THE OHIO STATE UNIVERSITY

Soil Restoration for Ecosystem Services

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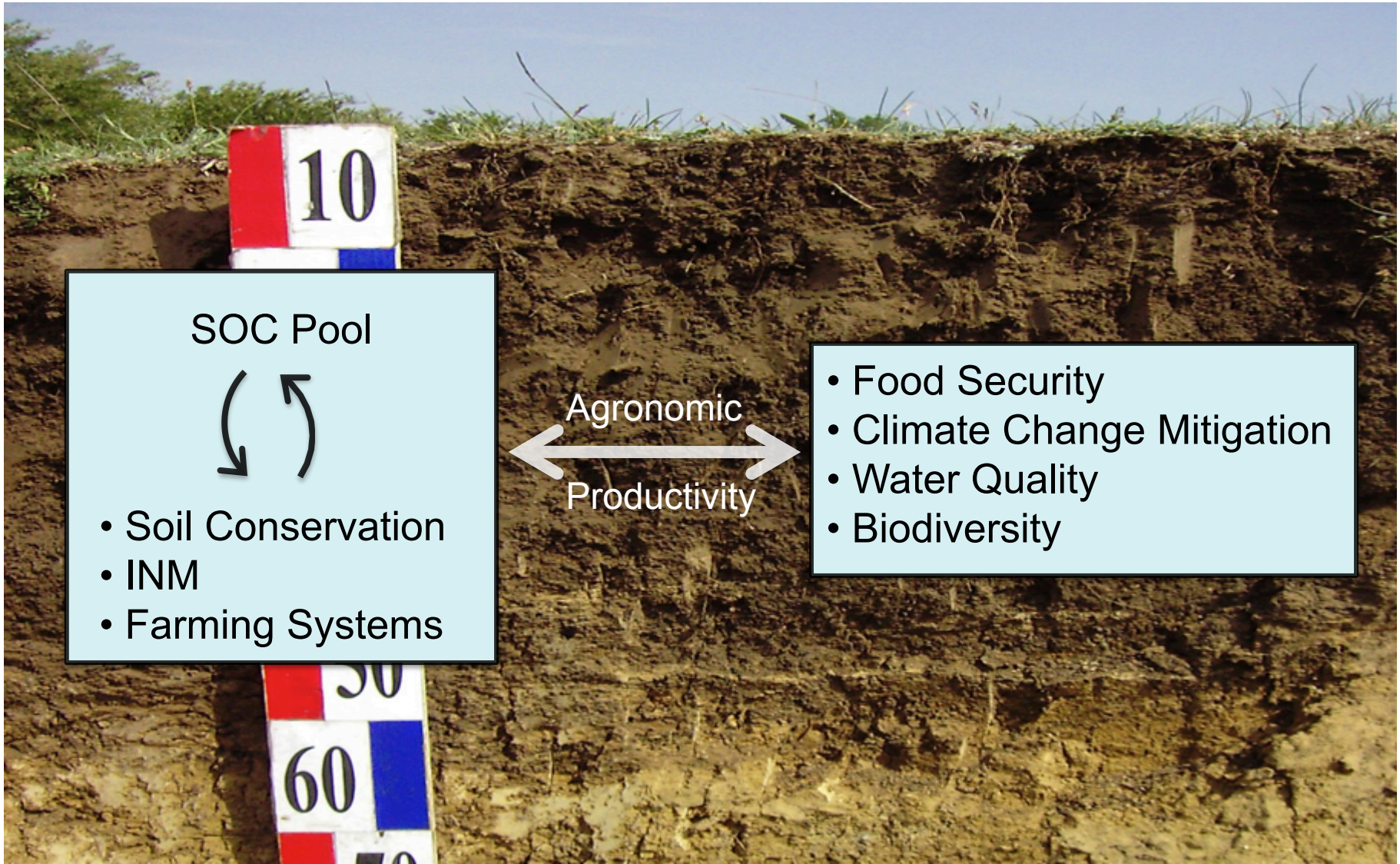
ECOSYSTEM SERVICES

Multitude of resources and benefits that are supplied by natural ecosystems

- "A framework for structuring and synthesizing biophysical understanding of ecosystem processes in terms of human well being".

