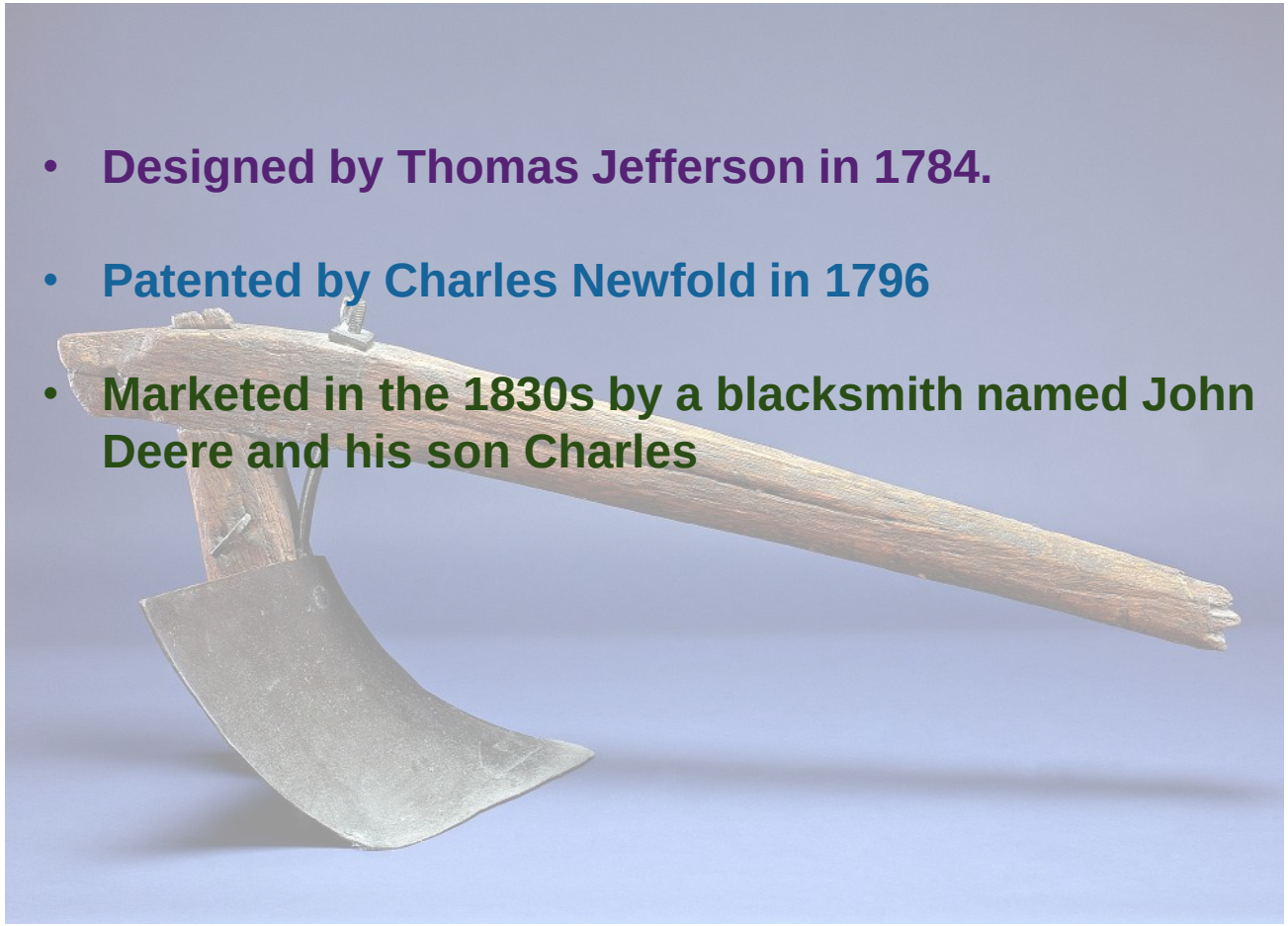
Managing Soils for Negative Feedback to Climate Change and Positive Impact on Food and Nutritional Security

Dr. Rattan Lal

Carbon Management and Sequestration Center, The Ohio State University , Columbus, OH

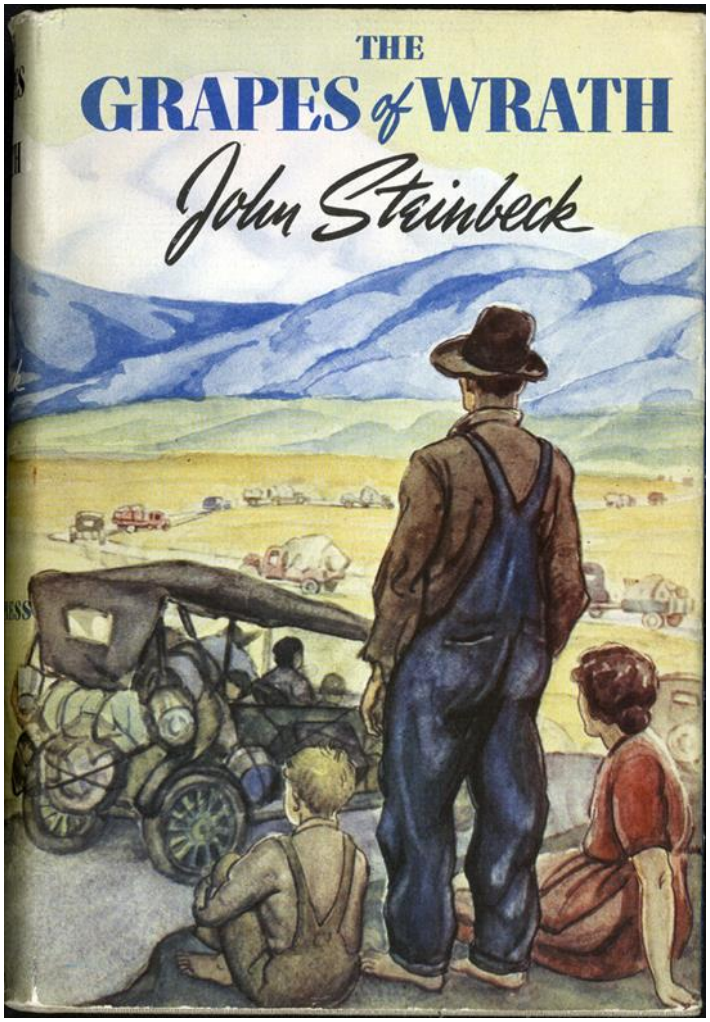
Annual Meeting of the Japanese Society of Soil Science and Plant Nutrition
3-5 September,2019
Shizuoka, Japan

THE FIRST MOLDBOARD PLOW IN THE U.S.



