Give me any word, I’ll show the Greek root....
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Agroecology: An uneasy marriage?
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Agronomy

- Applied Science
- Human Practices
- Artificial Patterns
- Economic Valuation (Yield)
Agroecology: An uneasy marriage?

Agronomy
- Applied Science
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Ecology
- Basic Science
- Natural Patterns
- Energetic or Elemental Valuation (Productivity)
Agroecology: An uneasy marriage?

Agronomy
- Applied Science
- Human Practices
- Artificial Patterns
- Economic Valuation (Yield)

Ecology
- Biological Mechanisms
- Natural Process
- Measures of system productivity

- Basic Science
- Natural Patterns
- Energetic or Elemental Valuation (Productivity)
Agroecology: A Brief History

- 1920's: Birth of Crop Ecology/Biogeography
- 1930's-1940's: Genesis of input agriculture
- 1950's: Ecosystem concept re-developed
- 1960-1970's: Agricultural systems used for ecological research
- 1980's: Development of textbooks
- 1990's: Recognition by ESA, Agroecology Subsection
- Present: Agroecology expanded to include Food Systems
A Few Important Agroecologists

• Steve Gliessman (UCSC)
• Miguel Altieri (UCB)
• John Vandermeer (UM)
Agroecology in Action
Extending Alternative Agriculture through Social Networks

Keith Douglass Warner
Foreword by Fred Koehl

Image of a tractor in a field and a landscape with green fields.
Autotroph Density in Marine and Terrestrial Ecosystems

NPP by Ecosystem

<table>
<thead>
<tr>
<th>Type of Ecosystem</th>
<th>Average World Net Primary Productivity (billion kcal/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open ocean</td>
<td>180</td>
</tr>
<tr>
<td>Tropical rain forest</td>
<td>130</td>
</tr>
<tr>
<td>Temperate forest</td>
<td>90</td>
</tr>
<tr>
<td>Savanna</td>
<td>80</td>
</tr>
<tr>
<td>Northern coniferous forest (taiga)</td>
<td>70</td>
</tr>
<tr>
<td>Continental shelf</td>
<td>60</td>
</tr>
<tr>
<td>Agricultural land</td>
<td>50</td>
</tr>
<tr>
<td>Temperate grassland</td>
<td>40</td>
</tr>
<tr>
<td>Woodland and shrubland</td>
<td>30</td>
</tr>
<tr>
<td>Estuaries</td>
<td>20</td>
</tr>
<tr>
<td>Swamps and marshes</td>
<td>10</td>
</tr>
<tr>
<td>Desert scrub</td>
<td>5</td>
</tr>
<tr>
<td>Lakes and streams</td>
<td>2</td>
</tr>
<tr>
<td>Tundra (artic and alpine)</td>
<td>1</td>
</tr>
<tr>
<td>Extreme desert</td>
<td>0</td>
</tr>
</tbody>
</table>
Ecosystem Trophic Structure

- Producers: 1,000 kcal
- Primary Consumers: 100 kcal
- Secondary Consumers: 10 kcal
- Tertiary Consumers: 1 kcal
Ecosystem Trophic Structure

The Soil Food Web

Producer

First trophic level: Photosynthesizers

Second trophic level: Decomposers
Mycorrhizal fungi
Mutualists
Saprophytic fungi
Pathogens, parasites
Root-feeders

Third trophic level: Shredders
Protozoa
Nematodes
Nematodes
Fungal- and bacterial-feeders
Animals

Fourth trophic level: Higher level predators

Fifth and higher trophic levels: Higher level predators
Ecosystem Trophic Structure

The Soil Food Web

Producer

1° Consumers

Plants
Shoots and roots

Organic Matter
Waste, residue and metabolites from plants, animals and microbes.

Fungi
Mycorrhizal fungi
Saprophytic fungi

Nematodes
Root-feeders

Arthropods
Shredders

Protozoa
Amoebae, flagellates, and ciliates

Bacteria

Nematodes
Fungal- and bacterial-feeders

Nematodes
Predators

Arthropods
Predators

Birds

Animals

First trophic level:
Photosynthesizers

Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders

Third trophic level:
Shredders
Predators
Grazers

Fourth trophic level:
Higher level predators

Fifth and higher trophic levels:
Higher level predators
Ecosystem Trophic Structure

1° Consumers

- Nematodes (Root-feeders)
- Fungi (Mycorrhizal fungi, Saprophytic fungi)
- Bacteria

2° Consumers

- Arthropods (Shredders, Predators)
- Protozoa (Amoebae, flagellates, ciliates)
- Nematodes (Predators)
- Animals
- Birds

