Aerospace Information Research Institute (AIR)
Chinese Academy of Sciences (CAS)

Crop Diversity Monitoring by Remote Sensing

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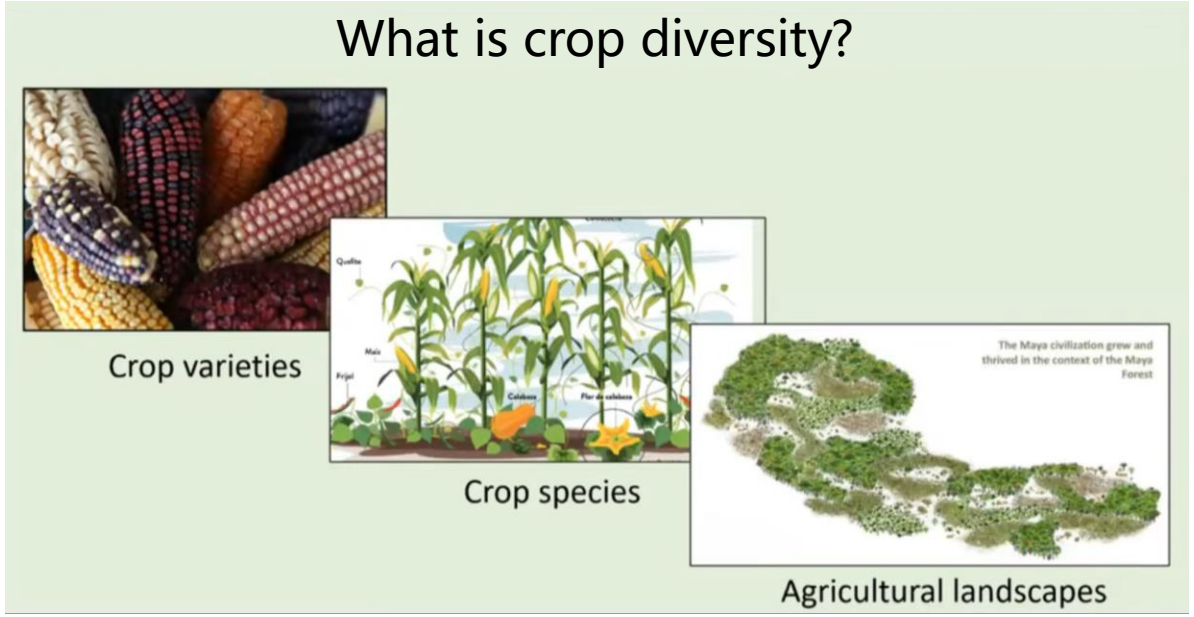
Large-scale intensive agriculture

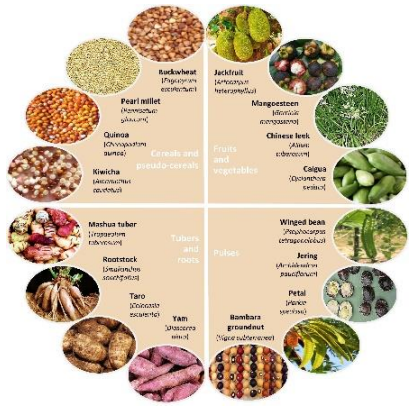
Large-scale intensive agriculture is the main trend to feed a growing global population, however, it might simplify agricultural systems, reduce biodiversity, and potentially lead to ecological instability

Crop Diversity

Crop diversity: planting of different crops across spatio-temporal scales

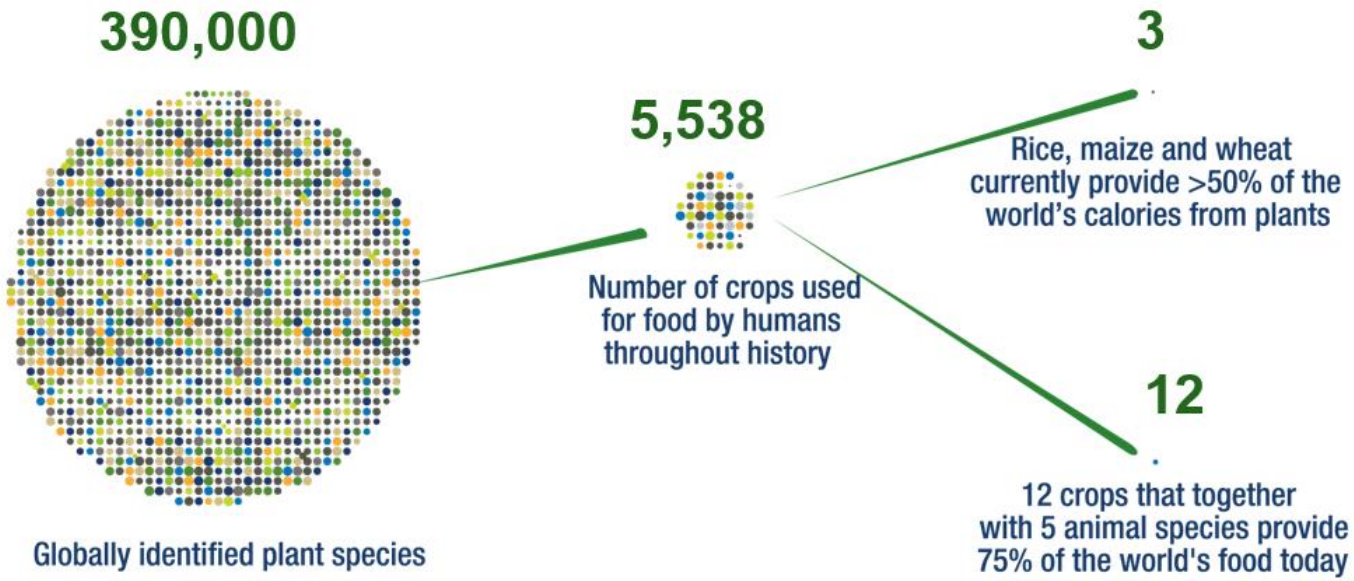
- Varieties of one crop (different species of tomatoes) and genetic (within varieties)
- Crop types (planting tomatoes, carrots, lettuce and beans on the same farm)
- Agricultural landscapes



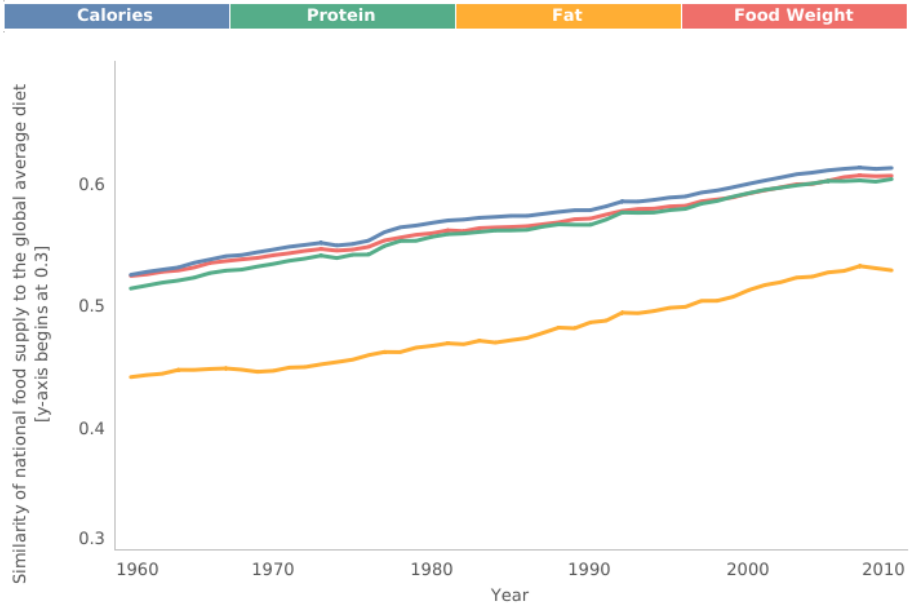


Losing Crop Diversity

- **75% of crop genetic diversity and some traits disappeared in the 20th century**
  - **3 staple crops provide more than 50% of the world's calories**
  - **12 crops with 5 animals provide 75% of the world's calories**
- **Food supplies and diets became more similar worldwide**



