NAME OF THE COURSE WORK
ENVIRONMENT & AGRICULTURAL MICROBIOLOGY

UNIT-IV
AGROECOSYSTEM

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Agroecosystems

- Agroecosystems include the soil, plants, and animals that make up farms, croplands, orchards, pastures, and rangelands.
- If 30% of land is used for cropland or pasture, the land is considered an agroecosystem.
- Agroecosystems cover 28% of the earth's land area, or 12.16 billion acres (4.92 billion hectares).

1960's	**Today**	**By 2050**
• 2/3 of the world's population lived in **rural areas** • 60% of the **economically active** population worked in **agriculture**	• **Half of the people** live in **rural areas**, and • 40% of the **active population** depend directly on **agriculture** for their livelihoods (FAO, 2007)	• 2/3 of the world's population will live in **cities** • **Competition for water** • **Different expectations** on how rural land and water sources are used

AGRICULTURAL MICROBIOLOGY

Soil & Microbes

5 billion – unknown period

No continents as we see them today – earth was one mass of archipelagos of volcanic rock

Before 3 billion

Origin of solar system, photochemical reaction – precursor to life on earth

3 billion years ago,

Prokaryotes (N2 fixing, sulphate reducing, iron oxidizing bacteria) → photosynthetic- N2 fixing algae → Eukaryotes

Microbes - Primer & Premier

Soil Microbes

Fertility of soil depends not only on its chemical composition, but also on the qualitative & quantitative nature of microorganisms

Estimation of Microbes in soil

Plate counts-1 gram of dry soil
Bacteria – up to 200 million
Actinomyces – up to 1,00,00,000
Fungi – up to 10,00,000
Yeast – 1,00,000
Algae – 50,000
Protozoa – 3,00,000

Pioneers of soil bacteriologist
1888, Dutch scientist, MW. Beijerinck
1856-1953, Russian microbiologist, SN. Winogradsky

Large Percentage of Species of Soil Organisms is Unknown

Size	Group	Known species	Estimated total species	% Known
	Vascular plants	270,000	300,000	90
Macrofauna	Ants	8,800	15,000	58.7
	Termites	1,600	3,000	53.3
	Earthworms	3,600	No estimate	No estimate
Mesofauna	Mites	20,000–30,000	900,000	2.2–3.3
	Collembola	6,500	24,000	27.1
Microfauna	Protozoa	1,500	200,000	7.5
	Nematodes	5,000	400,000	1.3
Microflora	Bacteria	13,000	1,000,000	1
	Fungi	18,000–35,000	1,500,000	1–2

Methods used in soil microbiological studies

- Sterilization methods
- Obtaining soil samples
- Soil dilution & Plate Counts
- Soil plate
- Direct microscopic examination of soil
- Fluorescent staining

Chemical methods to determine microbial biomass

- Soil percolation techniques (VAM)
- Soil enzymes estimation
- Methods for assaying antibiosis

Determination of MPN

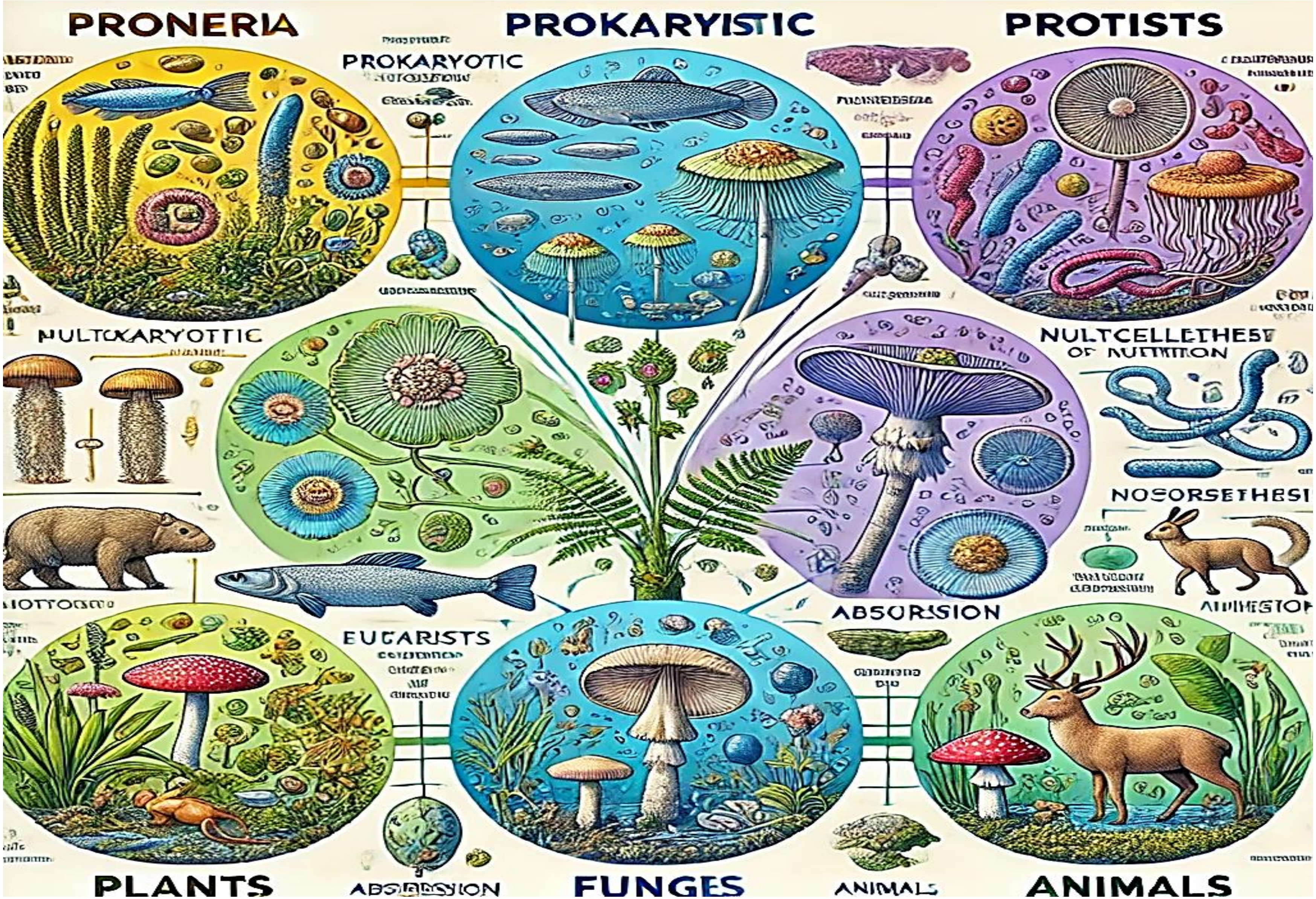
Soil respiration

Molecular methods in soil microbiology

- Extraction & purification of nucleic acid from soil
- DNA Hybridization
- Amplification by PCR
- Detection & Identification of rRNA Genes
- Amplified length polymorphism (AFLP)
- Pulse-field Gel Electrophoresis (PFGE)

General Classification of Soil Organisms

FIVE KINGDOMS



Soil Microflora

There are many ways to classify

One useful way is into these two major groups based on how they get energy:

1. Autotrophic: Use sunlight or inorganic chemical reactions for energy
2. Heterotrophic: Use organic compounds for energy

Fungi: molds, mushrooms, yeast, rusts

- Heterotrophic
- Tolerate low pH (most important in decomposition in acid forest soils (bacteria are acid-sensitive)

Can be beneficial (even essential):

Decomposers of MO

Mycorrhizae "fungus root" symbiotic

Symbiotic with plant roots - essential to growth in many cases (e.g.,pines)

Aid in taking up water and nutrients (especially P), and

they get carbohydrates in return

Protista : Protozoans, Algae and Slime Mold

Protozoa:
-Consume decomposing organic matter, bacteria, and fungi

-1-celled organisms, motile (cilia or flagellum) eat bacteria, fungi
Cause of several human diseases (malaria, sleeping sickness, dysentery)

Algae
- Carry on photosynthesis (autotrophic)
- Not decomposers
- Green, blue-green (the latter now called cyanobacteria) to fix-N_2

Monera: Bacteria and Actinomycete

1. Decomposers
2. Nutrient-fixing/solubilizing/mobilizing monera

Decomposing bacteria
Both aerobes and anaerobes
Very important for nutrient cycling: convert nutrients from solid phase to ions which go into soil solution

Bacteria:

Single-celled rod or spherical, 1-2 µm
1 tsp = 100,000,000 bacteria = 1,000,000 actinomycetes
Three subdivisions based on how they handle oxygen
Anaerobes: Live only in the absence of O_2
Facultative: Can live in either the presence or absence of O_2
Aerobes: Live only in the presence of O_2

Major subdivisions based on how they get energy:
Hetertrophs: Live on dead organic matter
Autotrophs: energy from sunlight or chemical reactions
Photoautotrophs: use sunlight
Chemautotrophs: use inorganic chemical reactions

