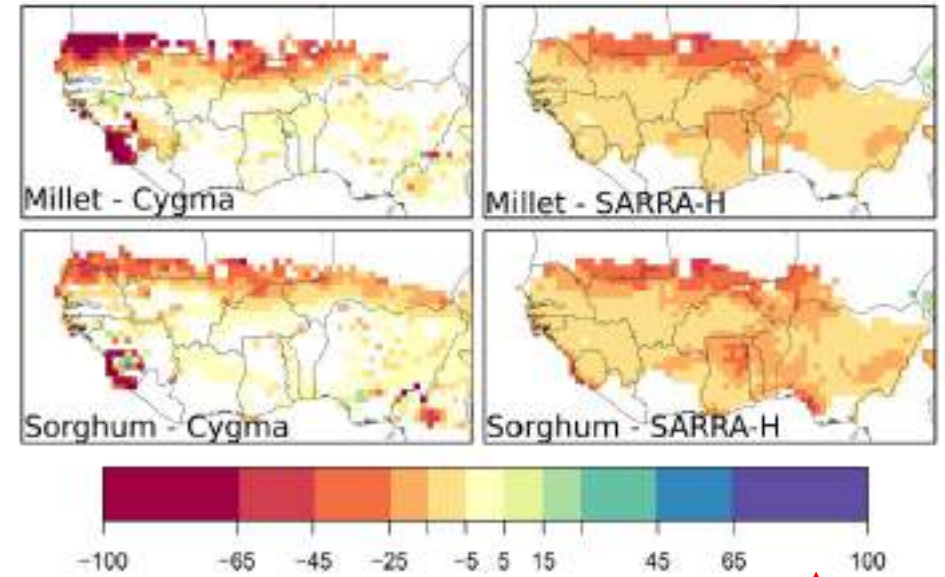


Figure 6: Mean and confidence interval for yield impact averaged across countries and West Africa as a whole for millet and sorghum.

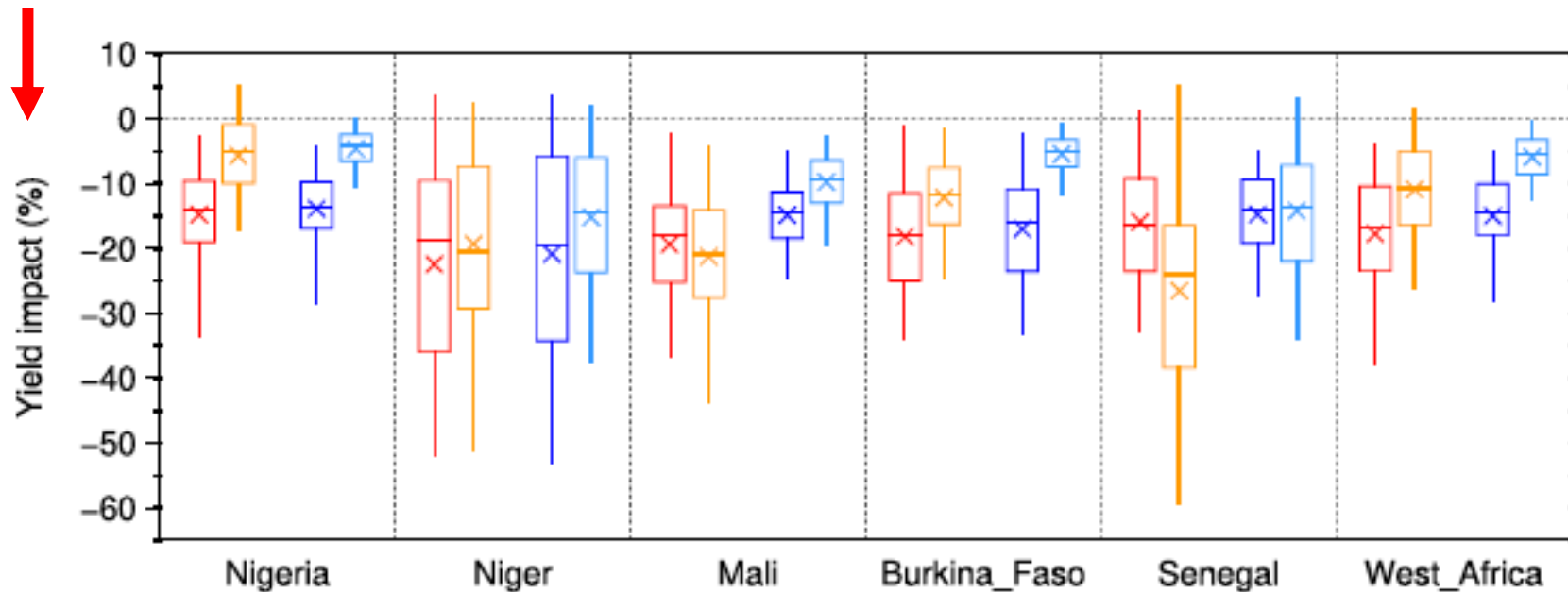


Figure 5: Change in yield in 2000-2009 relative to a “counterfactual” climate assessed with two crop models.

