TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

Faculty of Environmental Sciences

Invited Lecture

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Land-use Effects on Coupled Cycling of Carbon and Water in a Changing Climate

Photo: D. Gerlach

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Carbon Management and
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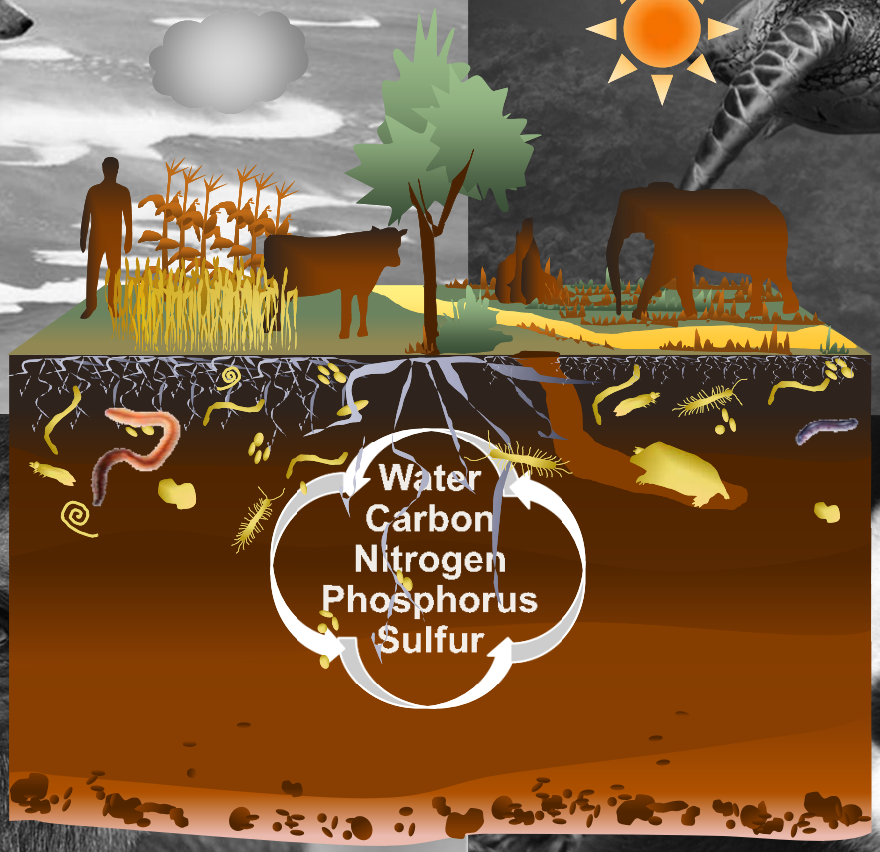
SOIL: THE GLOBAL ICON



HANDOUT / Reuters

www.seeturtles.org

www.worldwildlife.org

en.wikipedia.org

Soil is Life and Life is Soil

Lal (2014)