Free living N-fixers

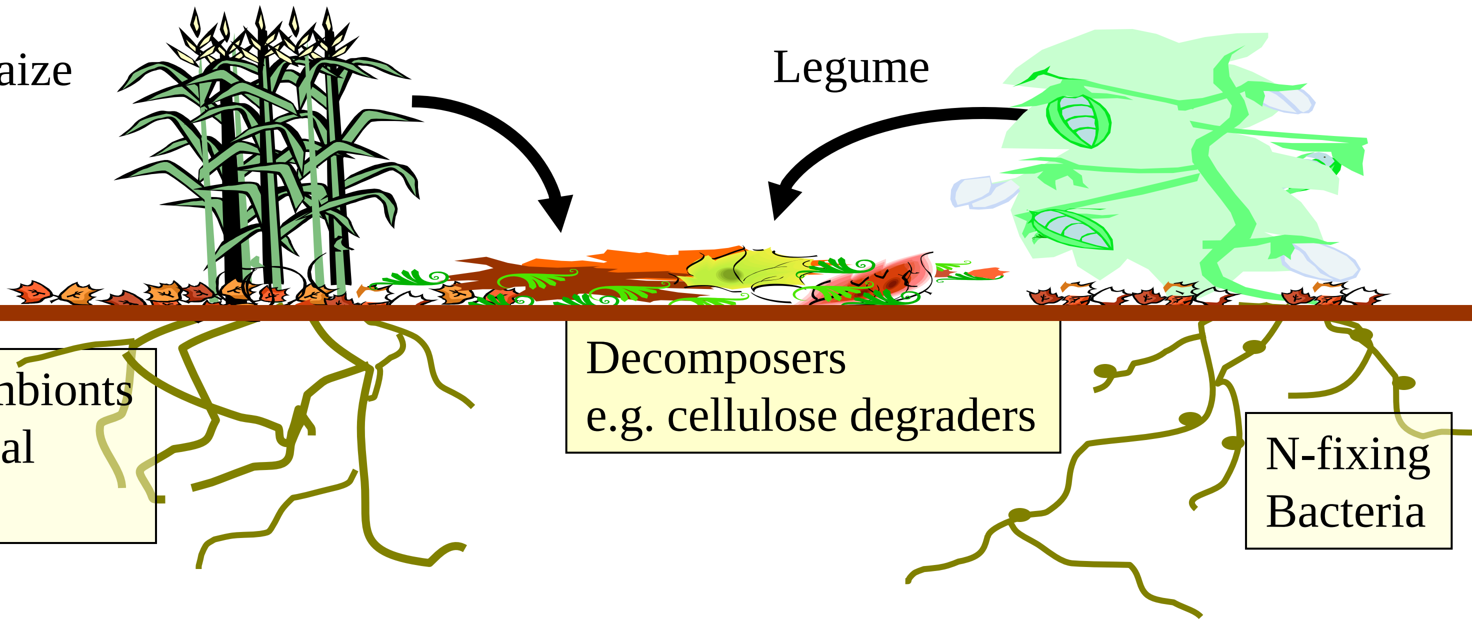
- Do not need a host plant
- Usually fix much less than symbiotic fixers
- Aerobes: *Azotobacter, A. beijerinckia*, (hetero)
- Anaerobes: *Clostridium*, (most common)
- Blue-green algae (Cyanobacteria).
- Often associated with plant roots; present in cryptogamic / biotic crusts.
- Believed to be first fixers 2-3 billion years ago.

Actinomycetes

- 5-20 μm dia, 0.1 - 1 m long (filaments, but more similar to bacteria)
- Morphologically transitional from bacteria to filamentous fungi
- Unicellular, slender branched mycelium
- Numerically second only to bacteria
- Aerobic, like pH > 5
- Active in decay of cellulose and other organics (hetero)
- Frankia genus active in nitrogen fixation (as noted above)
- Some produce antibiotics (exudates which kill bacteria)

Frankia spp.
Various tree and shrub species (*Alnus*, *Myrica*, *Elaeagnus*, *Ceanothus*, *Casuarina* etc.)
These are more important than legumes in forests.
Can also fix N_2 up to 300 kg ha-1 yr-1(atmospheric dep = 1-25).

KEY FUNCTIONAL GROUPS OF SOIL BIOTA



Micro-symbionts
mycorrhizal
Fungi

Decomposers
e.g. cellulose degraders

N-fixing
Bacteria

Macrofauna
(Ecosystem Engineers)
- Earthworms
- Termites

Microregulators
Nematodes

C&N transformers
e.g.methanogens &
nitrifiers

Pests and
Diseases
e.g. fungi, invertebrates

Source Swift (2002)

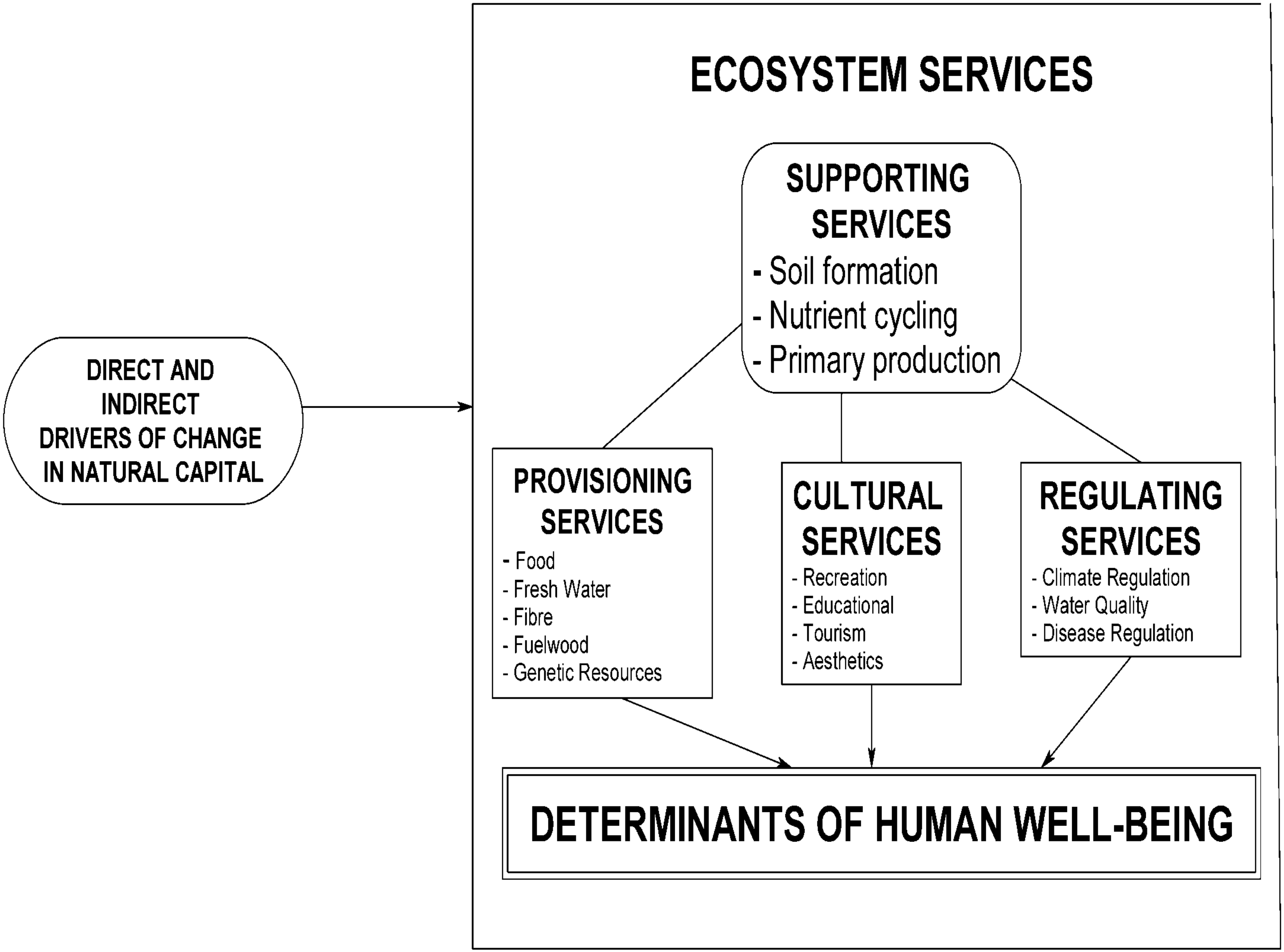
Organisms, Functional Groups and Ecosystem Process

Examples of diverse biota within functional groups are listed for a few ecosystem processes that are similar in soils and sediments

Organisms	*Functional groups*	*Ecosystem process*
Vertebrates (lizards, beavers); invertebrates (crustaceans, molluscks in sediments; ants, termites in soils)	Bioturbators, ecosystem engineers	Soil and sediment alteration and structure, laterally and to greater depths, redistribute organic matter and microbes
Plant roots, algae, diatoms	Primary producers	Create biomass, stabilize soils and sediments
Decapods, millipedes	Shredders	Fragment, rip, and tear organic matter, providing smaller pieces for decay by organisms
Bacteria and Fungi	Decomposers	Recycle nutrients, increase nutrient availability for primary production
Symbiotic (e.g *Rhizobium)* and asymbiotic (e.g. *Azobacter, Cyanobacter*)	Nitrogen fixers	Biologically fix atmospheric N_2
Methanogenic bacteria, denitrifying bacteria	Trace-gas producers	Transfer of C, N_2, N_2O, CH_4 denitrification
Roots, soil organisms	CO_2 producers	Respiration, emission of CO_2