# Key lessons from the last 20 years:

1. Most important aspect of changing climate is increased ***extreme events***.
2. ***Building resilience*** is critical adaptation strategy



# 20<sup>th</sup> C approach to increase resilience in agriculture was technology

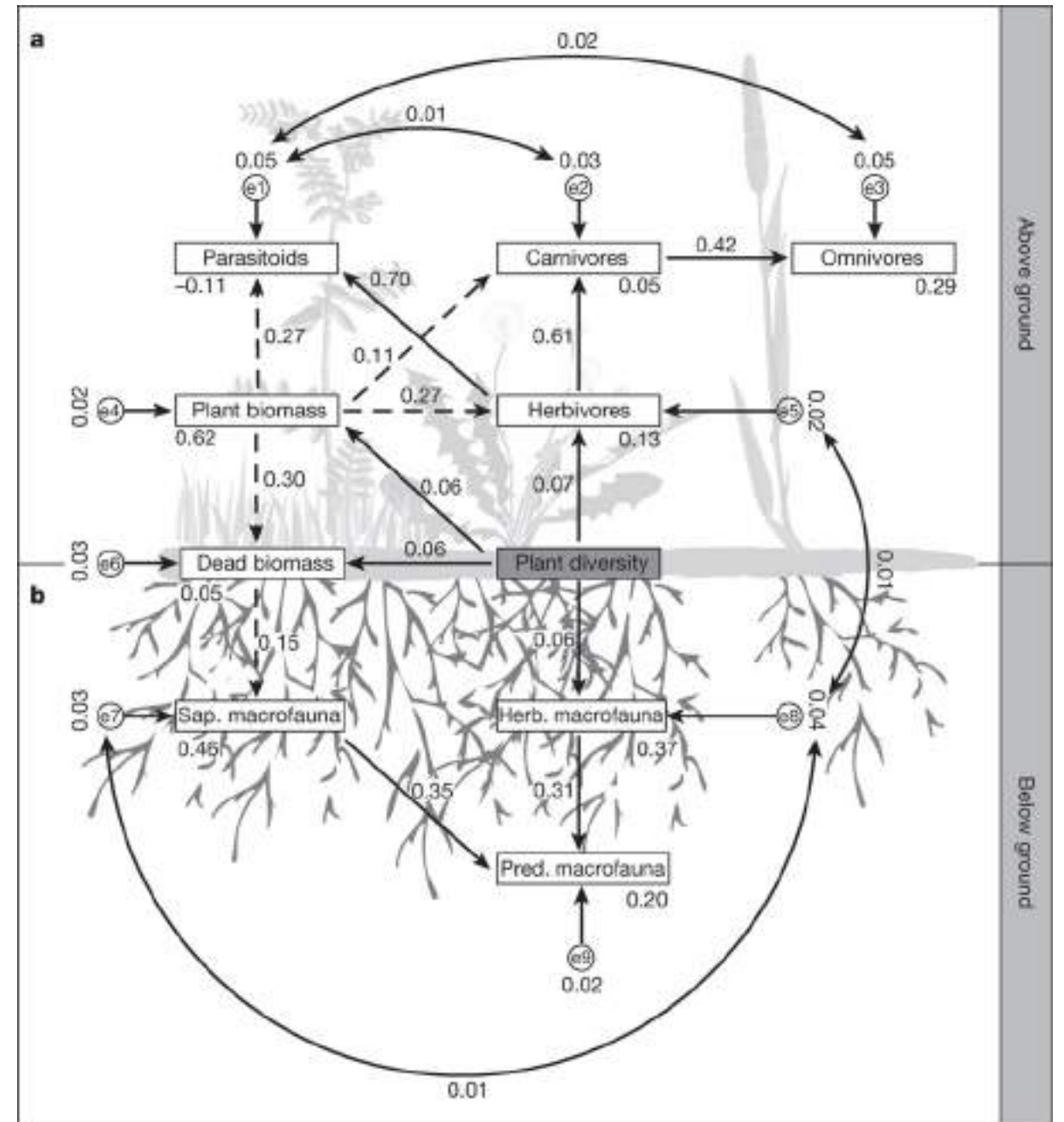
- The objective was to control as much as possible:
  - Irrigation
  - Chemical fertilizer
  - Herbicide and pesticides



In the 21<sup>st</sup> C, paradigm is shifting to an ecological model of resilience.