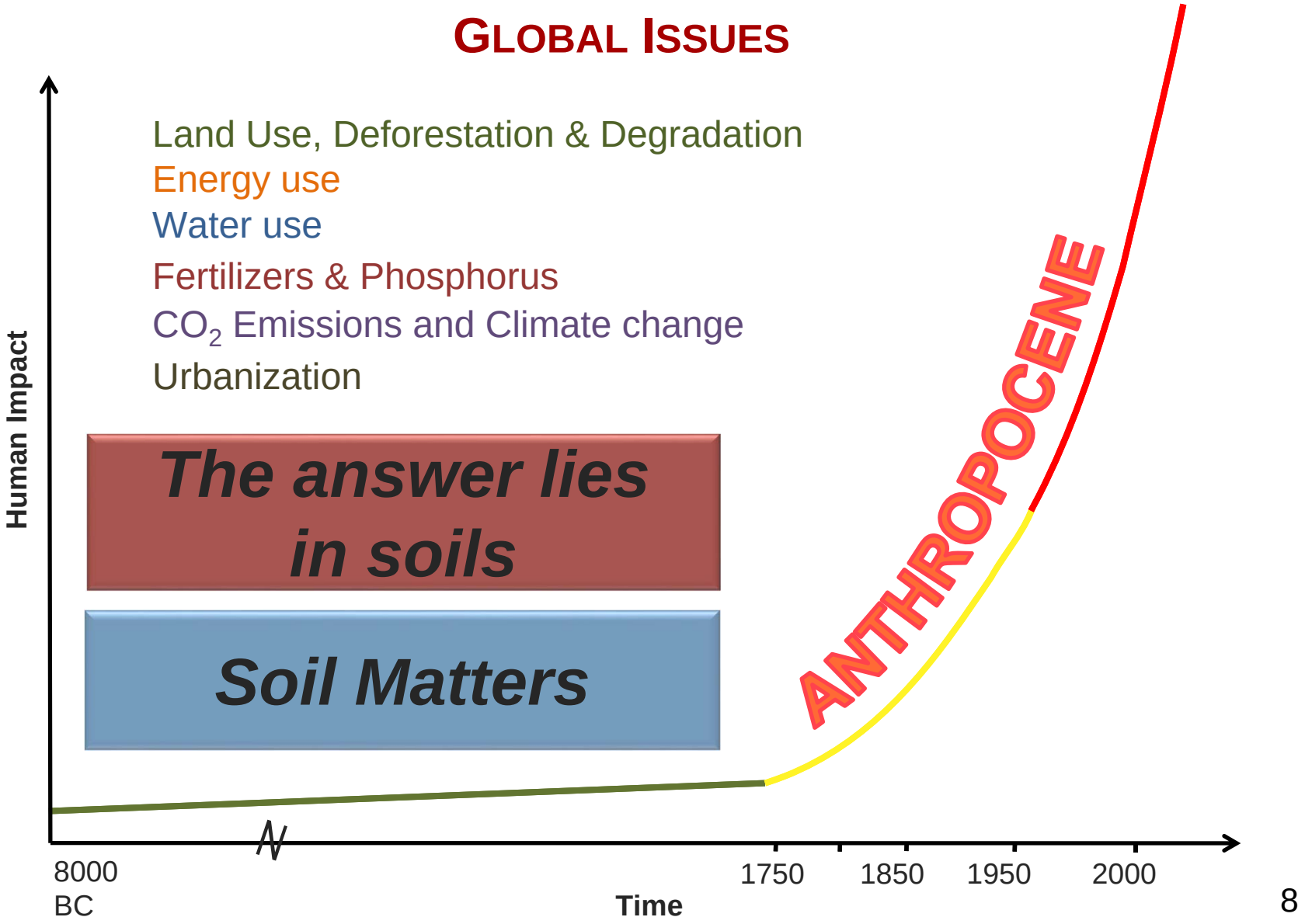
THE SOCIETAL VALUE OF SOIL

The bible depicts Moses stating around circa 1400 BC as they entered Canaan:

"See what the land is like and whether the people who live there are strong or weak, few or many. What kind of land do they live in? Is it good or bad?--- How is the soil? Is it fertile or poor? Are there trees on it or not? Do your best to bring back some fruit of the land" (Numbers 13:18-20)

Brevik and Sauer (2015)

GLOBAL ISSUES



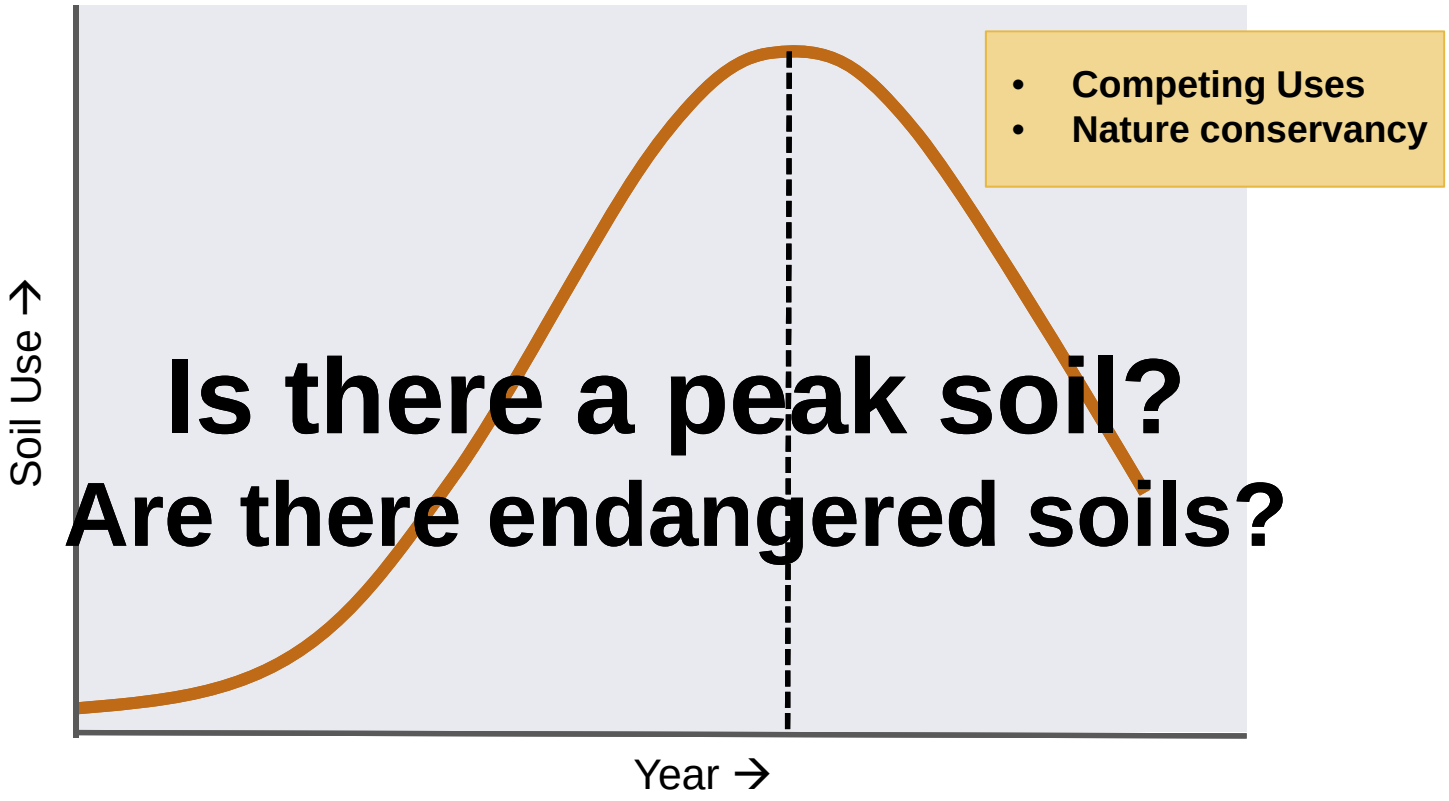
GLOBAL DEFORESTATION AND LAND USE CHANGE