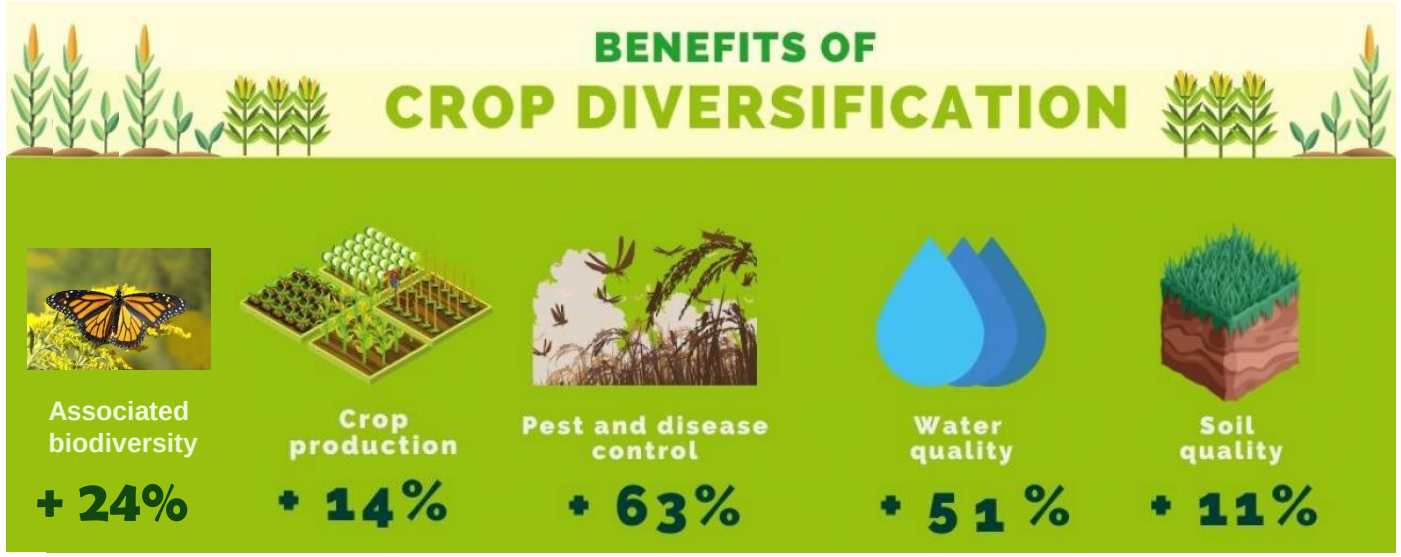
FAO 2009



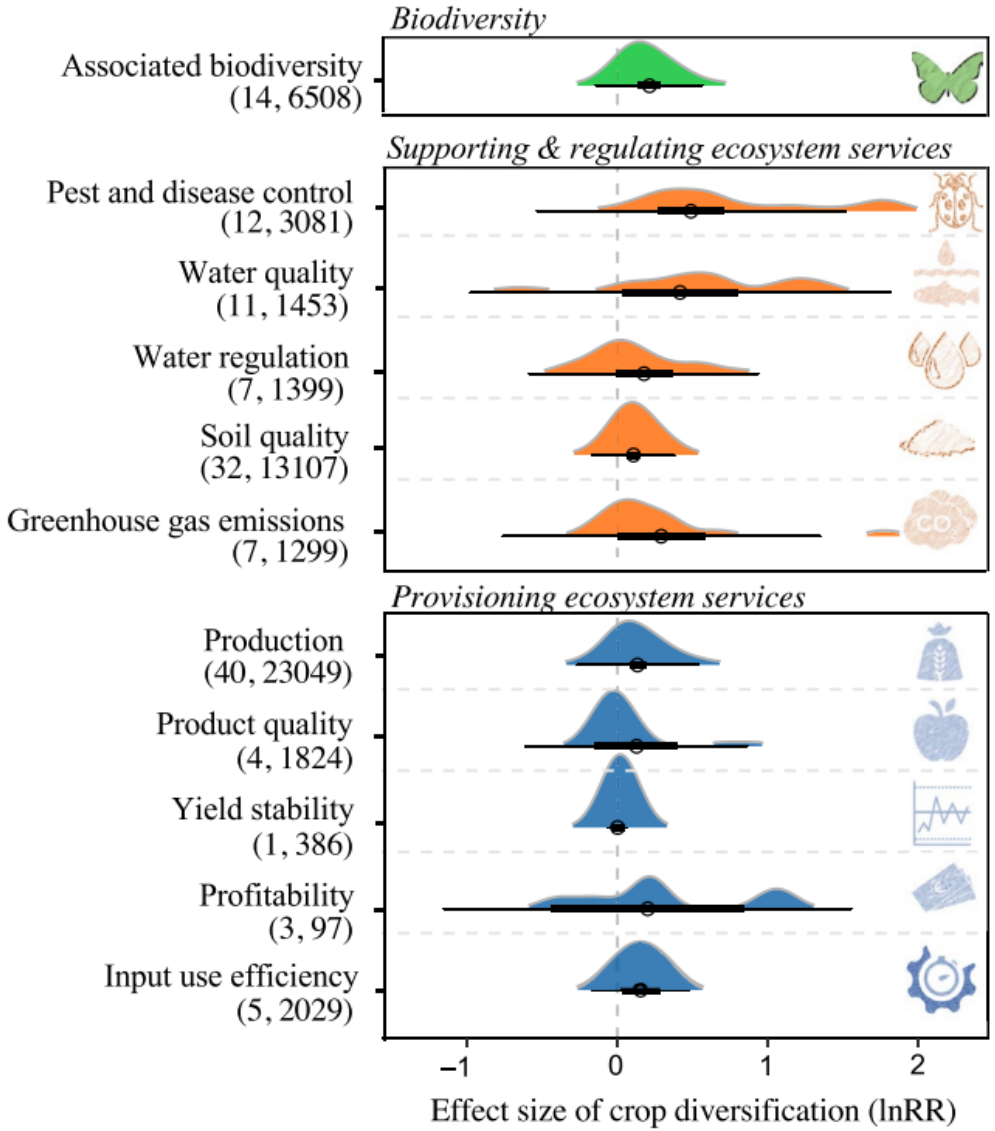
Khoury et al., 2014, PNAS

Crop Diversity is important

- **We need to preserve crop diversity for three reasons**
  - the need for genetic diversity to protect the world's food supply
  - the impact of diversity on the resilience of agricultural ecosystems
  - the contribution of diversity to nutrition and health



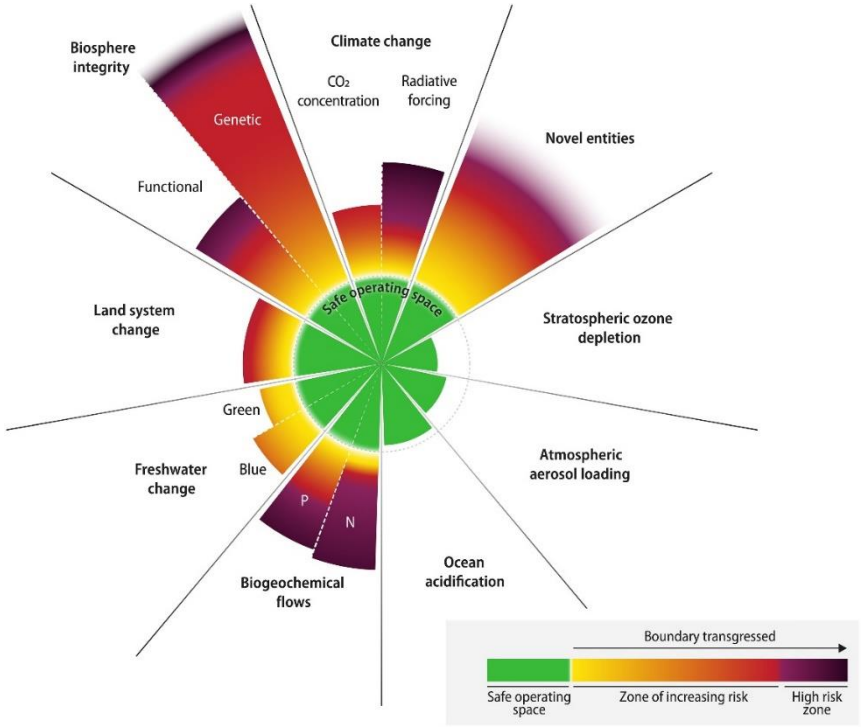
Beillouin et al., 2021, GCB

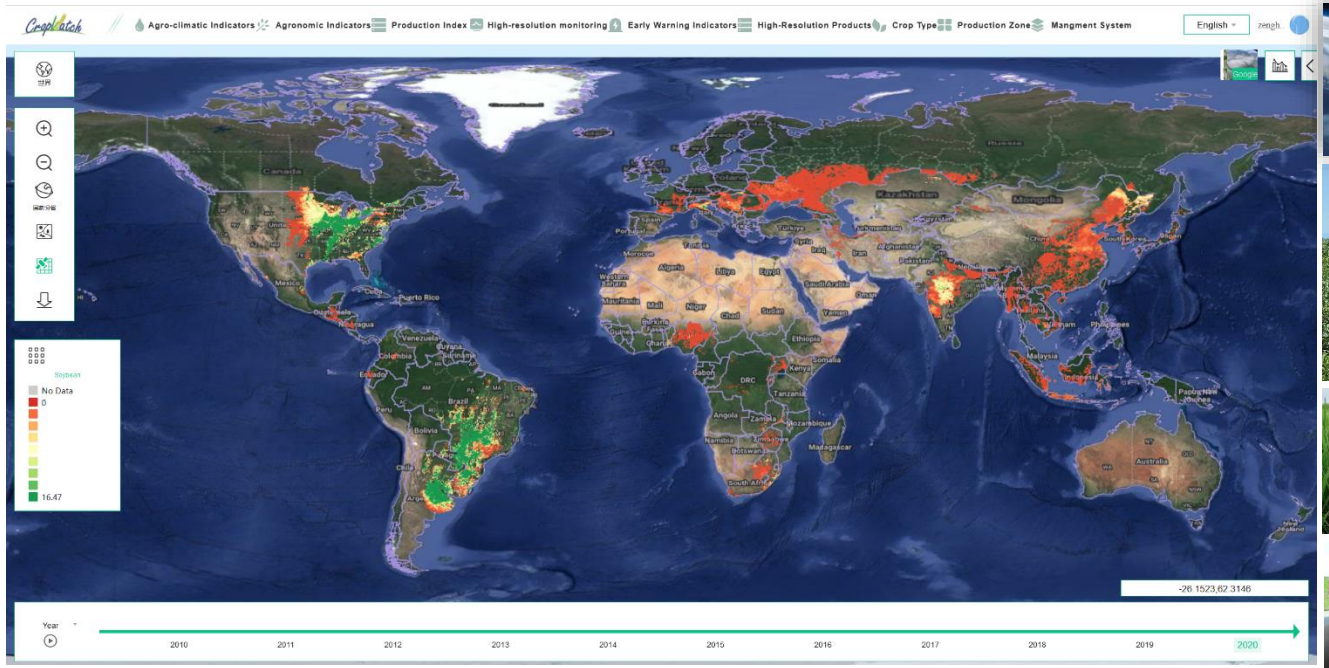


Urgency of Crop Diversity Monitoring

Prospects: EO data can support crop diversity monitoring at field-air-space scales

Obstacles: Identifying crop varieties or genetically modified crops remains challenging





CropBio Project

- UNESCAP and AIRCAS jointly introduced the CropBio project, Dec. 2023 in Kunming
- Core participant countries: China, Malaysia, Indonesia, Philippines
- The CropBio project inception meeting was hosted in June, 2024 in Malaysia
- Investigate crop diversity and comparatively evaluate its implications in South-East Asian study sites through innovative space applications

Regional Forum on Geospatial Information Applications for Resilient Agriculture in South-East Asia (Dec. 2023)

CropBio Project Inception Meeting & Field Demonstration (June 2024)

CropBio – Study area in China

Ganlanba (GLB), Yunnan, China

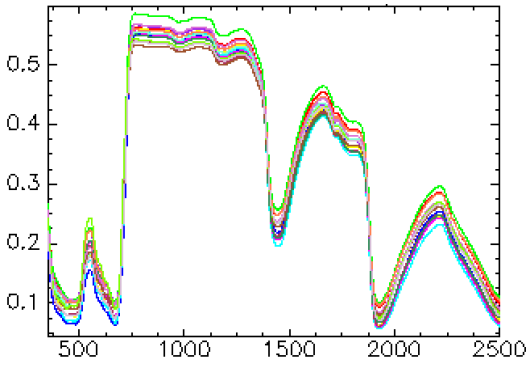
- **Biodiversity & cultural hotspot**
- **Temp: 7-21.8℃, Rainfall: 1067.9mm**
- **A wide variety of tropical fruits**
- **Interests of relevant policymakers**
- **Development benefits**