A healthy ecosystem is resilient to shocks and extremes. So how can we design farming systems on nature's model?

- Figure at right: Schuber et al., Nature 2010



# Resilient, multifunctional landscapes rely on two kinds of biodiversity:

## 1) *Functional diversity*

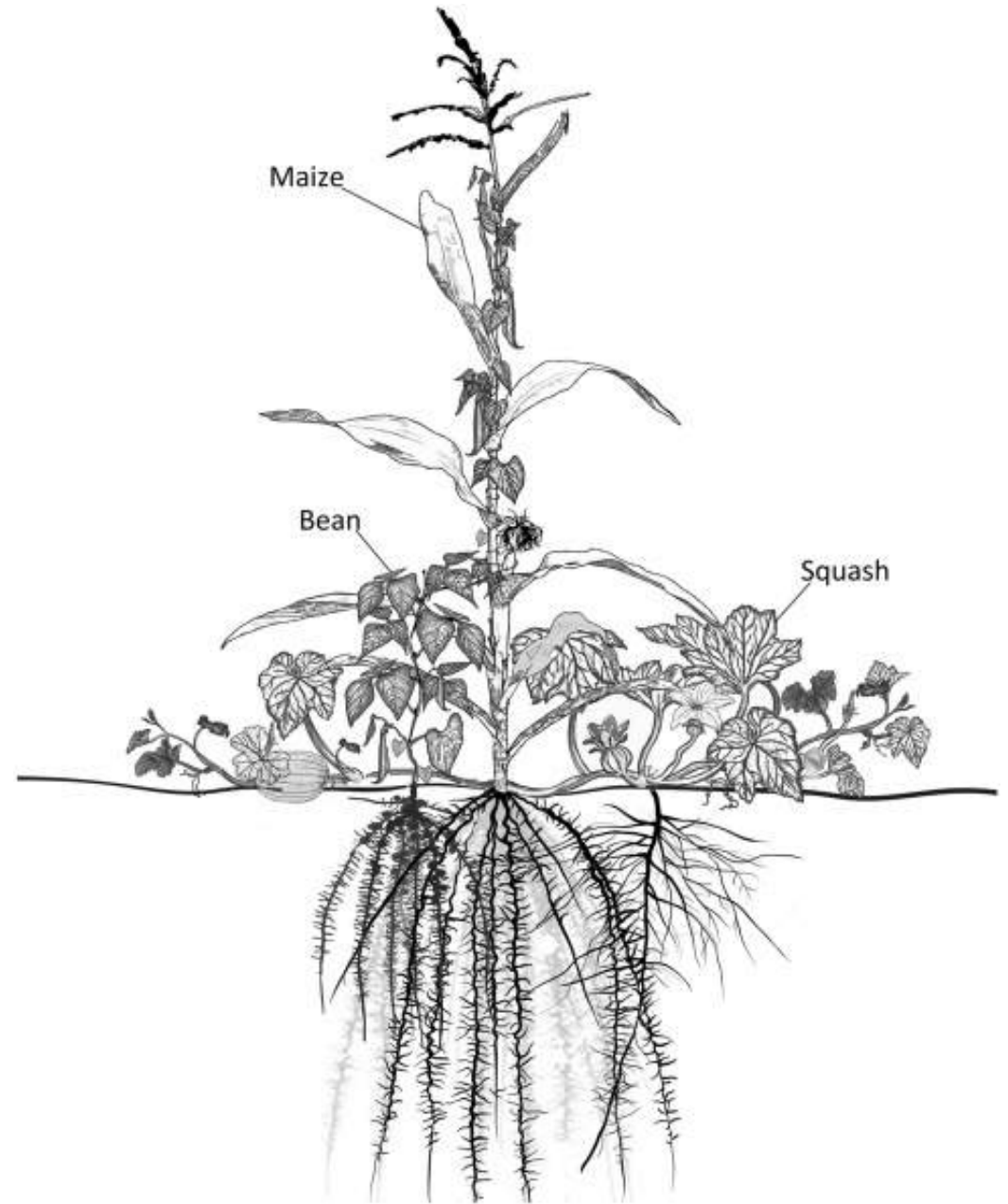
- Refers to diversity of functional traits included in a system
- Functional traits provide different services such as N-fixation, habitat for beneficial insects, carbon storage, etc.)

## 2) *Response diversity*

- Similar functional group, but differing in response to environmental drivers

*Functional diversity* provides provisioning, supporting and regulation services. An example is the “three sisters”.

The classic “three sisters” from American native cultures combines beans to fix nitrogen, squash to suppress weeds, and maize to provide scaffolding for the beans.

