THE OHIO STATE UNIVERSITY

Soil Resilience and Climate Change

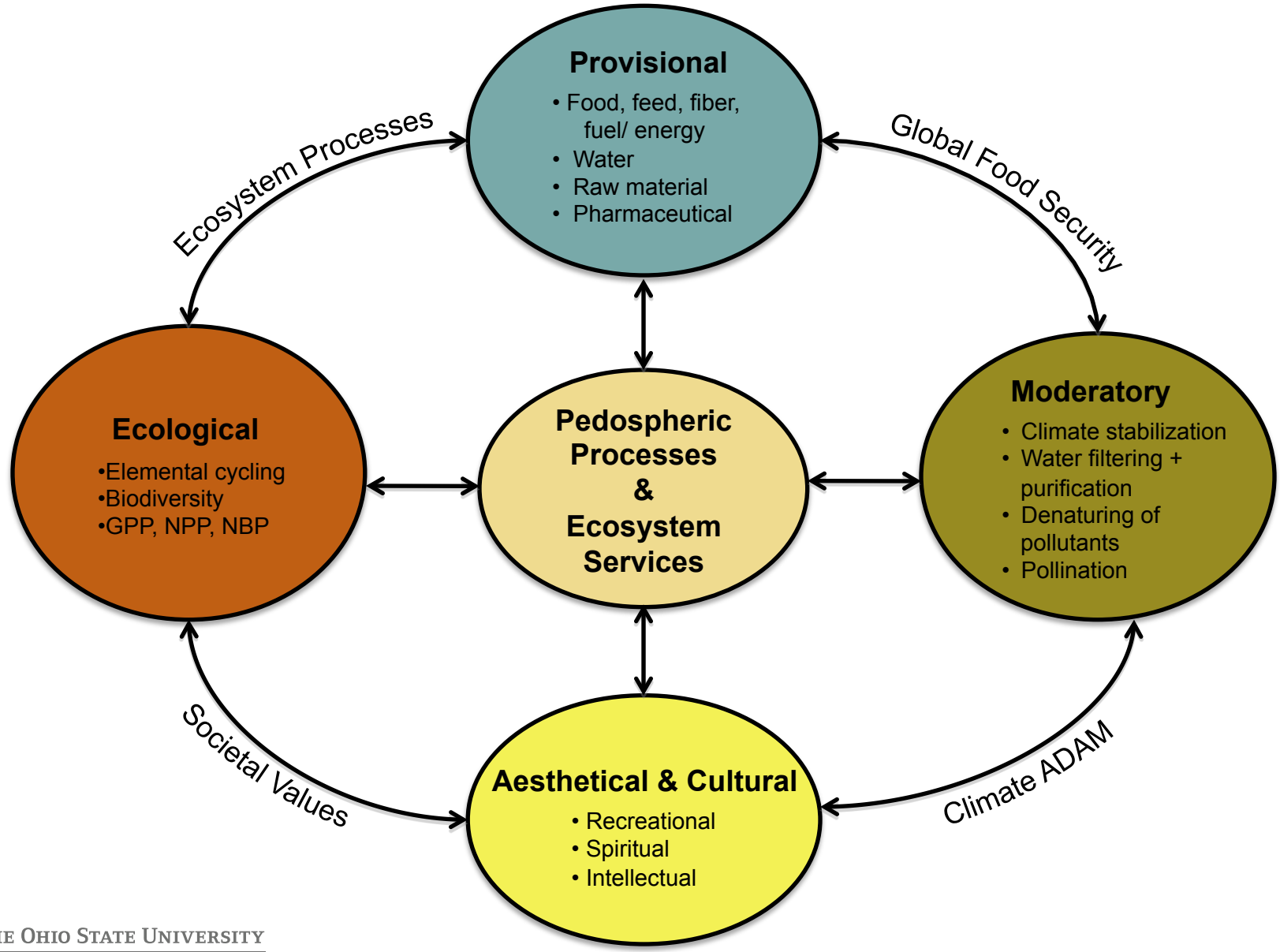
Carbon Management and Sequestration Center
Dr. Rattan Lal

THE ESSENCE OF LIFE

"Hello there folks. Do you know who or what I am? I am the geomembrane of the Earth. I am your protective filter, your buffer, your mediator of energy, water, and biogeochemical compounds. I am your sustainer of productive life, your ultimate sources of elements, and the habitat for most biota. I am the foundation that supports you, the cradle of your myths, and the dust to which you will return. I am a soil".

