Quantifying ecosystem services

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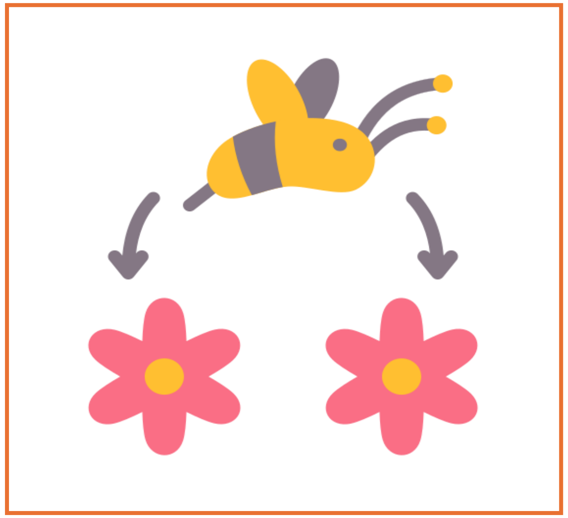
To help inform decisions and investments in farm and ranchland support and protection.

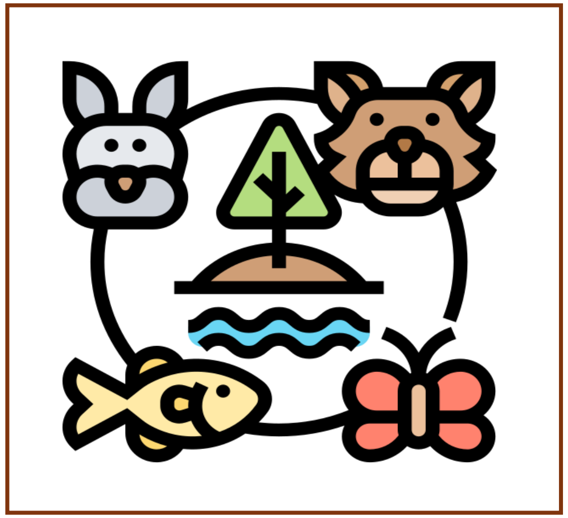
Ecosystem services are grouped.