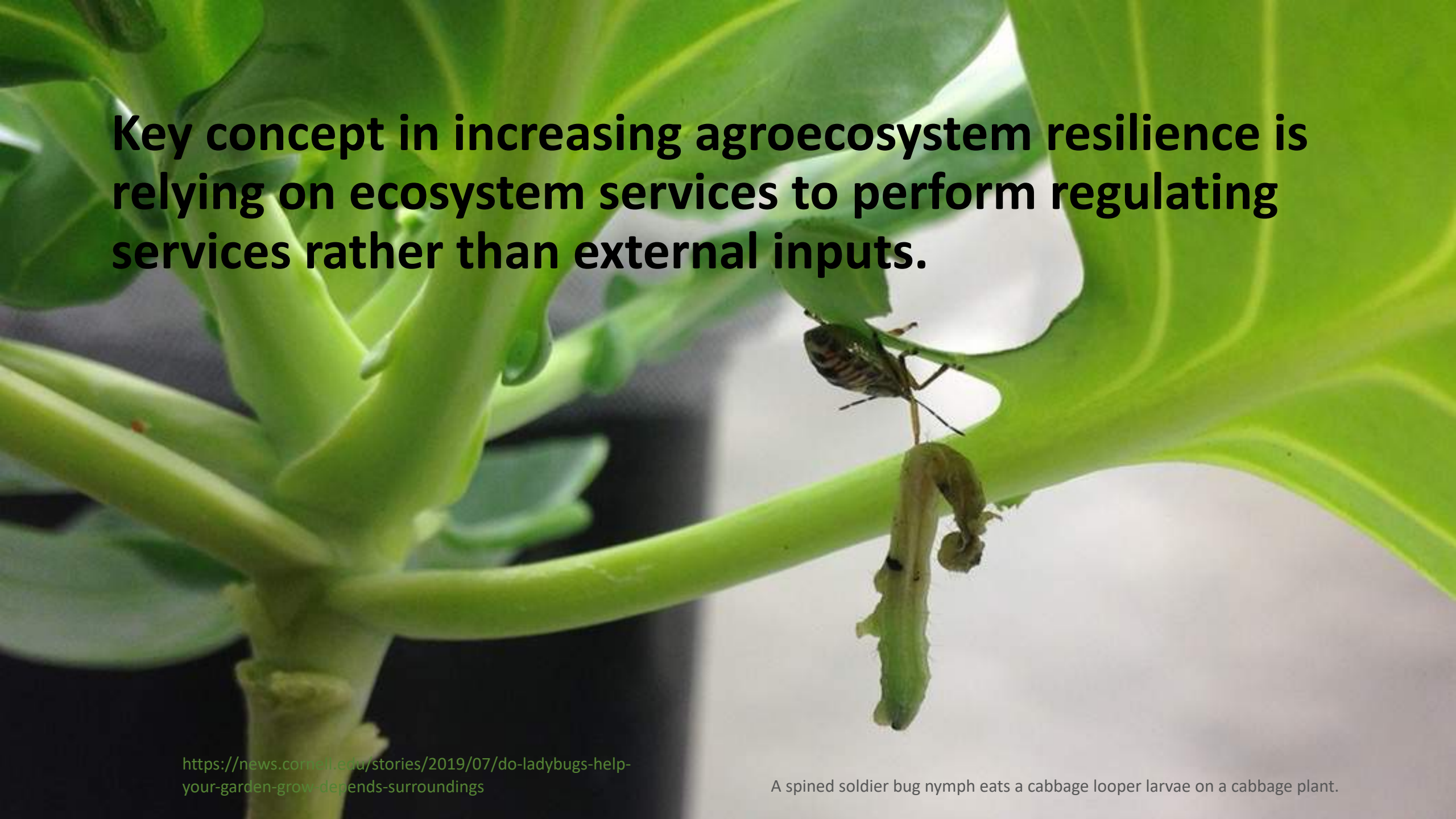


# Alley cropping with fast-growing N-fixing trees also an example of enhanced functional diversity.

- Trees provide fuelwood, livestock fodder, and nitrogen
- Structural diversity leads to physical protection, habitat, and microclimate “niches”
- Ecological interactions between species can lead to improved soil and plant health



**Key concept in increasing agroecosystem resilience is relying on ecosystem services to perform regulating services rather than external inputs.**



# The ecosystem services farmers rely on to perform regulating services mainly involve pest, nutrient and water regulation

- Primary examples include
  - Pest control
    - Supporting insect predators
    - Providing habitat for birds that eat insects
  - Nutrient management
    - C:N ratios manage nitrogen
    - N-fixing bacteria
    - Fungi that mobilize and transport N and P
  - Water management
    - Organic matter controls on infiltration and water holding capacity