Ecosystem Services

- Ecosystem services provided by soil and sediment biota
- Regulating biogeochemical cycles
- Retention and delivery of nutrients to plants and algae
- Generation and renewal of soil and sediment structure
- Bioremediation
- Provision of clean drinking water
- Modification of the hydrological cycle (e.g. erosion control)
- Translocation of nutrient, particles and gases
- Regulation of atmospheric trace gasses
- Modification of anthropogenically driven global change
- Regulation of animal and plant populations
- Contribution to plant production for food, fuel and fiber
- Contribution to landscape heterogeneity and stability
- Vital component of habitats important for recreation and natural history


ECOSYSTEM SERVICES
DIRECT AND INDIRECT DRIVERS OF CHANGE IN NATURAL CAPITAL
SUPPORTING SERVICES
- Soil formation
- Nutrient cycling
- Primary production
PROVISIONING SERVICES
- Food
- Fresh Water
- Fibre
- Fuelwood
- Genetic Resources
CULTURAL SERVICES
- Recreation
- Educational
- Tourism
- Aesthetics
REGULATING SERVICES
- Climate Regulation
- Water Quality
- Disease Regulation
DETERMINANTS OF HUMAN WELL-BEING

Provisioning

Goods produced or provided by ecosystems

- food
- fresh water
- fuel wood
- fiber
- biochemicals
- genetic resources

Regulating

Benefits obtained from regulation of ecosystem processes

- climate regulation
- disease control
- flood control
- detoxification

Cultural

Non - material benefits obtained from ecosystems

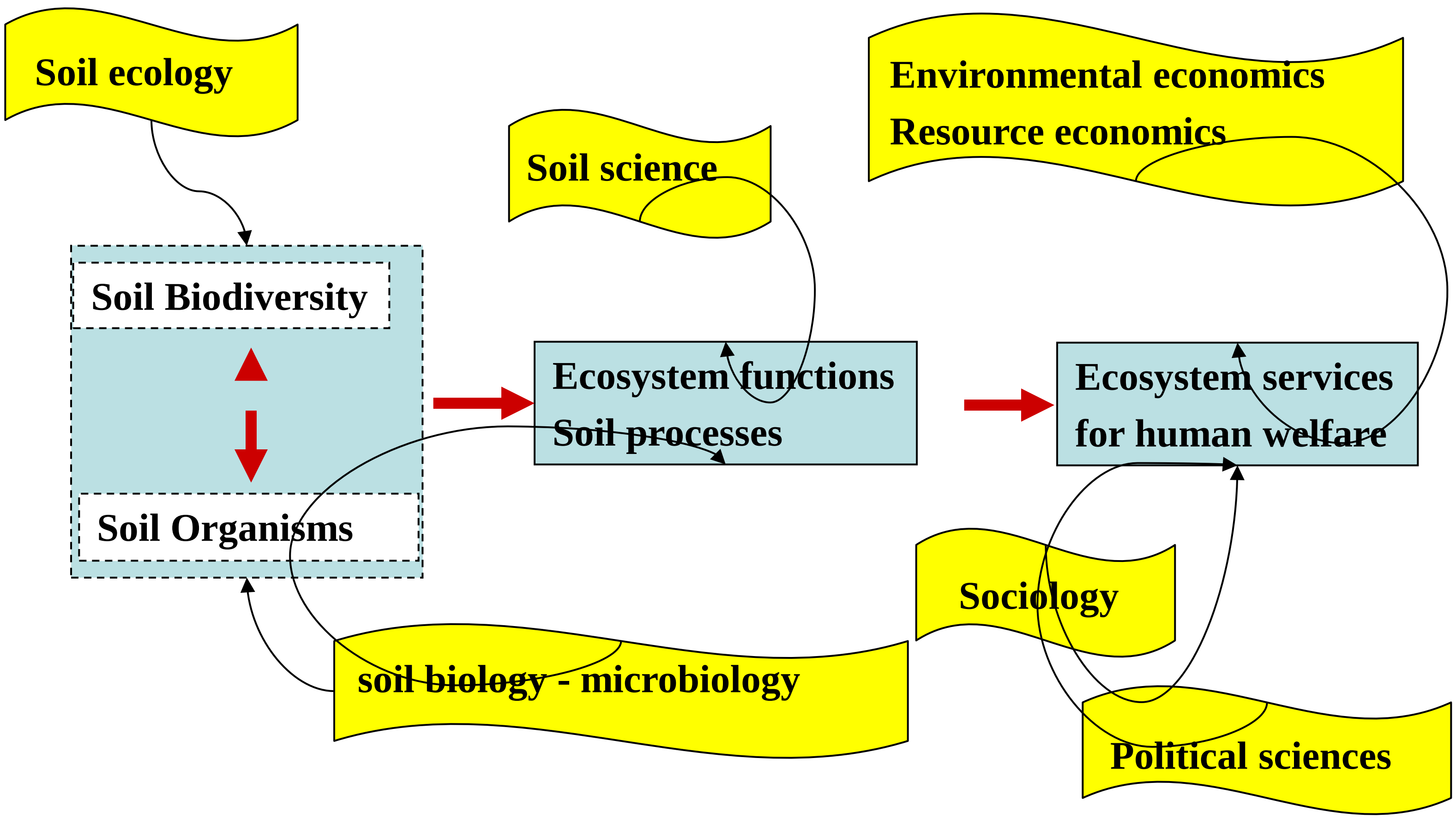
- spiritual
- recreational
- aesthetic
- inspirational
- educational
- communal
- symbolic

Supporting

Services that maintain the conditions for life on earth.

- Soil formation
- Nutrient cycling
- Pollination

A multi-disciplinary approach to research in soil related ecosystem services



Agroecosystems - context

Material human requirements

- Water, air
- Food
- Fibre
- Fodder
- Fuel
- Shelter
- Space
- Goods

Human activities for food production

- Hunting
- Gathering
- Fishing
- Grazing
- Farming
- Bio-industry

Human land-use

- Cropland
- Rangeland
- Woodland
- Urban/industrial
- Nature

Agroecosystems: perspectives

• Historical • Social • Ecological • Biological • Technical

Historical perspectives

Time-line (yrs)

Archaic	- 250,000	hunting-gathering, nomadic
Prehistoric	- 15,000	domesticated plants and grazers
Ancient	- 5,000	soil cultivation, irrigation
Medieval	- 1,500	deep plowing, manure, selection, profit
Modern	- 200	scientific approach
Contemporary	- 50	industrialization, ecological sustainability (?)

Increasing trends in

- human arrival and local population size
- control over food production
- dependence on technology, transport

Early Human Foraging

- • 250,000 years ago
- • Nomadic hunter- gatherers
- • Small communities in open landscapes
- Human evolution and early cultural
- Social structure: clan/family groups
- Food: wild animals, grains, nuts, berries, tubers
- Problems: predators, resource depletion, adverse selection, rival clans
- Innovations: domestication of dogs

Prehistoric Agriculture

- ❖ Started 15,000 years ago
- ❖ Small semi-sedentary communities
- ❖ Stone tools
- ❖ Early agriculture
- ❖ Early art

- ❖ Social structure: larger clan/family groups
- ❖ Food: wild animals and plants, local produce
- ❖ Problems: predators, resource depletion, rival clans
- ❖ Innovations: domestication of grains, herbivores

Ancient Agriculture

- ❖ •Started 5,000 years ago •Larger villages, cities
- ❖ • Large-scale agriculture
- ❖ •Metal tools
- ❖ •Soil cultivation, irrigation
- ❖ • Food storage
- ❖ • Burocracy

- ❖ Social structure: large non-family groups
- ❖ Food: local produce, storage
- ❖ Problems: predators, resource depletion, rival clans
- ❖ Innovations: domestication of vegetables, fruit trees, cats

Medieval Agriculture

- Started 1,500 years ago
- Feudal relations
- Large cities, manors Large-scale agriculture Sustenance and profit Plowing, fertilization
- Social structure: serfdom
- Food: local produce, storage, import
- Problems: food shortage, desease
- Innovations: selection, work
- differentiation

Modern Agriculture

- Started 200 years ago
- Population increase
- Land development
- Production maximization
- Mechanization
- Profit
- Social structure: family business
- Food: local produce, storage, import, industrial processing
- Problems: pests, pollution, subsidies, capital investment
- Innovations: science-based, hybrid crops