…Richard Arnold, 2005, Senior Soil Scientist

SOILS AND ECOSYSTEM SERVICES (LAL, 2012)



CLIMATE

"It refers to an aggregate of both average and extreme conditions of temperature, humidity and precipitation, winds and cloud cover, measured over an extended period of time."

"Climate is what you expect, weather is what you get."
Samuel Langhorne Clemens (Mark Twain)

ANTHROPOGENIC EMISSIONS (Pg) BY CARBON CIVILIZATION

I. Land use : 486
(i) Prehistoric : 320
(ii) 1750-2010 : 1
(iii) 2010-203

II. ustion: 390
: 200
030 : 190

The cause of Super-interglaciation

issions have and will affect the ecosystems
fro which we derive food, feed, fiber, fuel and shelter.

MODIFYING EARTHS RADIATION BALANCE

To diminish solar radiation incident on Earth's surface

1. **Reflectors or scatterers in the stratosphere or in orbit between the Earth and Sun**
2. **Deflection of sunlight from the Earth through the use of giant space mirror "spanning 60,000 square miles"**
3. **Sunscreen for Planet Earth (Edward Teller, 1997): 107Mg of dielectric aerosols of ~100nm diameter would increase albedo of the Earth by 1% (alumina particles)**
4. **Artificial Trees which are machines, which like trees, can remove CO_2 from the atmosphere. CO_2 sticks to the sorbent, it is then removed and buried underground by CCS techniques**
5. **Algae-coated buildings have strips of algae are fitted to the outside of the buildings, and periodically harvested as "biofuel"**
6. **Reflective buildings make use of reflective surfaces**
7. **Reactions with minerals**
   Forsterite : $Mg2SiO4 + 2CO2 = 2MgCO3 + SiO2$
   Serpentine : $Mg3Si2O5(OH)4 + 3CO2 = 3MgCO3 + 2SiO2 + 2H2O$
8. **Basalt storage in the ocean**
9. **Mineralization of CO_2**

SOIL RESILIENCE

Ability of soil to resist change or recover to th

i. **Elasticity:** The rate of recovery

ii. **Amplitude:** The range of … which recovery is possible

iii. **Hysteres**… covery path or pattern

… erence is new vs. the antecedent state

All these attributes depend on S_q & SOC

SOIL QUALITY VS. RESILIENCE

- These are inter-related but different
- Quality refers to ecosystem functions and services.
- Resilience refers to ability of a soil to restore itself.