  Improve farmers' awareness and encourage them to protect local varieties

Field – UAV & Spectra & Traits

- DJI Mavic 3 Multispectral drone

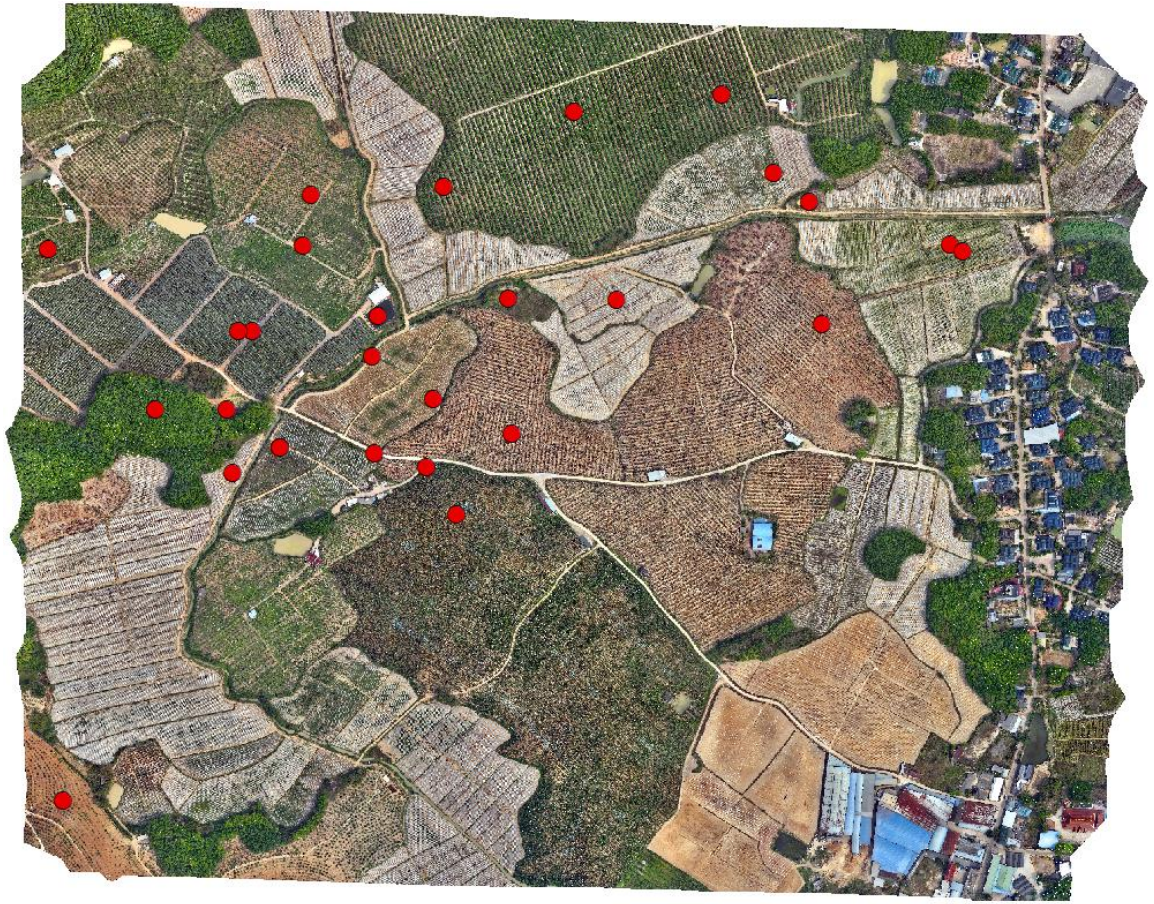
Time: April 2024

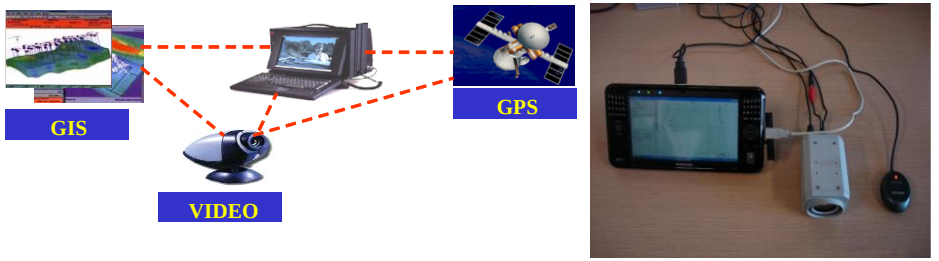


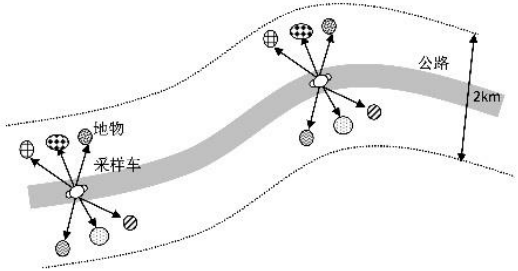
About 1x1km

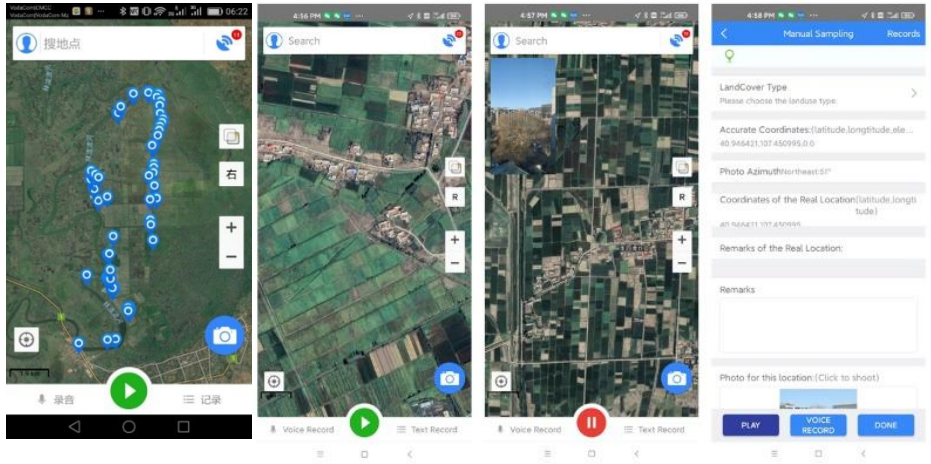
Field - GVG Sampling points

Crop type and species sampling







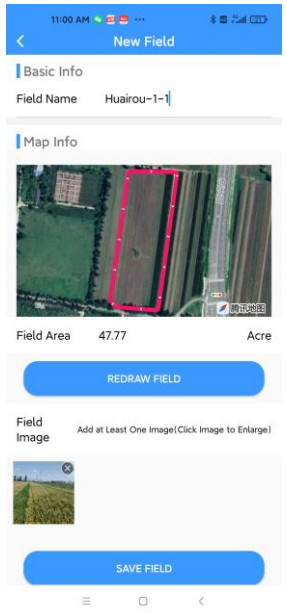


Field – FieldWatch Sampling boundary

Draw field boundary manually or by walking

Key functions:

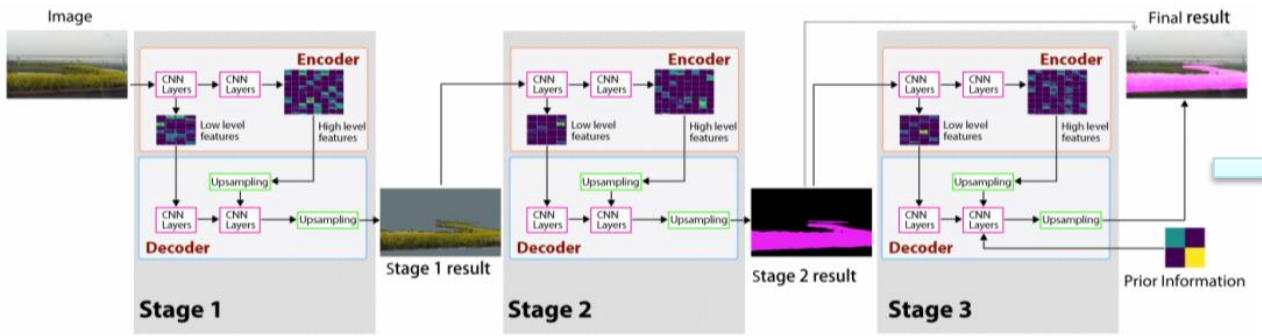
- Add a new field
- Forecast crop yield
- Show crop growth conditions of the field
- Show the weather conditions of the filed
- Recognize pest from smart phone image
- Show historical RS images of the field
- Record farming activities in the field



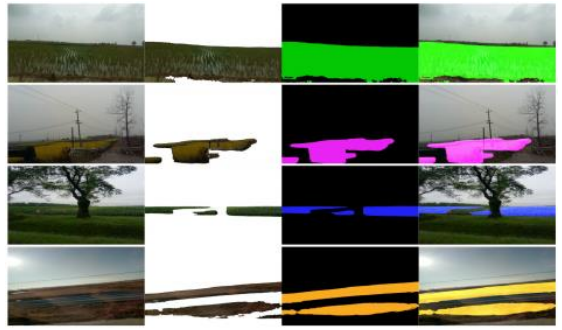
Field - Database

Mobile application can also identify crop type and varieties by deep learning model to build local crop type & species database