First trophic level: Photosynthesizers
Second trophic level: Decomposers, Mutualists, Pathogens, parasites Root-feeders
Third trophic level: Shredders, Predators, Grazers
Fourth trophic level: Higher level predators
Fifth and higher trophic levels: Higher level predators
Systems Theory

- Ecosystems are one type of system
- System: a group of independent but interrelated elements comprising a unified whole
- Systems are composed of components linked by flows enclosed in a boundary
- Systems typically exhibit "emergent properties"
- Complex behaviors that appear from simpler interactions
- Energy flow, nutrient cycles, dynamic equilibrium
Often used for energy but can be adapted to any type of flow
Systems Diagrams

Howard T. Odum’s Generic Symbols for System Diagrams

- SOURCE
- CONSUMER
- STORE
- PRODUCER
- SINK
- FLOW
- SWITCH
- TRANSACTION
- SELF LIMITER
- INTERACTION

Often used for energy but can be adapted to any type of flow.
photosynthesis

WATER + LIGHT = CHEMICAL ENERGY

1. Chloroplasts trap light energy

2. Water enters leaf

3. Carbon dioxide enters leaf through stomata

4. Sugar leaves leaf

CHEMICAL ENERGY + CARBON DIOXIDE = SUGAR
Figure 24. Photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant.
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Water

Nutrients

Light

Carbon Dioxide

Evaporation transpiration

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C3 --> optimized for cool temps.
C4 --> optimized for warmer temps.
Light and Moisture are Controlled by Microclimate

• A microclimate is a local atmospheric zone where the climate differs from the surrounding area. The term may refer to areas as small as a few square feet (for example a garden bed) or as large as many square miles (for example a valley or lake effect).

• Light, Temp., Humidity, and Wind are all components of microclimate
Also PAR

Blue and Red Primary Photo. Wavelengths
Light Quality, Intensity, and Duration

- **Quality**: The ratio of different spectra
  - Differs among plant species

- **Intensity**: The total energy content of all PAR light (cal/cm² or W)

- **Duration**: Time spent with adequate light (photoperiod)

- **Saturation Point**: is the intensity at which a leaf no longer absorbs more energy

- **Compensation point**: intensity at which photosynthesis takes place
## Light Environment Determinants

<table>
<thead>
<tr>
<th>Determinant</th>
<th>Quality</th>
<th>Intensity</th>
<th>Duration</th>
<th>Managable?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonality</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>With large E inputs</td>
</tr>
<tr>
<td>Altitude</td>
<td>X</td>
<td>X</td>
<td></td>
<td>NO</td>
</tr>
<tr>
<td>Topography</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>NO</td>
</tr>
<tr>
<td>Air Quality</td>
<td>X</td>
<td>X</td>
<td></td>
<td>NO</td>
</tr>
<tr>
<td>Canopy Structure</td>
<td>X</td>
<td>X</td>
<td></td>
<td>YES</td>
</tr>
</tbody>
</table>
Relative Rate of Transmission and LAI

**FIGURE 4.6** Light attenuation under the canopy of a squash monoculture, a corn monoculture, and a corn/squash intercrop. The data for each crop show the percentage of full sunlight remaining at each of six horizontal levels. (From Fujiyoshi, 1997)
Temperature

- Temperature is the result of IR absorption by the earth and atmosphere
- Temperature moderates the metabolism of all living things
- In Plants high temps. lead to desiccation
- Low temps lead to freezing
Components of Temperature Variation

- **Latitudinal Variation**: The angle intercept of EM radiation
- **Altitudinal Variation**: Decrease with increasing elevation
- **Seasonal Variation**: Orientation of earth's axis
- **Maritime Variation**: Thermal mass of water
- **Topographic Variation**: Aspect + valley effect
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**FIGURE 5.1** The effect of latitude on solar gain. The higher the latitude, the greater the distance that solar radiation must travel through the atmosphere ($D_2 > D_1$) and the greater the surface area over which a certain amount of solar radiation is spread ($A_2 > A_1$).
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Variations in Temperature

- **Latitudinal Variation**: The angle intercept of EM radiation
- **Altitudinal Variation**: Decrease with increasing elevation
- **Seasonal Variation**: Orientation of earth's axis
- **Maritime Variation**: Thermal mass of water
- **Topographic Variation**: Aspect + valley effect
"La Milpa": Corn/bean/squash interplanting

Corn provides scaffold for beans

Squash "fills in" below corn

Corn = C4, Bean and Squash = C3
Ammonium or Nitrates
Micronutrients
Potassium
Phosphates

Figure 24. Photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant.
FIGURE 1.3 The many functions of soil can be grouped into five crucial ecological roles.
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Chemical Weathering