Year	Area (10^9 ha)
8000 BC	6.5
2000	4.0

Crop land = 1.42 Bha

Grazing land = 2.23 Bha

HUBERT CURVE



- **Land resources already allocated to agriculture production are adequate through sustainable intensification, soil restoration, and carbon sequestration.**

Lal (2015)

Desperateness

Increase in erosion risks between 1980s and 2090:
Africa….+36%
World....+14%

GLOBAL ENERGY USE (EIA, 2015)

Year	EJ/yr
1980	299
1990	366
2000	420
2005	480
2010	536
2012	553

+8 EJ/yr

Source	%
Fossil Fuel =	80.0
Bioenergy =	11.3
Nuclear =	5.5
Hydro =	2.2
Others =	0.4

(wood)

GLOBAL WATER USE

Year	Total	Agricultural	Industrial	Municipal
1900	579	513	22	44
1950	1382	1080	87	204
2000	3973	2605	384	776
2010	4431	2817	472	908
2025	5235	3189	607	1170
Factor	**9.04**	**6.21**	**27.59**	**26.59**

Webworld.unesco.org

THE PHOSPHORUS SYNDROME

- The Haber-Bosch process has increased the availability of N.
- However, availability of P is limited because of its finite reserves.
- This change in stoichiometry of C and N relative to P since the second half of the 20th Century is a unique phenomenon in Earth's history, and is one of the effects of Anthropocene.
- The severe problem of algal bloom is related to an excessive transport of P from agro-ecosystems to aquatic ecosystems

P AVAILABILITY AND BIOMASS PRODUCTION

Plant growth is...

- N limited at N:P ratio of <14
- P limited at N:P ratio of >16
- Co-limited N:P ratio of intermediate

In unfertilized ecosystems, P comes only from the parent rock, and its availability decreases with increase in soil age.

INDICATORS OF HUMAN-ECOSYSTEM INTERACTIONS

Loss of Terrestrial C Pool

Land Use = 486 Pg
Soil = 78 Pg

Tropical Deforestation

1990s = 8 Mha/yr
2000s = 7.6 Mha/yr
A region equivalent to Sri Lanka

Soil Erosion

Water = 1.1Bha
Wind = 0.55Bha

Loss of Biodiversity

1000 to 10,000 sp./yr, background rate of 5 sp./yr

Secondary Salinization

20% of all irrigated lands

Loss of Agric. Land to Sealing and Urbanization

By 2030, global urban land cover will increase by 152 Mha or 10% of current arable land area

People living in water-stressed river basins:

2000 = 2.3 bn
2025 = 3.5 bn

Scarce Water Resources:

Ogalalla, IGP, NCP, etc.

Algal Blooms

Regions: Great Lakes, Gulf of Mexico, Chesapeake Bay, Lake Taihu in China, Baltic Sea etc.

THE RESOURCES USED FOR AGRICULTURE

- 38% of the Earth's terrestrial surface is used for agriculture,
- 75% of agricultural land (3.73 Bha) is allocated to raising animals,
- 70% of the global freshwater withdrawals are used for irrigation,
- 30-35% of global greenhouse gas emissions are contributed by agriculture,

And yet 1 in 7 persons is food-insecure and 2-3 in 7 are malnourished.

MEETING FOOD DEMAND BY 2050

The world produces enough food to feed 10 billion people . Thus, food and nutritional security must be achieved by:

- **Reducing** waste (30-50%),
- **Increasing** access to food by addressing poverty, inequality, wars and political instability,
- **Improving** distribution,
- **Increasing** use of plant-based diet,
- **Accepting** personal responsibility of not taking things for granted, and
- **Increasing** agronomic productivity from existing land, restoring degraded lands ,and converting some agricultural land for nature conservancy without any conversion of natural land to agroecosystems.