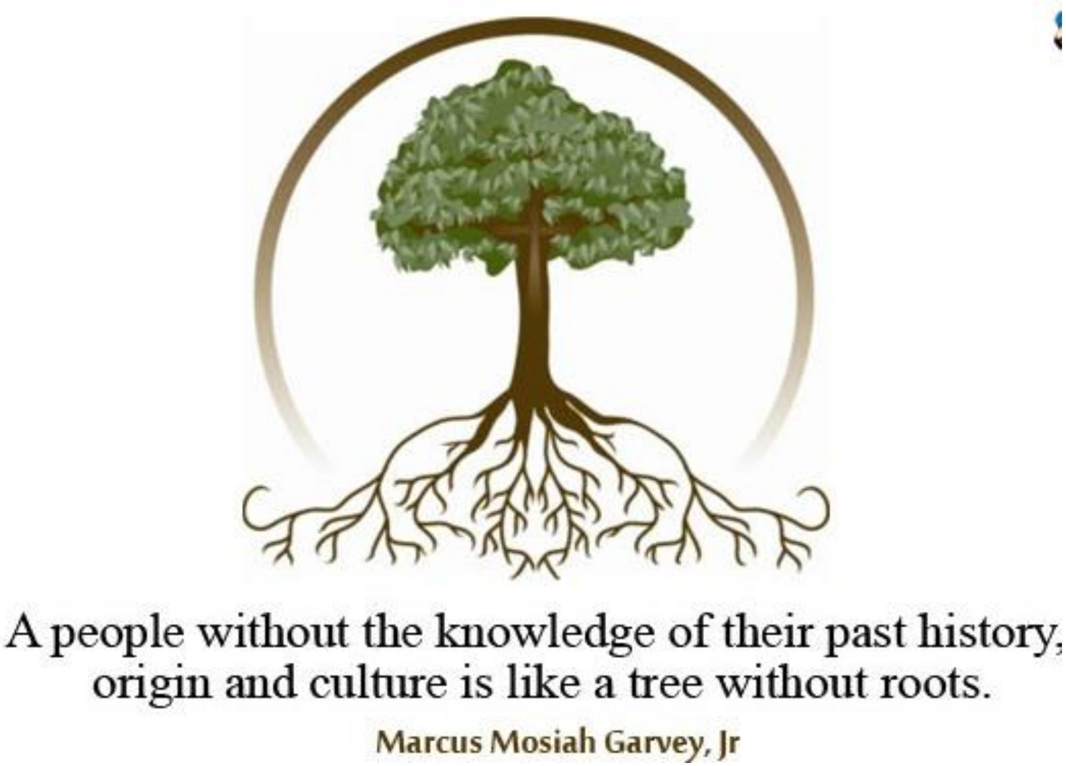
Contemporary Agriculture

- ❖ Started ca 60 years ago
- ❖ Population increase
- ❖ Reduced natural area
- ❖ Production maximization
- ❖ Globalization
- ❖ Profit

- ❖ Social structure: private and corporate business
- ❖ Food: import/export, industrial processing
- ❖ Problems: pests, pollution, subsidies, capital investment, encroachment on nature, global warming
- ❖ Innovations: bio-industry, precision agriculture, genetic engineering, alternative life-styles

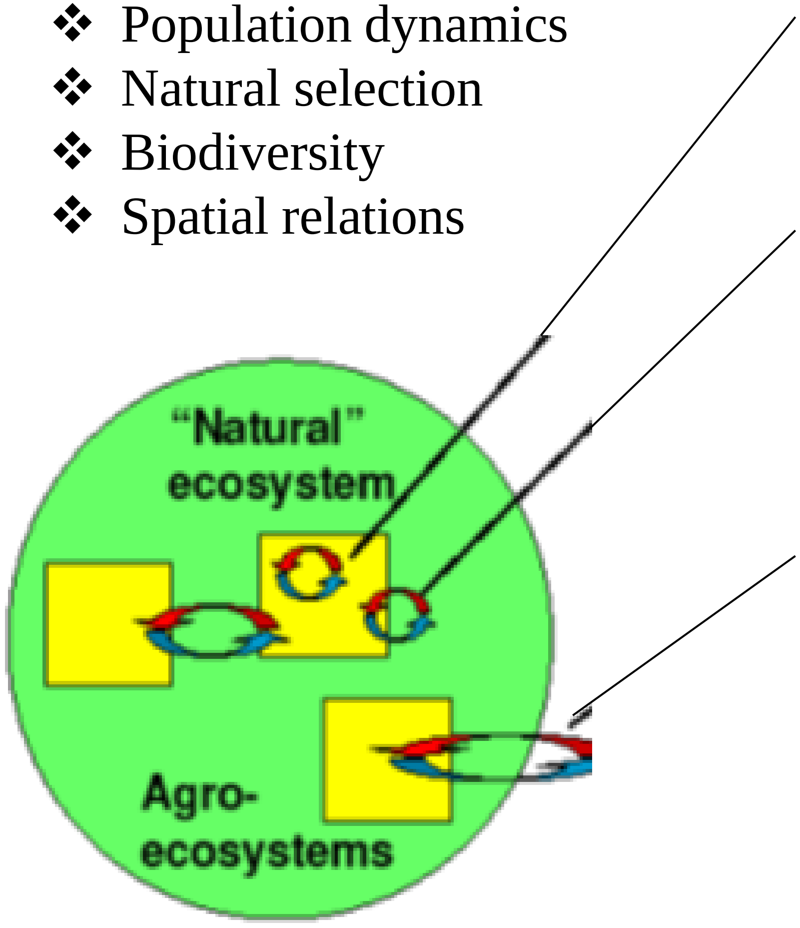
Social Perspectives

- ❖ • Sociology
- ❖ • Economy
- ❖ • Politics
- ❖ • Culture
- ❖ • Religion
- ❖ • Heritage
- ❖ • Education



Ecological Perspectives

- Energy and resources
- Trophic structure
- Population dynamics
- Natural selection
- Biodiversity
- Spatial relations



Processes within agro-ecosystems
Energy, resource flows
Crop plant performance
Biotic communities
Soil processes

Relationships among agro- and natural ecosystems
Resource flows from outside
Predators, pests and weed invasion
Export of plant and animal products

Relationships between agro-ecosystems and the 'rest of the world'
Resource subsidies
Pest and weed invasion
Export of plant and animal products
Pollution

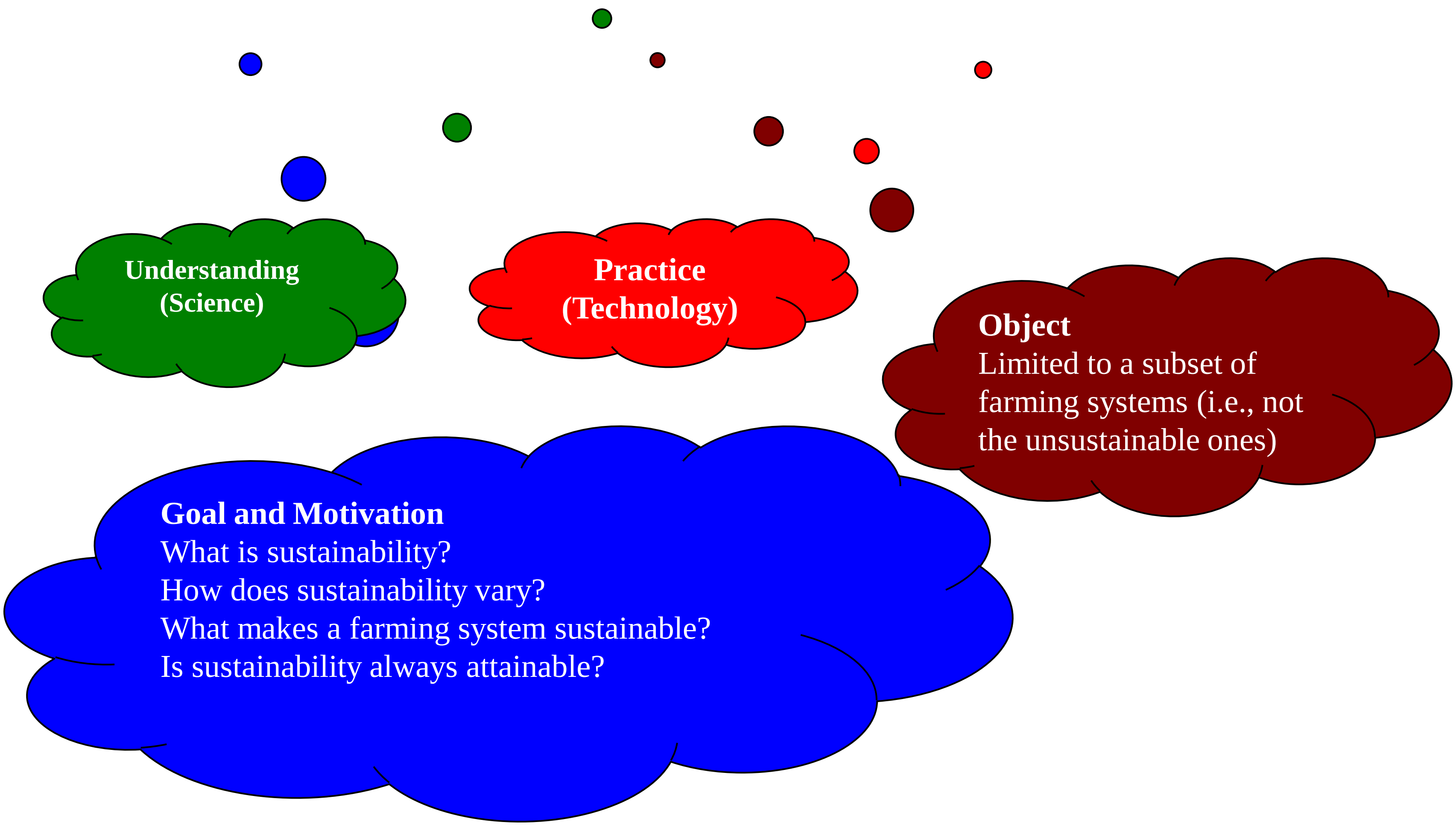
Technical Perspectives

- Irrigation
- Soil preparation
- Planting and sowing
- Fertilizer application
- Harvesting