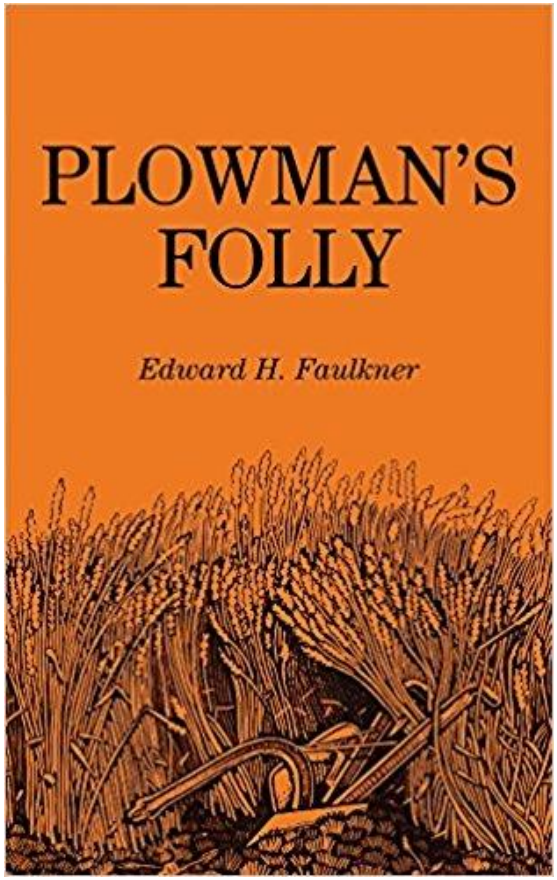
- Designed by Thomas Jefferson in 1784.
- Patented by Charles Newfold in 1796
- Marketed in the 1830s by a blacksmith named John Deere and his son Charles

A Dust Storm in West Texas in 1934

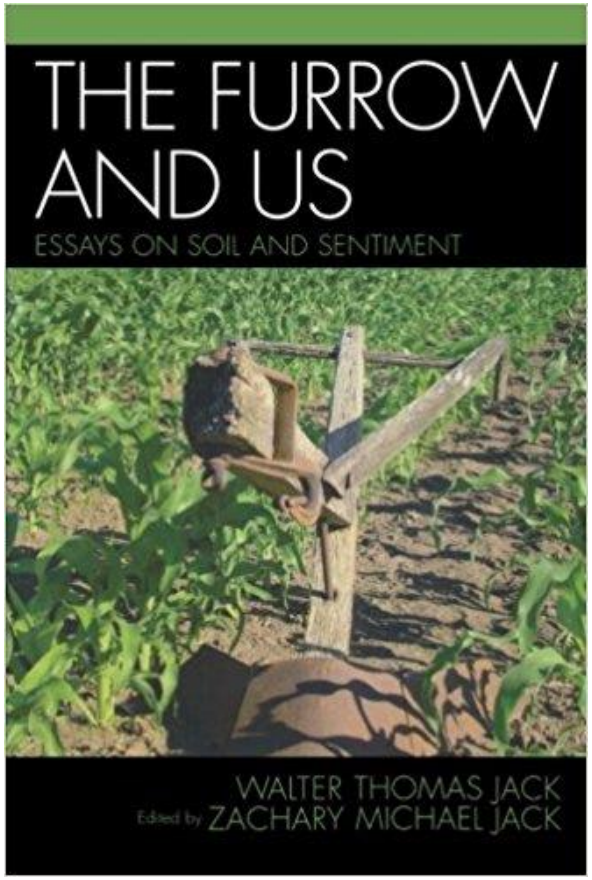


(1939)

WATER EROSION


PLOWMAN'S FOLLY
Edward H. Faulkner

(1945)

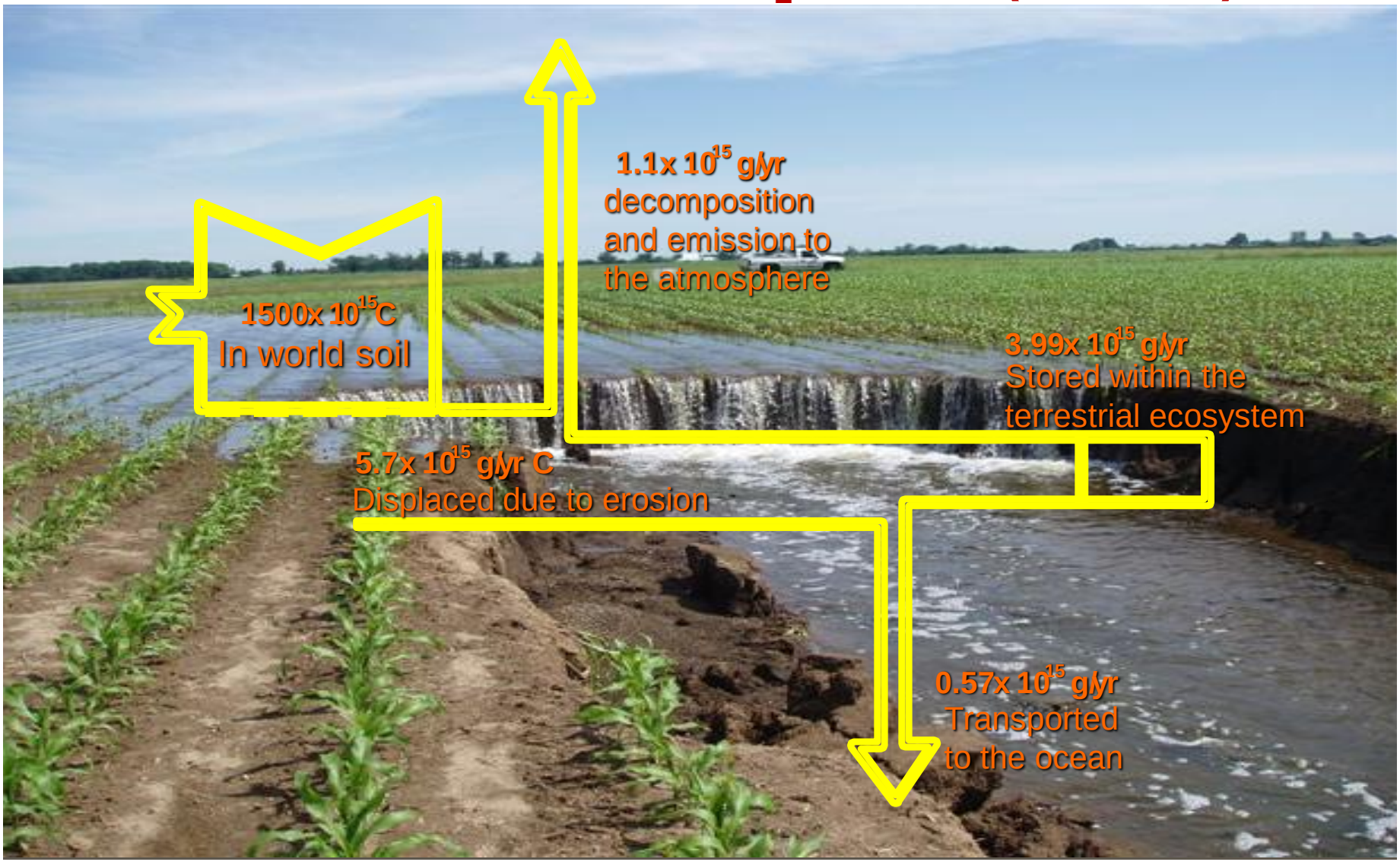

THE FURROW AND US
ESSAYS ON SOIL AND SENTIMENT
WALTER THOMAS JACK
Edited by ZACHARY MICHAEL JACK

(1946)

SOIL PLOWING AND THE GLOBAL CARBON CYCLE: EMERGING ISSUES

- However , plowing and soil erosion also affect the global carbon cycle and exacerbate the anthropogenic climate change.
- Soil erosion aggravates emission of greenhouse gases and is a source of atmospheric CO_2.
- Erosion-induced gaseous emissions must be accounted for in the Global Carbon Budget .It cannot be ignored

GLOBAL SOIL EROSION & CO_2 EMISSION(LAL,2003)



SOIL EROSION AS A CARBON SOURCE(LAL,2003)

World	1.1 Pg C/y
USA	15 Tg C/y
Brazil	60 Tg C/y
India	4.8 - 7.2 Tg C/y
Iceland	0.01-0.02 Tg C/y

SOIL MANAGEMENT & THE CARBON CYCLE

- Thus , it is important to understand the global carbon cycle and how it is affected by plowing and other soil management practices ?
- How can soils be managed to make them a sink rather the source of atmospheric CO_2?

SHORT VS. LONG-TERM CYCLE

Long-Term : Geochemical cycles which affect C exchange between rocks and the surficial reservoirs.

Short-Term : Exchange of C between atmosphere, biosphere, soil and the ocean.