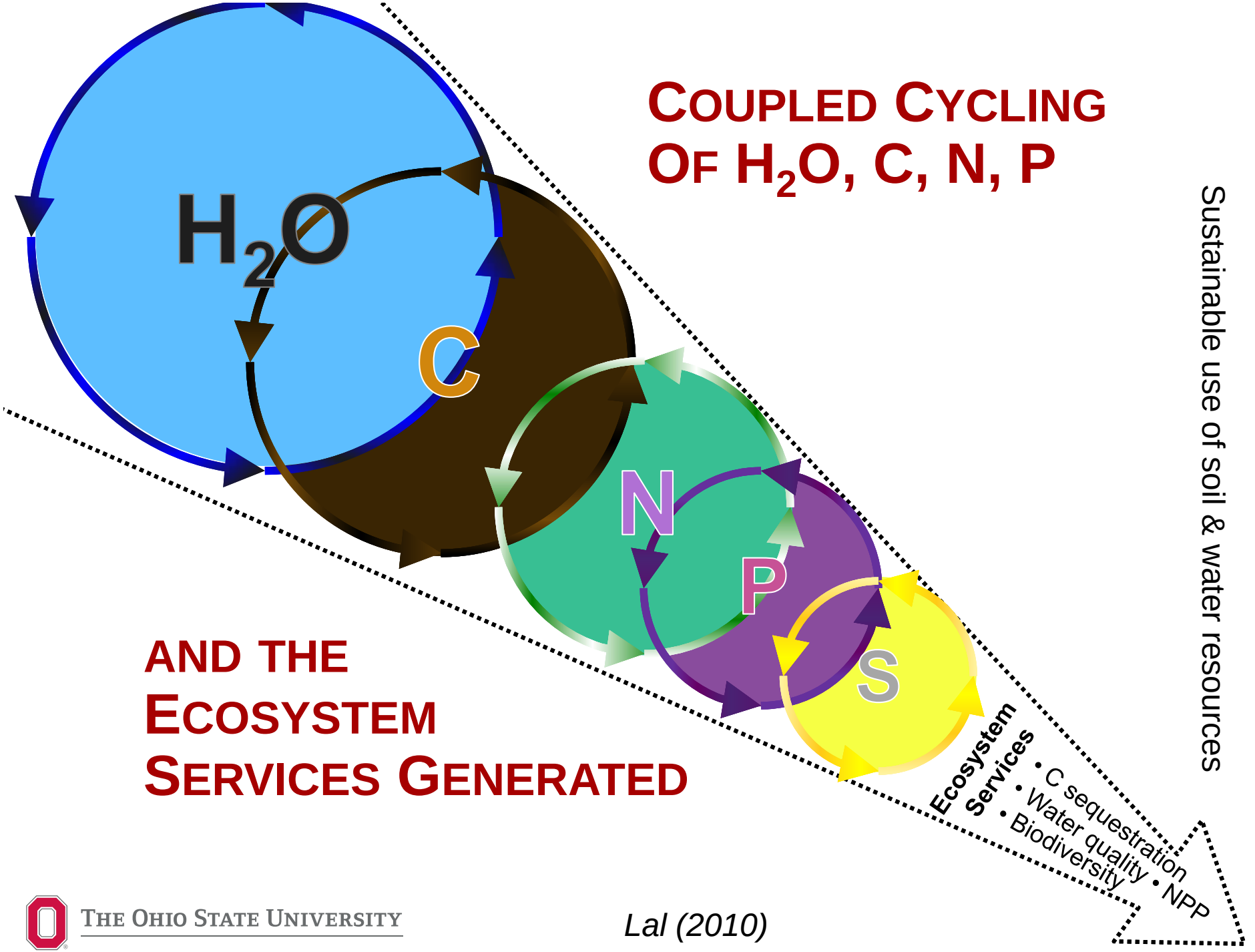
SUSTAINABLE INTENSIFICATION

The strategy is to produce more crops:

Produce more from less

- from less land,
- per drop of water,
- per unit input of fertilizers and pesticides,
- per unit of energy, and
- per unit of C emission.