…Mooney and Ehrlich (1997)

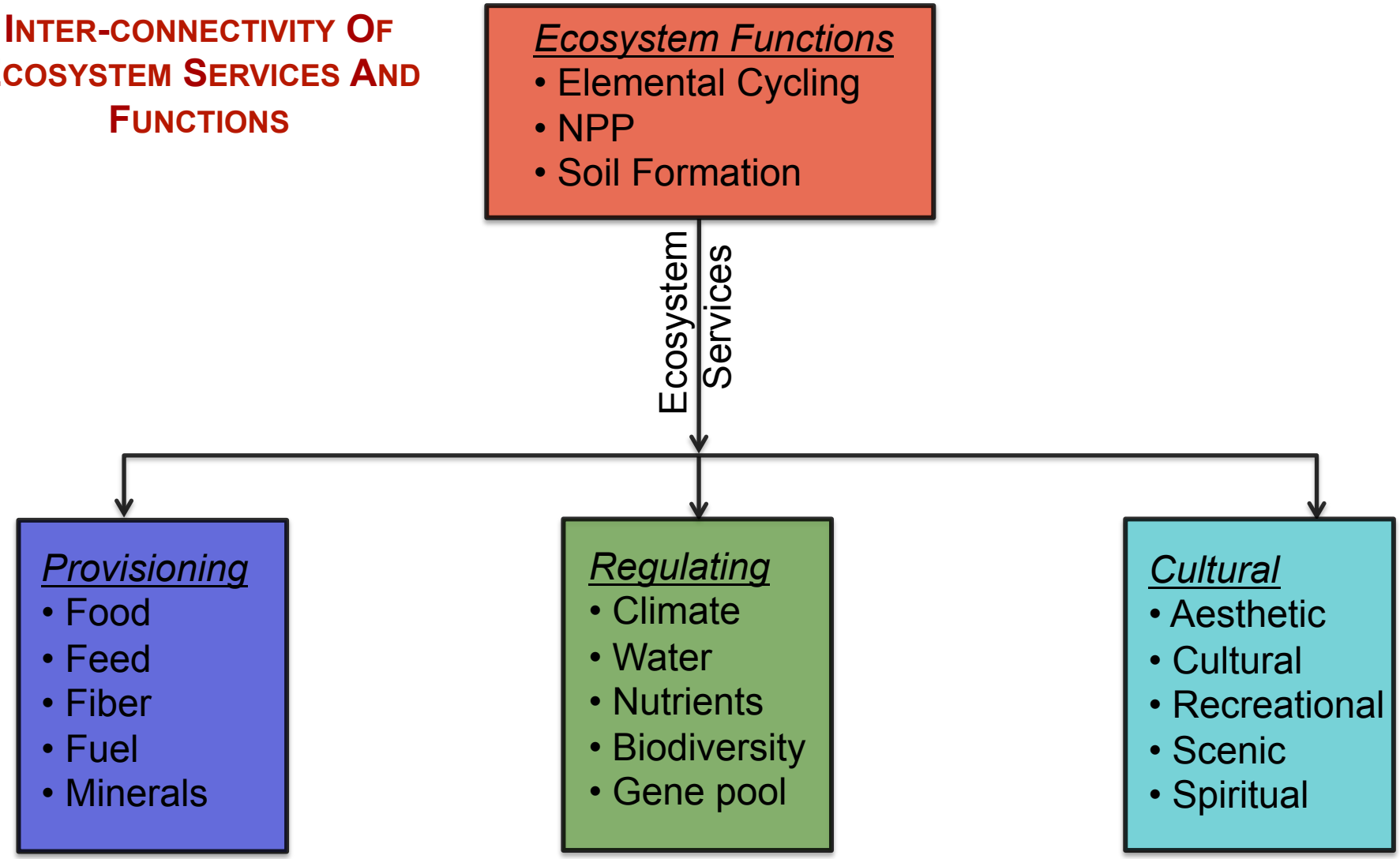
NATURAL CAPITAL VS. ECOSYSTEM SERVICES



SOILS AND ECOSYSTEM SERVICES

Soils are the basic substrate for natural ecosystems, but have not been adequately emphasized in sustainable development nor in sustainable management of natural resources.