Provisioning services:
e.g., food



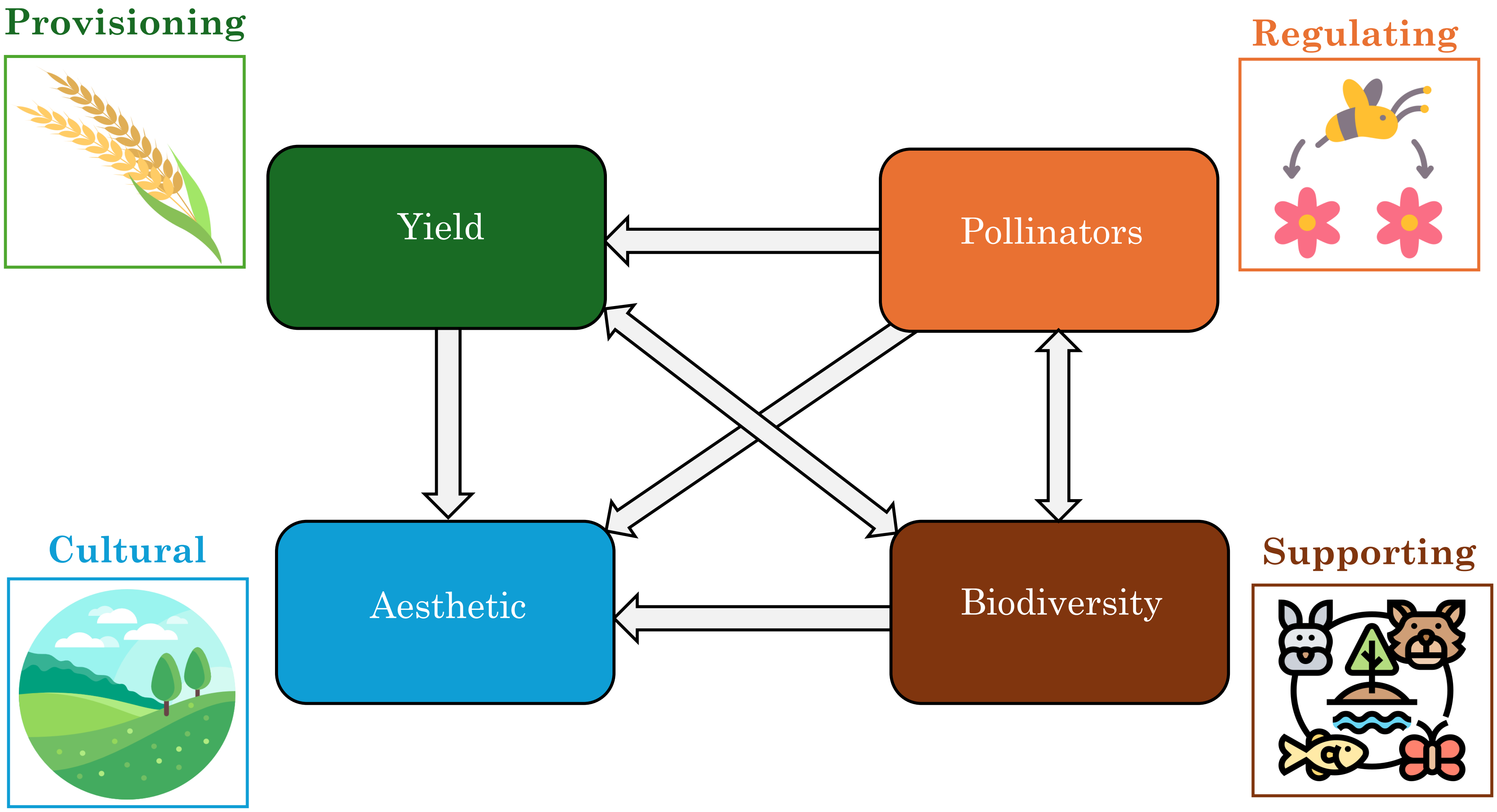
Regulating services:
e.g., soil quality

Cultural services:
e.g., recreation



Supporting services:
e.g., wildlife habitat

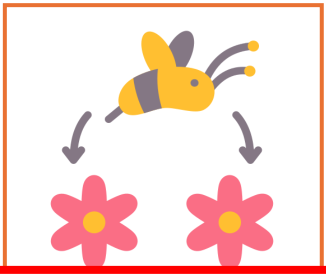
Ecosystem services interact in a complex system.



Ecosystem services interact in a complex system.

Provisioning

Regulating



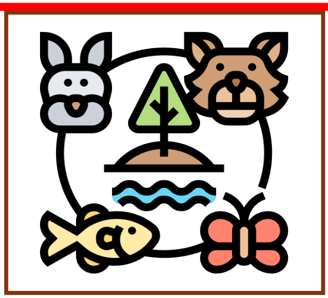
Yield

Pollinators

How can we
<u>tease apart, define, and quantify</u>
these dynamic relationships?

Aesthetic

Biodiversity



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We live in data abundance! First, manage it properly.

A data inventory example:

Variable(s)	Source	Spatial scope	Spatial resolution	Temporal scope	Temporal resolution
P, PET (Penman-Monteith), temp (mean, min, max, diurnal range), vapor pressure, wet days, cloud cover, frost days	Climate Research Unit (CRU)	Global	0.5°x0.5° (~45km at equator)	1901-2021	Monthly
Actual ET, soil E, interception loss, PET (Priestly-Taylor), snow sublimation, transpiration, open water evaporation, evaporative stress, root-zone soil moisture, surface soil moisture	Global Land Evaporation Amsterdam Model (GLEAM)	Global	0.25°x0.25°	1980-2021	Monthly
PET (Penman-Monteith), actual ET, runoff, temp (max, min), vapor pressure, precipitation accumulation, downward surface shortwave radiation, wind-speed, Climate Water Deficit, Soil Moisture, Snow Water Equivalent, Palmer Drought Severity Index, Vapor pressure deficit	TerraClimate (note: forced in part by CRU data; runoff = water balance model)	Global	0.1/24°x1/24° (~4km at equator)	1958-2020	Monthly
Runoff	Global Runoff Reconstruction (GRUN)	Global	0.5°x0.5°	1902-2014	Monthly
Land cover (% coverage per pixel): crop, desert, forest, tundra, pasture, grass, shrub, urban, water	NOAA-NCDC; 3 sources from Ramunkutty & Foley, 1999, HYDE, and Phillippean (?) & Jain (note: link is currently broken)	Global	0.5°x0.5°	1770-2020	Annual
Land cover (% coverage per pixel): cropland, pasture, primary land, secondary (recovering) land, and urban land, and underlying annual land-use transitions	ORNL Distributed Active Archive Center (DAAC)	Global	0.5°x0.5°	1500-2100	Annual
World light map (proxy for economic development)	NASA	Global	15 arc sec (~450 m)	2012-YTD	Daily to annual
For 42 crops: physical area, harvest area, production ($) and yield (disaggregates based on rainfed, irrigated, high/low input and subsistence systems) – "SPAM" maps	Yu et al., 2020. *Earth System Science Data*.	Global	10km x 10km	2000-2020	Every 5 years

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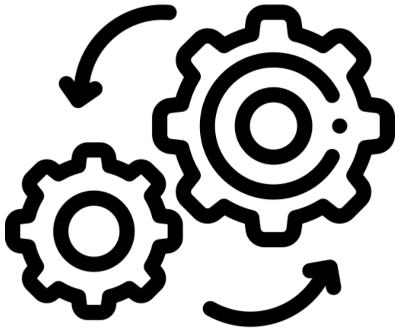
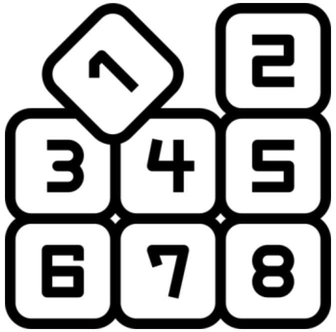
Approaches for quantifying ecosystem services.

