Agricultural Sustainability in the 21st Century

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Population Increase

- Hunting and gathering
- Agricultural revolution
- Industrial

Time

2-5 million years
8000 6000 4000 2000
Black Death—the Plague

Billions of people

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How can we grow food for 9-, 10-, 11-, or even 12-billion people?

By Changing Our Ways
Agricultural Sustainability
Problems & Solutions

I. Planetary Boundaries

II. Damaging Effects of Industrialized Agriculture

III. Sustainable Agriculture
Lessons from Traditional Agriculture
Natural Soil Resources

IV. Can We Do This? Grass Roots Movements
I. Global Warming: the Planetary Boundaries

- "Does earth have adequate resources—water, land, air, and ecosystem services such as the harvests of forests and fisheries—to sustain a growing world economy?"

- "In short, can economic growth be reconciled with environmental sustainability?"

Jeffrey Sachs, Age of Sustainable Development. 2015
-crossing the PB’s

** 1. Human-induced climate change: GHGs (CO$_2$, CH$_4$, NO$_2$)
2. Ocean acidification: carbonic acid (HCO$_3^-$)
3. Ozone depletion: (O$_3$ and CFCs)

** 4. Water pollution: (N/P, other chemicals)

** Agriculture has major effect.
**5. Freshwater depletion (70% for agriculture)**

**6. Destruction of natural lands for ag, cities, etc.**

**7. Biological diversity.**

**8. Aerosol loading (air pollution).**


**Agriculture has major effect**
trespassing on the PBs

‘When human pressures are greater than the natural systems’ ability to absorb or clean themselves, then there are major changes in ecosystems that threaten human well-being and survival, especially in poor areas.’

UN, Sustainable Development Plan
Crossing the Planetary Boundaries affects everyone, but especially the poor who contribute least to the problems but suffer the most. The Age of Sustainable Development calls for raising the standards of living to a sustainable level for all people.
II. Damaging Effects of Industrialized Agriculture
II. Industrial Agriculture

Although Fossil Fuels were discovered in the 1700’s, the beginning of true industrialized agriculture began in the 20\textsuperscript{th} century by capitalizing on the technological advances of the second world war.
the “Green Revolution”

- started after WWII — increased yields
  - new strains, ‘ferts’, -cides’, heavy machinery
  - monocropping, water waste, etc.
- big increase in production until 80’s
  then, dropped to less that 1% in 2000’s

-problems: we started crossing PB’s
Monoculture
Tilling
Erosion
Ag’s trespass on PB’s

- uses 70% of earth’s freshwater
- releases large amount of \( CO_2 \) into atmosphere by
  -- tilling the soil
  -- running farm machinery on Fossil Fuels
- uses fertilizers that
  -- disrupt soil nutrient and biome balance
  -- cause runoff of N and P to “waters” (eutrophication)
- uses pesticides that kill the microherd, impede nutrient cycling, and damage soil fertility.
...and climate change affects Ag

- drought, diseases, and weather extremes
- polluted water, limited water
- more pests, new pests
- limited expansion opportunities but growing population
- social disruptions: economic downturns
so: The Challenge for Agriculture

-future need for increased food, fiber and fuel
-requires approximately 20-25% cropland expansion.

-but current yield is decreasing due to infertile soils, etc.

-so, how much land use change can occur before there is irreversible damage to the Planetary Boundaries? Good Question
III. Sustainable Agriculture: What is it?

A. Lessons from Traditional Agriculture

B. Natural Resources: the Soil
A. Lessons from Traditional Ag.

-Traditional agriculture uses natural ecosystem services
  - no fertilizers, pesticides, herbicides, physical disturbance, etc.
-Adds composted waste (plant and animal)
-Avoids tilling
-Uses appropriate crops for the land and the climate
-Avoids compacting the soil, etc
-Respects and cares for the soil and it’s “work”
Farming in the 3rd World
III. B. Natural Soil Resources

• soil is a highly complex mixture of minerals, organic material, and the MICROHERD does the soil’s work
In one liter of “healthy” soil there are:

100,000,000,000 Bacteria that decompose matter and fix nitrogen

10,000,000,000 Actinomycetes that help decompose matter.

