Agroecology Basics

1 The Basics of Agroecology
- Matthew J. Grieshop
- MSU Entomology

2 Agroecosystems Etymology
- Agro: from the Greek *agros* meaning "field"
- Ecology from the Greek *oikos* meaning "house or household"
- System: From the Greek *systema* meaning "organized whole"
- "Organized field-house"

3 Agroecology = Agronomy + Ecology
- Uneasy hybrid
- Agronomy = applied science with focus on yield
- Ecology = basic science focused on elucidating natural processes
- Human vs. Nature Dichotomy

4 Agroecology: A Brief History
- 1920's: Birth of Crop Ecology
- 1930's-1940's: Genesis of input agriculture
- 1950's: Ecosystem concept provided a new perspective
- 1960-1970's: Agricultural systems used for ecological research
- 1980's: Development of textbooks
- 1990's: Recognition by ESA

5 Agroecology Pioneers
- Steve Gleissman (UCSC)
- Miguel Altieri (UCB)
- Yvette Perfecto (UM)

6 Agroecosystem: Defined
- Site or regional system of agricultural production
- Can be as small as a field
- or as large as a food system
- An agroecosystem is a specific kind of ecosystem
- Natural components
- Implied anthropogenic manipulation

7 What do Agroecologists Study?
- *Net Primary Productivity* (NPP) = Yield?
  - The transformation and use of energy and matter
  - Ecological relationships of *Producers, Consumers, and Detritivors*
- *Energy Flows and Nutrient Cycles*
- *Community Dynamics and Succession*
- Design of efficient Agroecosystems

8 Gross and Net Primary Productivity
- GPP is the total K calories of solar radiation captured by producers per m²
- NPP is GPP minus energy used by plants in their life processes
- Determined by available solar energy, nutrients, and biotic factors
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- Agronomists view: NPP equals yield + non-yield biomass + loss to pest interactions.

9 Ecosystems

- A place in which matter and energy are moved, transformed, or stored
- Ecosystems components
  - Abiotic
    - Landscape
    - Geology
    - Climate
    - Microclimate?
  - Biotic
    - Producers
    - Consumers
    - Trophic interactions
- Energy Flows
- Nutrient Cycles

10 Ecosystem Trophic Structure

- Ecosystems are organized as trophic levels
- Each trophic level derives its energy and matter (nutrients) from the one below it.
- Thus, energy and matter diffuse through ecosystems with more energy and matter available in lower trophic levels
- Producers make up the first trophic level
- Consumers make up the remaining levels
  - Herbivores
  - Predators
  - Parasites
  - Detritivores
- Detritivores are special because they link producers back to higher trophic levels by making matter available to plants

11 Putting it all together: Systems

- Ecosystems are one type of system
- System: a group of independent but interrelated elements comprising a unified whole
- Systems are composed of elements or states and flows enclosed in a boundary
- Systems typically exhibit "emergent properties"
- Complex behaviors that appear from simpler interactions
- Energy, nutrient flow, dynamic equilibrium

12 Systems Diagrams

- Howard T. Odum was an ecologist by training but his pictographs are incredibly flexible and have been applied to ecology, economics, and engineering problems
- Both qualitative and quantitative models can be created
- The use of different shapes to describe basic system components communicates a lot of information
- Size of arrows and or components can indicate properties as well as labeling (including formula)