Carbon Pools in Different Reservoirs for the Long-Term Cycle

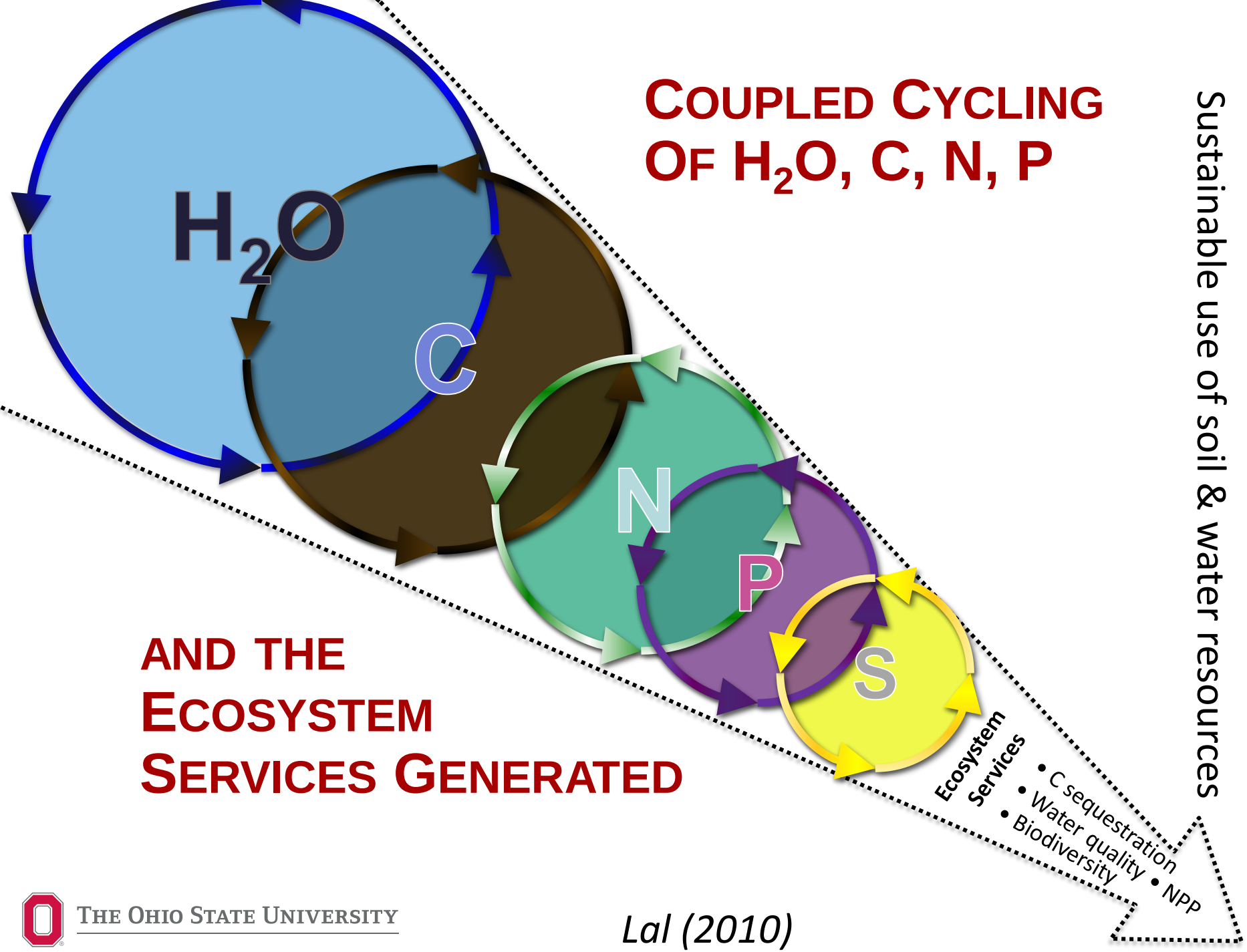
Reservoir	C Pool (10^{18} g)
Carbonate in Rocks	60,000
Organic C in Rocks	15,000
Ocean (HCO_3^-, CO_3^{-2})	42
Soils	6
Atmosphere	0.8
Biosphere	0.6

There is extremely little CO_2 in the atmosphere compared to that in the rocks. Thus, if inputs and outputs are not closely balanced, the atmosphere would become overwhelmed with CO_2.

Carbon Pools in Different Reservoirs for the Short-Term Cycle

Reservoir	Pool (10^{15} g)
Ocean	42,000
Fossil Fuel	5,000
Soils (3-m)	6,000
Atmosphere	820
Biota	620

Coupled Cycling Of H_2O, C, N, P



And the Ecosystem Services Generated

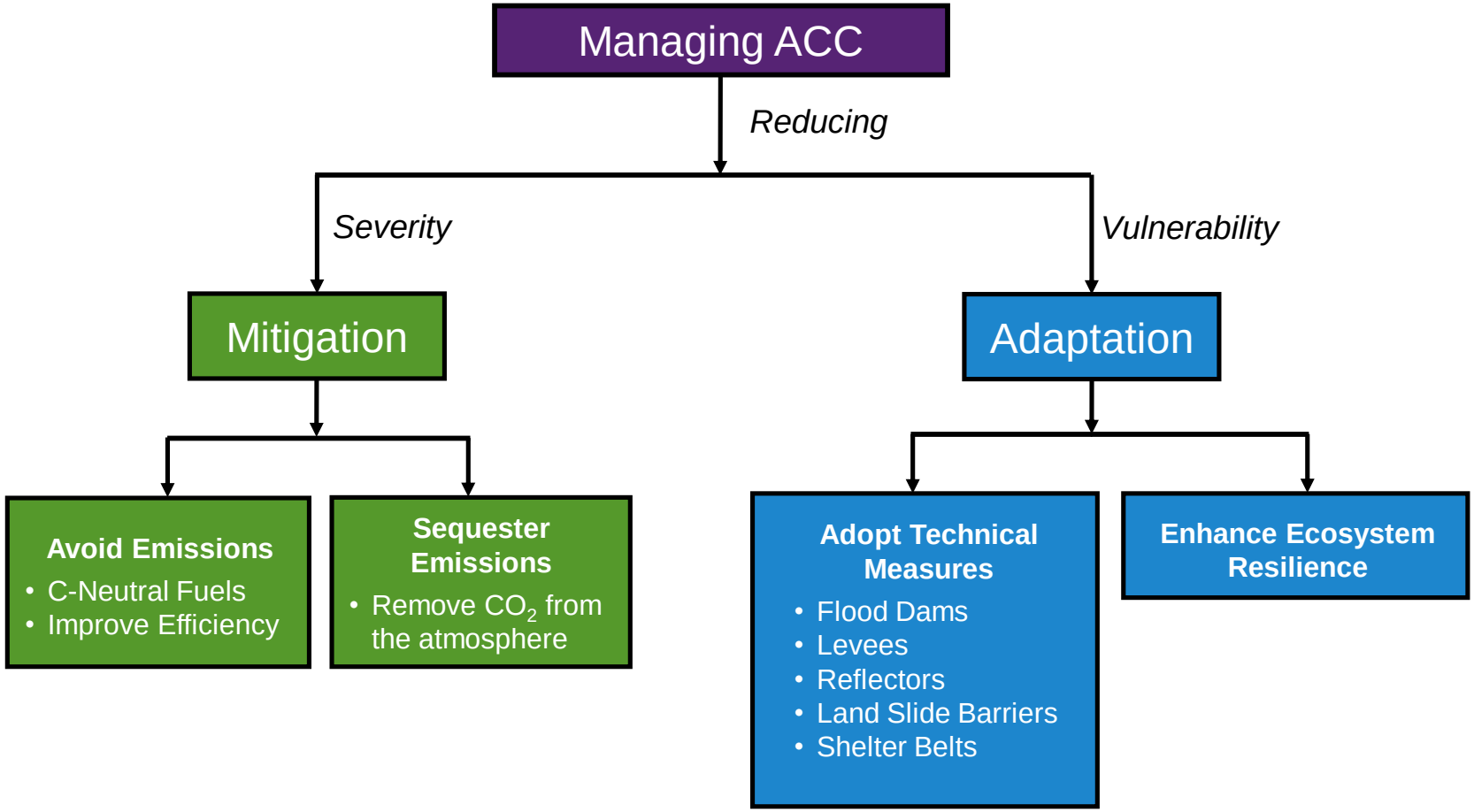
Sustainable use of soil & water resources