INTER-CONNECTIVITY OF ECOSYSTEM SERVICES AND FUNCTIONS



SOME ECOSYSTEM SERVICES PROVIDED BY SOILS

1. Climate Change Moderation
2. Carbon Sequestration
3. Water Storage and Purification
4. Biodiversity
5. Food Security
6. Poverty Alleviation
7. Soil quality

1. CLIMATE CHANGE MODERATION

CLIMATE CHANGE

It is the most dangerous and interactable problem:

Dangerous : Because it encompasses many issues,

Interactable : (i) 80% of the energy demand is met from the fossil fuel,

(ii) $20 trillion of infra-structure is built around fuel,

(iii) Deforestation and land use are intricately linked with food security, water quality, and biodiversity

STRATEGY

Reduce vulnerability

Increase adaptive capacity

Can humans solve this problem?

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**

"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)

1. CARBON SEQUESTRATION

SOIL CARBON SEQUESTRATION

Refers to the process of restoring depleted soil carbon through recommended land use and soil management.

CARBON POOL IN WORLD SOILS TO 1-m DEPTH

Reservoir	Magnitude (Pg)
Soil organic C	1530
Soil Inorganic C	
(i) Carbonates	940
(ii) Bicarbonates in groundwater	1404
Total	**3874**

Monger et al. (2015)

C SEQUESTRATION AS SECONDARY CARBONATES

Rate ... 2-5 kgC/ha per yr

Total area of Arid/Semi-Arid Regions = 6150 Mha

Technical Potential of Secondary Carbonates = 0.01-0.03 PgC/yr

Monger et al. (2015)

TOTAL POTENTIAL OF SIC SEQUESTRATION

Process	Technical Potential (PgC/yr)
Secondary Carbonates	0.01-0.03
Leaching of Bicarbonates	0.20-0.36
Total	0.21-0.39

Monger et al. (2015)

GLOBAL POTENTIAL OF SOC SEQUESTRATION (Pg C/YR)

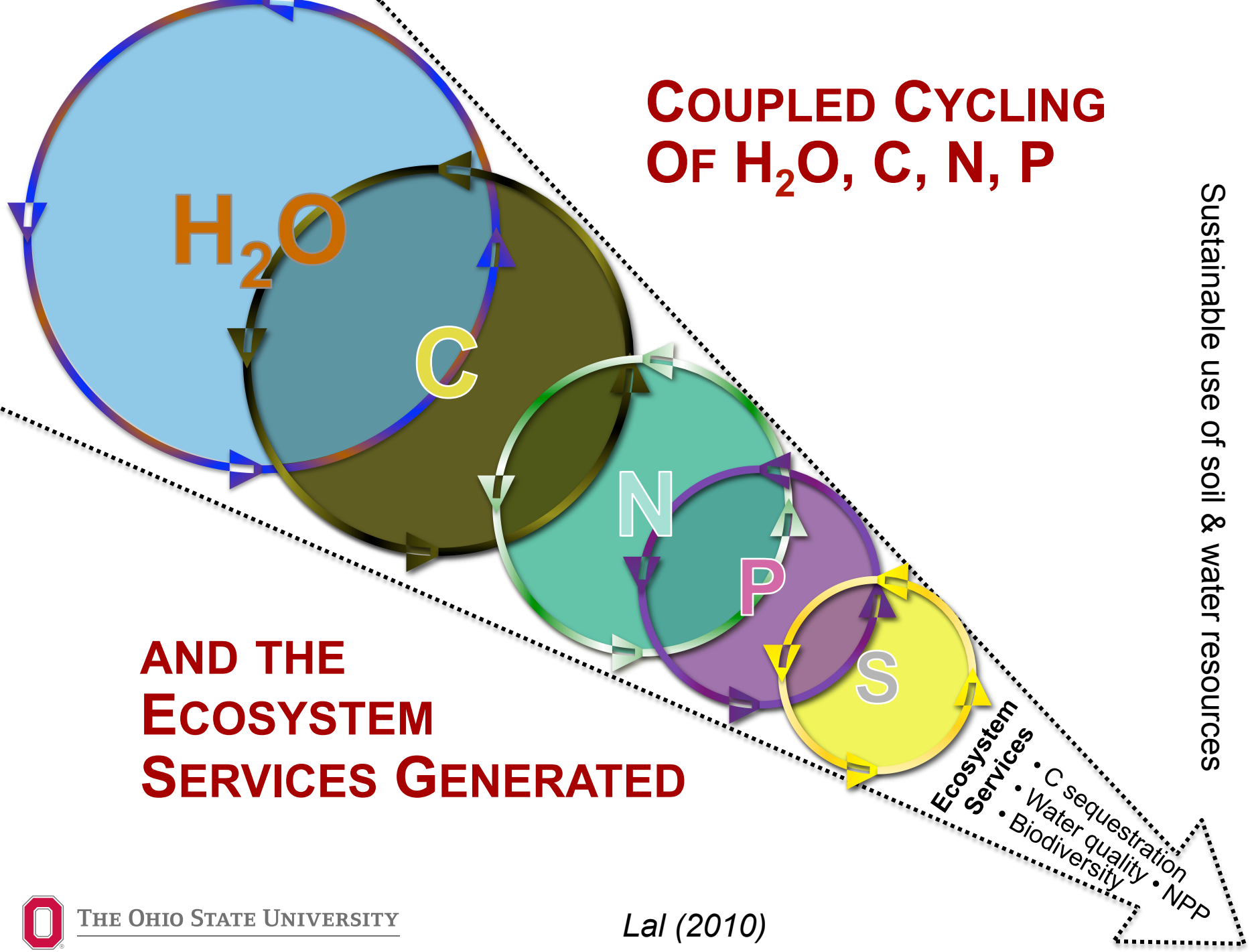
Cropland:	0.4-1.2
Grazing land:	0.3-0.5
Salt-affected soils:	0.3-0.7
Desertified soils:	0.2-0.7
Total:	**1.2-3.1**