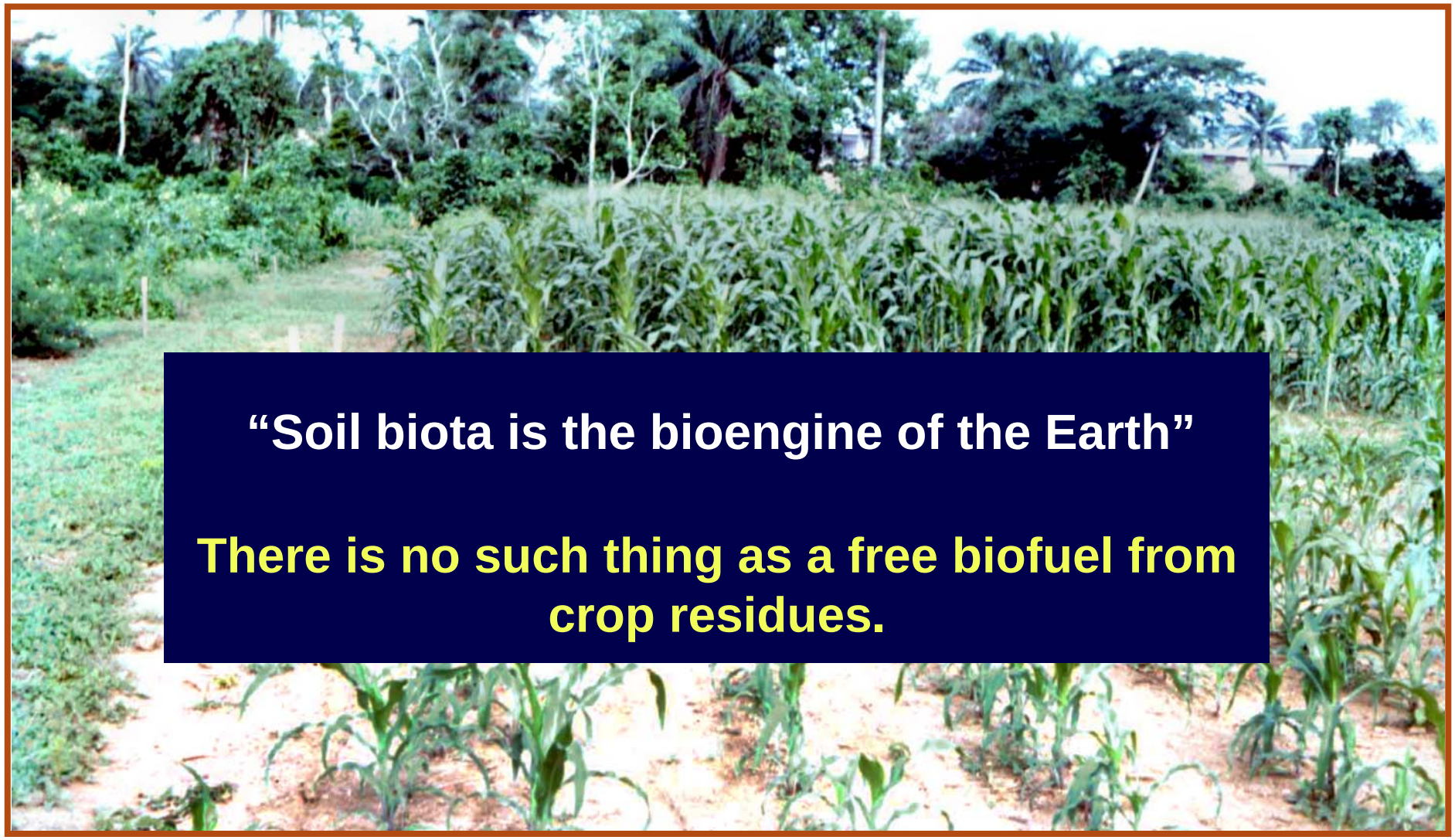
Coupled Cycling Of H_2O, C, N, P



And the Ecosystem Services Generated

Lal (2010)

ECONOMICS OF RESIDUE REMOVAL FOR BIOFUEL

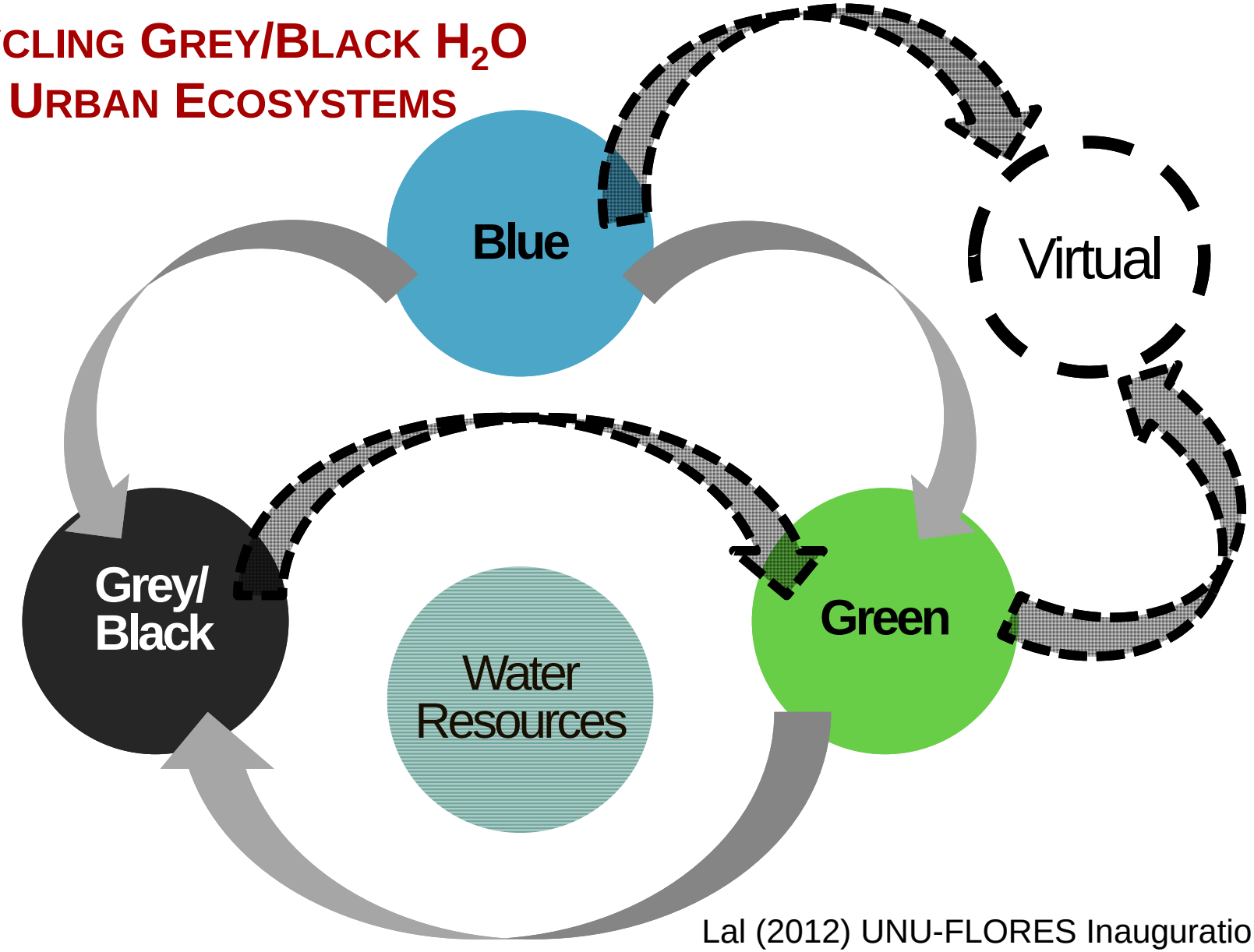


DROUGHT OF 2012

Corn with no residue.