Relationships between ecosystem services are generally quantified by
using or forming equations that describe different processes (i.e., modeling).

Mechanistic	Numerical	Statistical
		 O/M

O = observational
M = modeling

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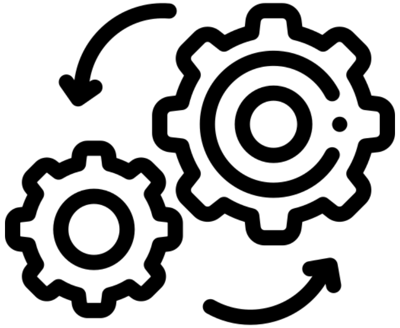	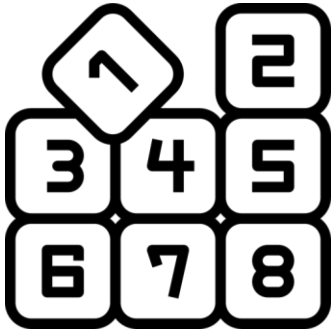	 O/M

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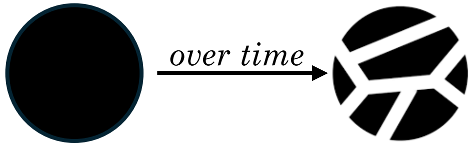
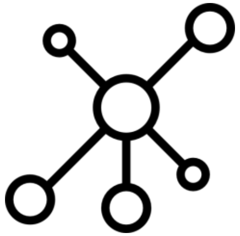
Quantify ecosystem services by **observing relationships**.

1. Assess landscape **patterning**.



2. Determine **network** dynamics.



3. Identify **common regions** across landscape.
(can be observational or modeling based)

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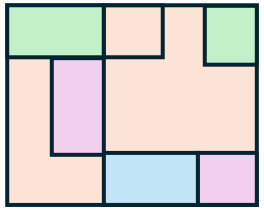
Assess landscape patterning.

Quantify landscape patterns to assess their broader impacts (e.g., on biodiversity, supporting service).

O

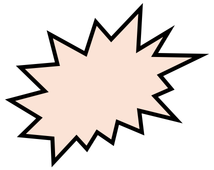
Richness
(how many kinds of patches/land cover types)



Patch size
(how big)

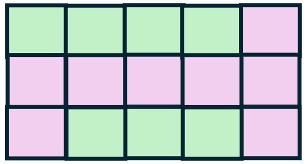
vs.

Patch shape complexity
(how irregular)

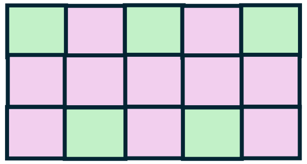


vs.

Connectivity/fragmentation
(# groups of connected patches)



vs.



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Example: Figure 4 in Pisarello & Jawitz, 2021.
First URL in speaker profile.

Determine production-consumption network dynamics.

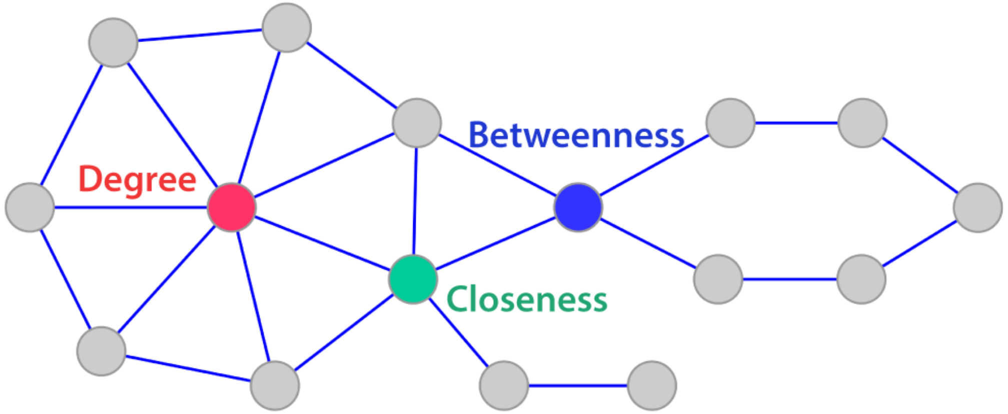
Quantify partnerships to assess overall network strength (e.g., on food, provisioning service).