13 Generalized Agroecosystem

- Arrows Represent Energy
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- The Basal levels of this system are plants and their needs
- **14 So first we will talk about "producers" 1st trophic level or plants**
  - We'll also talk about the ultimate source of all energy the sun and where nutrients come from
- **15 Photosynthesis**
  - Plants or *Autotrophs* capture solar energy and fix carbon, oxygen, and hydrogen through the process of *photosynthesis*
  - Photosynthesis has both a light and a dark cycle
    - Light cycle = capture of energy in ATP and NADPH
    - Dark cycle = fixation of carbon (manufacture of sugars) from ATP and NADPH and CO2
  - Primary *photosynthates* are later transformed into more complex molecules (*complex carbohydrates, amino acids, proteins, fatty acids*)
  - There are three types of photosynthesis: We'll talk about two.
- **16 Requirements of photosynthesis and Plants**
  - **H20, CO2, Light limit photosynthesis**
  - Plants typically gather water through their roots (*transpiration*) and light and CO2 through their leaves
    - Light is captured using *chlorophyll*
    - CO2 enters the plant via *stomata* plants also loose water through *stomata*
    - Stomata can be opened or closed
    - Closed stomata cannot absorb CO2 but also don't transpire H2O
    - *Compensation point*: level of CO2 at which *photorespiration* occurs yielding net energy loss
- **17 C3 --> optimized for cool temps.**
  - First stable DS compound 3 C
  - Requires Open Stomata
  - Most crops: solanaceae, leafy vegetables, cucurbits, brassicas, beans and peas
  - Prone to drought stress
- **18 C4 --> optimized for warmer temps.**
  - C4 --> 4 C compound prior to dark cycle
  - Can occur with closed Stomata
  - Lower compensation point than C3 plants
  - Corn, Sorghum, Sugarcane
  - Require warmer temperatures
- **19 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
- **20 Light**
  - Light refers to a range of the electromagnetic spectrum
  - EM radiation consists of self propagating waves
  - EM is measured by Frequency (cycles per second) and Wavelength (nm)
  - Light is EM radiation between 1 and 1 million nm
- **21 Light**
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- The visible range is between 400 and 760 nm
- This is also considered the Photosynthetically Active Radiation (PAR) range
- Blue (400-500 nm) and Red (650-700 nm) are the most active portion of PAR
- The Infrared range (800-3000 nm) converts to heat and is also important
- Light effects plant growth, germination, flowering, and respiration

22 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)
- **Saturation Point**: The intensity at which a leaf no longer absorbs more energy
- **Compensation Point**: Intensity at which photosynthesis takes place
- **Duration**: Time spent with adequate light (photoperiod)

23 Light Environment Determinants

- **Seasonality**: Quality, Intensity, and Duration
- **Altitude**: Intensity increases with altitude
- **Topography**: Aspect
- **Air Quality**: Quality and Intensity
- **Canopy Structure**: Quality and intensity (10%)
- Make into table with check boxes

24 Relative Rate of Transmission and LAI

- **Leaf Area Index (LAI)**: total leaf area above ground
- Leaves will allow 10% light transmission
- **Relative Rate of Transmission**: average light penetration: total incident light
- **Light Attenuation**: Total amount of light absorbed under canopy

25 Temperature

- Temp. is the result of EM from the sun
- Temp. moderates the metabolism of all living things

26 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

27 Practice Based Microclimate Manipulation

- "La Milpa": Corn/bean/squash interplanting
- Corn provides scaffold for beans
- Squash "fills in" below corn
- Corn = C₄, Bean and Squash = C₃

28 Now that we've covered Producers and photosynthesis, we'll talk about nutrients, soils, and biogeochemical nutrient cycles.

29 Nitrogen, Phosphorus, Potassium and Micronutrients

- N to synthesize amino acids
- P for cell membranes
- K for protein synthesis, osmoregulation
- Other micronutrients such as Fe, Cu, Zn, Mn, Mo, B, Cl, S
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- Taken up by roots
- N as Ammonium or nitrates
- P as Phosphates
- K as K+

30 Soil: Interface for plant roots and most nutrient uptake

- Many Perspectives...
  - Geologist: Decomposed rocks
  - Engineer: Physical characteristics: compressibility, permeability, strength, etc.
  - Pedologist: A natural body occurring in various layers, composed of unconsolidated rock fragments and organic matter
  - Agronomist: The unconsolidated cover of the earth, made up of mineral and organic components, water and air and capable of supporting plant growth
  - Ecologist: Recycling system/habitat for living organisms

- Broad Functions of Soil
  - Food and other biomass production
  - Environmental Interaction: storage, filtering, and transformation
  - Biological habitat and gene pool
  - Source of raw materials
  - Physical and cultural heritage
  - Platform for man-made structures: buildings, highways

31 Plant Growth Functions of Soil

- Support: anchor for plant roots
- Moisture: supplies H2O to roots
- Gaseous Exchange: supplies air to soil flora and fauna
- Nutrient Exchange: supplies macro and micro nutrients

32 Soil is Composed of....

- Mineral particles
- Organic Matter (SOM)
- Air (Pore Spaces)
- Water

33 Soil Formation

- Minerals broken down and transformed
- Weathering
  - Physical
    - H2O, Wind, Freezing, Gravity
    - Abrasion via tectonic shifts
  - Biological Processes
  - Plants
  - Animals
  - Microorganisms

34 Chemical Weathering

- Hydration: addition of water
- Hydolysis: cation replacement with Hydrogen ions
- Solution: Carbonic leaching
- Ca and Mg carbonates
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- Oxidation: conversion of Fe