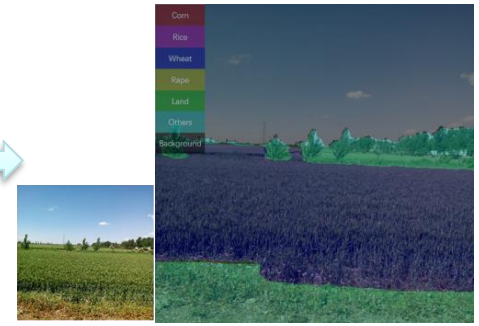
Wu et al., Sensor, 2021



The framework of crop type identification in GVG crowdsourced crop photos

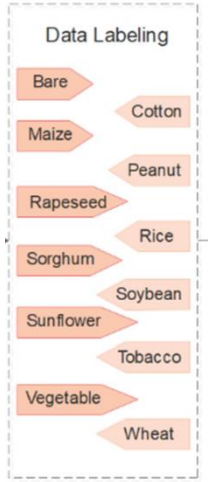


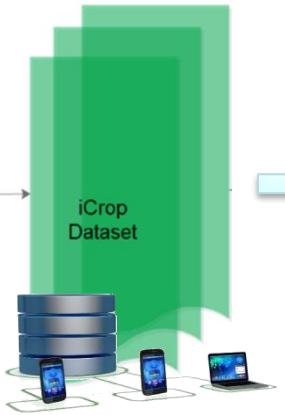
Segmentation of photos



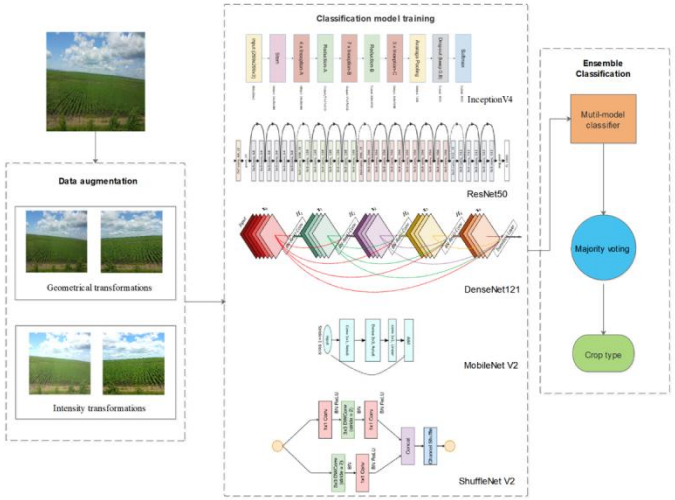
Classification results

GVG crop photos collection & labelling





iCrop Dataset



CNN model for crop photo classification

Categories	Voting-5
Bare land	85.3
Cotton	84.7
Maize	95.3
Peanut	72.7
Rapeseed	96.1
Rice	95.7
Sorghum	73.0
Soybean	86.8
Sunflower	70.5
Tobacco	77.1
Vegetable	86.5
Wheat	92.8
Average accuracy	91.1

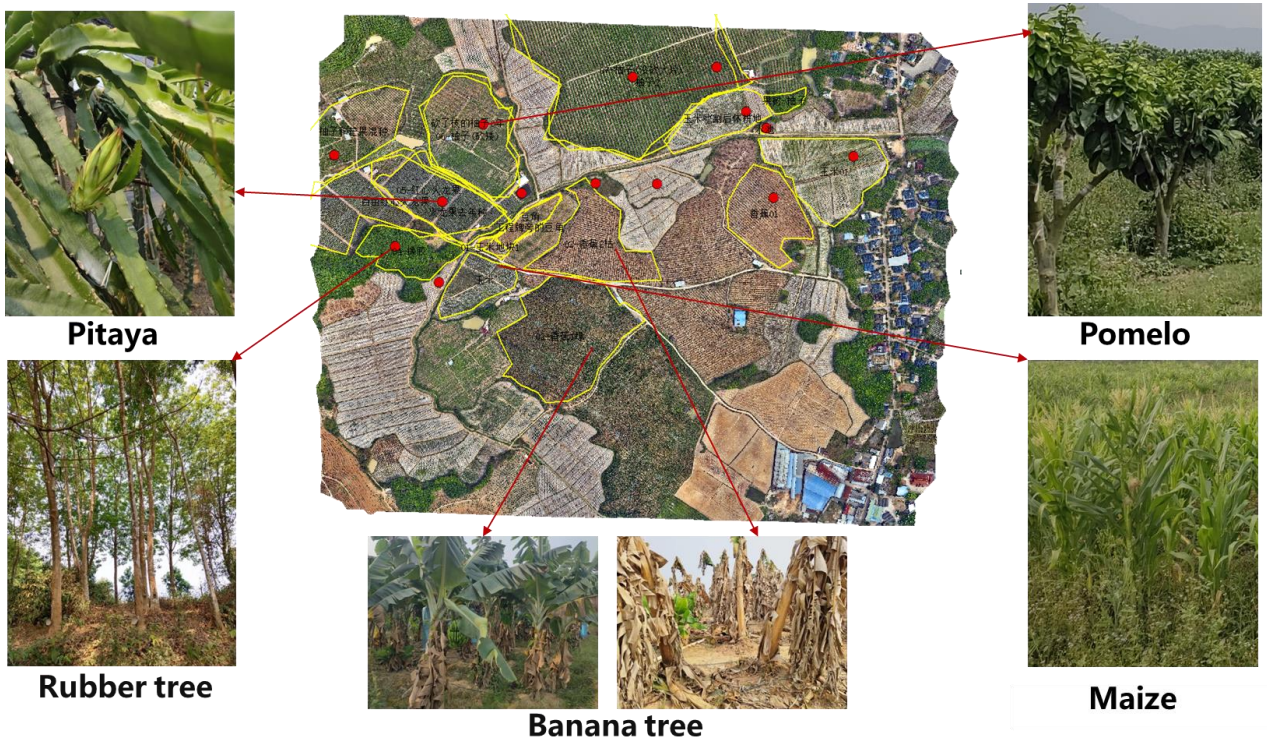
Accuracy

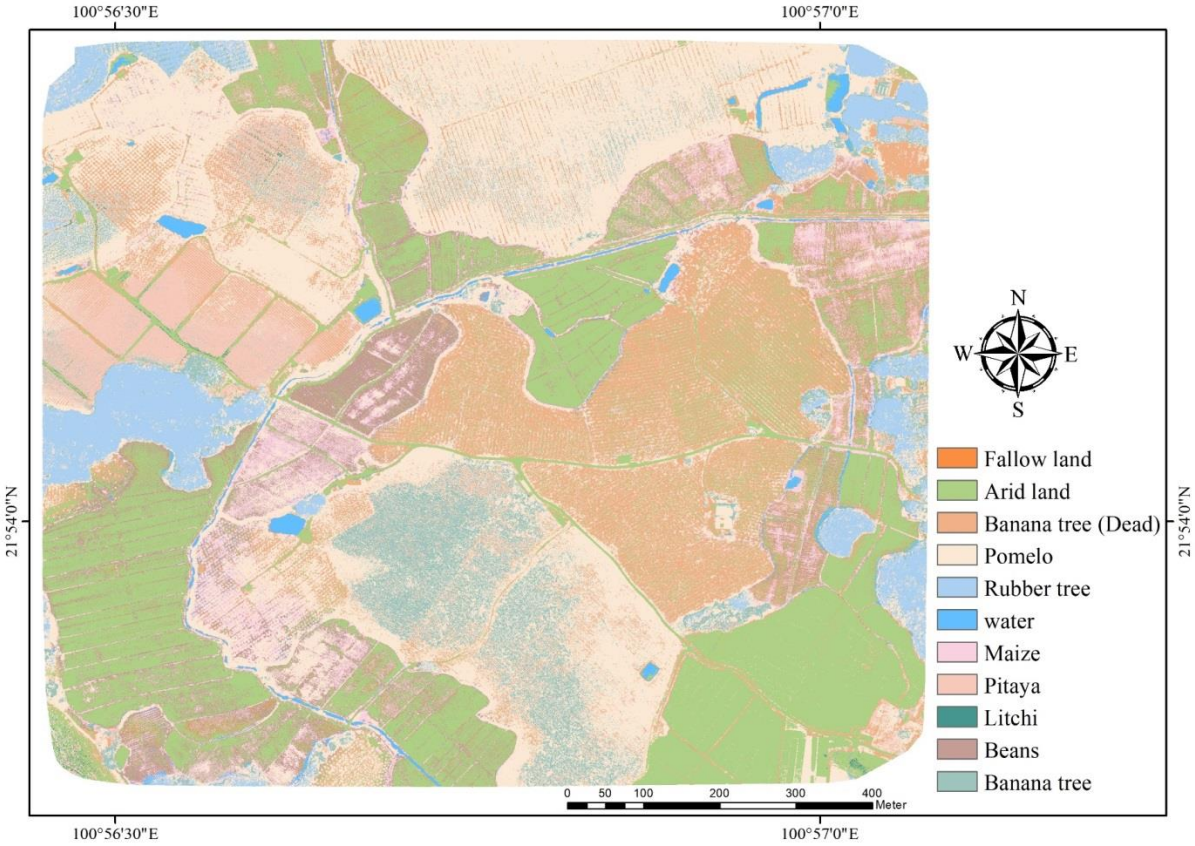
Monitoring – Crop types

Pixel-level classification methods

Variable selection (31 variables to 6 important ones)