O

Degree
(how many connections)

Closeness centrality
(how close one is to the rest)

Betweenness centrality
(how much one acts as a "bridge" to others)



https://cytoscape.org/cytoscape-tutorials/presentations/modules/network-analysis/index.html#/0/1

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Example: Figure 2/Table 3 in McCurley (Pisarello) & Jawitz, 2017.
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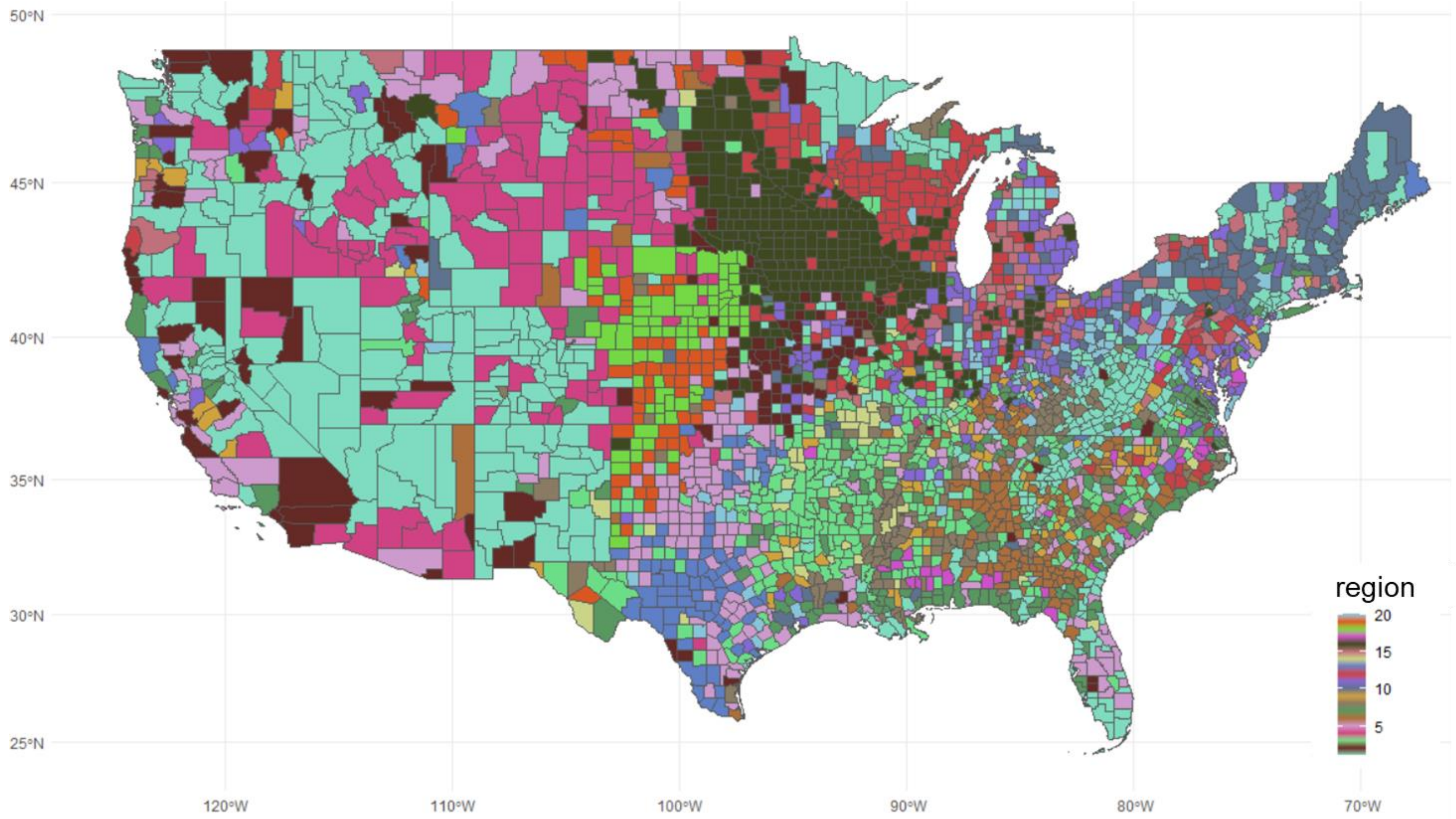
Identify common regions across the landscape - observing.

Delineate boundaries that capture similar within-region dynamics
(e.g., comprehensive agricultural system, all complex interactions of services)



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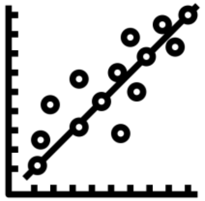
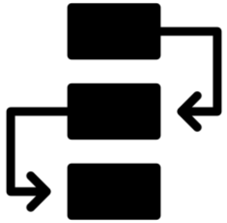
See me for more detail:
This work is in progress.

Quantify ecosystem services by **modeling relationships**.

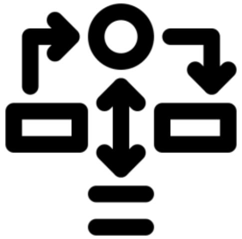
1. Regression-based modeling (simple and machine learning).