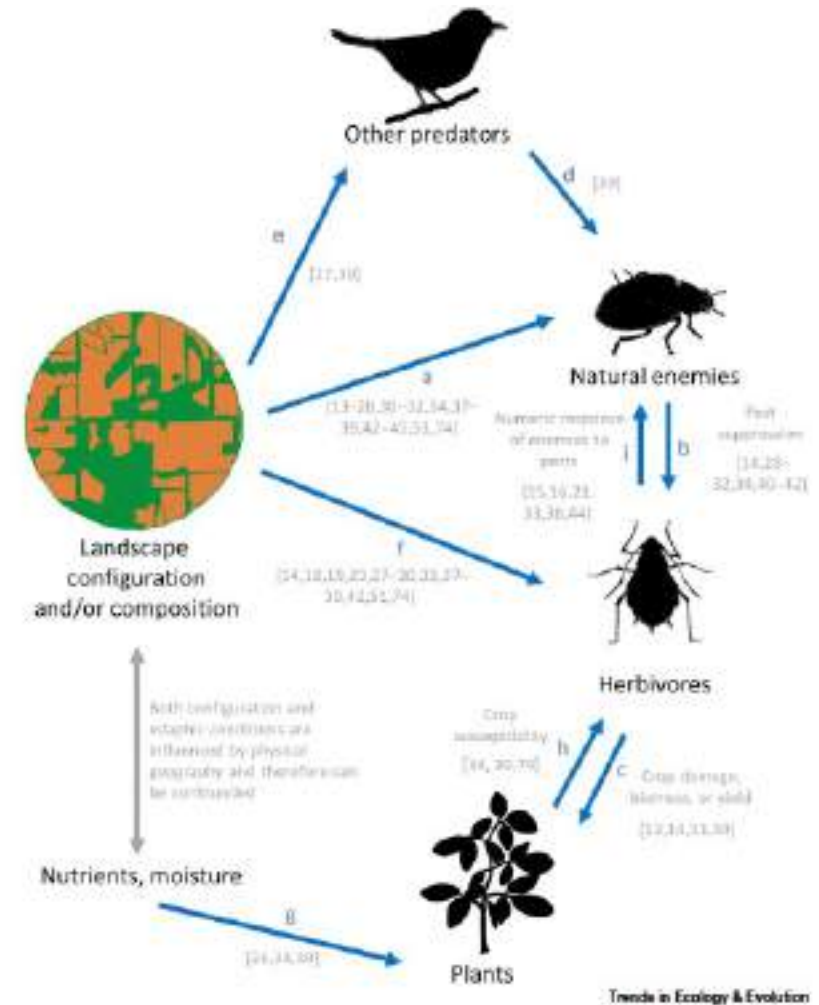


Figure 2: Viewing Pest Suppression through the Lens of Multitrophic Interactions Reveals Indirect Effect Pathways That Could Change Interpretation of Landscape Configuration Effects.

## Review

# Predicting Landscape Configuration Effects on Agricultural Pest Suppression

Nathan L. Hsen,<sup>1,2,4,\*</sup> Yajun Zhang,<sup>1</sup> and Douglas A. Landis<sup>1</sup>

# A biodiverse overstory in coffee or cacao systems provides a good example of these services.

- Higher pollinator populations lead to increased yields, a service worth \$1.7 billion per year

(Jha & Vandermeer, 2010; Ricketts et al., 2004)

- Natural pest control can increase yields up to 14%

(Kellermann et al., 2008; Karp et al., 2013; Staver, Guharay, Monterroso & Muschle, 2001; Williams-Guillén et al. 2008)

- Improved microclimate for coffee and cacao plants

(Siles, Harmand, & Vaast, 2010)