SOIL QUALITY VS. SOIL RESILIENCE *...LAL, 1997*

$S_r = - dS_q/dt$

S_s = soil resilience

S_q = soil quality

t = time

SOIL RESILIENCE *...LAL, 1997*

$$S_r = S_a + \int_0^t (S_n - S_d + I_m)\, dt$$

S_a = antecedent condition

S_n = rate of soil renewal

S_d = rate of soil degradation

I_m = management input

t = time

MITIGATION OF CLIMATE CHANGE

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

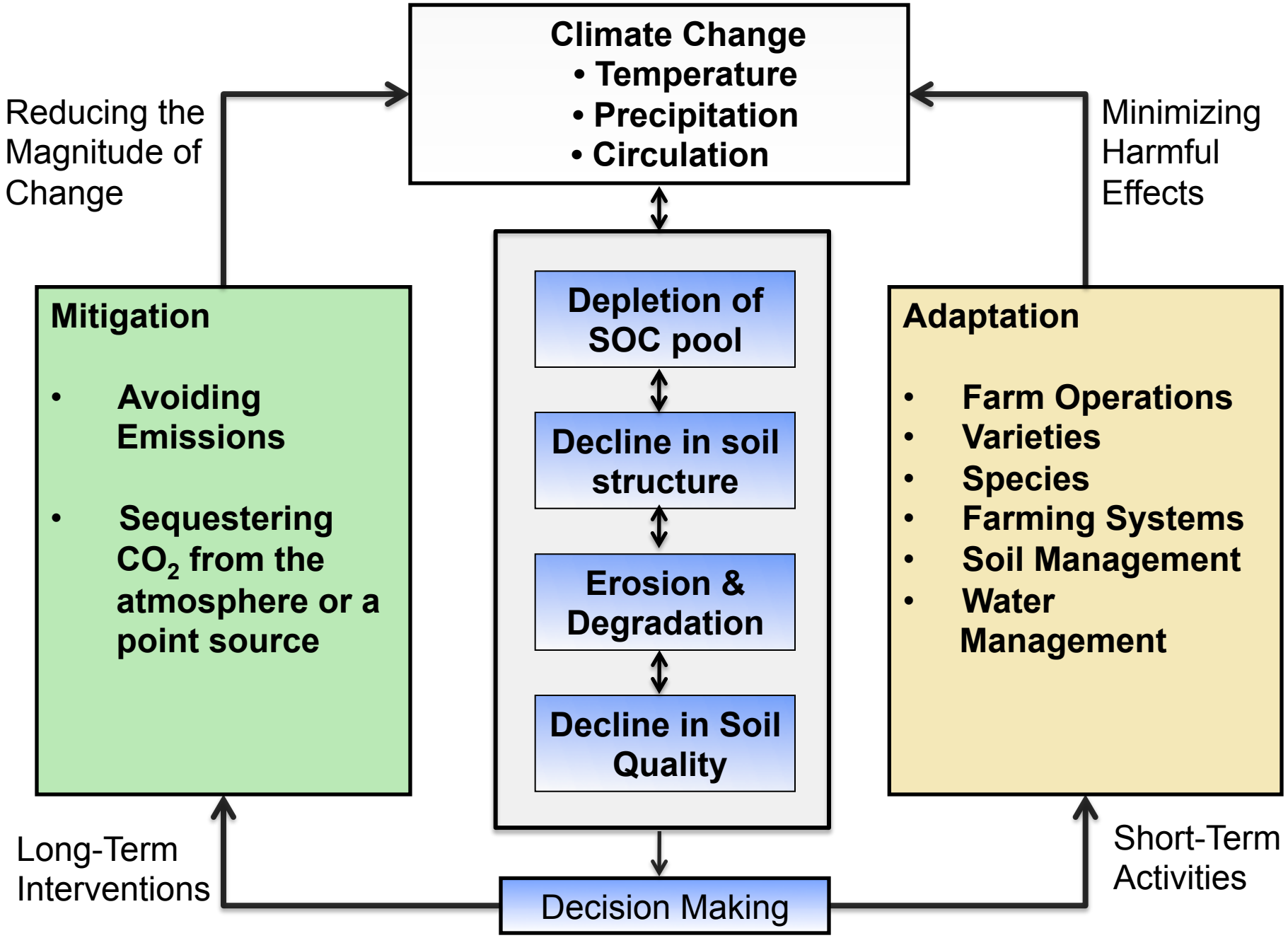
- The goal of mitigation strategies to enhance C sink capacity of soil and vegetation, and reduce the net anthropogenic emissions.