Random forest model for classification at pixel level



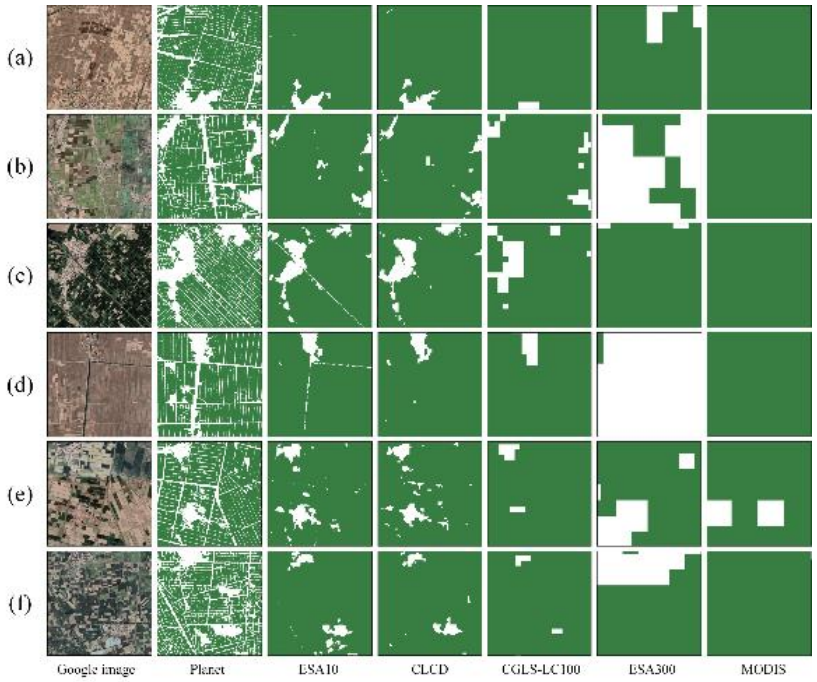


Monitoring – Crop types

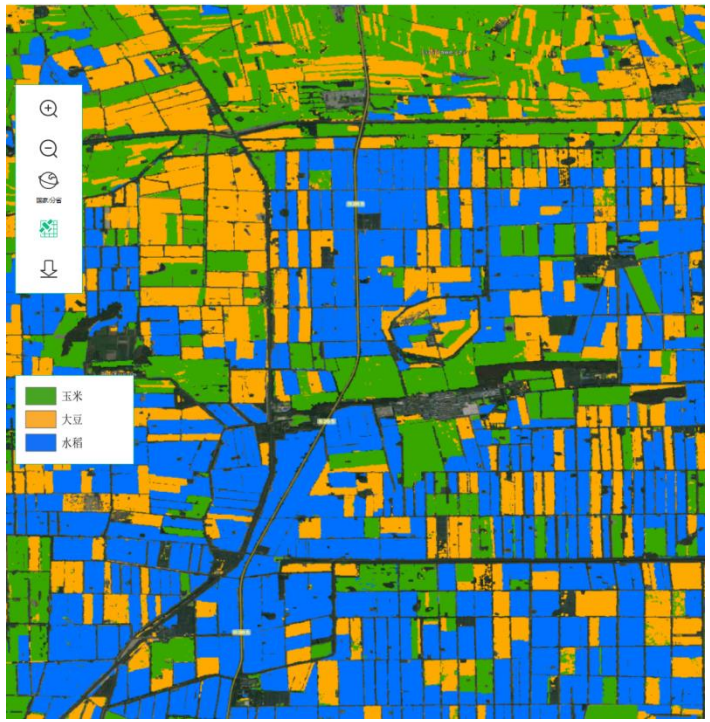
Cloud-based classification methods

1. Parcel segmentation 2. Random forest 3. Self-organized learning …

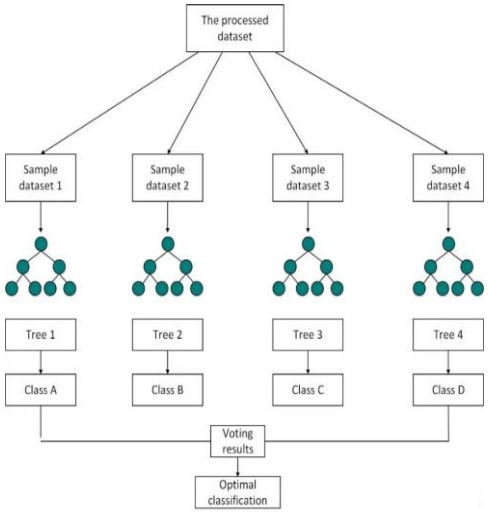
Tian et al., GIScience & remote sensing,2023



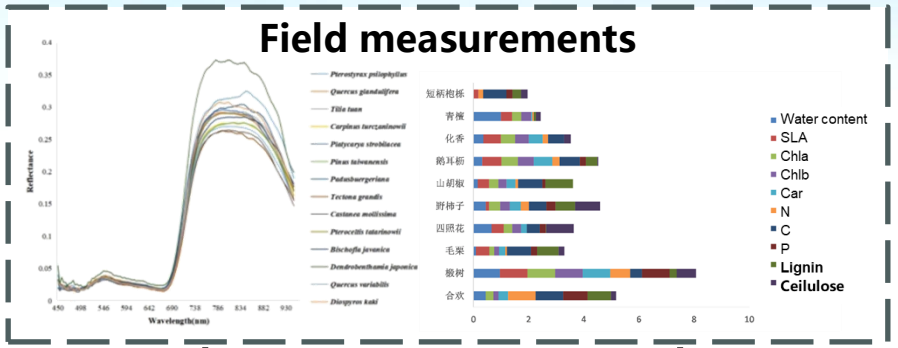
High-resolution parcel segmentation over large areas

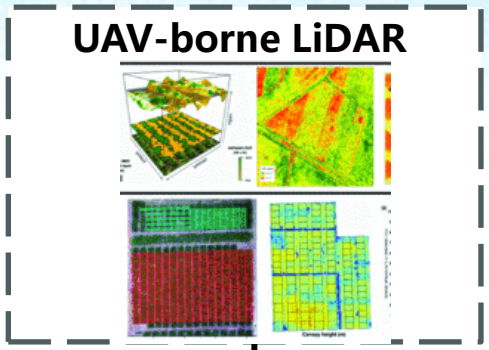


Parcel-based fine classification



Monitoring – Crop species diversity





Leaf spectra

Leaf biochemical variables

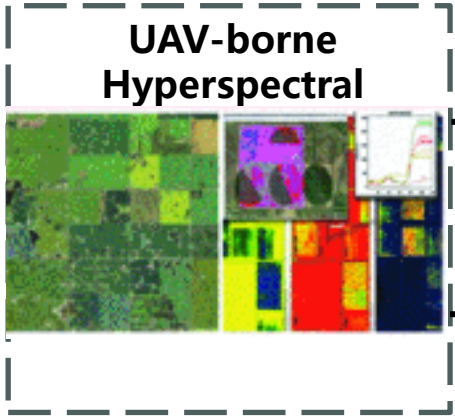
PLSR

Optimal RS variables

Correlation

Structural features

Zhao, Zeng*, et al., 2018, RSE



Optimal VIs

Spectral features

Clustering algorithms

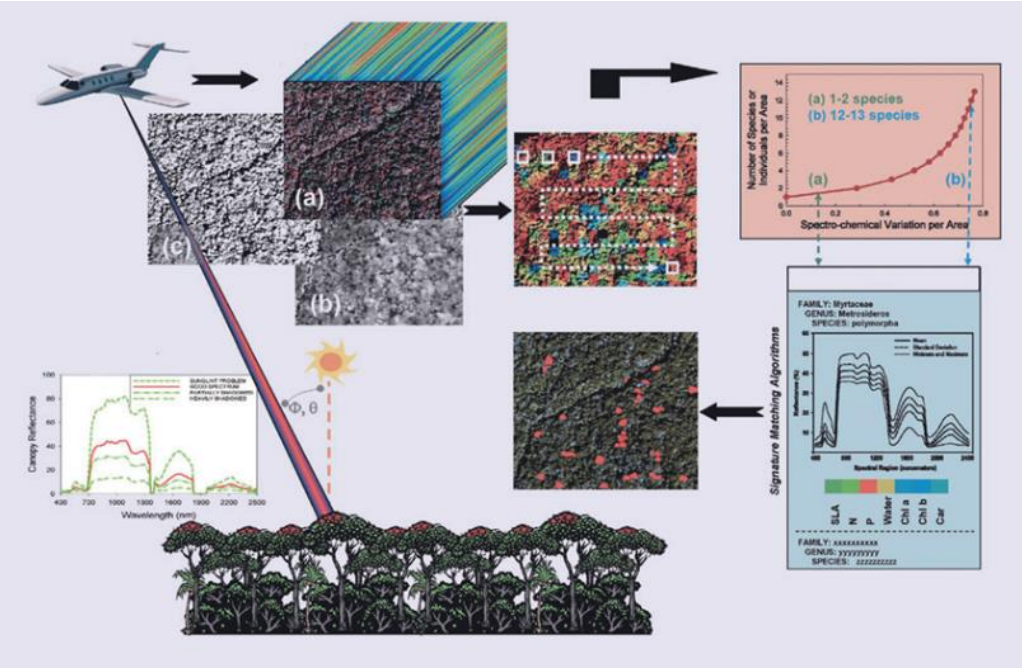
Spectral diversity index

Generalized additive model

Monitoring – Crop functional diversity

Functional traits

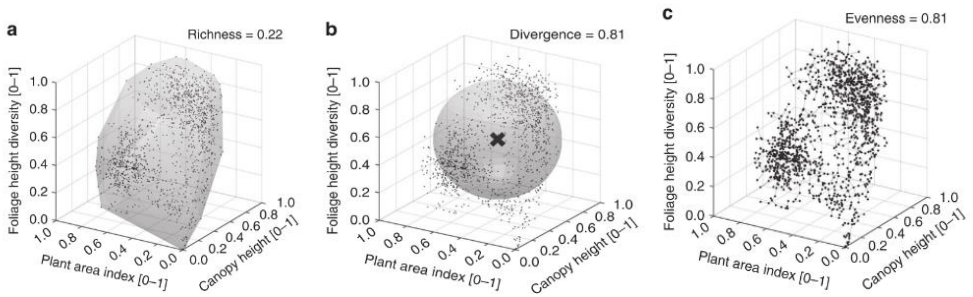
- Morphological traits from LiDAR
- Physiological traits from hyperspectral data



Zheng, Zeng*, et al., 2021, RSE

Functional diversity Index

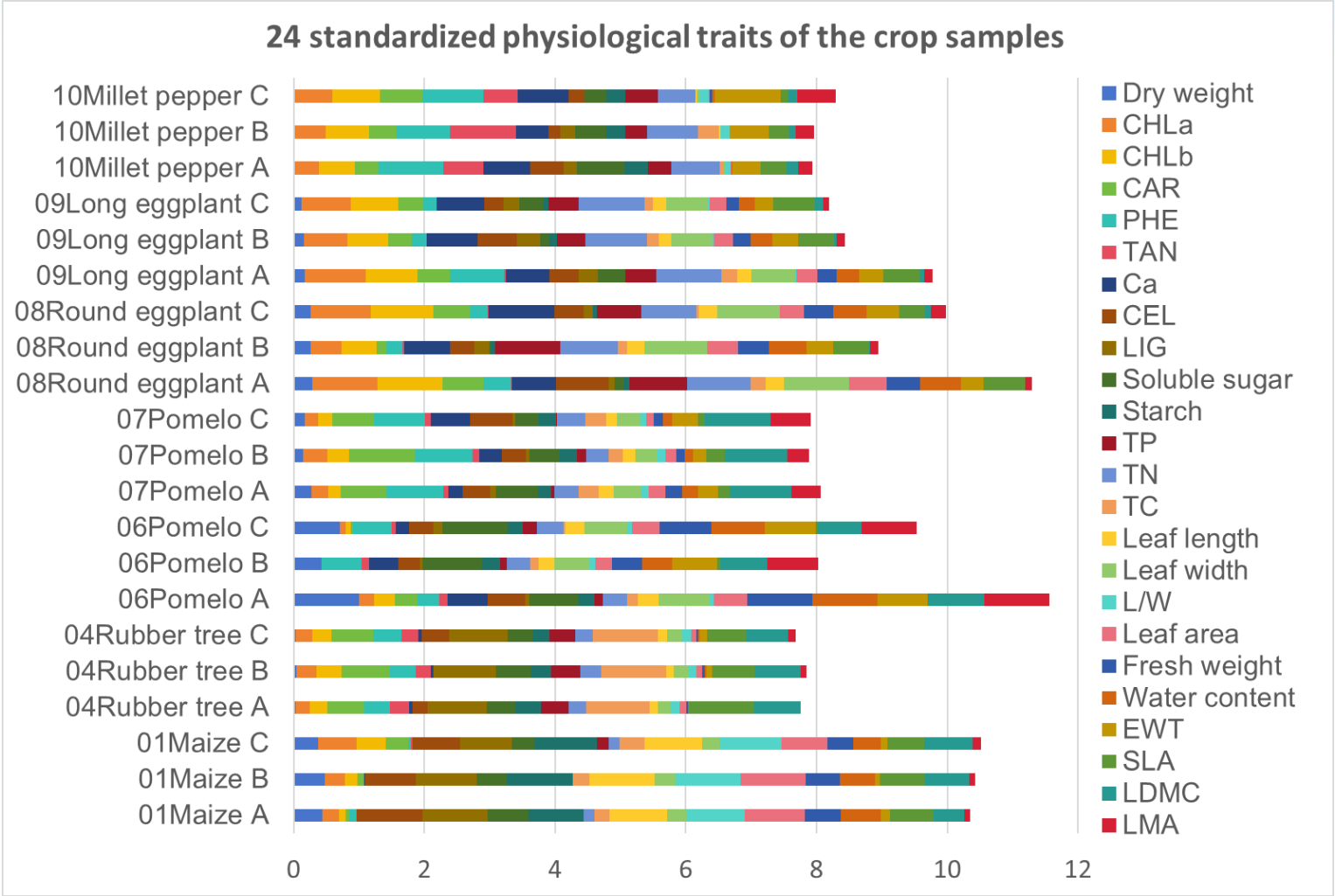
Index	Description
Functional Richness (FRic)	functional volume, the convex hull volume of the community niche; The shaded volume
Functional Divergence (FDiv)	mean deviation of the distance of the center of gravity; The distance from the surface of the shaded sphere
Functional Evenness (FEve)	evenness of minimum spanning tree branch lengths; The variation of segment length in the minimum spanning tree