# Species included with coffee or cocoa provide additional benefits for small producers

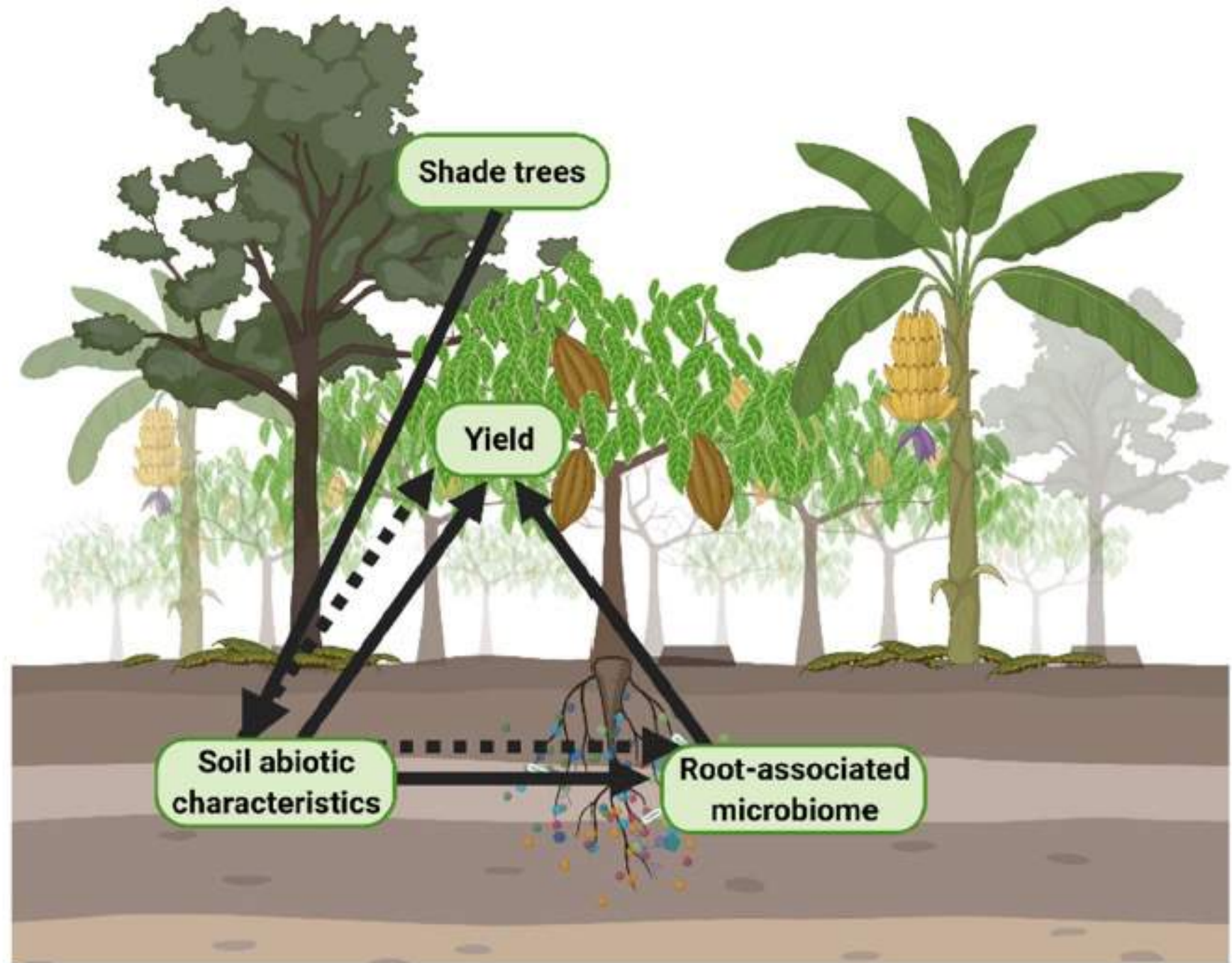
- Fruit
- Timber
- Fuelwood
- Medicinal plants
- Protection from extreme weather events

(Philpott, Lin, Jha, & Brines, 2008)