2. Ensemble modeling.



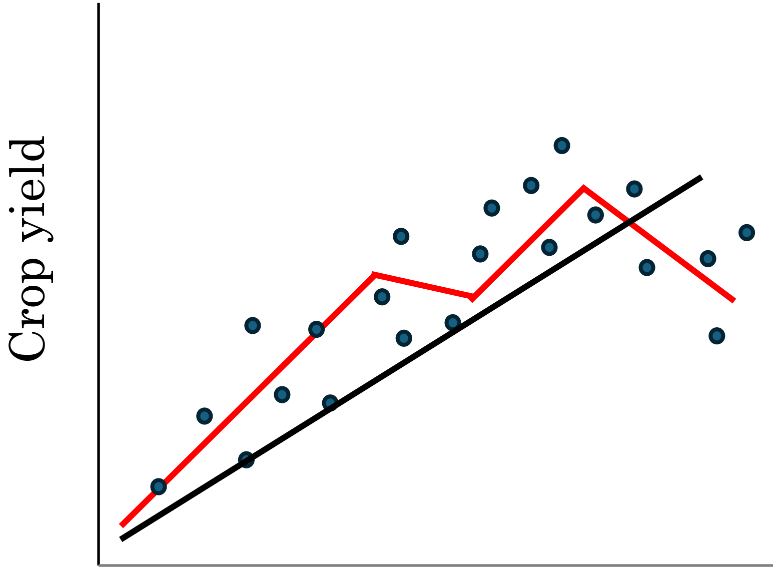
3. Systems modeling.



4. Identify common regions across the landscape.

Regression-based modeling.

Describe a variable of interest (e.g., yield) using a suite of other variables we assume impact the variable of interest (e.g., rainfall, temperature, cover crops, etc.).



$$Precip * X_1 + Temp * X_2 + Cover\ crop * X_3$$

Multi-linear regression

Machine learning (ML) regression

M

ML regression modeling:

Accounts for complex relationships within the data.

Does not just assume there is always a 1:1 relationship between the variable of interest and the describing variables.

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See for an example:
Pisani…Pisarello, et al., 2024.

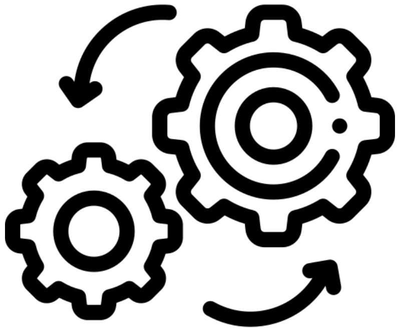
Ensemble modeling – combination of modeling approaches.

How might pine plantation management strategies impact water availability?

Growth, Yield and Carbon Balance Model

For Planted Longleaf Pine

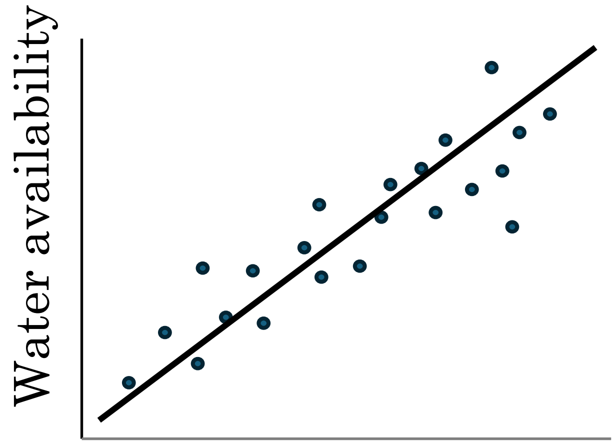
Model Version 1.31



<u>Modeled leaf area index (LAI)</u>

(density of pine plantation tree leaves)
under different management scenarios

Previous study defined relationship between water availability and LAI using multilinear regression.



$$\text{Water availability} = 14.1 * \textit{Precip} - 5.9 * \boxed{\textit{LAI}}$$