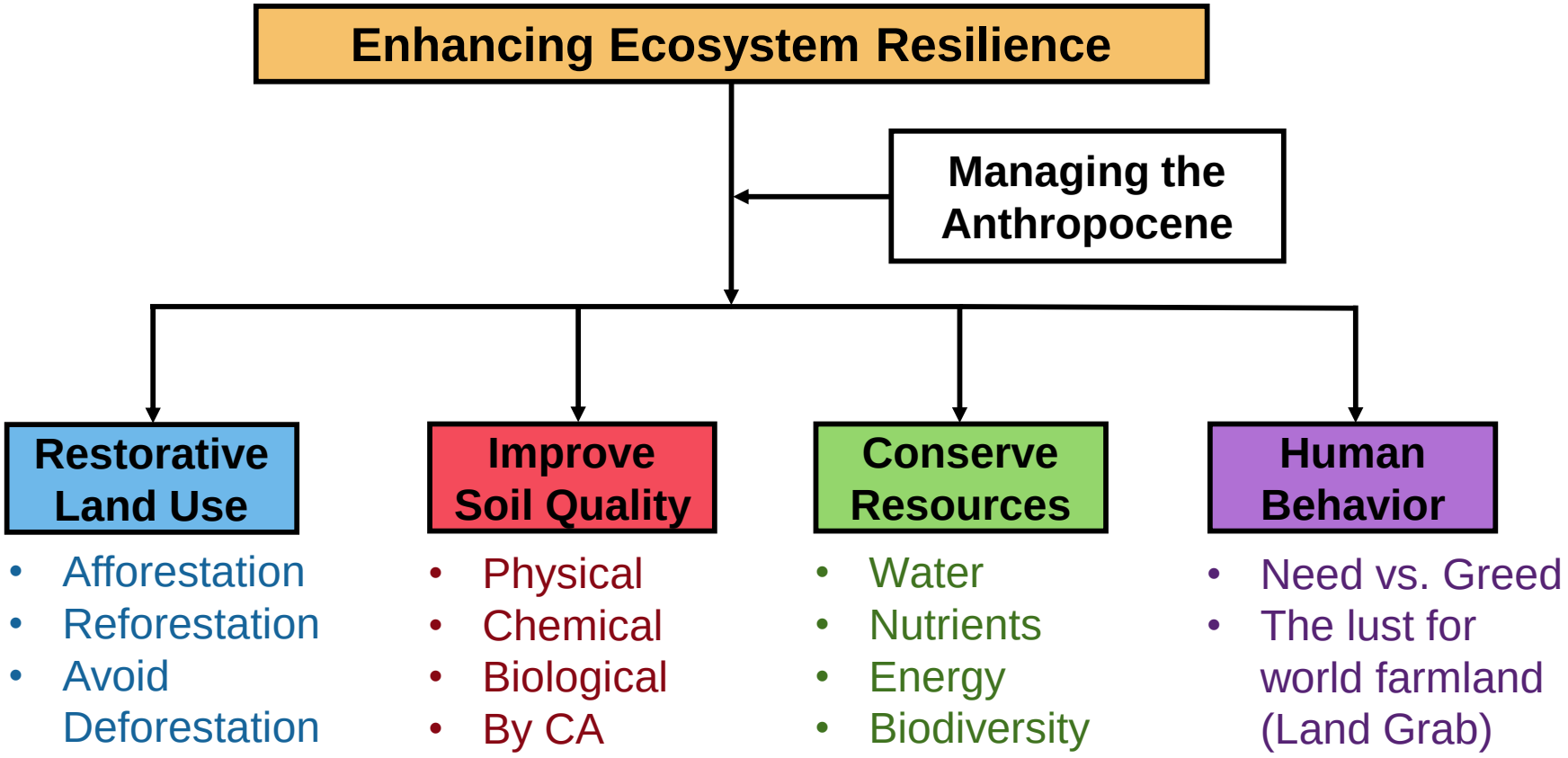
Lal (2010)

SOIL MANAGEMENT FOR ADAM OF ACC

- Soil & adaptation to ACC
- Soil & mitigation of ACC
- Can soil management achieve both ?

MANAGING THE ABRUPT CLIMATE CHANGE




Enhancing Ecosystem Resilience
Managing the Anthropocene
Restorative Land Use
Improve Soil Quality
Conserve Resources
Human Behavior
• Afforestation
• Reforestation
• Avoid Deforestation
• Physical
• Chemical
• Biological
• By CA
• Water
• Nutrients
• Energy
• Biodiversity
• Need vs. Greed
• The lust for world farmland (Land Grab)

MITIGATION OF CLIMATE CHANGE

- It involves specific soil and land (soil , vegetation) management activities to reduce the extent and severity of ACC.

- The goal of mitigation strategies is to enhance C sink capacity of soil and vegetation, and reduce the net anthropogenic emissions.

Adaptation to Climate Change

1. Adjustments in a system's behavior and characteristics that enhance its ability to cope with external stress. (*Brooks 2003)*

2. Changes in ecological-socio-economic systems in response to actual or expected climate stimuli, their effects or impacts. (*Smith et al. 2000)*

3. Alterations in individual groups and institutional behavior in order to reduce society's vulnerability to climate. (*Pielke 1998)*

4. Adaptations can be anticipatory or reactive based on their timing, and autonomous or planned depending on their degree of opportunity. (*Fankhauser et al. (2000)*

5. Adaptation also implies looking for new opportunities that may arise due to ACC

BIOSEQUESTRATION OF ATMOSPHERIC CO_2

Only 0.05% of the 3800 zettajoules (10^{21}J) of solar energy is absorbed annually as GPP