100,000,000 Fungi that decompose matter and transport nutrients into plants

10,000,000 Algae that assist with nitrogen fixing in plant roots

10,000,000 Protozoans that consume soil bacteria

10,000 Nematodes (roundworms) that feed on bacteria and fungi

500 Mites and Insects that decompose matter and eat nematodes

2 Earthworms that decompose, deposit castings, make burrows, etc
Energy flows in the direction of the arrow.

1 = First-level Consumers
2 = Second-level Consumers
3 = Third-level Consumers

Organisms not drawn to scale.
Soil Structure
Home to so many

Soil consists of organic matter and clay or silt or loam with small and large tunnels filled with air and water for the "microherd" to live in.

The microherd is it’s own ecosystem. One guy’s poop is another guy’s breakfast, until the “food” is metabolized to fundamental nutrients that can be used by the plants.
carbon and nitrogen

- **carbon and nitrogen**
  - required nutrients all organisms
  - come from the atmosphere, converted by plants and the **microherd** into nutrients for everybody.
  - complex cycles, and without the **microherd**, there would probably be no plants or animals
-dead plants and animals contain lots of carbon-based molecules that are decomposed by the microherd for their own nutrients.

-the end products of carbon decomposition are humus, and $\text{CO}_2$ which are stored in the soil in high amounts.

-normally this $\text{CO}_2$ will equilibrate with the air, but when the soil is tilled, $\text{CO}_2$ is released to the air and adds to the problem of Global Warming.
Carbon Cycle

Photosynthetic organisms eg. plants convert CO₂ to carbon chains that make the biological macromolecules, (DNA, Protein, Fats etc) that are the building blocks for the cell.

Animals get these molecules by ingesting plants. CO₂ is the end product of this digestion.
Micoherd Makes Humus

As the microherd metabolizes its own food, one important end-product is “humus”, a particle of stable carbon plates that can bind to certain basic nutrient and thus act as a reservoir or storage unit. These nutrients are needed for plant growth, and are made available as needed. Their release from the particle requires a pH below 7.0, and the process is known as Cation Exchange.

Humus makes soil or compost very dark brown. So adding dark compost is excellent for the soil.
Nitrogen Cycle

Nitrogen is required for macromolecules, and synthesized to its various nutrient forms by the microherd. Unlike CO$_2$, it is not sequestered in the soil, and so is a limiting nutrient. It is not easily stored on humus for instance, and so can be leached from the soil by excess water.
effects of -cides on the microherd

--kill soil organisms and decrease the microherd’s ability to metabolize nutrients.
--kill beneficial insects above ground
--destroy the ability of the microherd to adapt to soil conditions, to protect against pests or climate conditions, and maintain equilibrium.

The cost to counteract all of these is very high, ecologically and economically.
IV. Can we fix it?

It is said by a number of people involved in agriculture that it is possible to produce sufficient food on the same amount of land for everyone and at lower cost to the land and the consumer:

- organic methods can maintain the yield sustainably without the expense of so much machinery and chemicals.

- local distribution provides fresh food without the costs of transportation and refrigeration, etc. from traditional agriculture.
organic methods

“Organic farming depends on a healthy and genetically adaptable microherd that can efficiently cycle nutrients from organic material in the soil, but that can also resist pests and other challenges. It is this potential that is the most powerful for sustainable agriculture.”

-Composting is the way to build the microherd!
Organic Farming Toolkit

- Intercropping
- Companion planting
- Crop rotation
- Cover crops
- Appropriate crops
- Quality seeds
- Pay labor decently

- No-till
- Avoid soil compaction
- Drill seeding
- Composting
- Drip irrigation
- Rain water collection for irrigation
Traditional Guidelines

- Live on or close to the land.
- Follow it’s seasons.
- Return everything that is not edible or useable.
- Allow the animals to “fertilize” the land.
- It’s a community effort, so share.
Five BMPs for Agricultural Sustainability (Altieri)


1. Recycle and re-use all available biomass (crop residues, cuttings) from surrounding trees/shrubs/manures in order to replenish and constantly restore soil nutrients.

2. Grow plants by building soils, focusing in particular on soil organic matter and soil biotic activity by, for example, adding manures and promoting the growth of earthworm populations.
Altieri 5 principles

3. Minimize losses of growth factors above and below ground by protecting the soil from direct solar radiation, strong winds, and erosive water flows.

4. Maximize diversity in order to increase resilience.

5. Enhance beneficial biological interactions and synergies so that natural ecological processes can work to enhance rather than undermine agricultural production.

• These and similar principles have been successfully applied to sustain civilizations for millennia.
Sustainability: Rice Paddy in North Vietnam
“Ag” at the Urban Level

- School Gardens
- Community Gardens
- Backyard (and front yard) gardens
- Climate appropriate plantings
- Composting
- Water Saving, etc, etc, etc.