Leaf physiological traits

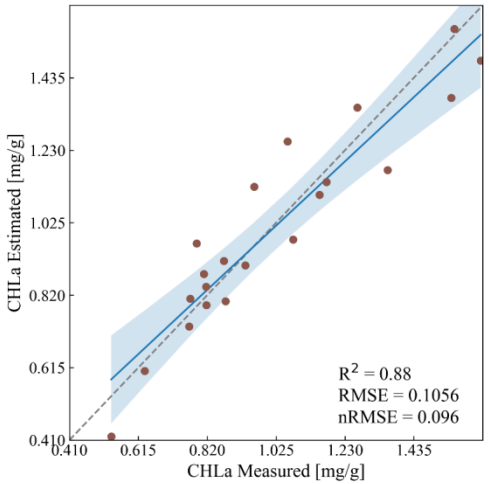
- **Leaf physiological traits**
  - 24 physiological traits (“fingerprint”)
  - min-max normalization

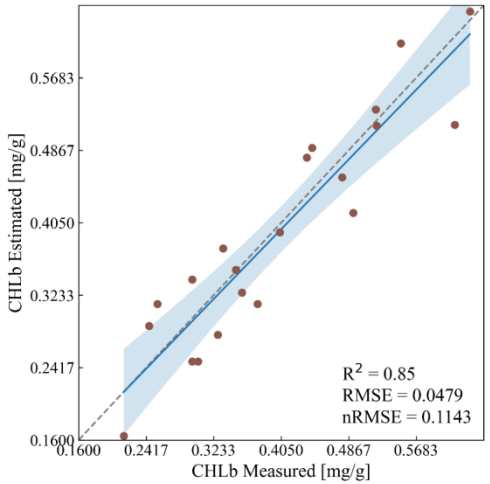
Unique biochemical properties √

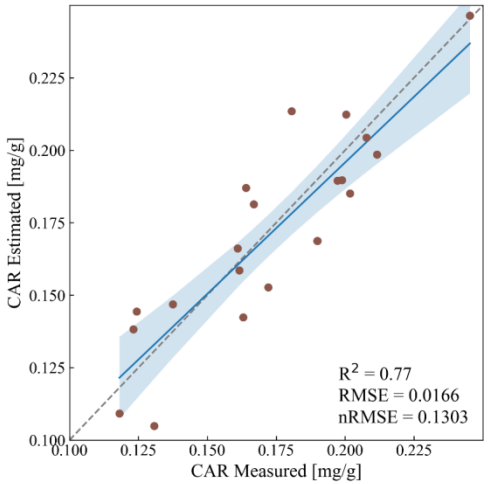


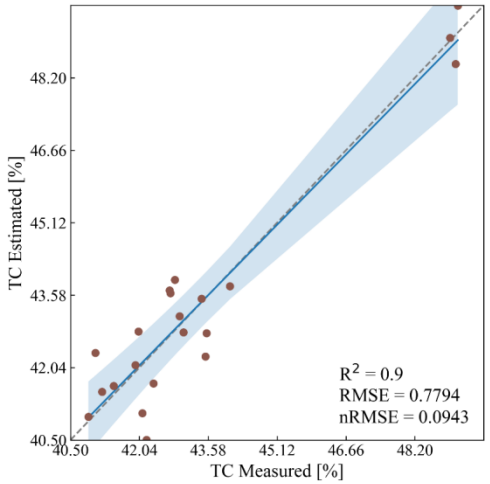
Traits retrieval

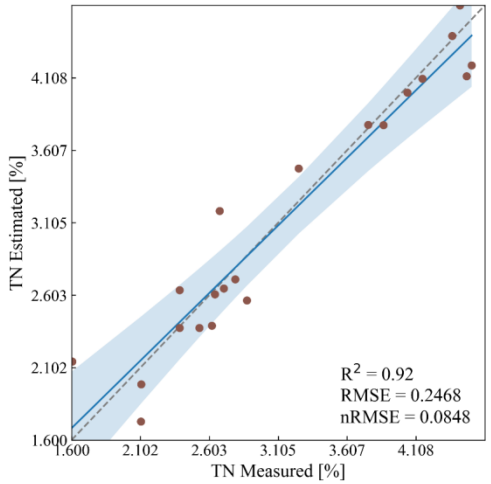
- Leaf spectra quantify physiological traits: PLSR (R^2=0.67-0.97)