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Example: Pisarello et al., 2022.
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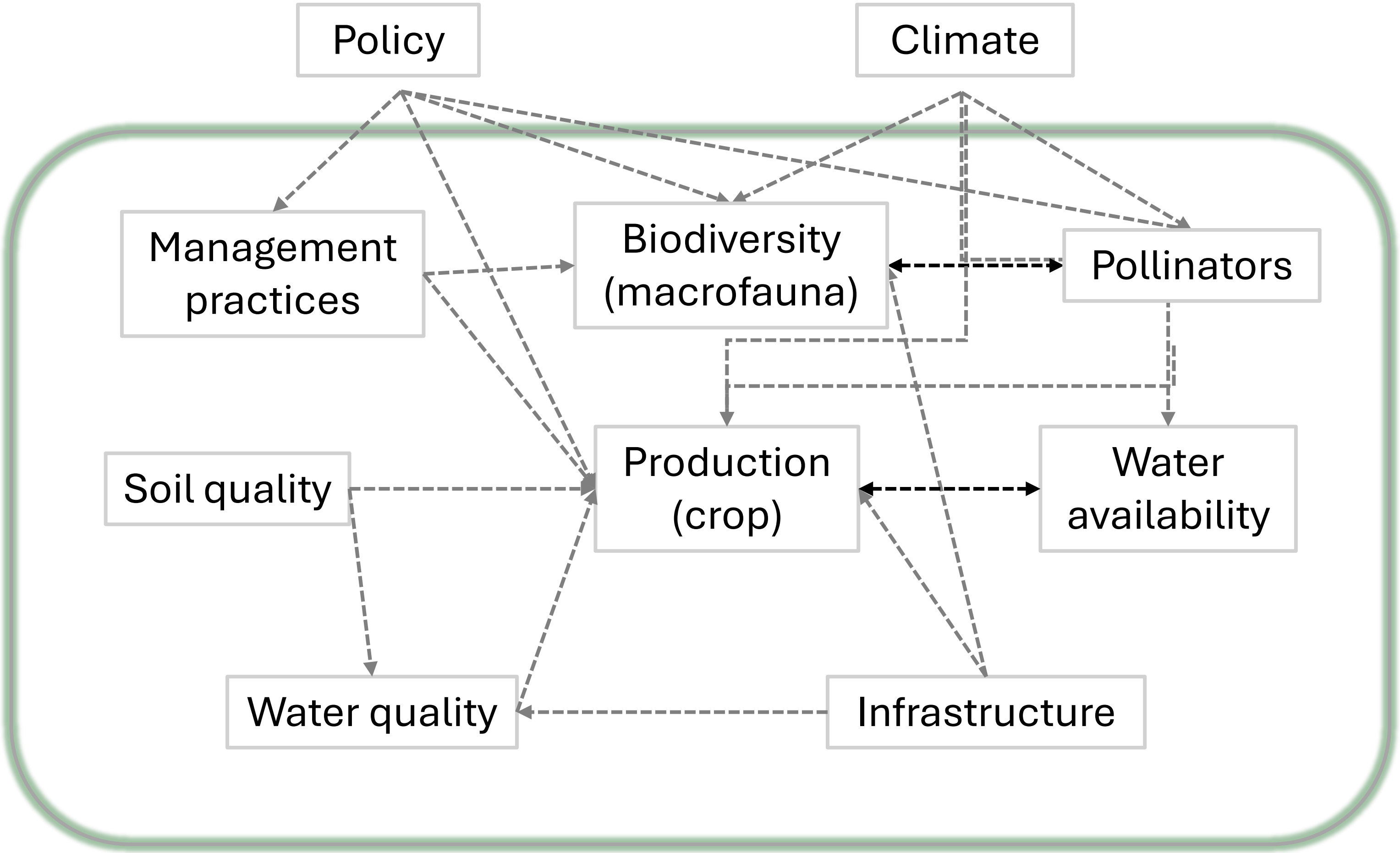
American Farmland Trust
SAVING THE LAND THAT SUSTAINS US

Systems modeling – agricultural system example.



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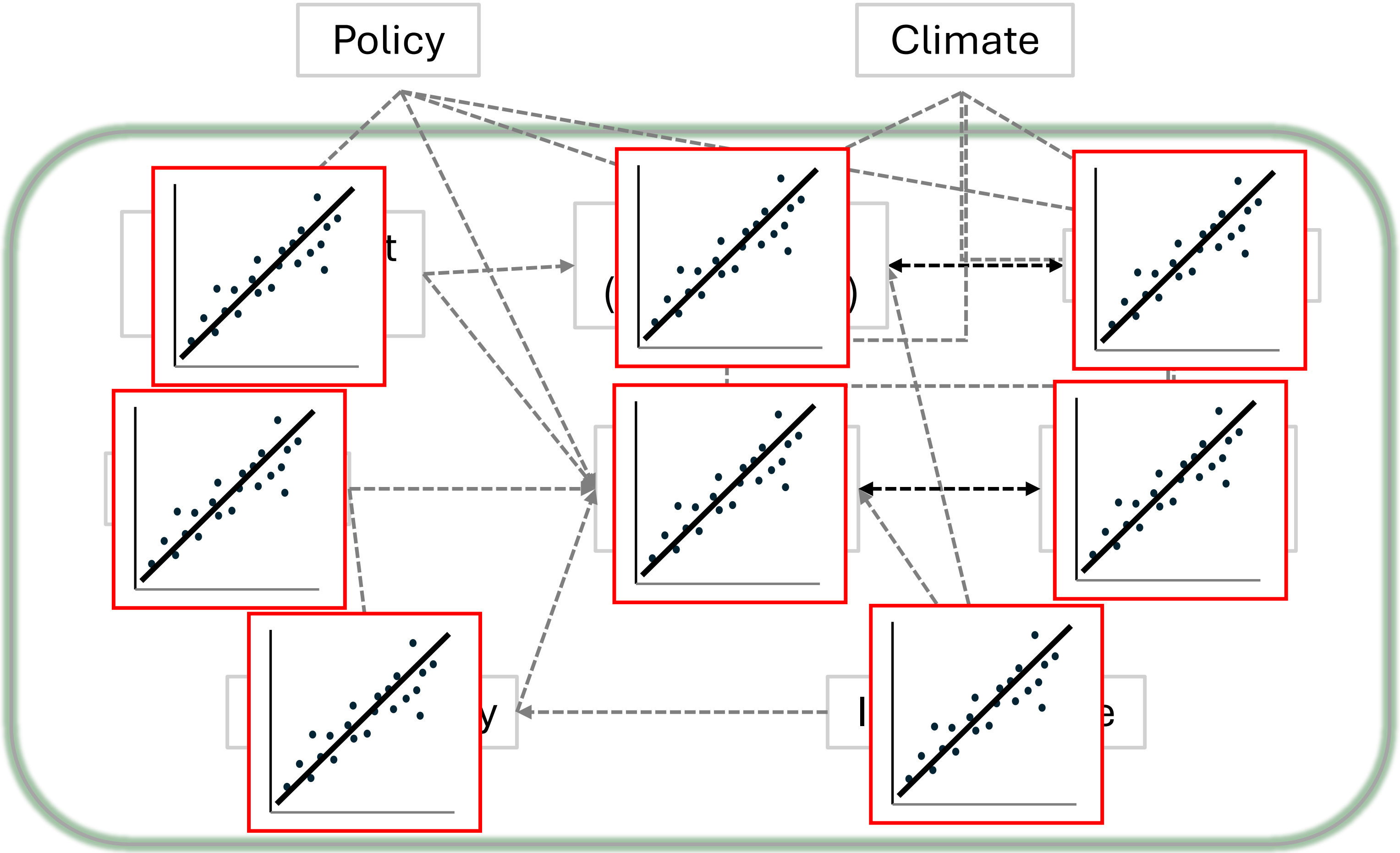
Systems modeling – agricultural system example.