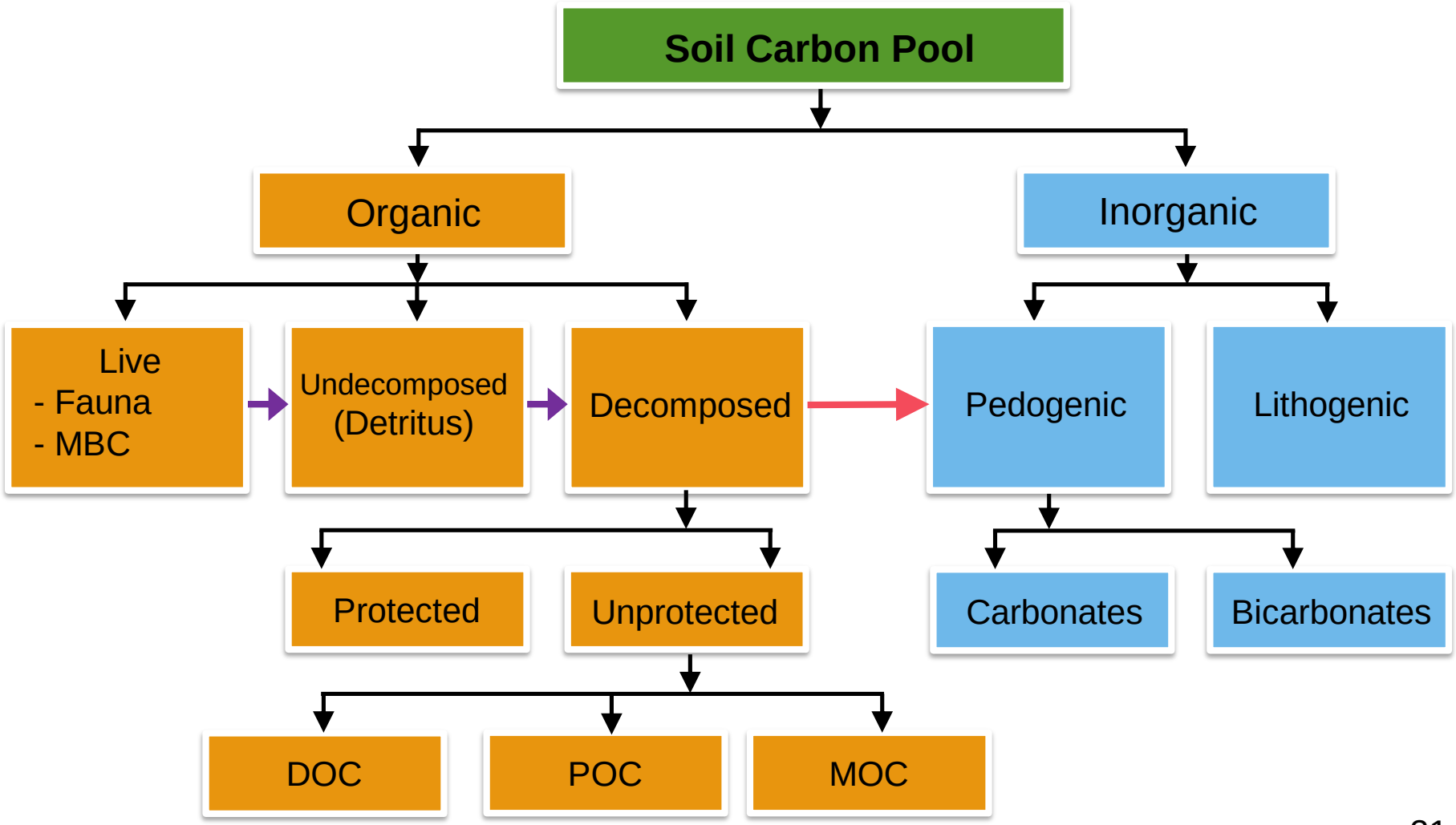
- **Gross Primary Productivity (GPP) = 123 Gt C/yr**
- **Net Primary Productivity (NPP) = 63 Gt C/yr**
- **Net Ecosystem Productivity (NEP) = 10 Gt C/yr**
- **Net Biome Productivity (NBP) = 3 Gt C/yr**

Jansson et al.(2010)

"If we control what plants do with carbon, the fate of CO_2 in the atmosphere is in our hands"

-Freman Dyson (2008), BioScience (10/10)

Constituents of Soil Carbon Pool



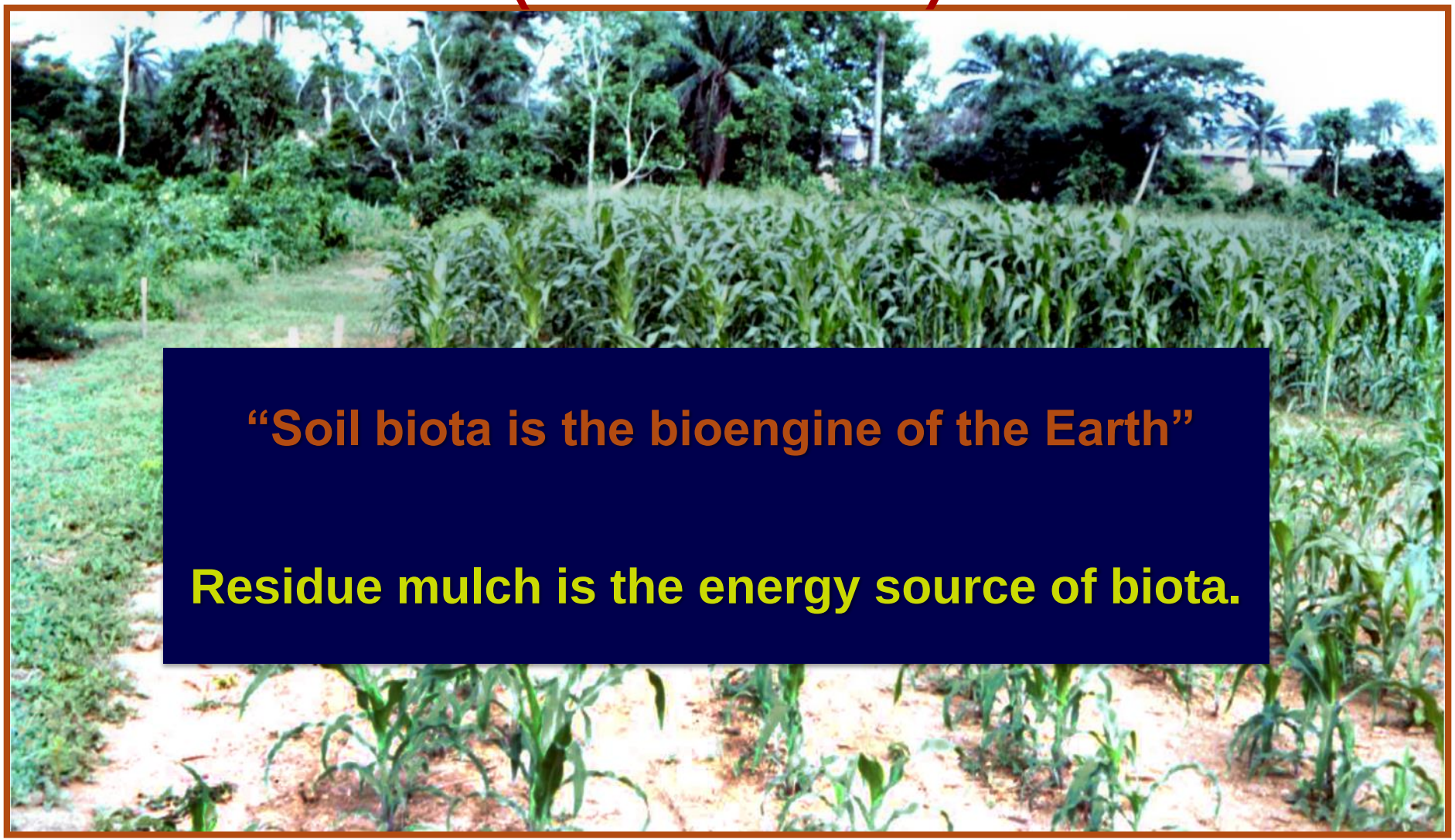
SOIL ORGANIC CARBON SEQUESTRATION

It is the process of transferring CO_2 from the atmosphere **into the soil of a land unit plant,** plant residues, and other organic solids which are ***stored or retained in the unit as a part of the soil organic matter*** **with a long mean residence time.**

Olson, Al-Kaisi, Lal, Lower (2014)

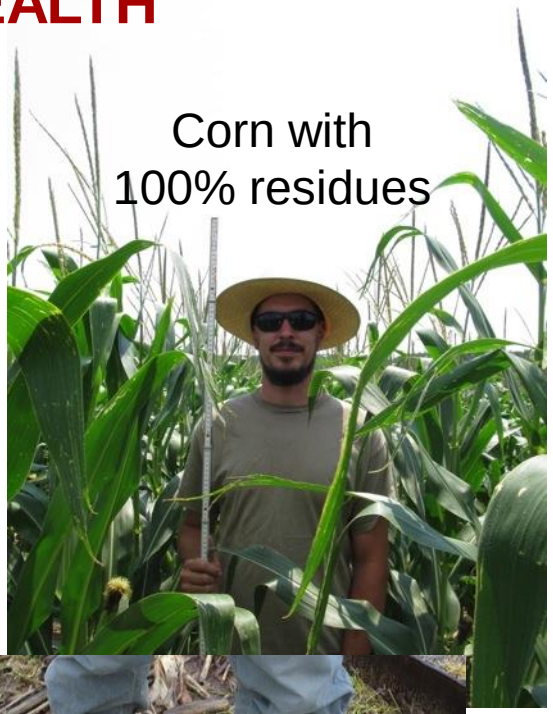
NO-TILL FARMING AS AN EMERGING GLOBAL TECHNOLOGY(IITA,1971)