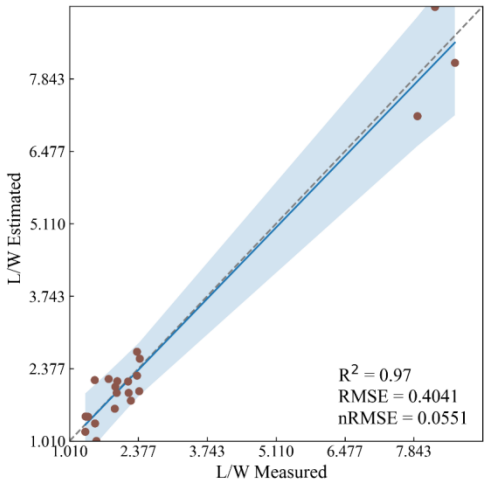


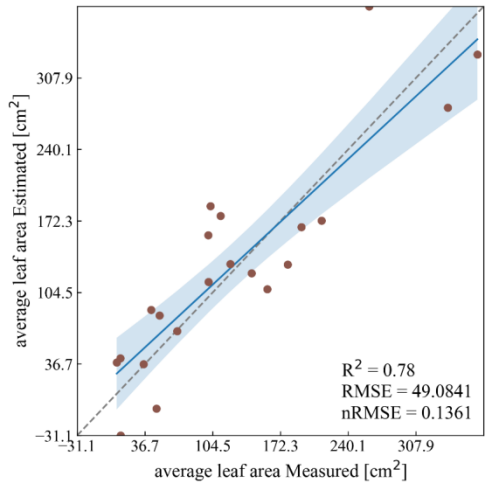


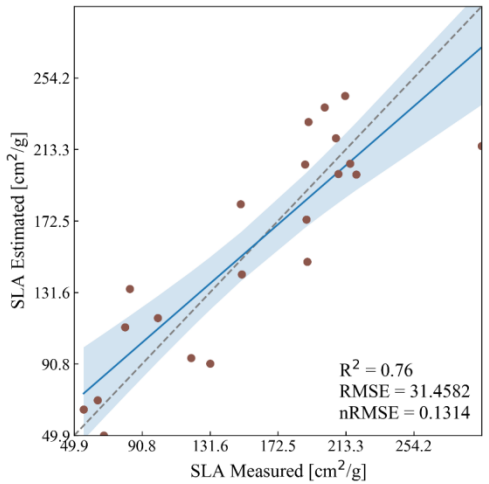


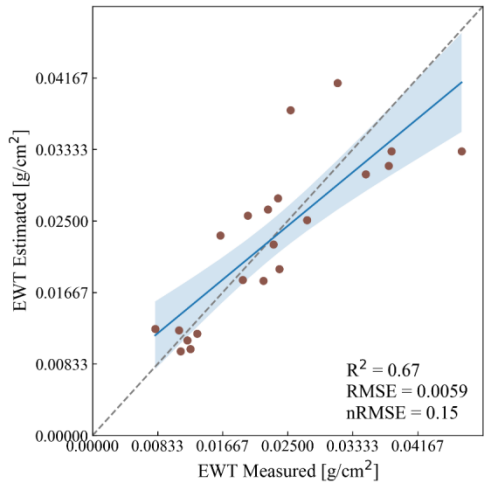


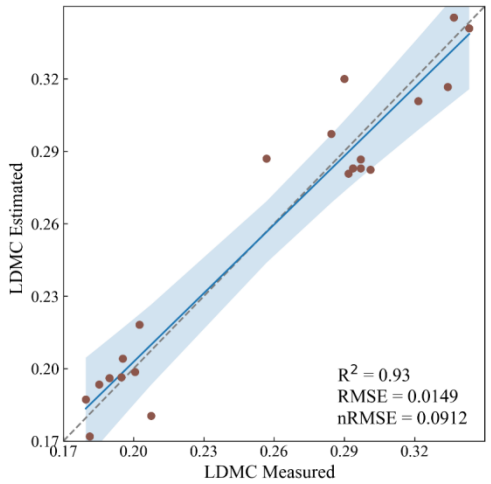




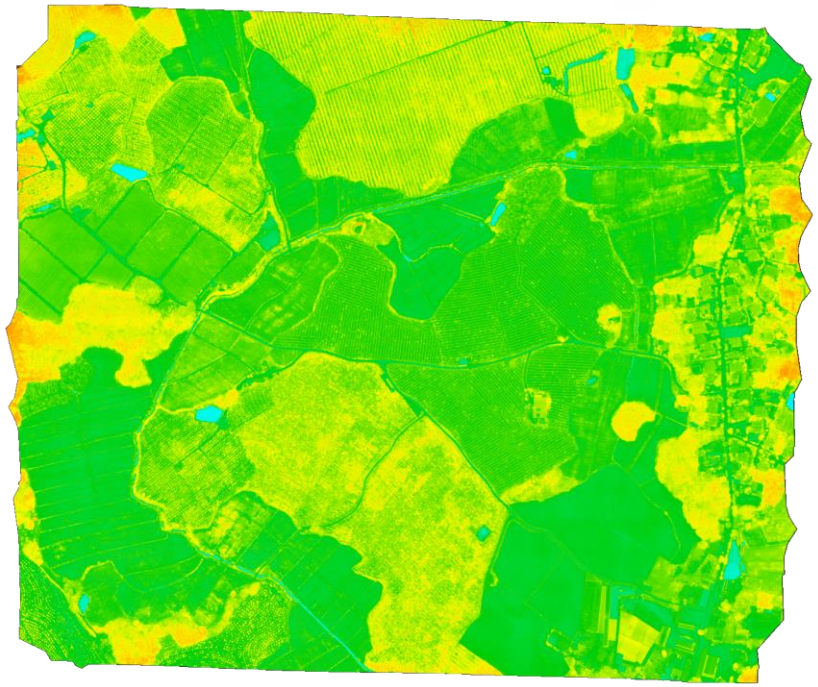






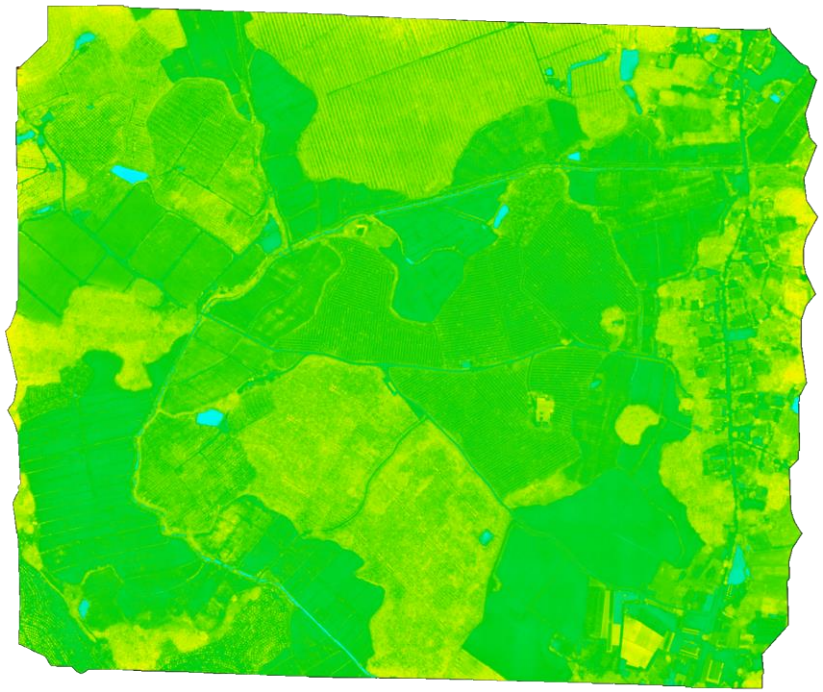


Trait mapping



Chlorophyll

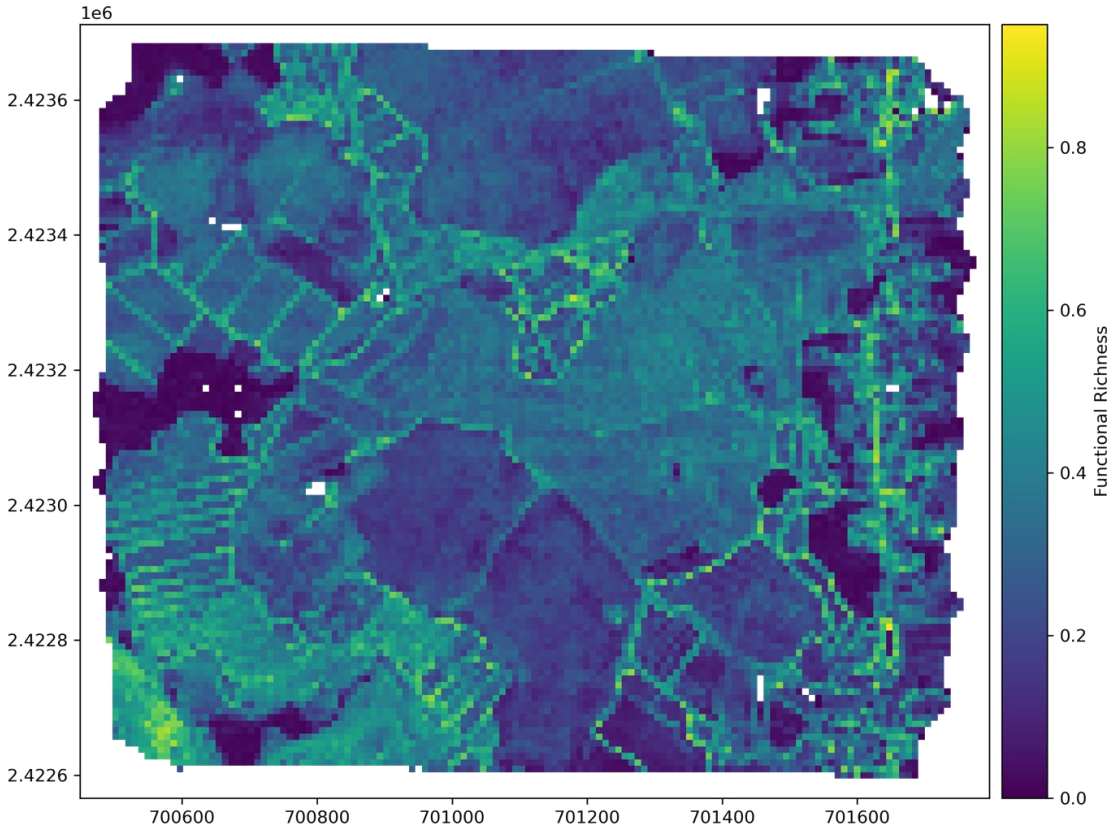
Carotenoids



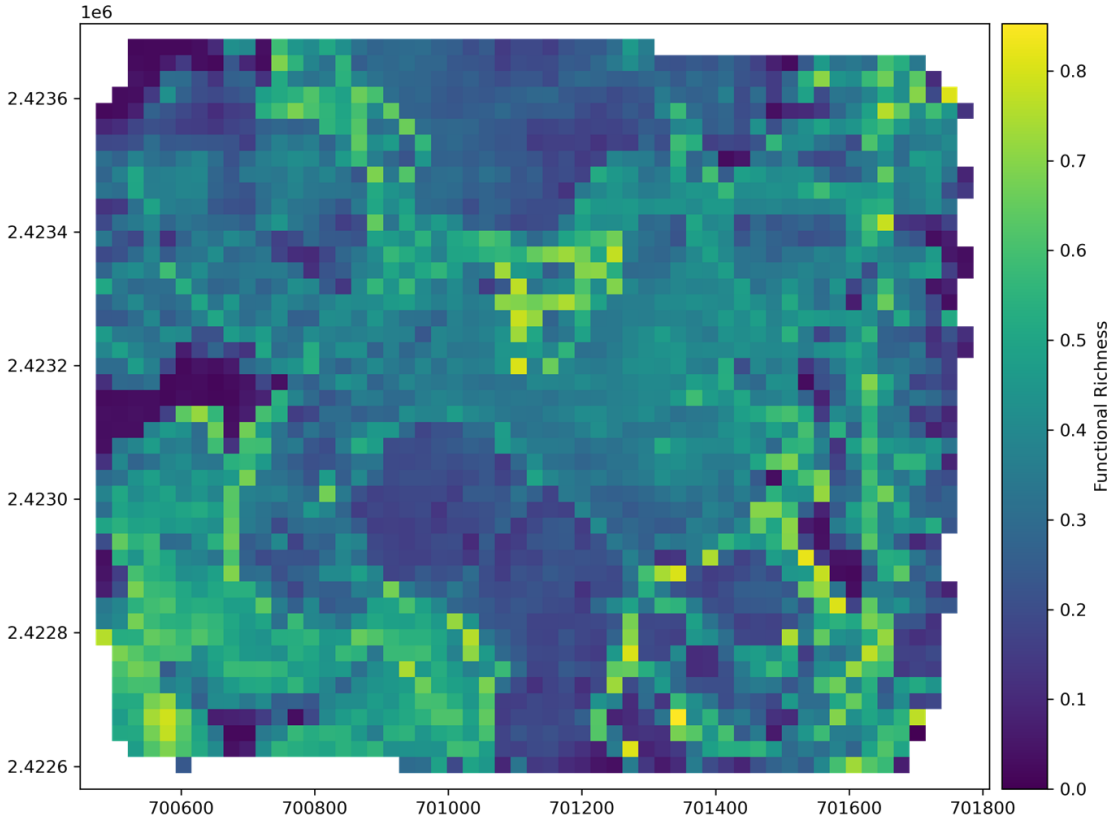
Nitrogen

Functional diversity mapping

Functional Richness at 10m scale

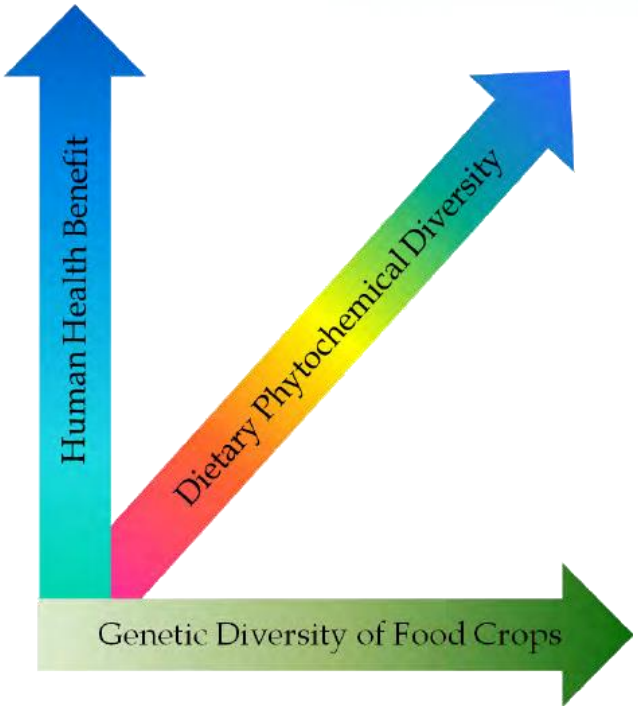


Functional Richness at 25m scale



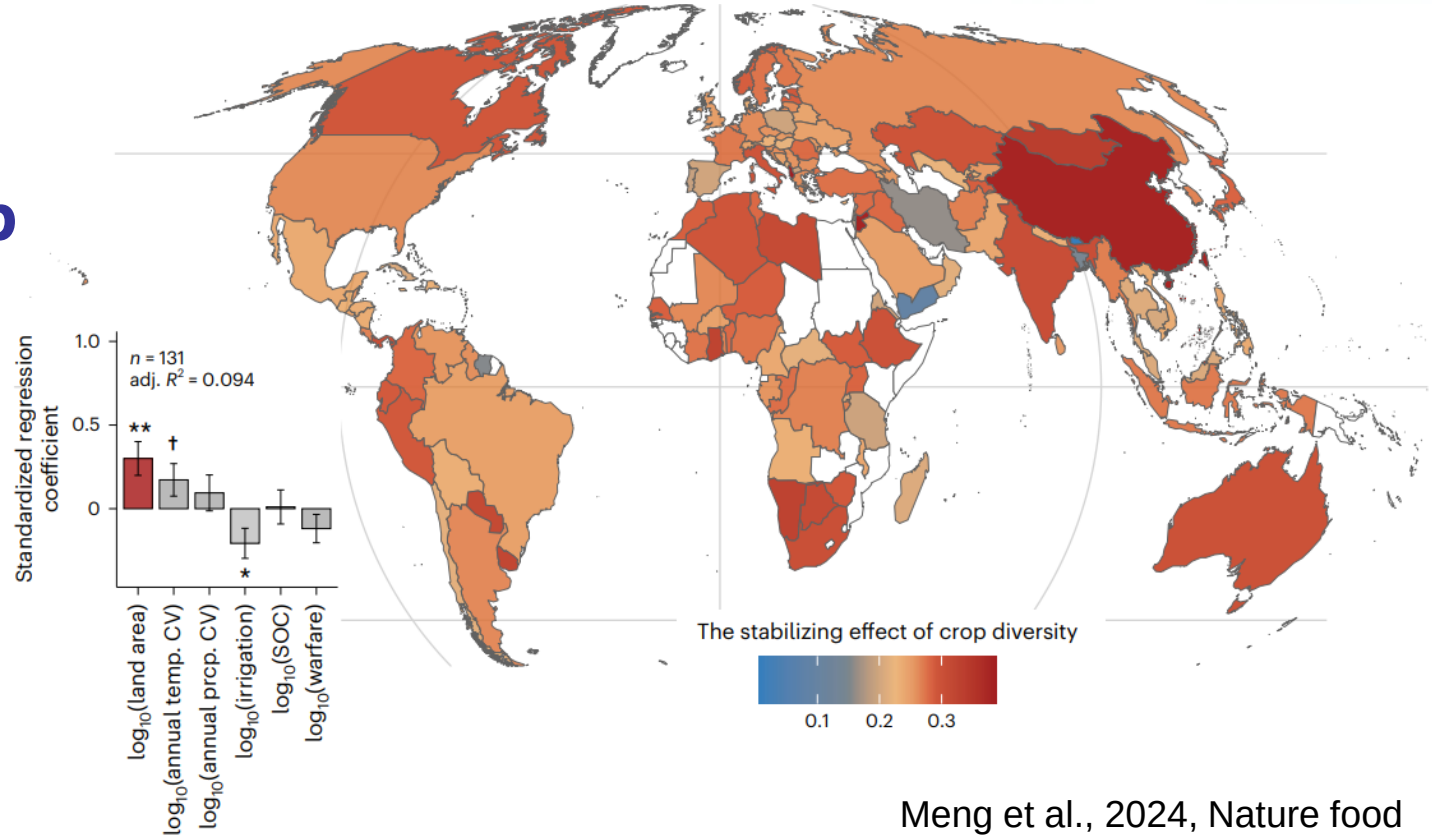
Assessment – Human health

- **Analyze the relationships between crop diversity and human health**
  - **health level (malnutrition, obesity, diet-related diseases, etc)**
  - **Life expectancy, Healthcare utilization intensity**
- **Support healthy and sustainable agri-food systems**
  - **Assessing the interactive influence among crop diversity, agricultural practices, dietary patterns, cultural preferences, and socio-economic factors**