Lal (2010)

CAPACITY OF LAND-BASED SINKS THROUGH BIOSEQUESTRATION OF C

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

Coupled Cycling Of H_2O, C, N, P



and the Ecosystem Services Generated

Lal (2010)

4 FOR 1000 : A NEW PROGRAM FOR CARBON SEQUESTRATION IN AGRICULTURE

With soil C pool of 700 Pg to 30 cm depth, 4/1000 =2.8 Pg C drawdown per year

= 1.4 ppm reduction of atmospheric carbon dioxide/yr

3. WATER STORAGE AND PURIFICATION

SOIL AND WATER

- Soil is one of the largest reservoirs of fresh water
- Water conservation in soils is crucial to sustainable management of natural resources

ALGAL BLOOM LAKE ERIE, 9TH AUGUST 2015

Photo Credit: M. Almond, 4 August 2015, Columbus Dispatch.

Columbus Dispatch, 27 August 2015

4. BIODIVERSITY

SOIL AND GENE POOL

Soil is a principal reservoir of gene pool.

Improvement of soil quality enhances biodiversity: both above and below ground.

SOIL IS FULL OF LIFE

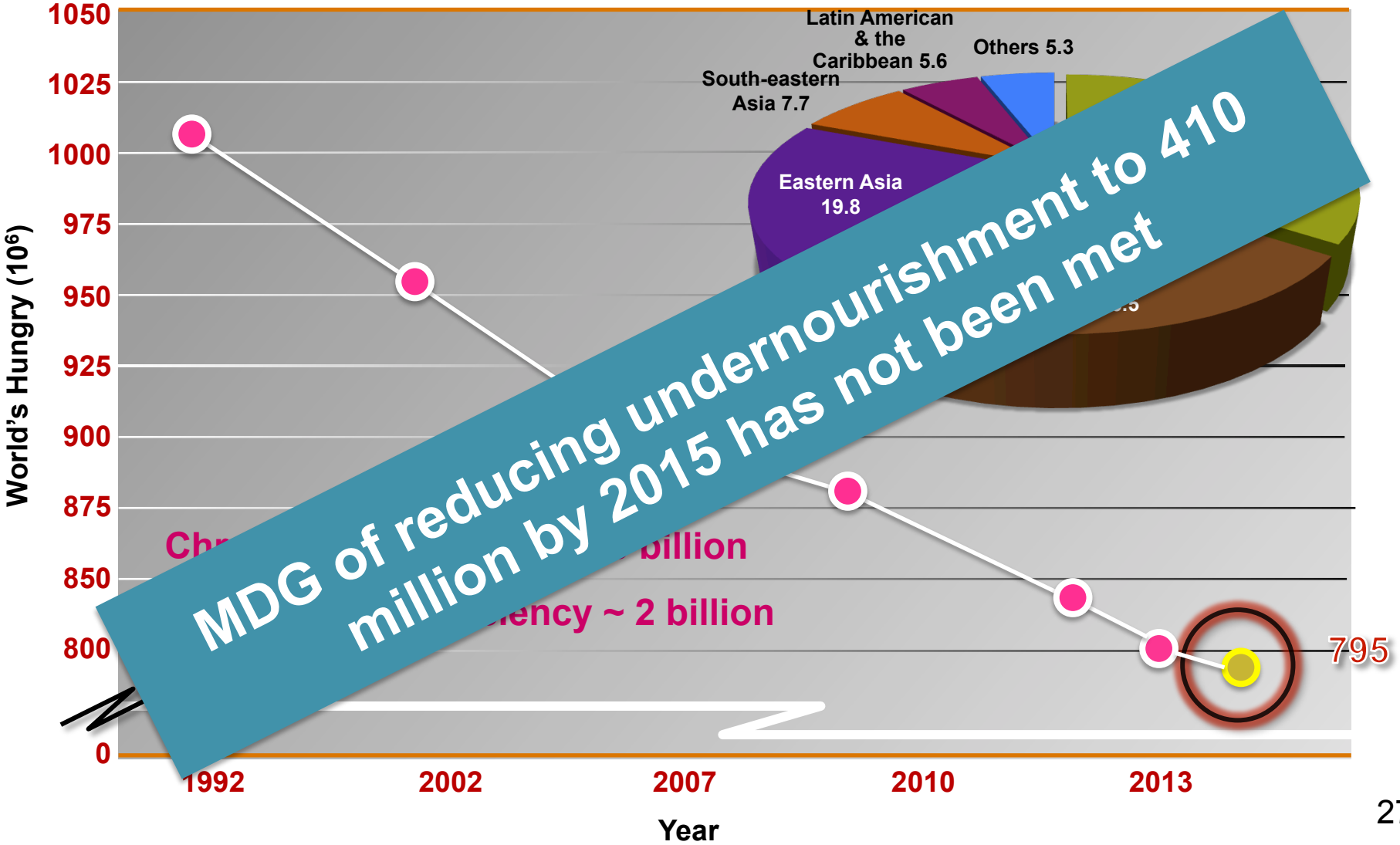
As much as 25% of all biodiversity is in soil.

Soil functions can be sustained by improving biodiversity.

5. FOOD SECURITY

GLOBAL FOOD INSECURITY

(FAO, 2015)



GLOBAL FOOD DEMAND IN 21ST CENTURY

Hunger-related death toll is 21,000/day (Chrispeds, 2002)

Global food demand would double over the period 1990-2030, and increase by 70% between 2010 and 2050

This would involve 3-4 times increase in the poorest countries

There have been severe droughts in Amazon in 2010, China in 2011, and West Africa in 2011

In Africa and Asia, plant-derived food requirements may increase by a factor of 2.5 to 7 in some countries