Corn with 100% residue

RECYCLING GREY/BLACK H_2O IN URBAN ECOSYSTEMS



CLIMATE CHANGE AND HUMAN RESPONSE

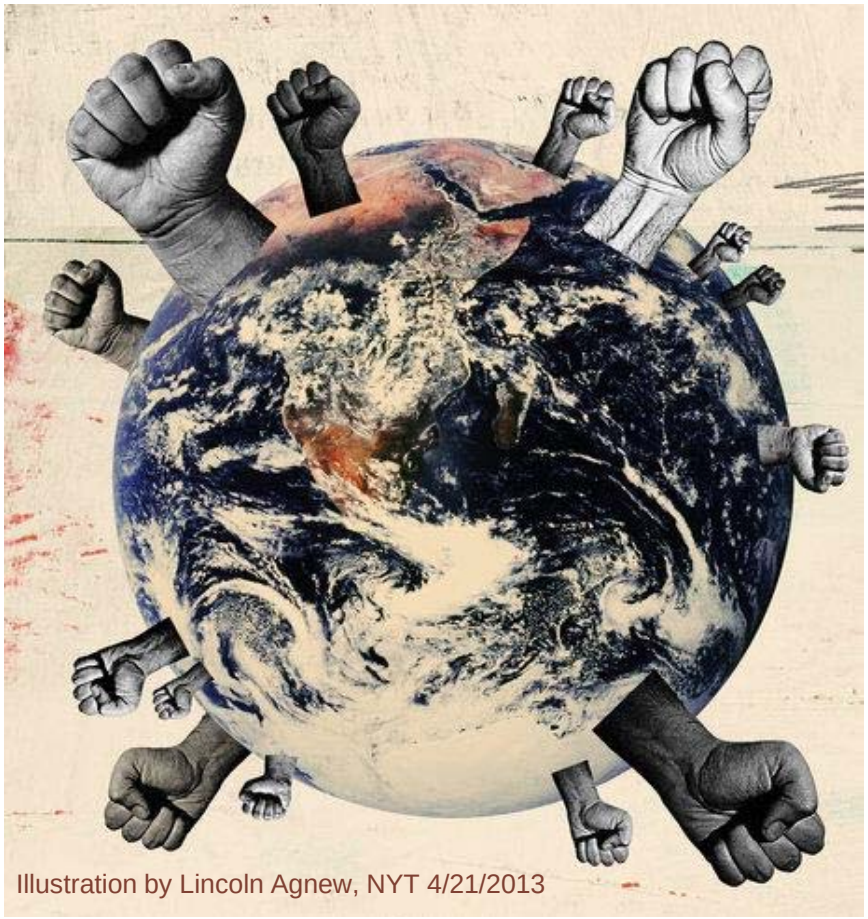


Illustration by Lincoln Agnew, NYT 4/21/2013

- Humans have not had to deal with such a drastic climate change since 10-12 millennia ago
- Now the humans, with population of 73 billion and projected to be 11 billion, have to deal with it and increasingly so in the future
- Yet, there is no consensus as in Rio +20

CARBON PIE

Total C Pie = (560ppm-400ppm) • 2Gt/1 ppm = 320 Gt

320 Gt

How do we divide the pie among nations?

GLOBAL SOIL ORGANIC CARBON POOL 0-30cm DEPTH

Total Pool = 684-724 (704) Gt *.... Batjes (1996)*

0.4% Increase/yr = 2.8 Gt C/yr

OFF-SETTING OIL BY SOIL C SEQUESTRATION

BIOREGENERATING SOIL-BASED SPACE AGRICULTURE

Multiple life support functions of plants:

- Removing CO_2 through photosynthesis,
- Generating O_2,
- Producing food,
- Purifying waste water applied to roots through transpiration,
- Composting inedible biomass,
- Denaturing pollutants by soil and filtering H_2O,
- Increasing harvest index from 50% to 70% to reduce per capita food production area from 40 to 28m2, with edible biomass productivity of 16 to 22g $^{m\text{-}1d\text{-}1}$

…Wheeler, 2003; Silverstone et al., 2003)

SKY FARMING OR VERTICAL FARMING

- Growing crops in a totally transparent building
- Capturing passive energy (wind, solar, geo, tidal)
- Recovering energy from inedible parts of crops to create zero energy building
- Returning land to perform ecosystem functions and services (nature conservancy)
- Reducing the ecological footprint
- Making agriculture weather-proof

THE SOIL LESS SOLUTION

Scarcity of arable land, projected climate change, water scarcity, growing urban and total population, necessitate soil scientists and agronomists to look beyond the traditional farming from soil-based operations to highly efficient greenhouse or vertical farms involving: **aquaculture, aquaponics, hydroponics, aeroponics, aerofarms and other soil-less cultures.**