- **Hydration**: addition of water
- **Hydrolysis**: cation replacement with H ions
- **Solution**: Carbonic leaching
  - Ca and Mg carbonates
- **Oxidation**: conversion of Fe or Al
Transported Soils

- **Colluvium**: gravity transport
- **Alluvium**: H2O transport
- **Glacial**: Glacial transport
- **Eolian**: wind transport
Biotic Processes

- Rooting
  - Physical breakage with roots
  - Transportation of minerals
- Decomposition and Mineralization
  - Cycling of biotic materials
  - Organic acids add to chemical weathering
- *Humus* formation: stable organic compounds
Soil Characteristics

- Texture
- Structure
- Color
- Cation-Exchange Capacity
- pH
- Salinity and Alkalinity
Soil Structure

- Granular
- Platy
- Blocky (Subangular)
- Angular
- Prismatic
- Columnar
Cation-Exchange Capacity

Diagram showing various cations such as H+, Na+, NH4+, Ca++, and Mg++ around a central structure.
Soil pH

- Nitrogen
- Phosphorus
- Potassium
- Calcium and Magnesium
- Sulphur
- Boron
- Copper and Zinc
- Molybdenum
- Iron and Managanese
- Aluminium

Soil pH Levels:
- Extremely Acidic
- Very Strongly Acidic
- Strongly Acidic
- Moderately Acidic
- Slightly Acidic
- Neutral
- Slightly Alkaline
- Moderately Alkaline
- Strongly Alkaline
- Very Strongly Alkaline

- Actinomycetes
- Fungi
### Soil Horizons

**Table 8.1: Four Types of Soil Development**

<table>
<thead>
<tr>
<th>Development Process</th>
<th>Moisture</th>
<th>Temperature</th>
<th>Typical Vegetation</th>
<th>Resulting Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gleization</td>
<td>High</td>
<td>Cold</td>
<td>Tundra</td>
<td>Compact horizons, little biological activity</td>
</tr>
<tr>
<td>Podzolization</td>
<td>High</td>
<td>Cool to warm</td>
<td>Needle-leaf forest, deciduous forest</td>
<td>Light-colored A horizon; yellow-brown B horizon high in iron and aluminum</td>
</tr>
<tr>
<td>Laterization</td>
<td>High</td>
<td>Warm to hot</td>
<td>Rainforest</td>
<td>Weathered to great depth; indistinct horizons; low in plant nutrients</td>
</tr>
<tr>
<td>Calcification</td>
<td>Low</td>
<td>Cool to hot</td>
<td>Prairie, steppe, desert</td>
<td>Thick A horizon rich in calcium, nitrogen, and organic matter (except in deserts)</td>
</tr>
</tbody>
</table>

- Profiles actually a continuum
- Four major types of soil development
  - Gleization
  - Podzolization
  - Laterization
  - Calcification
  
  **Strongly tied to Climate and Biotic Elements**
Soil Horizons

**Organic Matter:** Undecomposed Plant Materials

**Surface Soil:** Mineral and Organic Mix

**Subsoil:** Mineral, Clay, Aluminum, Organic Compounds

**Parent Rock:** Unbroken Rocks
Soils and Nutrient Availability

- Insufficient quantity = limiting nutrient
- "Law of the Limit" Lieburg
- Presence DOES NOT = Availability
- pH, CEC, soil texture affect availability
Soil Organic Matter

Where does it go?
(Decomposition pools)

Residues

Intermediate pool
Resists decomposition
Intermediate C:N ratio
Cellulose, hemicellulose

Labile pool
Readily decomposed
Low C:N ratio
Sugar, protein, starch

Resistant pool
Very resistant to decomposition
High C:N ratio
Lignin (Humus)
Soil Organic Matter

• Provides Nutrients
• Supports the Soil Food Web
• Increases H2O holding capacity
• Reduces bulk density
• Protects soil surface
• Reduced by tillage
Biogeochemical Cycles

- Atmosphere
- Biosphere
- Hydrosphere
- Geosphere
Carbon Cycle
Non-Gaseous Macronutrients
How might these elements figure into the Laws of Minimum and Return?
### TABLE 11.1
Types of Two-Species Interactions as Defined by Odum

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<td>A 0</td>
<td>A 0</td>
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<td>- - 0 0</td>
<td></td>
<td>Both A and B affected negatively</td>
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<td>+ + - -</td>
<td></td>
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<tr>
<td>Protocooperation</td>
<td>+ + 0 0</td>
<td></td>
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<td>+ - - 0</td>
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**Graph:**
- **Gossypium hirsutum yield reduction (%):**
  - 1998: \( y = \frac{(21.85 \times x)}{1 + (x \times 21.85/100)} \)
  - \( R^2 = 0.96 \)
  - 1999: \( y = \frac{(18.42 \times x)}{1 + (x \times 18.42/100)} \)
  - \( R^2 = 0.98 \)