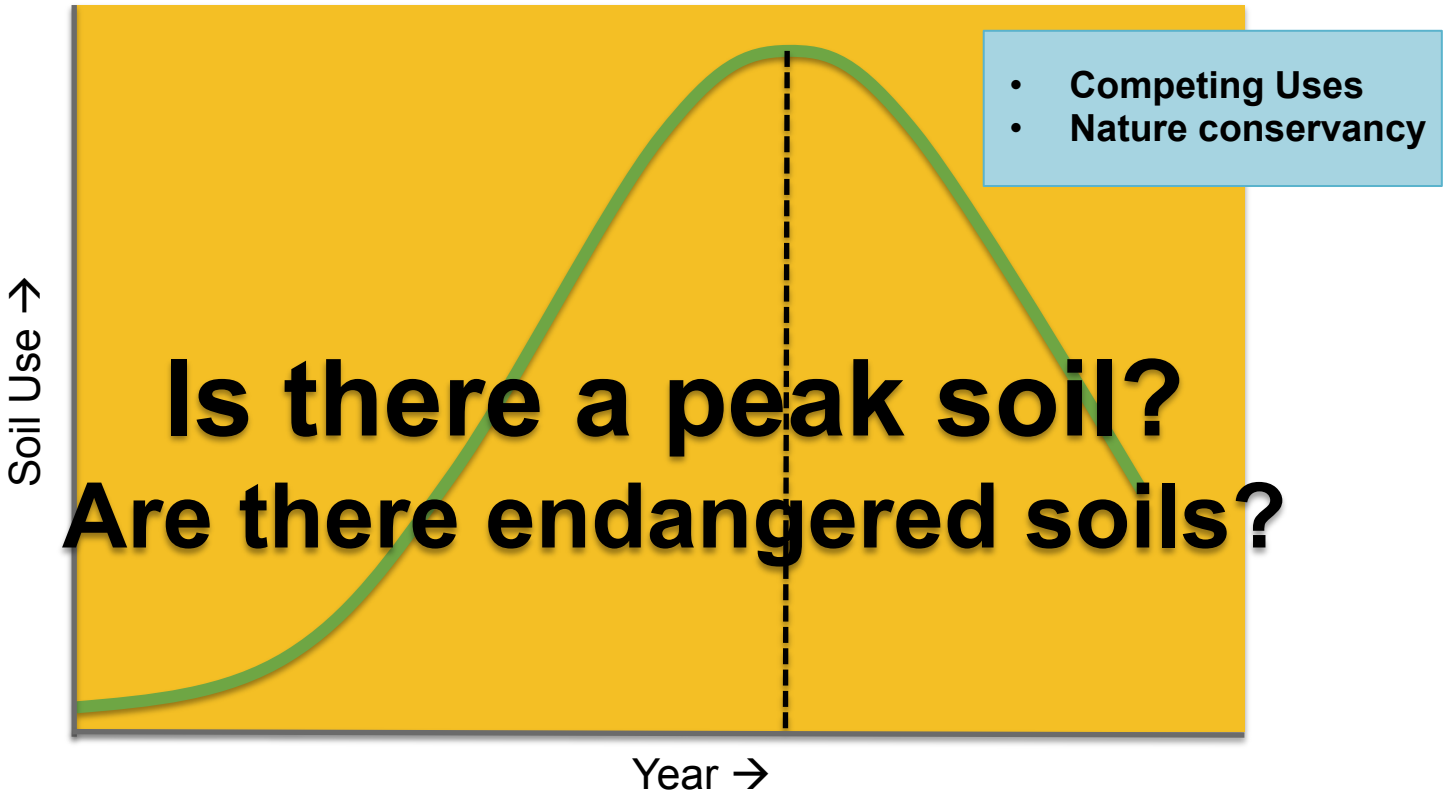
REQUIRED CEREAL YIELDS AND PRODUCTION TO MEET FUTURE DEMANDS

(WILD, 2003)

Year	Yield (Mg/ha)	Total Production (10^6M)
2005	3.27	2240
2025	3.60 (4.40)	2780 (3629)
2050	4.30 (6.00)	3255 (4553)

(with change to animal-based diet)

HUBERT CURVE



Is there a peak soil?
Are there endangered soils?