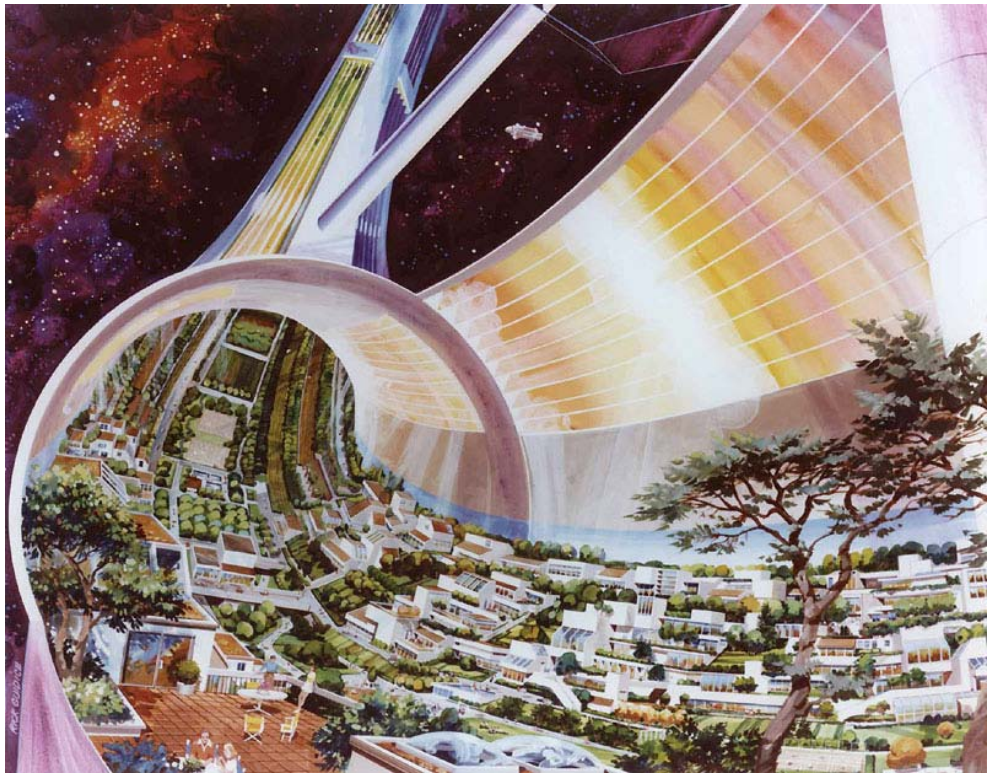
- This approach would be useful to water-scarce countries with little arable land (e.g., Middle East)
- This would minimize the problem of land grab

SYNTHETIC SOIL

Advantages of synthetic soil are:

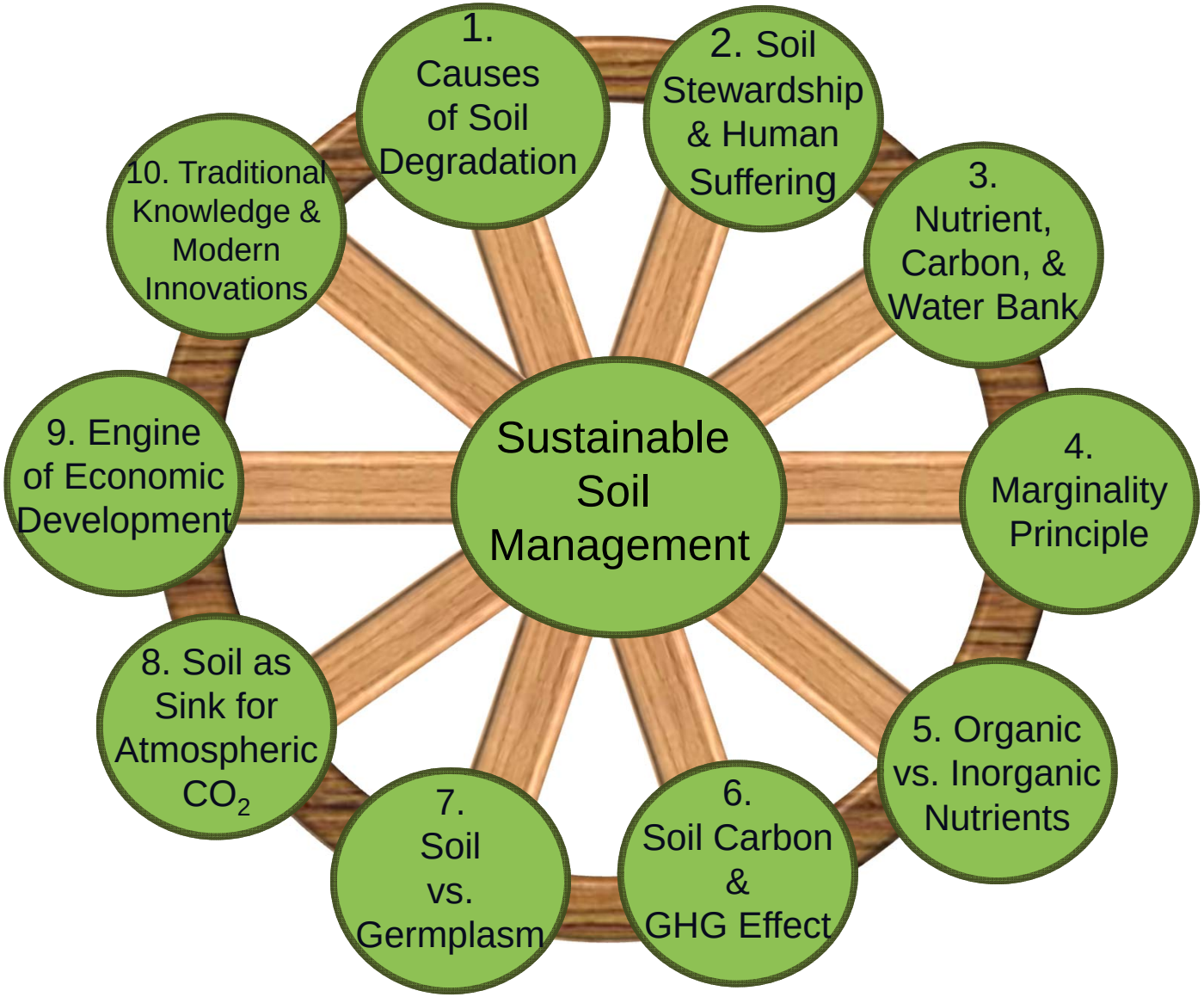
- A simple medium for cultivation of microorganisms
- A tool to study microbiological processes in soil
- Using industrial and agricultural by-products (FGD)
- Vegetation of eroded slopes
- Potting medium household plants
- Use as an urban soil in construction sites
- Production of crops in greenhouse
- Soil ameliorant
- Pharmaceuticals and antibiotics