RESIDUE MANAGEMENT IS CRITICAL TO NT FARMING (IITA 1972-1987)



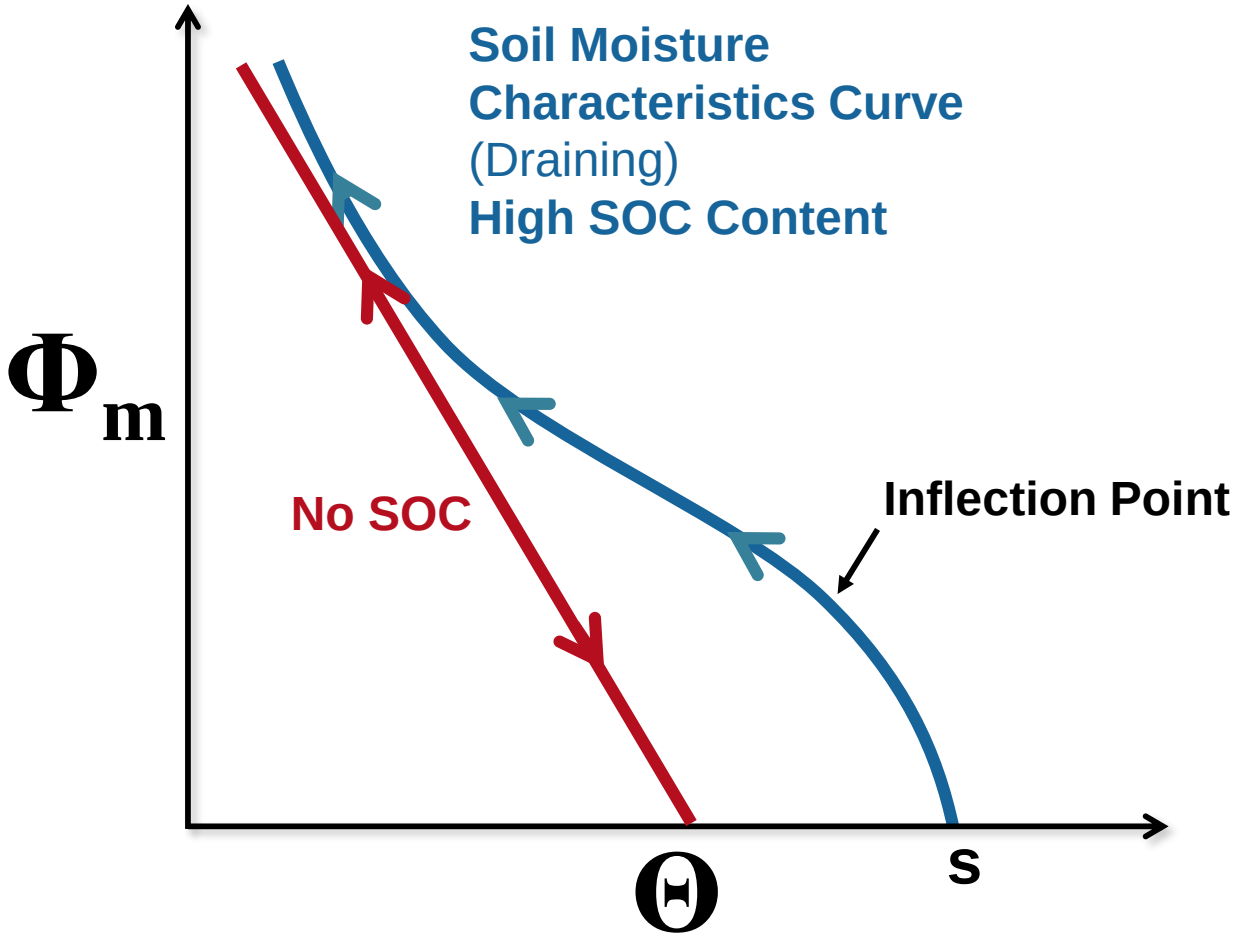
IMPORTANCE OF SOM & CROP RESIDUES TO SOIL QUALITY & HEALTH

Coshocton, 2012



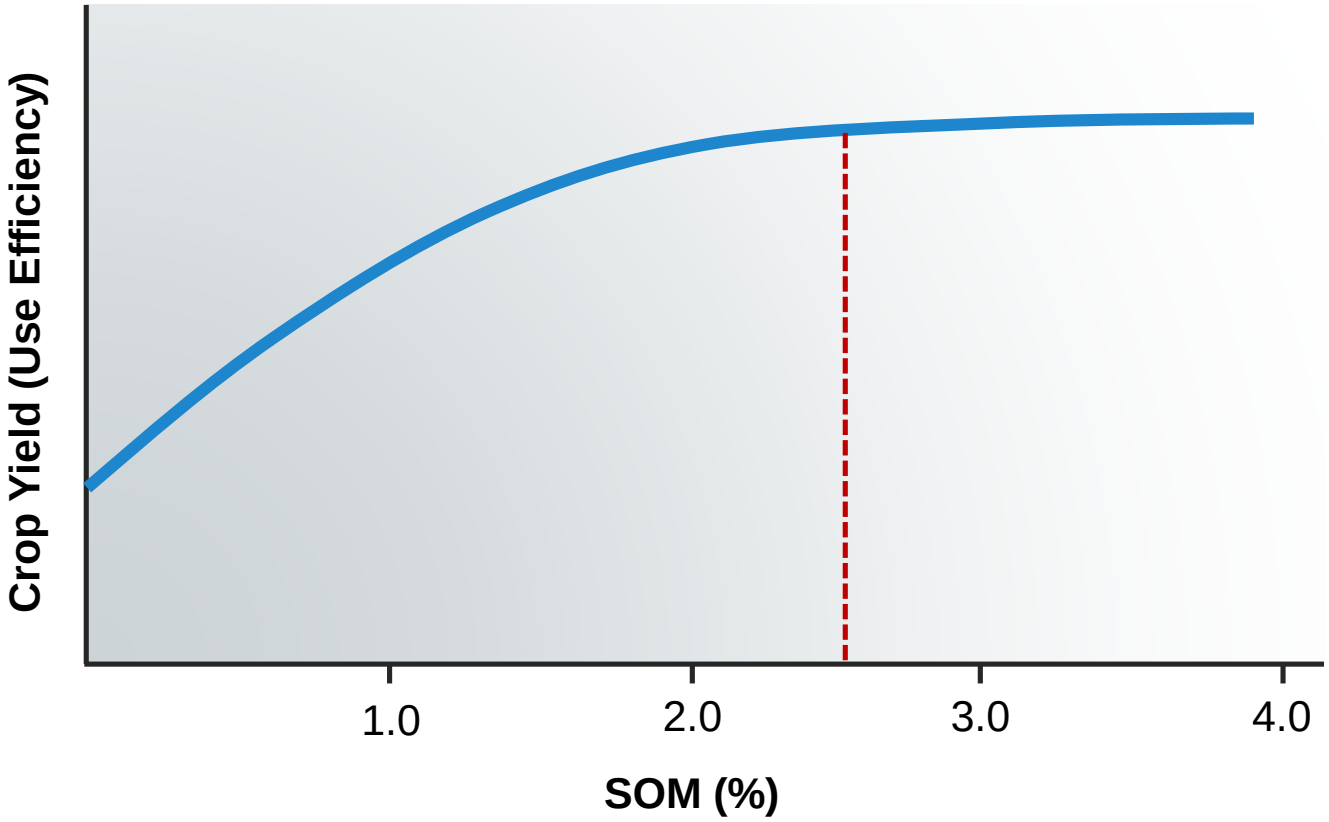
R. Lal, Coshocton, OH 2012,NC1178 Project