**Datura stramonium density** (no. 9.1 m\(^{-1}\) of row)
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</tr>
<tr>
<td>Neutralism</td>
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</tr>
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Note: + organism growth increased; – organism growth decreased; 0 organism growth not affected.
<table>
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<tr>
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*Note:* + organism growth increased; - organism growth decreased; 0 organism growth not affected.
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Nature of Interaction:
- Neutralism: Neither organism affects the other.
- Competition: Both A and B are affected negatively.
- Mutualism: Obligate interaction.
- Protocooperation: Not obligate.
- Commensalism: B host.
- Amensalism: A harmed by presence of B.
- Parasitism: A parasite, B host.
- Predation: A predator, B prey.

Note: + organism growth increased; - organism growth decreased; 0 organism growth not affected.
### TABLE 11.1
Types of Two-Species Interactions as Defined by Odum

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*Note: + organism growth increased; - organism growth decreased; 0 organism growth not affected.*
TABLE 11.2
Summary of Interference Interactions

<table>
<thead>
<tr>
<th>Creator of Interference (A)</th>
<th>Receiver(s) of Interference (B)</th>
<th>Type and Identity of Interference</th>
<th>Location of Interference</th>
<th>Effect on A*</th>
<th>Effect on B*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competition</td>
<td>Roles interchangeable</td>
<td>Removal of resources</td>
<td>Shared habitat</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Parasitism</td>
<td>Parasite</td>
<td>Removal of nutrients</td>
<td>Body of host</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Herbivory</td>
<td>Herbivore</td>
<td>Removal of biomass</td>
<td>Body of host:</td>
<td>+ or –</td>
<td>– or +</td>
</tr>
<tr>
<td></td>
<td>Consumeet</td>
<td></td>
<td>shared habitat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epiphytism</td>
<td>Host</td>
<td>Addition of habitat surface</td>
<td>Body of host</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Proto-cooperation</td>
<td>Roles interchangeable</td>
<td>Addition of material or structure</td>
<td>Shared habitat or body of A/B</td>
<td>+ (0)</td>
<td>+ (0)</td>
</tr>
<tr>
<td>Mutualism</td>
<td>Roles interchangeable</td>
<td>Addition of material or structure</td>
<td>Shared habitat or body of A/B</td>
<td>+ (-)</td>
<td>+ (-)</td>
</tr>
<tr>
<td>Allelopathy</td>
<td>Allelopathic plant</td>
<td>Addition of active compound</td>
<td>Habitat of organism A</td>
<td>+ or 0</td>
<td>+, -, or 0</td>
</tr>
<tr>
<td></td>
<td>Potential habitat associates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Symbols in parenthesis refer to the effect when the organisms are not interacting.
It can Get Complicated!

Simple Two Species

Removal and Addition Interference

Tri-Trophic Example
It can Get Complicated!

Simple Two Species

Tri-Trophic Example
It can Get Complicated!

Simple Two Species
Ecosystem Recovery and Diversity

- **Dynamic Equilibrium**: Stability resulting from opposing forces within a system
- **Succession**: Recovery after disturbance
- **Climax**: A community that demonstrates DE
- However, climax communities may not be the most diverse
- **Intermediate Disturbance Hypothesis**
  - Diversity is greatest when disturbance is neither too frequent or infrequent
  - Mosaic of successional stages
Disturbance

• An event of intense environmental stress occurring over a relatively short period of time and causing large changes in the affected ecosystem

• Natural Systems: Fire, Invasion, Storms, Earthquakes, Floods

• Agricultural Systems: Harvest, Cultivation, Pesticides

• Pest Management = Ecological Disturbance
• Different ecotypes lead to different climax communities
• Disturbance often leads to a mosaic of different stages
• Some agricultural rotations mimic this
Natural vs. Agroecosystems

- **Primary Difference:** System Boundaries
  - Natural systems have “harder” boundaries
  - Human interactions open systems up
    - Globalization of food systems represent the pinnacle of this trend

- **Secondary Difference:** Reduced Stability/Diversity
  - Maximization of harvestable NPP
  - Homogeneous Habitat, Open Niches = Pest potential
Sustainable Agroecosystems

- Ecological Stability + Yield
- Energy Efficient: Maximization of NPP
- Reduced inputs
- "Law of Return" practiced: conservation of nutrients