Agroecology

"The application of ecological concepts and principles to the design and management of sustainable farming systems"

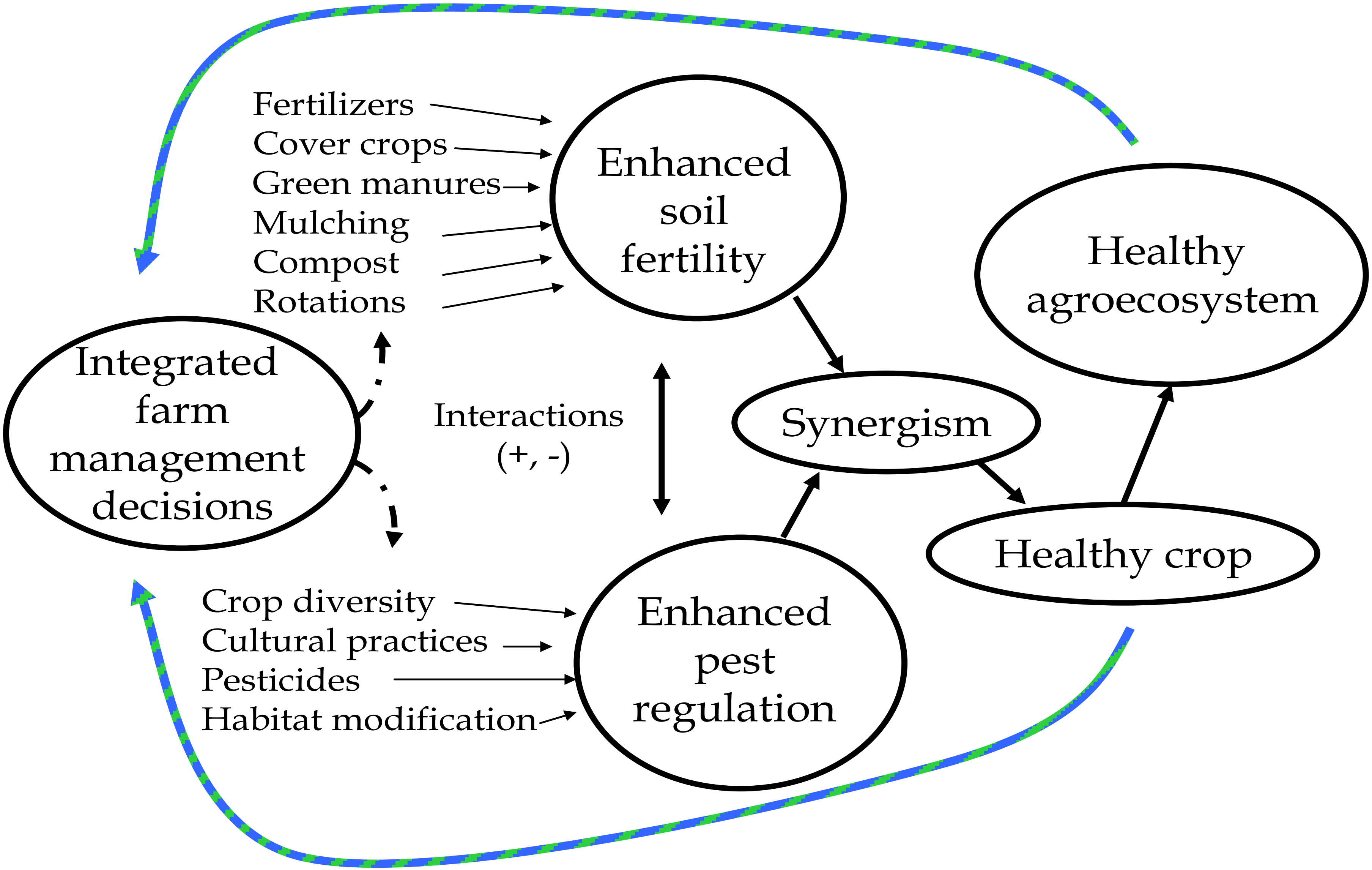
- Gliessman, 2000



Principles of Agroecology

- ❖ Use of renewable resources
- ❖ Minimize toxic compounds
- ❖ Conserve resources
- ❖ Manage ecological relationships
- ❖ Adjust to local environments
- ❖ Diversification
- ❖ Empower people
- ❖ Manage whole systems
- ❖ Maximize long-term benefits
- ❖ Value health

Agroecology: Science & Sustainability



Where Are We?

What are the Strengths & Weaknesses of our current agroecosystem/agricultural system?

Successes !!!

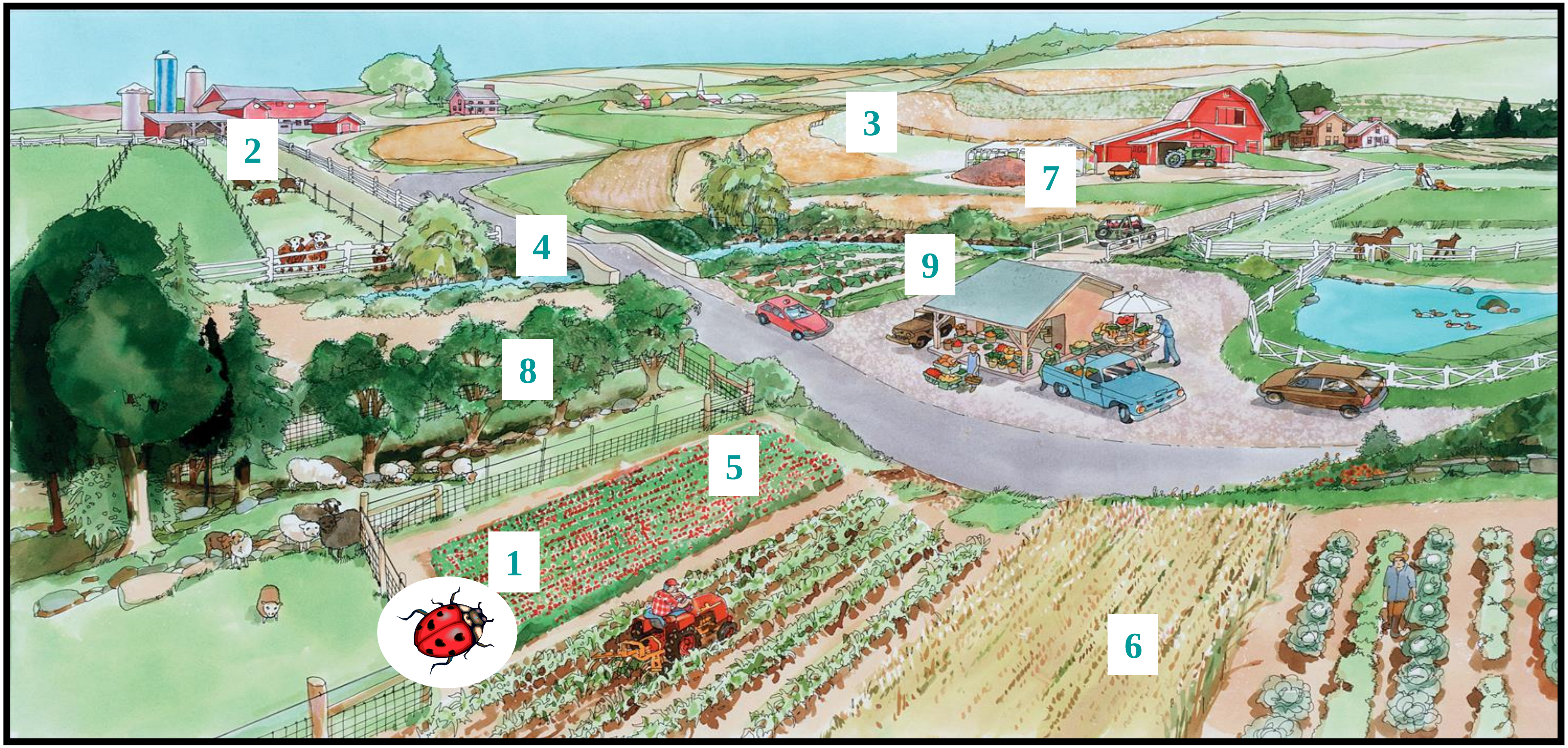
- Abundant food supply! in the developing world
- Fresh fruits and vegetables available year-round
- Cheap food
- Luxury foods such as coffee, tea, chocolate, and spices easily available around the world
- Effective food preservation technologies (refrigeration, freezing, canning, packaging)
- Convenience foods
- Mechanization produces high labor efficiency
- Improvements in soil conservation
- Availability of agricultural inputs for quick solutions to production problems




Problems

- Continuing soil loss
- Food safety concerns (mad cow disease, food poisoning outbreaks, antibiotic resistance, toxins and pesticides)
- Water pollution, air pollution (& odors), habitat loss, water depletion
- Continuing hunger – and rise of obesity
- Failing farms, economic uncertainty and stress
- Declining communities
- Farm accidents, chronic diseases linked to agricultural chemicals
- Reliance on fossil fuels, global warming
- Farmland loss to development, ugly countryside
- Difficulty of starting in farming


Elements of Sustainability



1 Integrated pest management
2 Management intensive grazing
3 Soil conservation
4 Water quality
5 Cover crops

6 Crop/landscape diversity
7 Nutrient management
8 Agroforestry
9 Marketing

What is Biodiversity and Why is it Important?