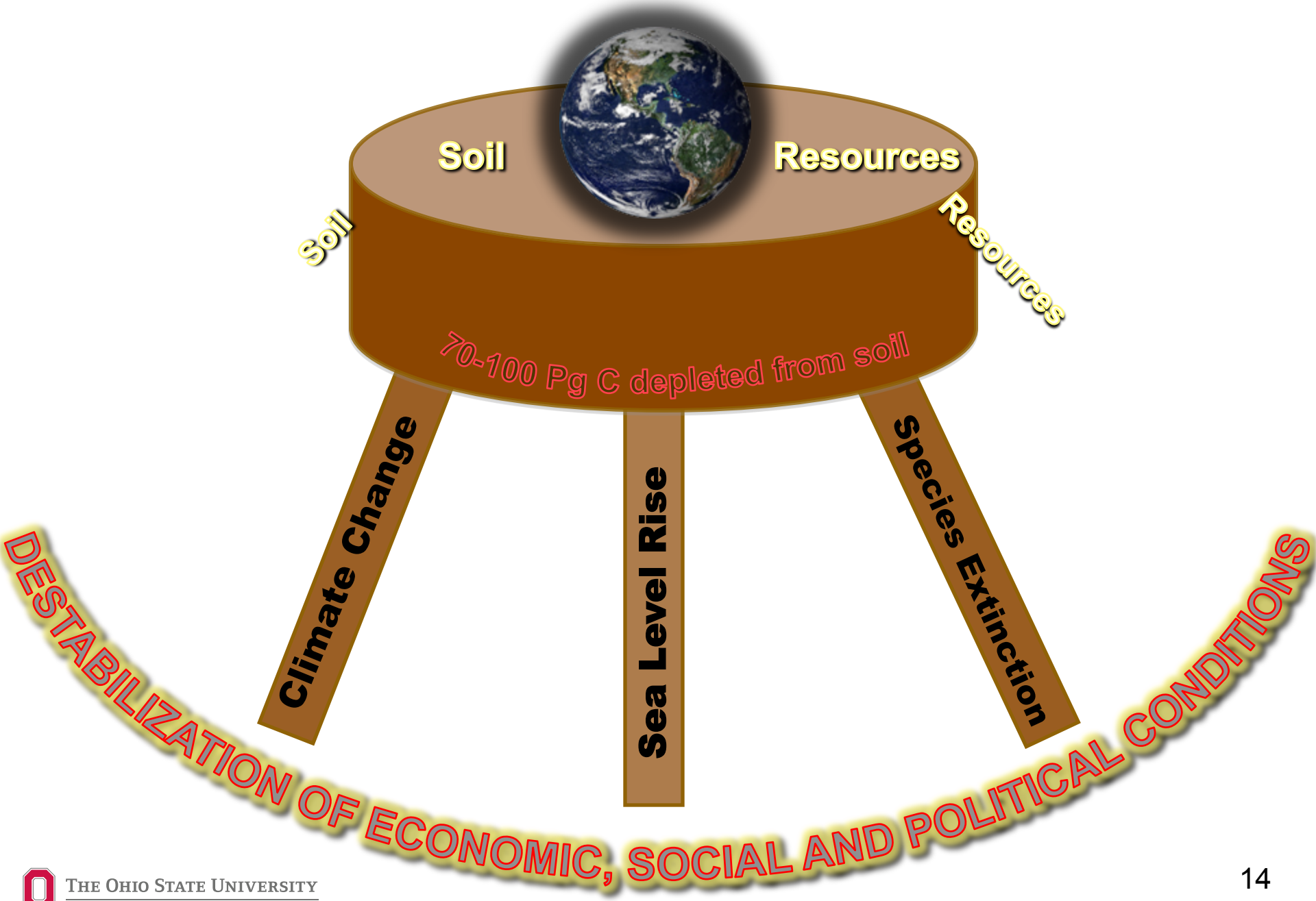
ADAPTATION TO CLIMATE CHANGE

It involves any activity that reduces the negative impacts of climate change through anticipatory or reactive strategies

and/or

take advantage of new and beneficial opportunities that may be presented


Climate Change
• Temperature
• Precipitation
• Circulation
Reducing the Magnitude of Change
Minimizing Harmful Effects
Mitigation
• Avoiding Emissions
• Sequestering CO_2 from the atmosphere or a point source
Depletion of SOC pool
Decline in soil structure
Erosion & Degradation
Decline in Soil Quality
Adaptation
• Farm Operations
• Varieties
• Species
• Farming Systems
• Soil Management
• Water Management
Long-Term Interventions
Decision Making
Short-Term Activities


Soil
Resources
Soil
Resources
70-100 Pg C depleted from soil
Climate Change
Sea Level Rise
Species Extinction
DESTABILIZATION OF ECONOMIC, SOCIAL AND POLITICAL CONDITIONS

SHADES OF CARBON IN SOIL

Color of the soil from Rothamsted long-term experiment (1850) with (right) and without (left) manure application.