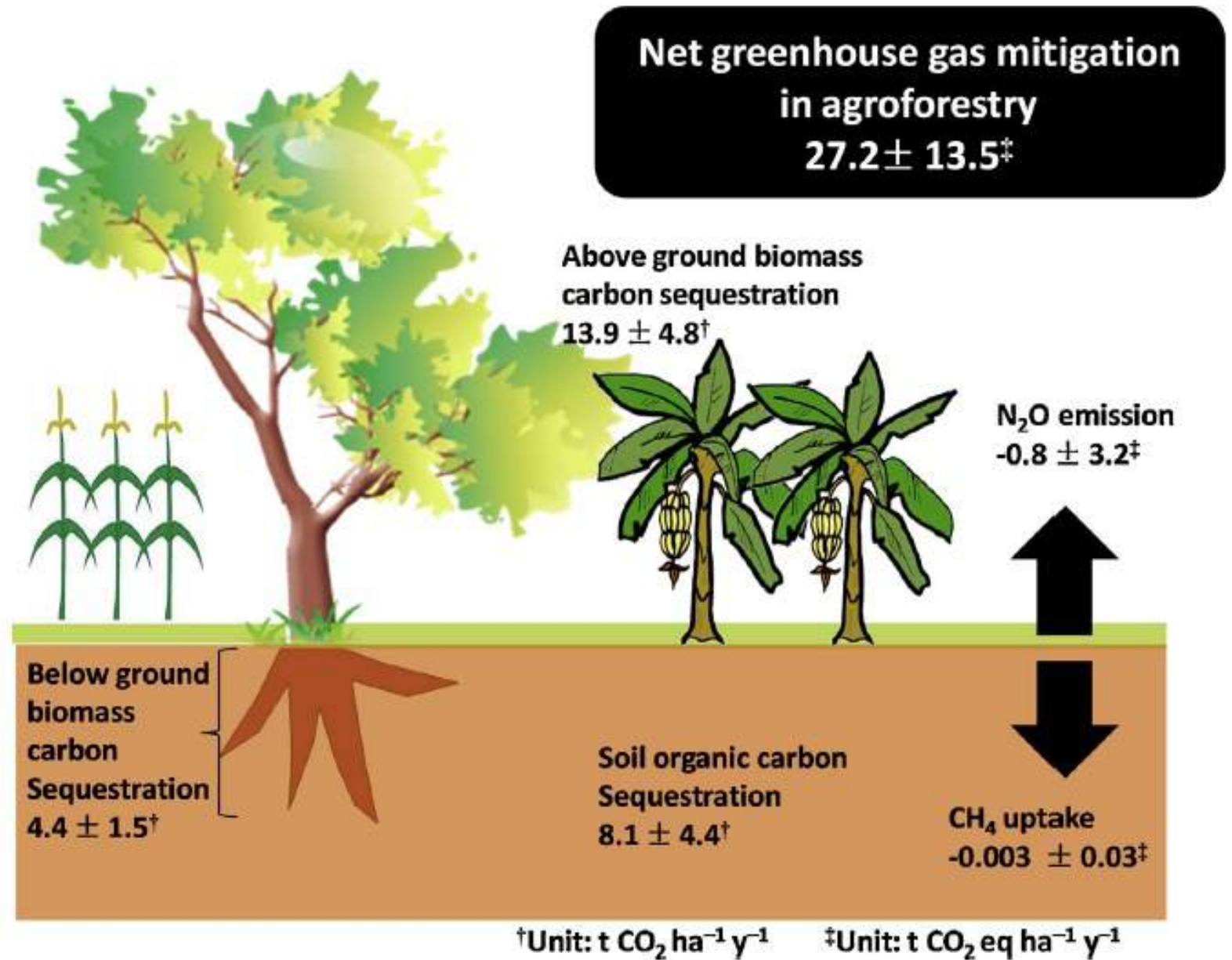
# Agroforest diversity also provides ecosystem services via soil health

The role of shade tree species in cacao agroforest is more complicated than just the amount of shade provided. Tree species influences soil nutrient fluxes and can improve yield indirectly (Schmidt et al. 2022, fig 7)



# Trees in farming systems not only store lots of carbon but also help reduce N<sub>2</sub>O emissions.

Estimated increase in rate of carbon sequestration due to change from agriculture to agroforestry (Kim et al. 2016). These estimates include the decrease in N<sub>2</sub>O emissions resulting from improved N-cycling.



***Response diversity* is having multiple crops that respond differently to climate extremes**

For example, maize and millet are not equal in sensitivity to drought. So planting them both provides insurance in case the season is drier than average.



***Response diversity*** can be accomplished with ***genetic diversity***, by planting multiple varieties of a single crop.

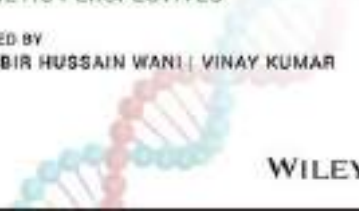


**Maize Handbook 2018**  
Maturity Class 10-13



**HEAT STRESS  
TOLERANCE IN PLANTS**  
PHYSIOLOGICAL, MOLECULAR AND  
GENETIC PERSPECTIVES

EDITED BY  
SHABIR HUSSAIN WANI | VINAY KUMAR



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# Landrace crops provide an important source of *response diversity*

With farmer-selected crop genetics, the high within-cultivar diversity in “landrace” crops may be particularly well suited to increase resilience to climate variability.




Product of conventional breeding



Product of traditional selection = “landrace”





**Biodiversity existing as genetic variation among cultivars of landrace crops provides a wealth of potential for use in crop breeding programs aimed at climate adaptation**

Example: in the study by Tadesse et al. (2019), the authors tested 197 spring wheat genotypes from the gene bank managed by ICARDA (International Center for Agricultural Research in Dry Areas) for Marker-Associated Traits for yield and heat tolerance. The cultivars associated with the identified genetic markers yielded 15% more than the rest of those tested. They have hence distributed 20 cultivars to national programs throughout Africa.