- “Biodiversity is the sum total of all the plants, animals, fungi, and microorganisms in the world, or in a particular area; all of their individual variation; and all the interactions between them.”— *Peter H. Raven, "Defining Biodiversity," Nature Conservancy (Jan.-Feb. 1994) 44(1): p.11*
- Farm Biodiversity is important because:
  Diverse species, which most of them are small in size,
- Serve as natural enemies to control pests,
- Help degrade wastes,
- Improve soil quality,
- Fix nitrogen for plants,
- Pollinate crops and other vegetation,
- and provide numerous other vital services for humans and their environment (*Pimentel et al., 1997b*).

Types & Activities

Cultivated or ‘planned’ biodiversity

Crops, livestock, aquaculture fisheries.

Associated biodiversity

Supports agricultural production through nutrient cycling, soil formation, pest control, pollination, etc.

Additional or other biodiversity

Also occurs within the agricultural ecosystem.

Wild biodiversity - outside agricultural ecosystems

Agrobiodiversity

- ❖ High diversity of agro-ecological practice reflected in terms of variability of landrace of crops, fruits, vegetables and indigenous livestock breeds
- ❖ Traditional farming systems essential to management of agrobiodiversity

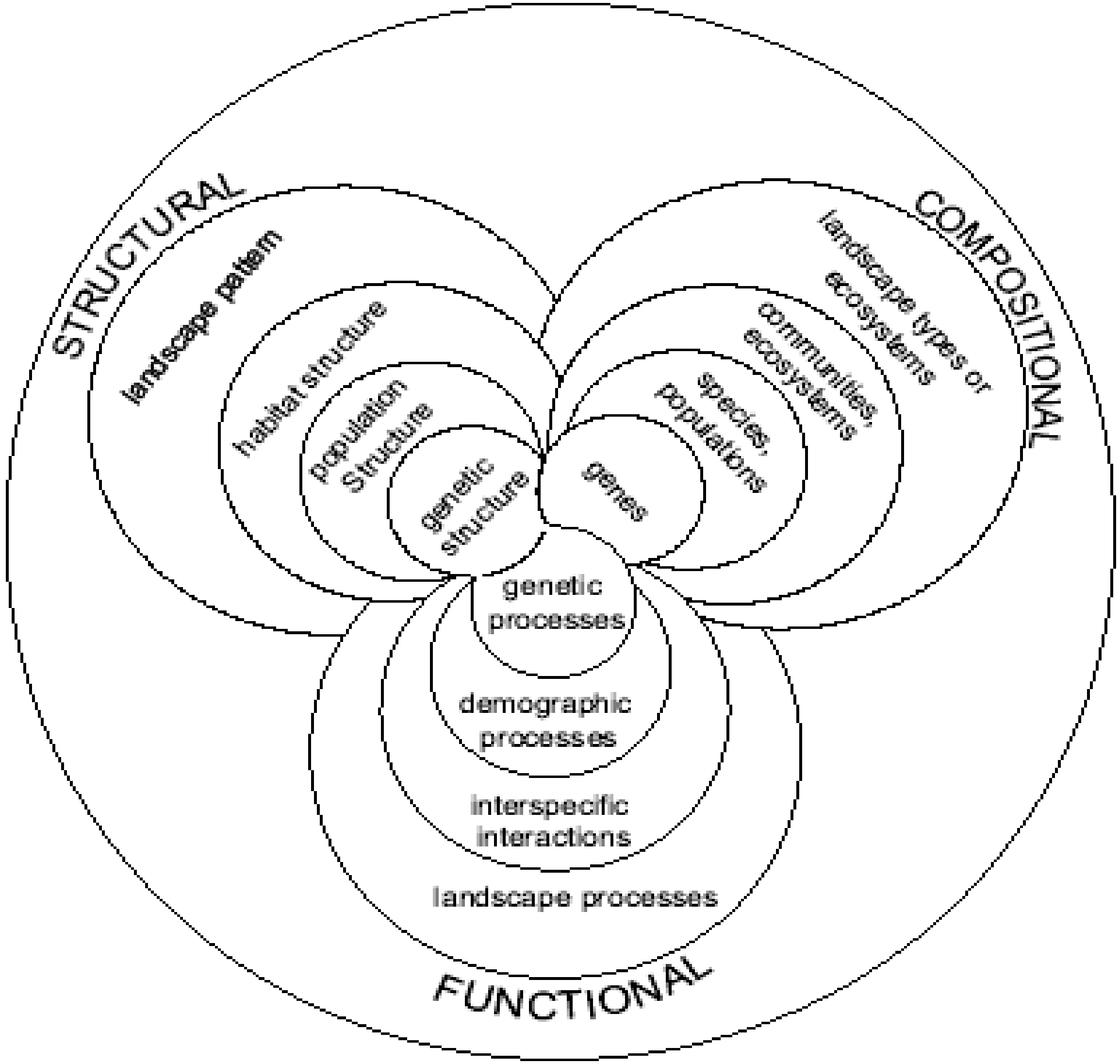
Wetlands biodiversity

- ❖ *Management*: Role of local communities (primary beneficiaries) crucial

Mountain biodiversity

- ❖ High level of plant *beta* diversity
- ❖ Sustainability of mountain development provides basis of livelihood of majority of people
- ❖ Integrated watershed management has been proven successful to rehabilitate watersheds using: vegetative, agronomic, and water resource management measures

Reed Noss, "Indicators for Monitoring Biodiversity:
A Hierarchial Approach", Conservation Biology 4(4):355-364. 1990.



MAJOR THREATS TO BIODIVERSITY

1. **Ecosystem loss**
2. **Species loss, and**
3. **Loss of genetic resourses**

Threats to ecosystem loss - Habitat loss and deforestation

Threats to protected areas

- Grazing
- Poaching
- Illegal timber harvesting

Threats to rangeland biodiversity

- Enormous pressure of rangelands ecosystem (high number of grazing domestic cattles)
- Depletion of palatable plant species

Threats to wetland biodiversity

- Encroachment of wetland habitat
- Unsustainable practice: overgrazing, use of pesticides and poisons

Threats to mountain biodiversity

- Overexploitation of selected plant species and poaching of animals for trade

Threats to agrobiodiversity

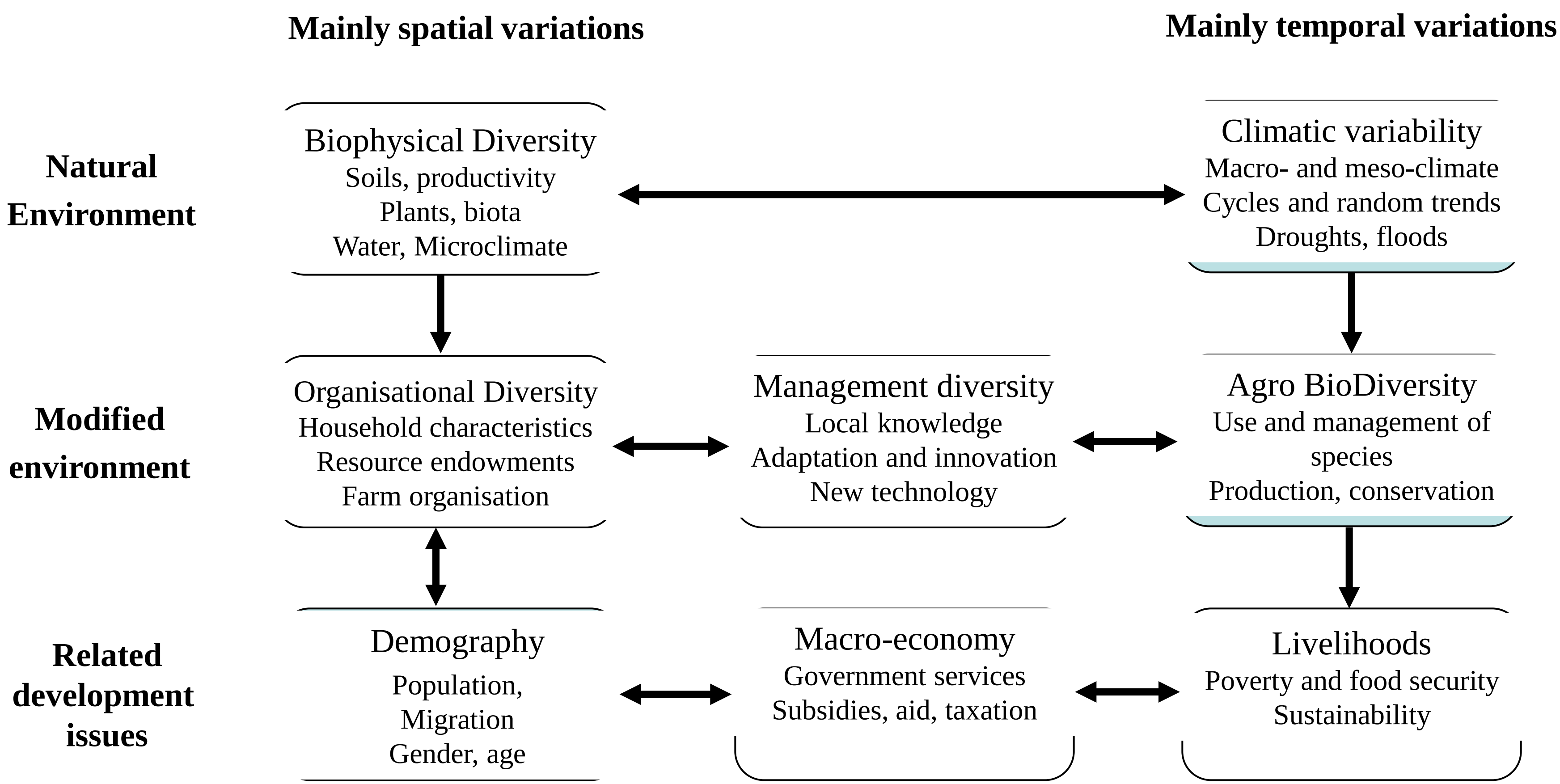
- Loss of indigenous/local landrace and their wild relatives
- Extension of high yielding crop varieties