Θ and Φ for Drought Management

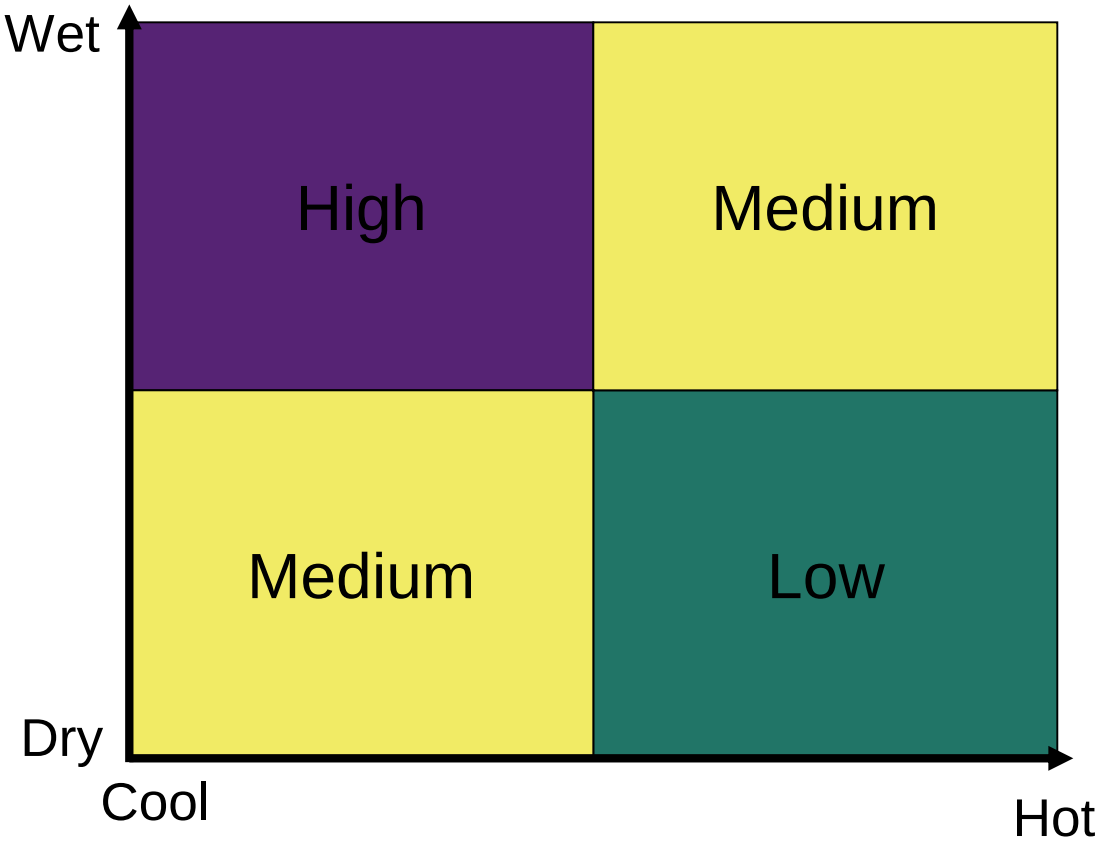


THRESHOLD LEVEL OF SOIL ORGANIC MATTER IN 0-30CM LAYER

SOM : 2.5 - 3.5%
SOC : 1.5 - 2.0%



CARBON SEQUESTRATION IN RELATION TO CLIMATE



NUTRIENTS REQUIRED TO CONVERT BIOMASS INTO HUMUS

Crop Residues

Biochemical Transformations

+ (N, P, S etc.)