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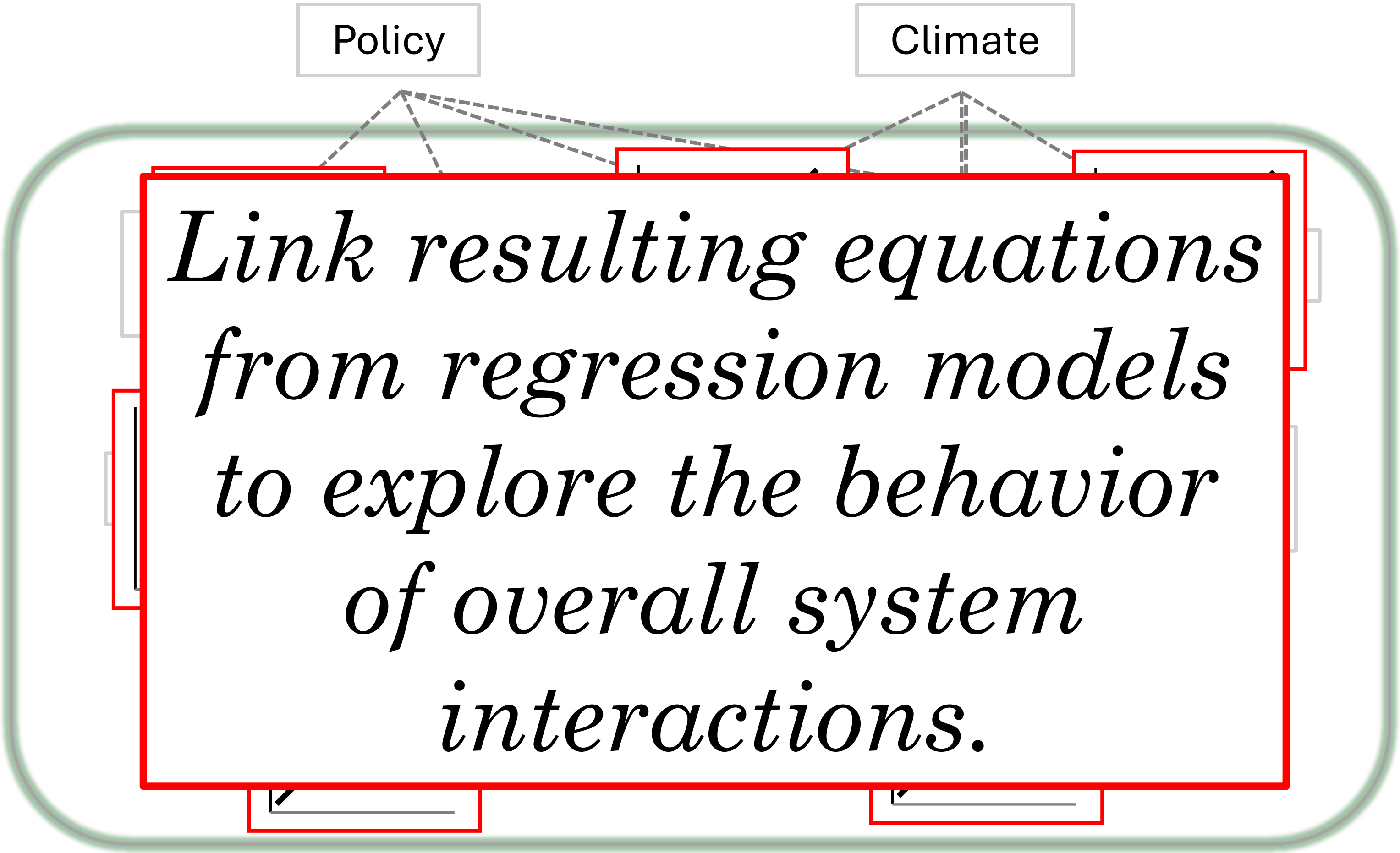

Link resulting equations from regression models to explore the behavior of overall system interactions.