Photos: Lal, 2013

POTENTIAL OF SOIL CARBON SEQUESTRATION (PG C/YR)

Cropland:	0.4 - 1.2
Grazing land:	0.3 - 0.5
Salt-affected soils:	0.3 - 0.7
Desertified soils:	0.2 - 0.7
Total:	**1.2 - 3.1**

SINK CAPACITY OF LAND-BASED SINKS THROUGH BIOSEQUESTRATION

Strategy	Sink Capacity (Pg C)
Permanent Forest	200-300
Soils	50-100

Drawdown of 50 ppm by the end of the century or early 21st century

PROPERTIES OF AGROECOSYSTEMS

1) Productivity : Total output

2) Stability : Consisten

3) Equitability : E all inhabitants

4) Autonor sufficiency

5) : Forever

6) ncy (Eco) : Producing more with less

All of these properties depend on soil carbon pool

EX NIHILO NIHIL FIT *(Nothing Comes From Nothing)*

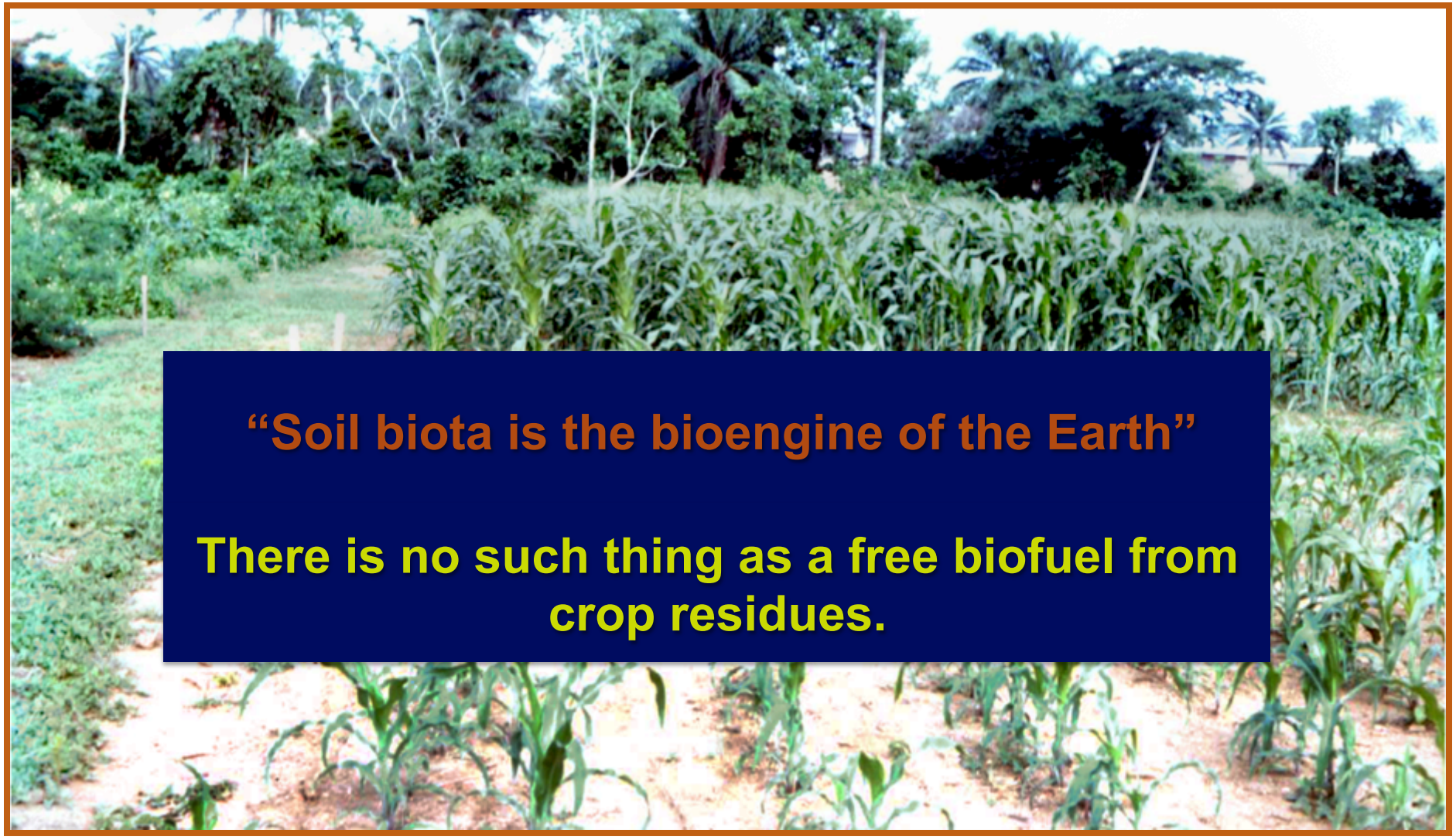
Law or Concept	Implications
1. **Nothing is appropriated:**	There are always trade offs (give and take).
2. **Nothing is permanent:**	Everything is in a dynamic equilibrium and a transient state.
3. **Nothing is absolute:**	All processes, properties and values are relative to a baseline.
4. **Nothing is a panacea**:	There is no silver bullet, there is a multitude/menu of options.
5. **Nothing is universal**:	Soil/site/region specificity is an important consideration which cannot be overlooked.
6. **Nothing tangible is free**:	Under valuing a commodity leads to "Tragedy of the Commons".
7. **Nothing is empty (vacuum) in nature:**	All space is occupied, pores in solid rock contain water or air and injecting something (liquid CO_2), fracking solutions can create shock waves.
8. **Nothing is given or for granted**:	It is the judicious use and management which produce goods and services.
9. **Nothing is a waste**:	Everything in nature has a use.
10. **Nothing is nothing:**	There is no such thing as nothing.