STRATEGIES TO CONSERVE BIODIVERSITY

- Landscape planning approach
- Integrating local participation
- Institutional strengthening
- *In-situ* conservation
- Strengthening the national biodiversity unit
- Increasing support for biodiversity research and conservation
- Endorsing indigenous knowledge and innovations
- Cross-sectoral co-ordination and implementation of policies
- Enhancing national capacity
- *Ex-situ* conservation/biotechnology
- Securing intellectual property and farmer's property rights
- Biodiversity prospecting
- Environmental Impact Assessment
- Women in biodiversity conservation
- Developing eco-tourism
- Increasing conservation awareness
- Biodiversity registration

People Land Management And Environmental Change (PLEC)

AGRODIVERSITY



Microbial Interactions

Intra-specific = interactions among members of the **same** species/population

Inter-specific = interactions among members of **different** species

Density-dependent population regulation
A population dynamic in which growth rate is regulated by the densities of individuals

Density-independent population regulation
A population dynamic in which growth rate is regulated by factors not related to population size

Effect of Interaction on:

Name if Interaction	**Population / Species A**	**Population / Species B**
Neutralism	**0**	**0**
Commensalism	**0**	+
Mutualism	+	+
Amensalism	**0**	-
Predation, Parasitism	+	-
Competition	-	-

Plant - Microbial Interaction

Phylloplane = leaf surface

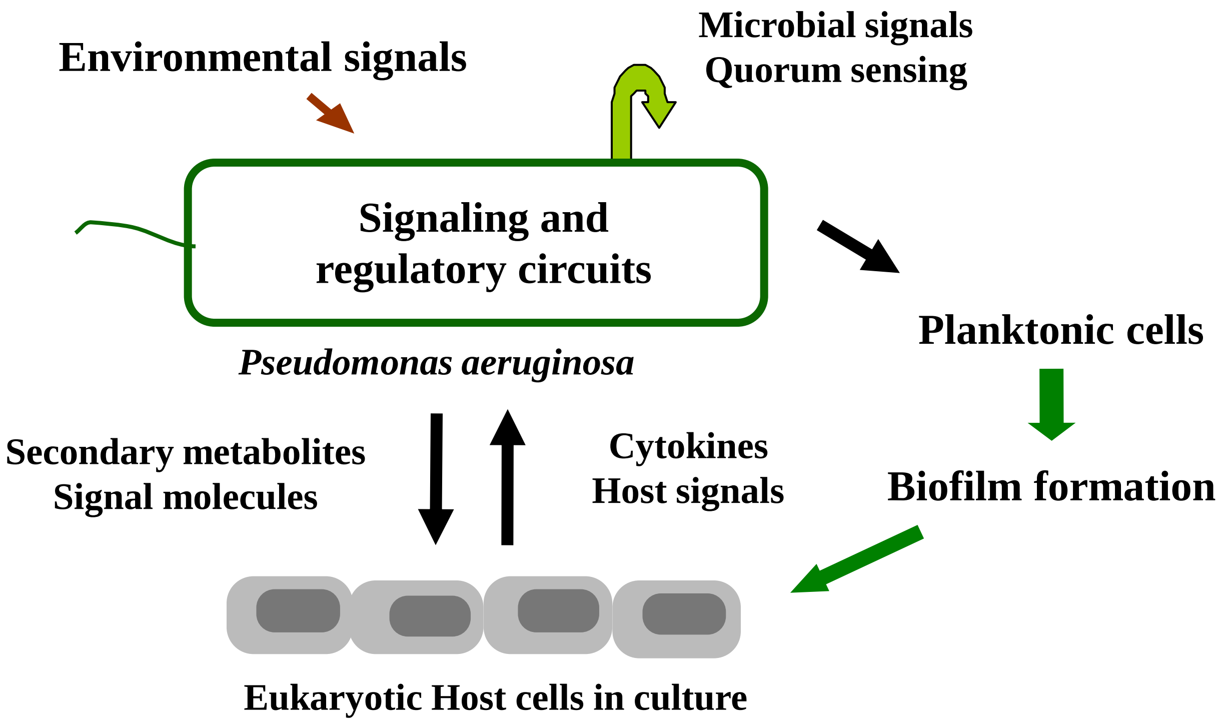
Phyllosphere = area surrounding the leaf and impacted by it

Rhizoplane = root surface

Rhizosphere = area surrounding the root and impacted by it

Association - Benefit
Infection - Pathogen

Molecular Signalling in Microbial-Host Interactions



Why Do Bacteria Talk To Each Other?

- ❖ Co-ordinate their behavior in the rhizosphere/habitat
- ❖ Survive
- ❖ Defend/complete against other microorganisms
- ❖ Avoid toxic compounds

What's Quorum sensing (QS)?

- Quorum sensing is the regulation of gene expression in response to variations in cell-population density

QS forms

Can occurs

- Plant growth-promoting .. *Pseudomonas*, bacilli

  at threshold cell-density level produce substance inhibit production of pathogens
- Beneficial bacteria .. *Rhizobium* spp
- Optimize nodule formation on plant roots

QS in Bacteria

- Complex communication mechanism
- Bacteria use signaling molecules to talk
- Molecules release into the environment
- Bacteria able to measure the concentration of the molecules within the population

How does QS work?

- Bacteria produce and secret chemical signal molecules called auto-inducers
- Auto-inducers increase in concentration
- Receptor recognizes and binds with inducer
- Activates and transcripts certain genes
- By detection, reacting to auto-inducers, bacteria able to sense to the surrounding cell density
- Then,,, make sure . Enough or not

Biogeochemical Cycles

- In Earth science, a biogeochemical cycle or substance turnover or cycling of substances is a pathway by which a chemical substance moves through both biotic (biosphere) and abiotic (lithosphere, atmosphere, and hydrosphere) compartments of Earth.

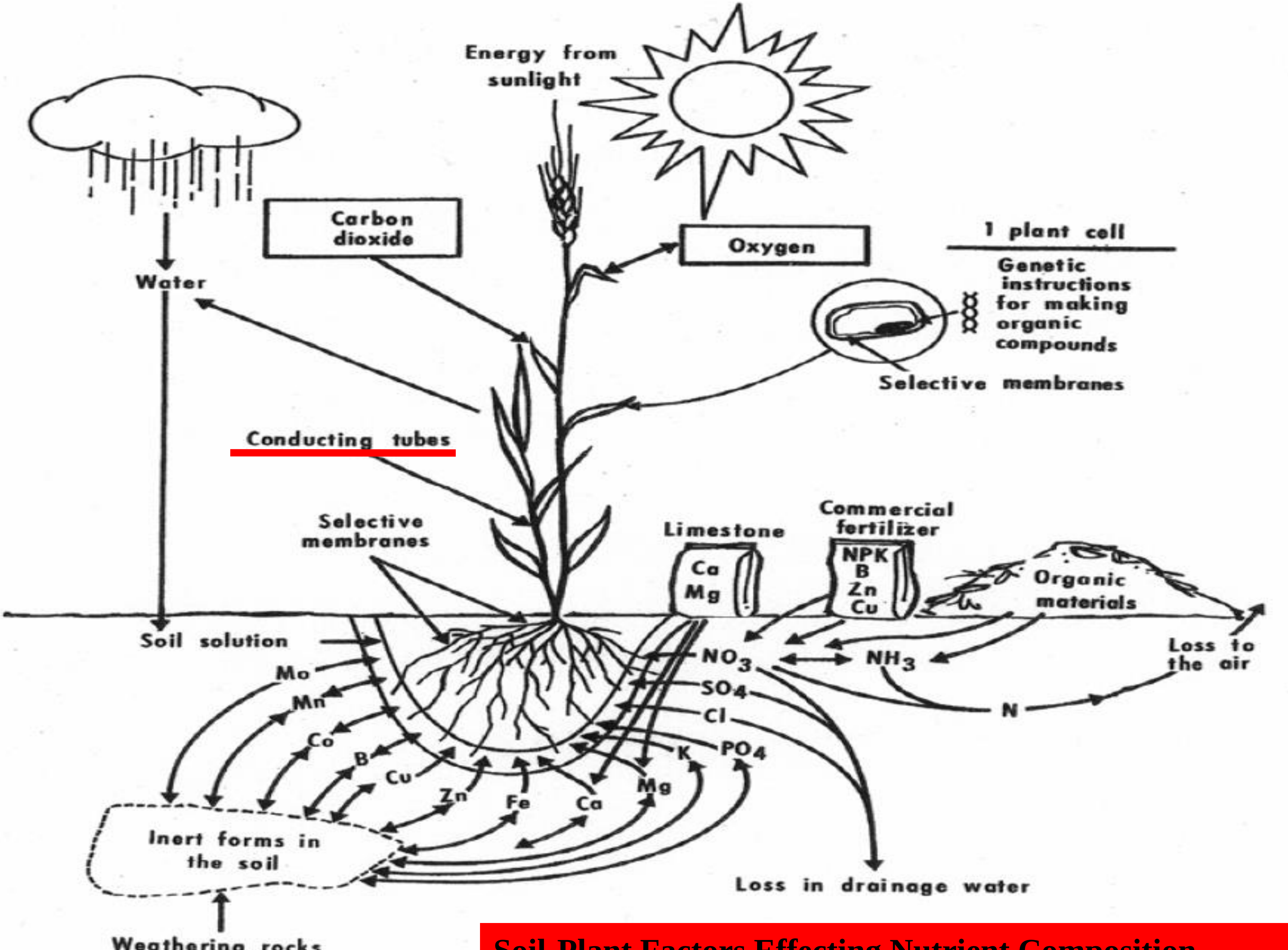
- A cycle is a series of change which comes back to the starting point and which can be repeated.