SPACE AGRICULTURE



It is soil-based for:

- Decomposing organic wastes
- Sequestering CO_2
- Filtering H_2O


Sustainable Soil Management
1. Causes of Soil Degradation
2. Soil Stewardship & Human Suffering
3. Nutrient, Carbon, & Water Bank
4. Marginality Principle
5. Organic vs. Inorganic Nutrients
6. Soil Carbon & GHG Effect
7. Soil vs. Germplasm
8. Soil as Sink for Atmospheric CO_2
9. Engine of Economic Development
10. Traditional Knowledge & Modern Innovations

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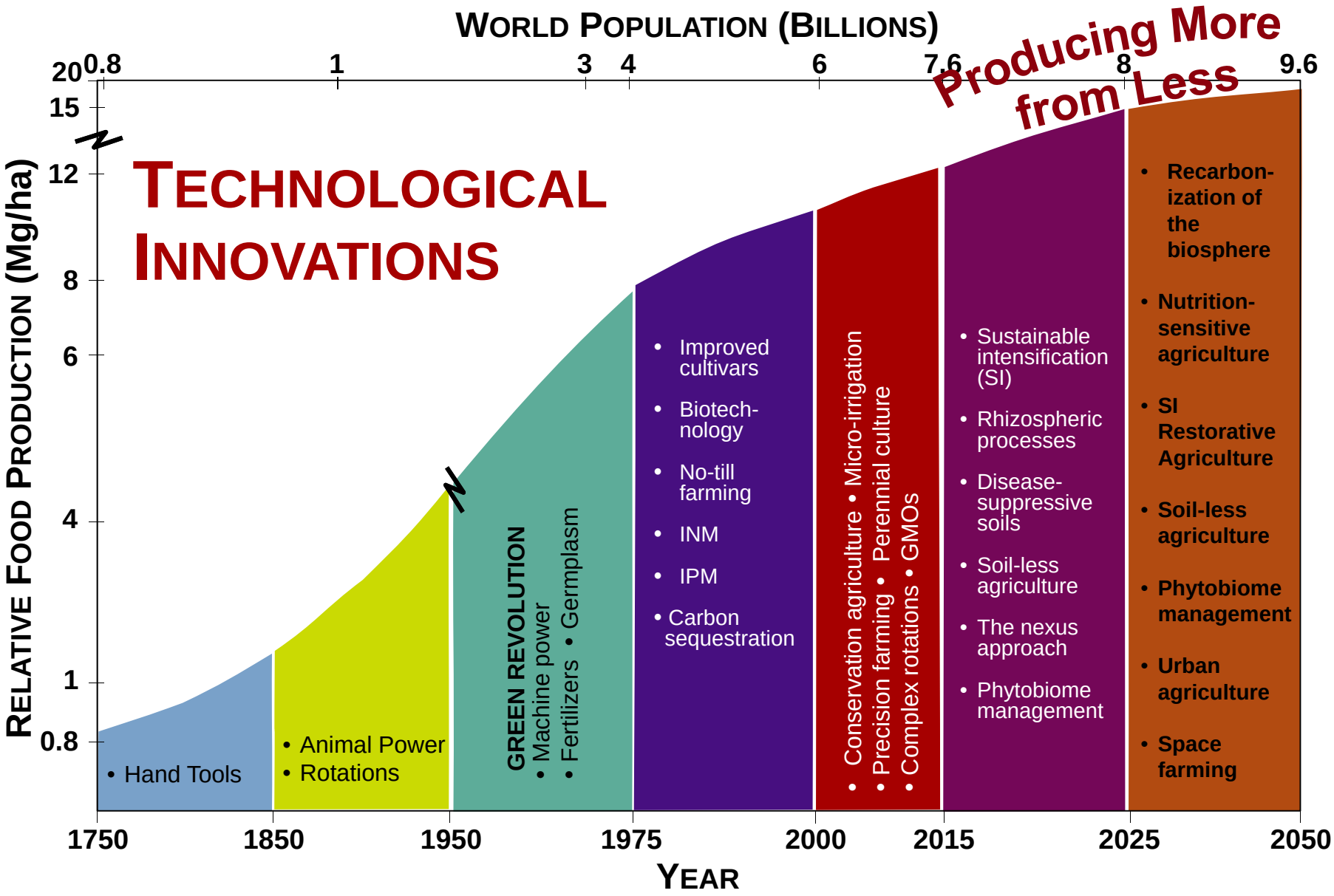

GANDHI'S 7 SINS OF HUMANITY

1. Wealth without work
2. Pleasure without conscience
3. Knowledge without character
4. Commerce without morality
5. Politics without principle
6. Religion without sacrifice
7. Science without humanity

GANDHI'S 7 SINS OF HUMANITY
(CONTINUED...)

8. Technology without wisdom

9. Education without relevance

10. Humanity without conscience