DROUGHT OF 2012

Corn with no residue.

Corn with 100% residue

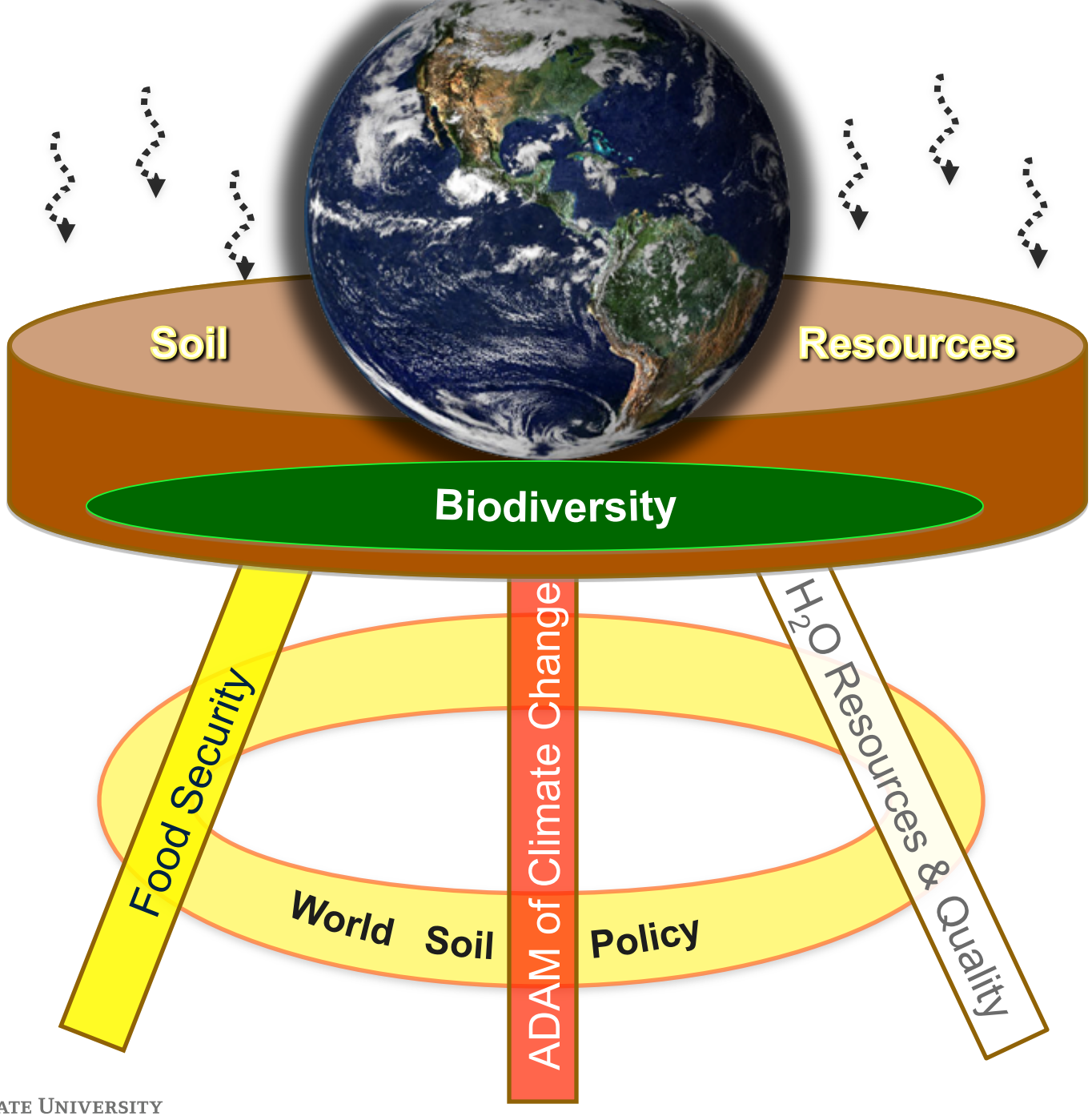
ECONOMICS OF RESIDUE REMOVAL FOR BIOFUEL