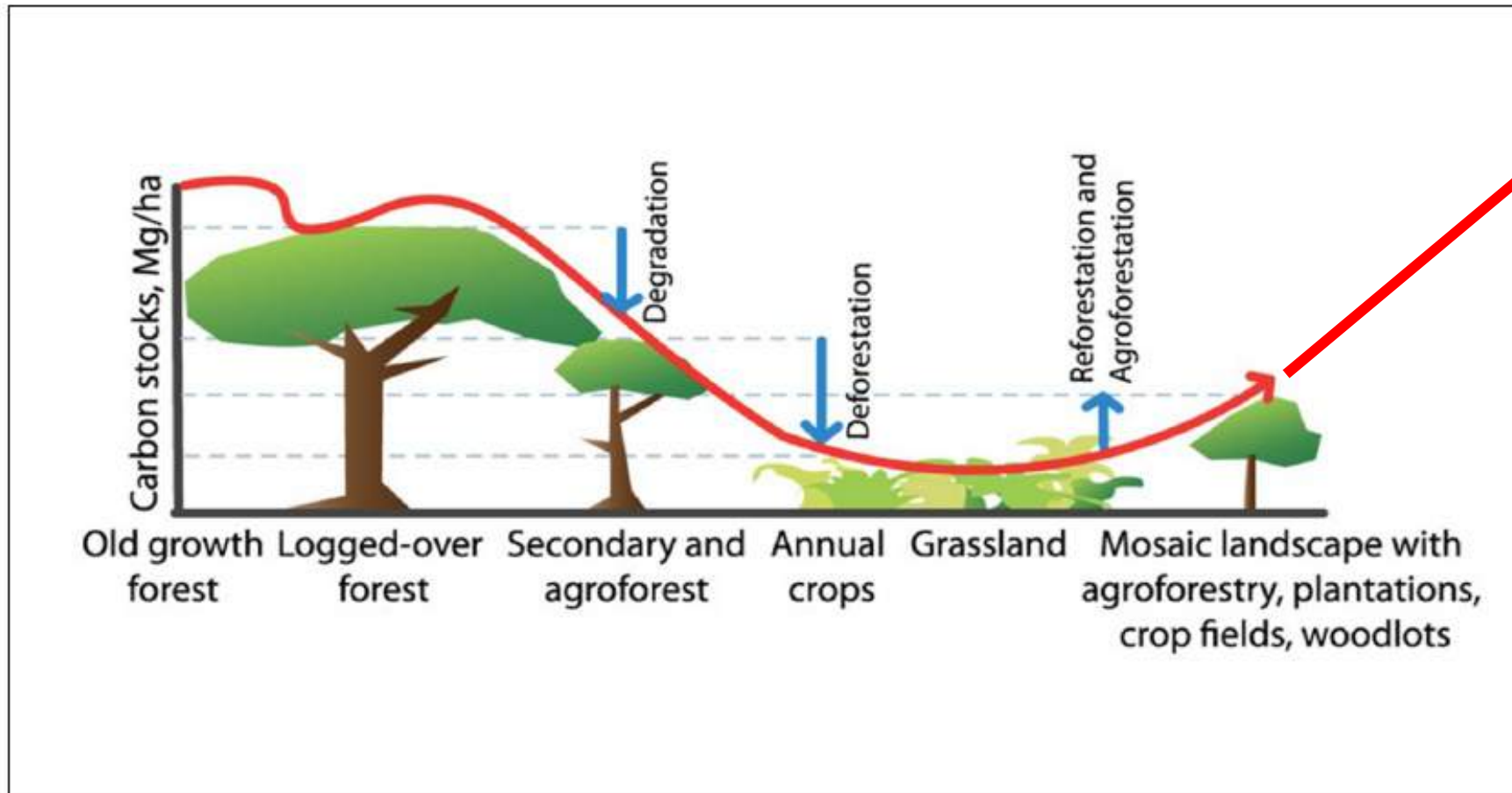
CROP SCIENCE, VOL. 59, JANUARY–FEBRUARY 2019

WWW.CROPS.ORG

## **Heat-Tolerant QTLs Associated with Grain Yield and Its Components in Spring Bread Wheat under Heat-Stressed Environments of Sudan and Egypt**

W. Tadesse,\* S. Suleiman, I. Tahir, M. Sanchez-Garcia, A. Jighly, A. Hagra, Sh. Thabet, and M. Baum

# The pathway to the future of resilient rural livelihoods and food security in the face of climate change is through embracing biodiverse, ecological farming systems



A photograph of an agroforestry system. In the foreground, there are neat rows of young green plants, possibly lettuce or similar leafy greens, growing in a field. The plants are spaced out, and there are dark mulch or plastic covers between the rows. In the background, a dense line of tall, thin trees with green foliage stands against a blue sky with some light clouds. The overall scene is vibrant and healthy, illustrating the integration of agriculture and forestry.

**Thank you!**