Assessment – Yield stability & resilience

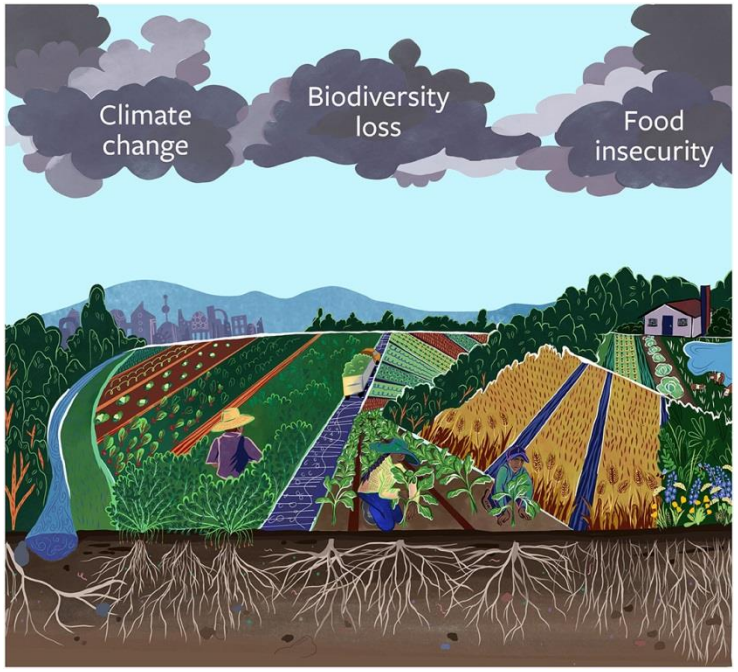
- Analyze the impact of crop diversity on crop yield
- Assess the response of crop diversity to extreme climate
- Guide diversification strategies, promote agroecosystems resilience



Meng et al., 2024, Nature food

Assessment – comparison

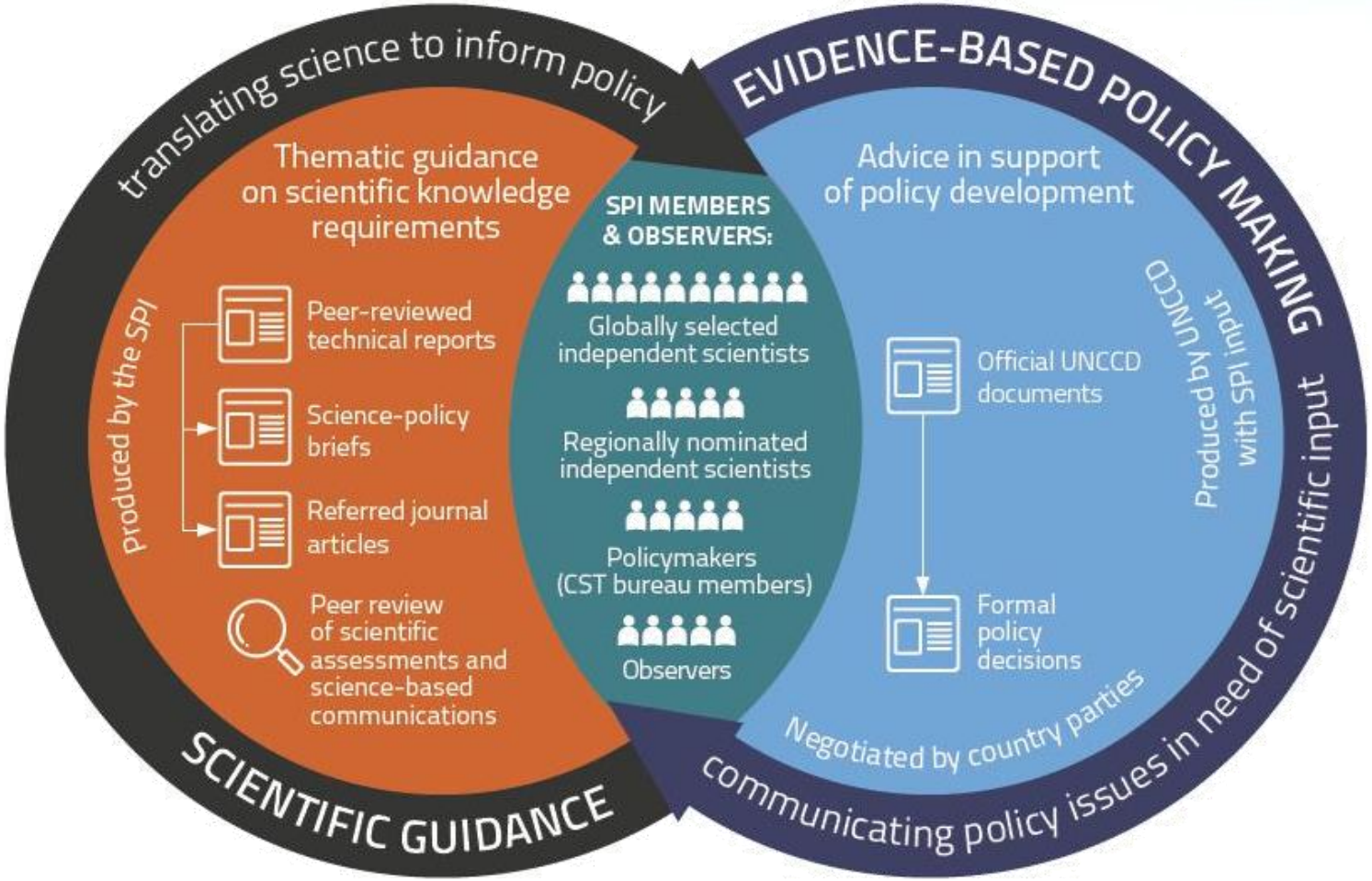
Integrating the crop planting structure, dietary patterns and socio-economic information of different countries to comprehensively analyze the role of crop diversity on crop yield, agroecosystems resilience and human health



Identify the common benefits of crop diversity and support policy-making by providing evidence-based recommendations

Policy outreach

- National and regional policy forums and reports
- Science-policy dialogues on crop biodiversity
- Disseminate findings to encourage replication where appropriate



Thank you！

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