Straley, Sarah J. <straley.23@osu.edu>

ATMOSPHERIC BROWN CLOUD CAUSED BY TRADITIONAL BIOFUELS

(NYT 4-16-09)


Soil
Resources
Biodiversity
Food Security
ADAM of Climate Change
H_2O Resources & Quality
World Soil Policy

FRUSTRATION OF SOIL SCIENTISTS

" Soil scientists have also been frustrated as their advice has gone apparently unheeded. This may be because the advise is couched in terms more easily understood by other soil scientists than by politicians and economists who control the disposition of the land.

If soil science is to serve society fully, it is essential that its arguments are presented in terms readily understood by all and with both scientific and economic rigor so that they are not easily refuted."

….Dennis Greenland (1991)

SOME INTERNATIONAL INITIATIVES

Year	Initiative	Organization
1972	European Soil Charter	Council of Europe
1980	IBSRAM	CIDA, ACIAR, GTZ, etc.
1980	SOS	IFIAS/UNEP
1982	World Soil Charter	FAO
1992	Agenda 21	UN
1994	UN Convention to Combat Desertification	UNEP
1996	Soil Fertility Initiative	FAO
1998	Convention on Sustainable Use of Soils	Tutzing Initiative
1998	Soil Protocol	Alpine Convention

SOME INTERNATIONAL INITIATIVES CONTINUED…

Year	Initiative	Organization
2000	Global Convention for Soils	IUCN
2000	UNMD Goals	U.N.
2001	The Challenge Program	CGIAR
2002	Global Soils Agenda	IUSS
2002 (2006)	Soil Thematic Strategy	EU
2005	Iceland Soil Protocol (Selfos)	IUCN
2006	Soil Protection	E.C.
2008	Atoms for Food	IAEA
2008	Senate Resolution	US Senate
2008	Sustainable Development	U.N.
2011 (May)	Global Soil Forum (GSF)	IASS
2011 (Sept.)	Global Soil Partnership	FAO
2011 (Oct.)	Interg. Panel on Land and Soil (IPLS)	UNCCD (COP-10)

RELIGIOUS BELIEFS IN AGRICULTURE 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	:	**Pa uṇ gurū pāṇī piṭā māṭā ḏẖaraṯ mahaṯ. Ḏinas rāṯ ḏu è 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)**
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.**

MANKIND AND THE ENVIRONMENT

"Mankind is on the horns of a dilemma.

For whether we like it or not, our collective way of life has become unsustainable and we need to do something about it – and soon.

The choices we have already made about the way we lead our lives have been slowly eating away at the very support system that enables us to live and breathe.

This cannot, and should not, go on.

We need to make some tough decisions, we need to make them now and we need to act on them as one, with total and undivided commitment – today and in the future.

Faced with facts we cannot argue against, we need to consider our priorities and accept that we have to make certain sacrifices; we need to start putting 'life' ahead of 'lifestyle'."

IMO, World Maritime Day (2009)