Humus

Elemental Ratio	Cereal Residues	Humus
C:N	100	12
C:P	200	50
C:S	500	70

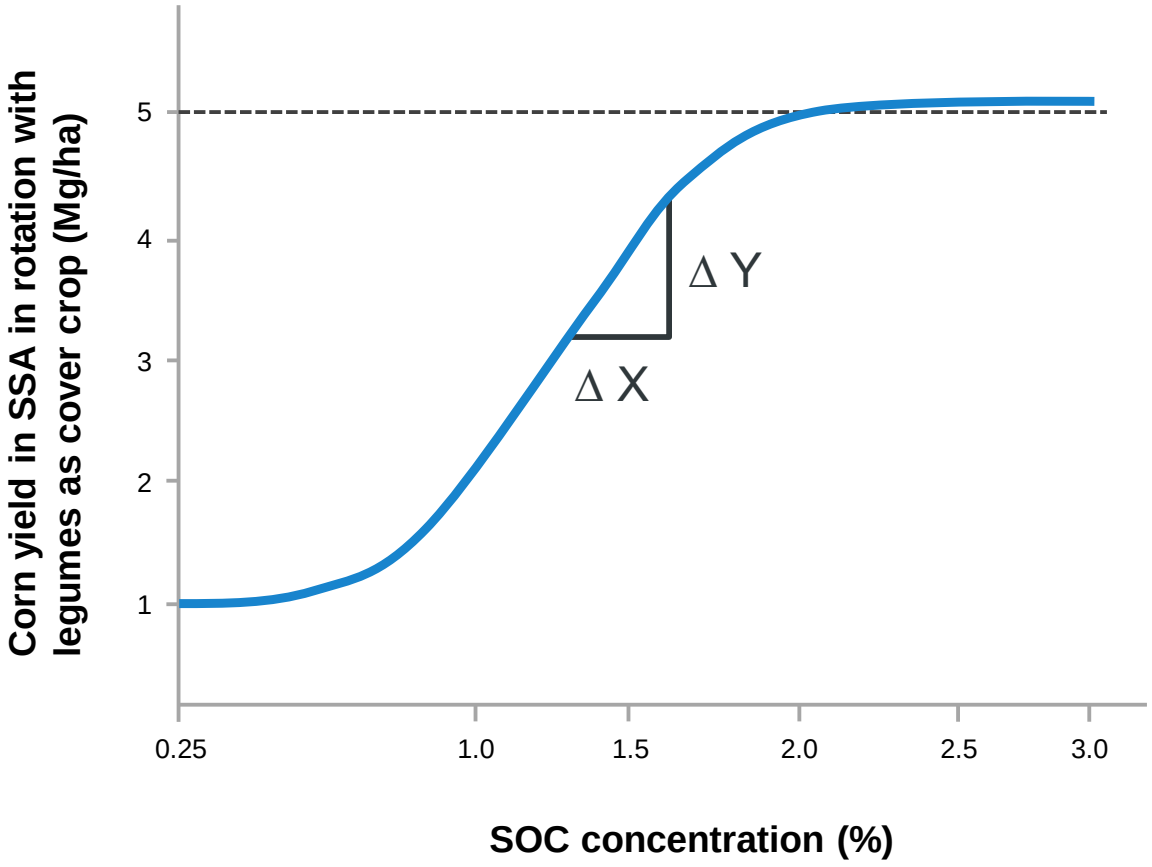
CARBON-BASED FERTILIZATION

CNPK

rather than

NPK

A HYPOTHETICAL CORN YIELD RESPONSE TO SOC WITH RECOMMENDED INPUTS



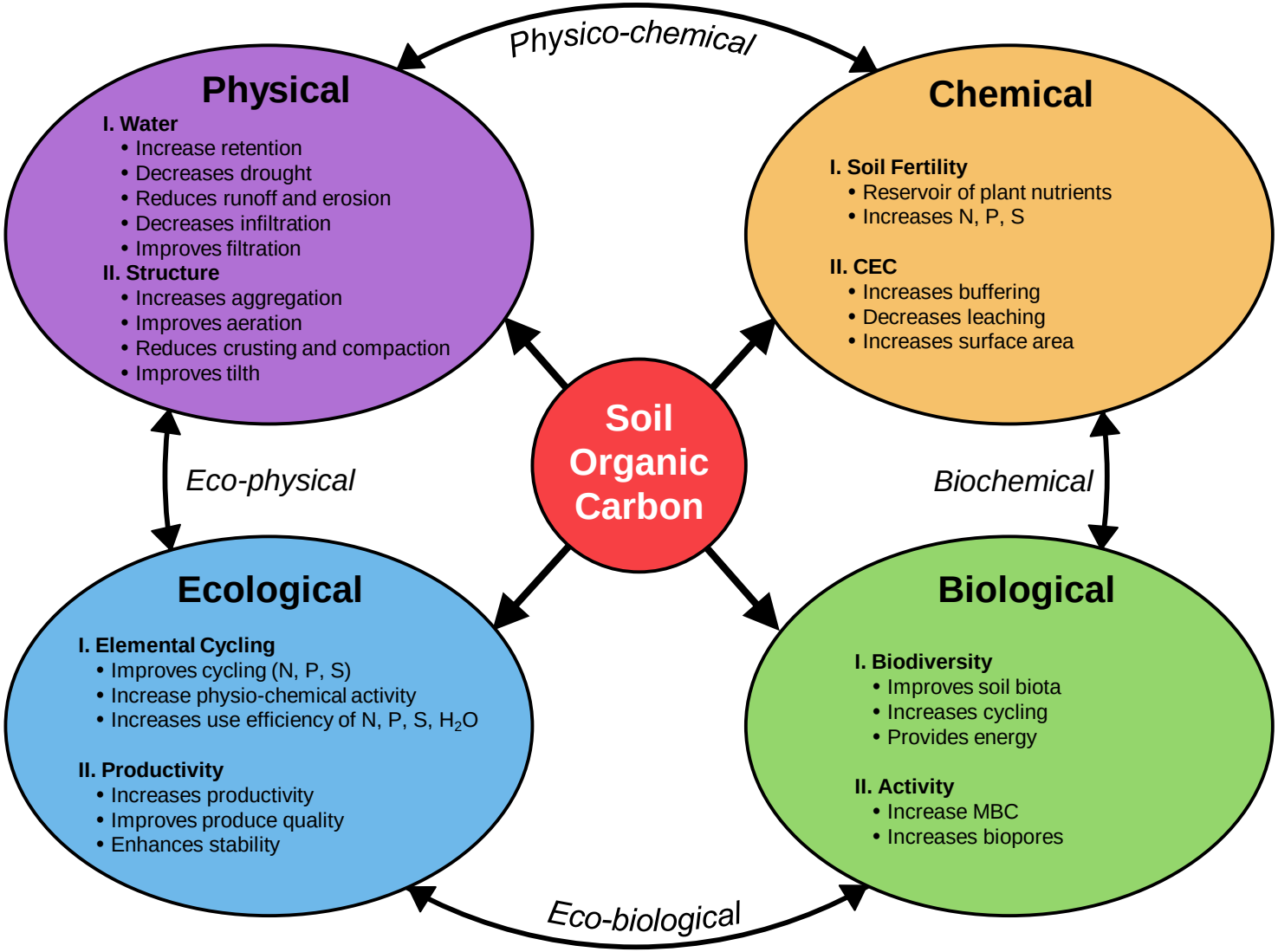
CROP YIELD INCREASE WITH INCREASE IN SOC BY 1 MgC/ha

Crop	Yield Increase (Kg/Ha.Mg C)
Maize	100 - 300
Soybeans	20 - 50
Wheat	20 - 70
Rice	10 - 50
Sorghum	80 - 140
Millet	30 - 70
Beans	30 - 60

30-50 million tons/yr in developing countries

Lal (2005)

SOC AND SOIL FUNCTIONALITY



Lal (2016)

SOIL C AS AN INDICATOR OF ENVIRONMENT

There are numerous advantages:

1. It is a familiar property,

2. It involves direct measurement,

3. It can be measured in 4 dimensions (length, width, depth, time),

4. It lends itself to repeated measurements over the same site,

SOIL C AS AN INDICATOR OF ENVIRONMENT (CONTINUED)

5. It is linked to ecosystem performance and services,

6. It is a key driver of soil formation,

7. It is important to soil fertility,

8. It has memory,

9. It has well defined properties,

SOIL C AS AN INDICATOR OF ENVIRONMENT (CONTINUED)

10. It can be used in synergism with other indicators,

11. Its uncertainty can be quantified,

12. Its pathways across the landscape can be followed,

13. It is an important archive of paleo-environmental conditions.

RESEARCH PRIORITIES IN SOC POOL AND GLOBAL ENVIRONMENTS

- **Studying** sensitivity to climate change, accelerated erosion, elevated CO_2,
- **Determining** the societal value of SOC
- **Translating** science into action (i. e., the French “4 per 1000” initiative),
- **Assessing** SOM pool in the entire profile (> 1m depth),
- **Evaluating** SOC dynamics over the landscape or watershed scale,
- **Establishing the threshold value for different land uses,**
- **Understanding** SOC pool in boreal ,arctic (permafrost),and arid regions,
- **Evaluating** the role of clay minerals,
- **Linking** SOC with SIC (secondary carbonates, HCO_3^-) dynamics, and
- **Sustaining** the global SOC pools in ecologically-sensitive eco-regions.
- Lal(2019)

STEWARDSHIP OF SOIL RESOURCES : PUTTING GOD BACK IN SCIENCE AND GOVERNMENT

1. Scriptures of all religions emphasize the importance of soil,

2. Religious organizations can promote soil protection,

3. Combining spiritual concepts with soil science is useful,

4. Putting spiritual ideas in government may also help the cause.

SPIRITUAL BELIEFS IN SOIL AND ENVIRONMENT

Judaism	:	The word "homo" (man) is derived from the Latin word "humus" or the decomposed organic matter in soil, which is the essence of all terrestrial life. The Hebrew phrase "Tikkun Olam" means "repairing restoring the world".
Hinduism	:	Human body is made of "Kshiti (soil), Jal (water), Pawak (energy), Gagan (sky/space), Sameere (air)" (Prasna Upanishad)
Sikhism	:	Pau'ṇ gurū pāṇī piṯā māṯā ḏẖaraṯ mahaṯ. Ḏinas rāṯ ḏu ė ḏā ī ḏā i ā kẖėlai sagal jagaṯ. (Gurbani)
Buddhism	:	"One should not break even the branch of a tree that has given one shelter" (Petavatthu II, 9, 3)
Christianity	:	The word "Adam" (man) is derived from the Hebrew word "adama" meaning "earth" or "soil"
Greek	:	The daughter of Earth goddess "Gaea" named Themis (goddess of Law), and her descendent Demeter was the goddess of agriculture and fertility
Romans	:	The Earth goddess (Tellus) was related to the goddess of fertility and harvest (Ceres), and named "Mater Terra"
Islam	:	"He created the man of clay like the potters" (Suhrah Al-Rhman, verse 14) "We made from water every living thing" (Quŕan 25:54) "Do not overuse water even if you are on a running river" (Prophet Mohammad)
Khalil Gibran	:	Trees are poems (rubbiat) that earth writes upon the sky. We fell them down and then turned them into paper, so that we may record our emptiness. (Lal,2011)

PLANET EARTH IN HUMAN HANDS

- We (7.7 Billion) are all perpetrators and victims of the severe problems of soil degradation, climate change and other environmental issues.
- Thus, each one of us, individually and as a corporate or industry, have a responsibility to take action and help protect the soil and the planet.
- Even a small but incremental improvement can make a big difference