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Identify common regions across the landscape - modeling.

Delineate boundaries that capture similar within-region dynamics
(e.g., zones of similar water availability, regulating service.)

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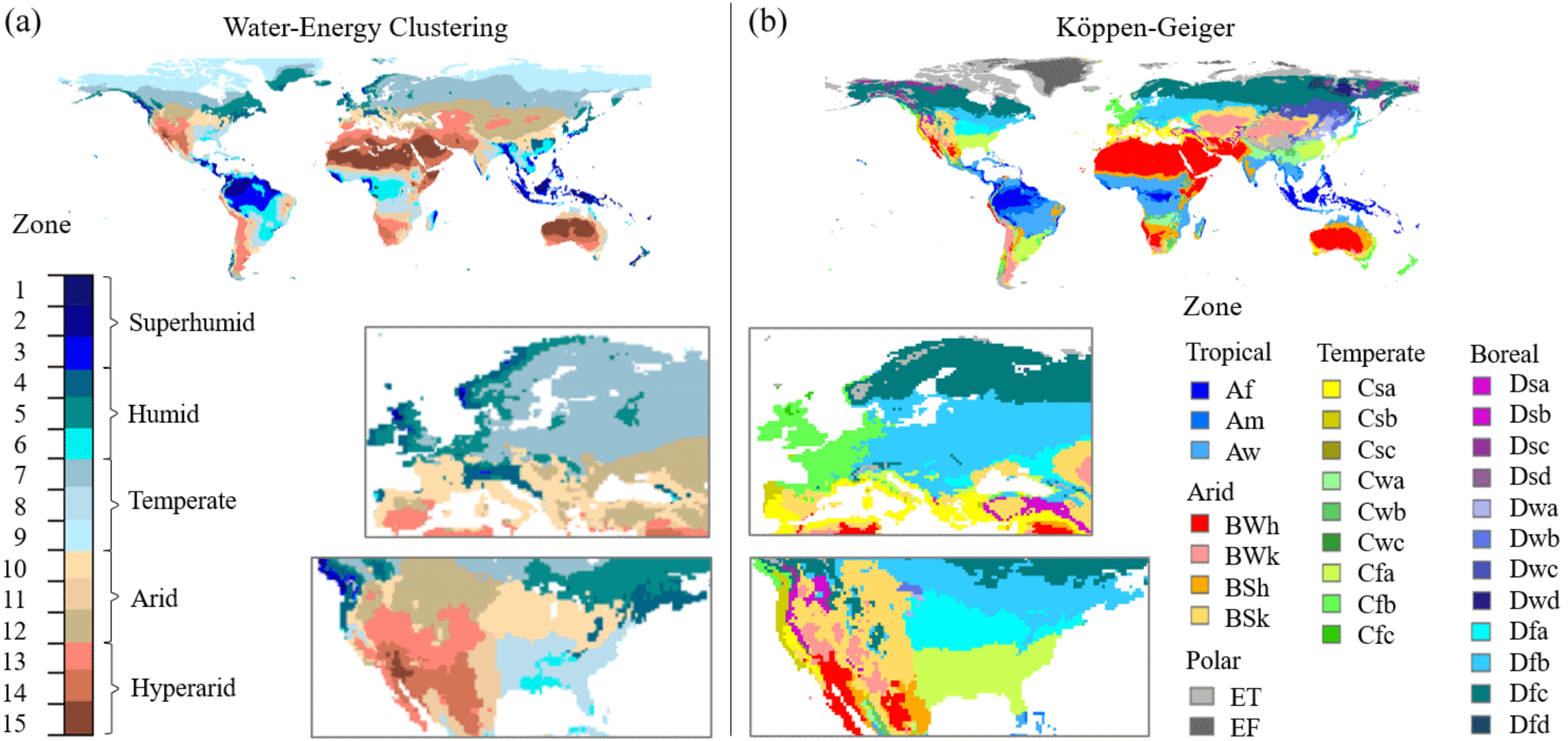

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More detail: Pisarello & Jawitz, 2021.
First URL in speaker profile.

Key takeaways.

- Quantifying ecosystem services is **important for supporting informed decision-making** on farm and ranchlands.
- There are **many ways** to quantitatively define and explore complex systems and their ecosystem services.
- **Manage data properly**, even third party, publicly available data.

Questions?