35 Transported Soils
- Colluvium: gravity transport
- Alluvium; H₂O transport
- Glacial: Glacial transport
- Eolian: wind transport

36 Biological Weathering
- Rooting
- Physical breakage with roots
- Transportation of minerals
- Decomposition and Mineralization
- Cycling of biotic materials
- Organic acids add to chemical weathering
- Humus formation: colloidal organic compounds

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

38 Soil Texture
- % by weight of Gravel, Sand, Silt, Clay
- Gravel >2mm diameter
- Sand > Silt > Clay
- Finer textured particles hold water and nutrients better
- Coarser textured particles help drainage
- The mix of textures determines name

39 Soil Structure
- How particles are bound together
- "Crumb" structure
- Aggregate Stability
- Bulk Density
- SOM very Important

40 Color
- Color provides clues to content
- Red or Yellow = Fe oxides
- Grey or Yellow Brown = Ferric Fe
- Dark = More carbon (SOM)
- Temperature dynamics

41 Cation-Exchange Capacity
- Cation exchange between the soil & soil solution
- Directly effects nutrient availability
- Clay and Humus (SOM) are key

42 Soil Acidity and pH
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- 5-8 range
- <6.6 = Acid Soil
- >7 = Basic Soil
- Effects CEC
- Effects soil biology
- Salinity and Alkalinity
  - Typically a problem of too much
  - Osmotic balance: hinder transpiration

43 Soil Horizons
- Four major profiles
  - O: Organic
  - A: Mineral and Humus
  - B: Deposited clays, oxides
  - C: Least Weathered
  - R: Unweathered Parent Material
- O and A Horizons
  - Most biologically active
  - O reduced in ag. soils
  - Key to Humus development
  - Important for Crumb Structure

44 Soil Horizons
- Profiles actually a continuum
- Four major types of soil development

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

46 Soil Organic Matter
- Decomposing plants, animals, wastes
- Soil Organic Matter Facts
  - Natural systems: 15% or more
  - Agricultural systems: <5%
  - % Closely linked to temperature
  - Why?

47 Soil Organic Matter functions
- Provides Nutrients
- Increases H2O holding capacity
- Reduces bulk density
- Protects soil surface
- Reduced by tillage

48 Biogeochemical cycles
- Storage, transformation and movement of elements in the
  - Atmosphere
  - Biosphere
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- hydrosphere
- geosphere
- Carbon and Nitrogen have a gas phase
- Most other nutrients do not

**49 Carbon Cycle**
- C is fixed during photosynthesis
- C is released during respiration
- Most C is fixed in the form of Carbohydrates

**50 Nitrogen Cycle**
- N exists in elemental, Inorganic, and organic forms
- N is crucial to the formation of Proteins
- Plants primarily take up inorganic nitrogen
- elemental and inorganic N is very mobile
- Organic N is less so

**51 Non-Gaseous Macronutrients**
- P, K do not readily volatilize
- Cycles are between mineral sources and living systems
- Very slow cycles Geologic Time Scale
- Localized cycles

**52 How might these elements figure into the Laws of Minimum and Return?**

**53 The Rest of the Course**

**54 Biotic Interactions**
- Organism to Organism Interference
  - Positive, Neutral or Negative interactions between two organisms
  - Table also shows whether relationship is obligate
- **Neutralism**: Daisies and owls
- **Competition**: Black Walnut vs.
- **Mutualism**: Rhizobium and Legumes
- **Commensalism**: non parasitic epiphytes
- **Amensalism**: Black walnut?
- **Parasitism**: Tobacco hornworm and ##
- **Predation**: Ladybird Beetle and Aphids
- **Symmetry**: Are impacts felt by both players? Are both players affected in the same direction? (+,-,0)
- We are typically interested in Competition, Mutualism, Parasitism, and Predation

**55 Interference Interactions**
- Considering the previous relationships as interference allows us to include indirect effects and the environment.
- **Interference Interaction**: Modification of the environment by one organism that affects another.
- **Addition interference**: Organism adds something to the environment that affects another
  - Allelopathy
  - Kairomones
- **Removal interference**: Organism removes something that affects another
  - Competition
  - Herbivory, Parasitism, predation
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- It can get complicated!
  - Simple form what kind of two species interaction? what kind of interference? Is it symmetrical?
  - Indirect form
  - Tri trophic How many relationships? what kind of interference? symmetry?