- For example, Water is always recycled through the water cycle. The water undergoes evaporation, condensation, and precipitation, falling back to Earth.

- ❖Elements, chemical compounds, and other forms of matter are passed from one organism to another and from one part of the biosphere to another through biogeochemical cycles.

- ❖ The term "biogeochemical" tells us that biological, geological and chemical factors are all involved. The circulation of chemical nutrients like carbon, oxygen, nitrogen, phosphorus, calcium, and water etc. through the biological and physical world are known as biogeochemical cycles.

- ❖ In effect, the element is recycled, although in some cycles there may be places (called *reservoirs*) where the element is accumulated or held for a long period of time (such as an ocean or lake for water).



Soil-Plant Factors Effecting Nutrient Composition

❖The **carbon cycle** is the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere, and atmosphere of the Earth.

❖Along with the nitrogen cycle and the water cycle, the carbon cycle comprises a sequence of events that are key to making the Earth capable of sustaining life; it describes the movement of carbon as it is recycled and reused throughout the biosphere.

❖The ***global carbon budget*** is the balance of the exchanges (incomes and losses) of carbon between the carbon reservoirs or between one specific loop (e.g., atmosphere <-> biosphere) of the carbon cycle.

❖ An examination of the carbon budget of a pool or reservoir can provide information about whether the pool or reservoir is functioning as a source or sink for carbon dioxide.

❖ The carbon cycle was initially discovered by Joseph Priestley and Antoine Lavoisier, and popularized by Humphry Davy.

❖ The **nitrogen cycle** is the process of converting nitrogen between its various chemical forms. This transformation can be carried out through both biological and physical processes.

❖Important processes in the nitrogen cycle include fixation ammonification, nitrification, and denitrification. The majority of Earth's atmosphere (78%) is nitrogen, making it the largest pool of nitrogen.

- However, atmospheric nitrogen has limited availability for biological use, leading to a scarcity of usable nitrogen in many types of ecosystems.

- The nitrogen cycle is of particular interest to ecologists because nitrogen availability can affect the rate of key ecosystem processes, including primary production and decomposition.

- Human activities such as fossil fuel combustion, use of artificial nitrogen fertilizers, and release of nitrogen in wastewater have dramatically altered the global nitrogen cycle.

Nitrogen Fixation

- Three processes are responsible for most of the nitrogen fixation in the biosphere:
- Atmospheric fixation
- Biological fixation
- Industrial fixation

Biological Fixation

The ability to fix nitrogen is found in certain microbes.

- ❖ Some live in a symbiotic relationship with plants of the legume family (e.g., soybeans, alfalfa).
- ❖ Some establish symbiotic relationships with plants other than legumes (e.g., alders).
- ❖ Some nitrogen-fixing bacteria live free in the soil.
- ❖ Nitrogen-fixing cyanobacteria are essential to maintaining the fertility of semi-aquatic environments like rice paddies.

Some Nitrogen Fixing Organisms

- **Free living aerobic bacteria**
  - *Azotobacter*
  - *Beijerinckia*
  - *Klebsiella*
  - *Cyanobacteria*

- **Free living anaerobic bacteria**
  - *Clostridium*
  - *Desulfovibrio*
  - *Purple sulphur bacteria*
  - *Purple non-sulphur bacteria*
  - *Green sulphur bacteria*

- **Free living associative bacteria**
  - *Azospirillum*

- **Symbionts**
  - *Rhizobium* (legumes)
  - *Frankia* (alden trees)

Nitrogen Fixation Through Industrial Process

- Under great pressure, at a temperature of 600oC, and with the use of a catalyst, atmospheric nitrogen and hydrogen (usually derived from natural gas or petroleum) can be combined to form ammonia (NH_3).
- Ammonia can be used directly as fertilizer, but most of its is further processed to urea and ammonium nitrate (NH_4NO_3).

- The **phosphorus cycle** is the biogeochemical cycle that describes the movement of phosphorus through the lithosphere, hydrosphere, and biosphere.

- Unlike many other biogeochemical cycles, the atmosphere does not play a significant role in the movement of phosphorus, because phosphorus and phosphorus based compounds are usually solids at the typical ranges of temperature and pressure found on Earth.

- The production of phosphine gas occurs only in specialized, local conditions.

❖On the land, phosphorus (chemical symbol, P) gradually becomes less available to plants over thousands of years, because it is slowly lost in runoff.

❖Low concentration of P in soils reduces plant growth, and slows soil microbial growth – as shown in studies of soil microbial biomass.

❖Soil microorganisms act as both sinks and sources of available P in the biogeochemical cycle. Locally, transformations of P are chemical, biological and microbiological: the major long-term transfers in the global cycle, however, are driven by tectonic movements in geologic time.

❖Humans have caused major changes to the global P cycle through shipping of P minerals, and use of P fertilizer, and also the shipping of food from farms to cities, where it is lost as effluent.

- ❖The **water cycle**, also known as the **hydrologic cycle** or the **H_2O cycle**, describes the continuous movement of water on, above and below the surface of the Earth.

- ❖The mass of water on Earth remains fairly constant over time but the partitioning of the water into the major reservoirs of ice, fresh water, saline water and atmospheric water is variable depending on a wide range of climatic variables.

- ❖The water moves from one reservoir to another, such as from river to ocean, or from the ocean to the atmosphere, by the physical processes of evaporation, condensation, precipitation, infiltration, runoff, and subsurface flow. In doing so, the water goes through different phases: liquid, solid (ice), and gas (vapor).

❖The water cycle involves the exchange of energy, which leads to temperature changes. For instance, when water evaporates, it takes up energy from its surroundings and cools the environment. When it condenses, it releases energy and warms the environment. These heat exchanges influence climate.

❖The evaporative phase of the cycle purifies water which then replaces the land with freshwater.

❖The water cycle is also essential for the maintenance of most life and ecosystems on the planet.

❖The **oxygen cycle** is the biogeochemical cycle that describes the movement of oxygen within its three main reservoirs: the atmosphere (air), the total content of biological matter within the biosphere (the global sum of all ecosystems), and the lithosphere (Earth's crust).

❖Failures in the oxygen cycle within the hydrosphere (the combined mass of water found on, under, and over the surface of planet Earth) can result in the development of hypoxic zones.

❖The main driving factor of the oxygen cycle is photosynthesis, which is responsible for the modern Earth's atmosphere and life on earth (see the Great Oxygenation Event).

Annual gain and loss of atmospheric oxygen (Units of 10^{10} kg O_2 per year)

Photosynthesis (land) Photosynthesis (ocean) Photolysis of N_2O Photolysis of H_2O	16,500 13,500 1.3 0.03
Total gains	~ 30,000
Losses - respiration and decay	
Aerobic respiration Microbial oxidation Combustion of fossil fuel (anthropogenic) Photochemical oxidation Fixation of N_2 by lightning Fixation of N_2 by industry (anthropogenic) Oxidation of volcanic gases	23,000 5,100 1,200 600 12 10 5
Losses - weathering	
Chemical weathering Surface reaction of O_3	50 12
Total losses	~ 30,000

R:S Ratio

1946, H. Katznelson suggested the R:S ratio

The ratio between the microbial population in the root (R) and in the soil (S).

R:S ratio gives a good picture of the relative stimulation of the microorganisms in the rhizosphere of different plant species.