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

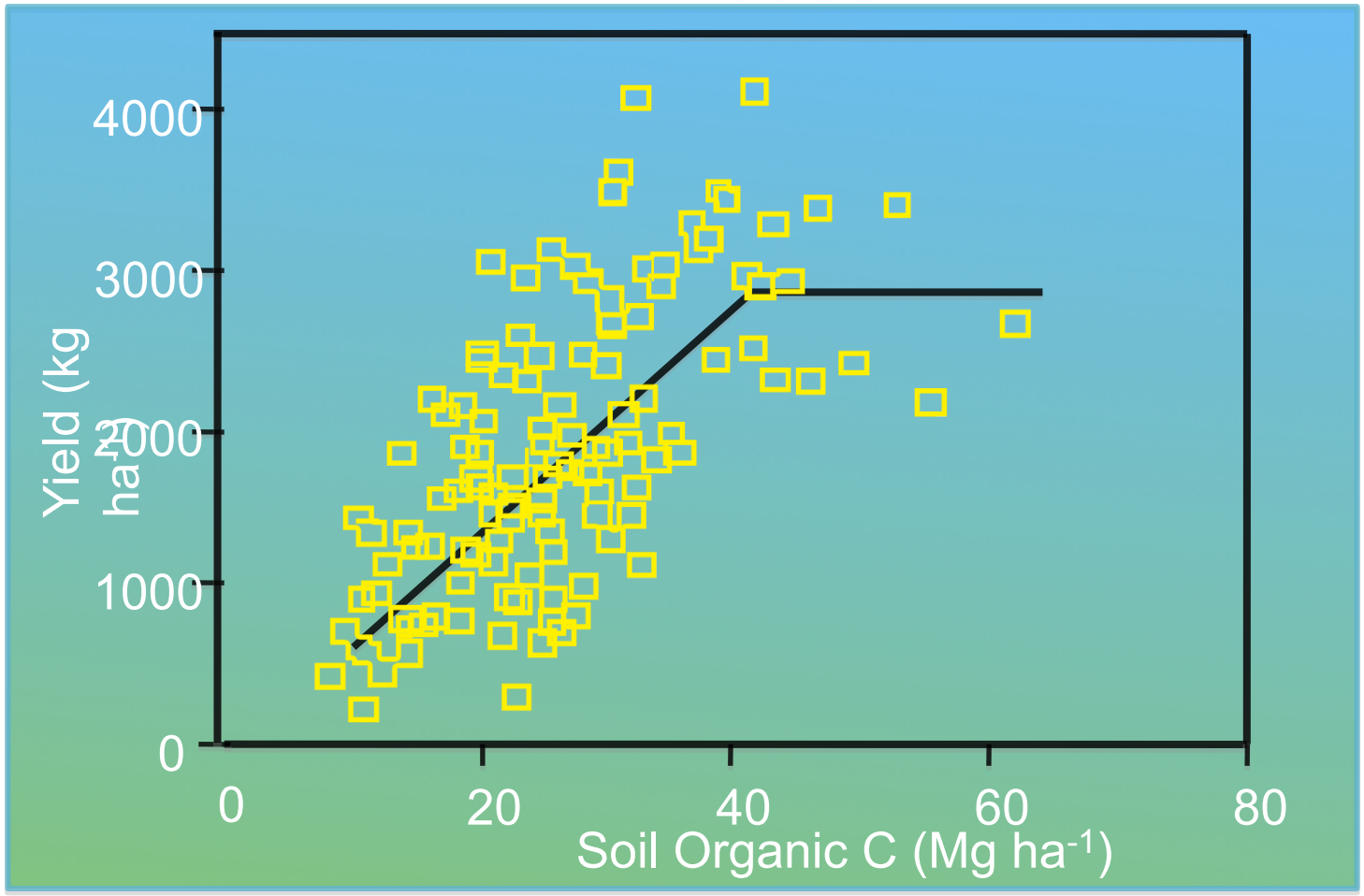
Lal (2015)

NUTRIENT USE EFFICIENCY

- Recycle and reuse nutrients(e.g., grey water)
- Adopt strategies of INM
- Enhance use efficiency of nutrients in agro-ecosystems
- Establish threshold level of SOC for soil quality

CRITICAL LEVEL OF SOC FOR WHEAT YIELD

(Diaz-Zorita et al., 2002)



FOOD PRODUCTION IN LDCS BY INCREASING SOC POOL BY 1 T/Ha per Yr

Crop	Area (Mha)	Production Increase (10^6 Mg yr^{-1})
Cereals	430	21.8 - 36.3
Legumes	68	2.0 - 3.2
Tubers	34	6.6 - 11.3
Total	532	30.4 - 50.8

6. POVERTY ALLEVIATION

PES'S AND ECONOMIC DEVELOPMENT

- Payments for ecosystems services is an important strategy to promote adoption of BMPs by the resource-poor farmer

- Land managers must be rewarded for services e.g.:

  - C sequestration
  - Water quality
  - Biodiversity
  - Reducing NPSP

SOCIETAL & MARKET VALUE OF SOC

- Cost of Residue + Nutrients: **$120/ Mg C**
- Cost of Nutrients Only : **$102/ Mg C**

- **Lal(2014)**

PAYMENTS FOR SOC SEQUESTRATION

With average C sequestration rate of 300 kg/ha per yr, payments are : $40/ha per yr

Lal(2014)

7. SOIL QUALITY

DISEASE-SUPPRESSIVE SOILS

1. Organic Amendments : Animal and green manure, compost, peat (partially decomposed)

2. Manage Beneficial Rhizosphere Micro-Organisms : Introduction of a small amount of disease-suppressive soil

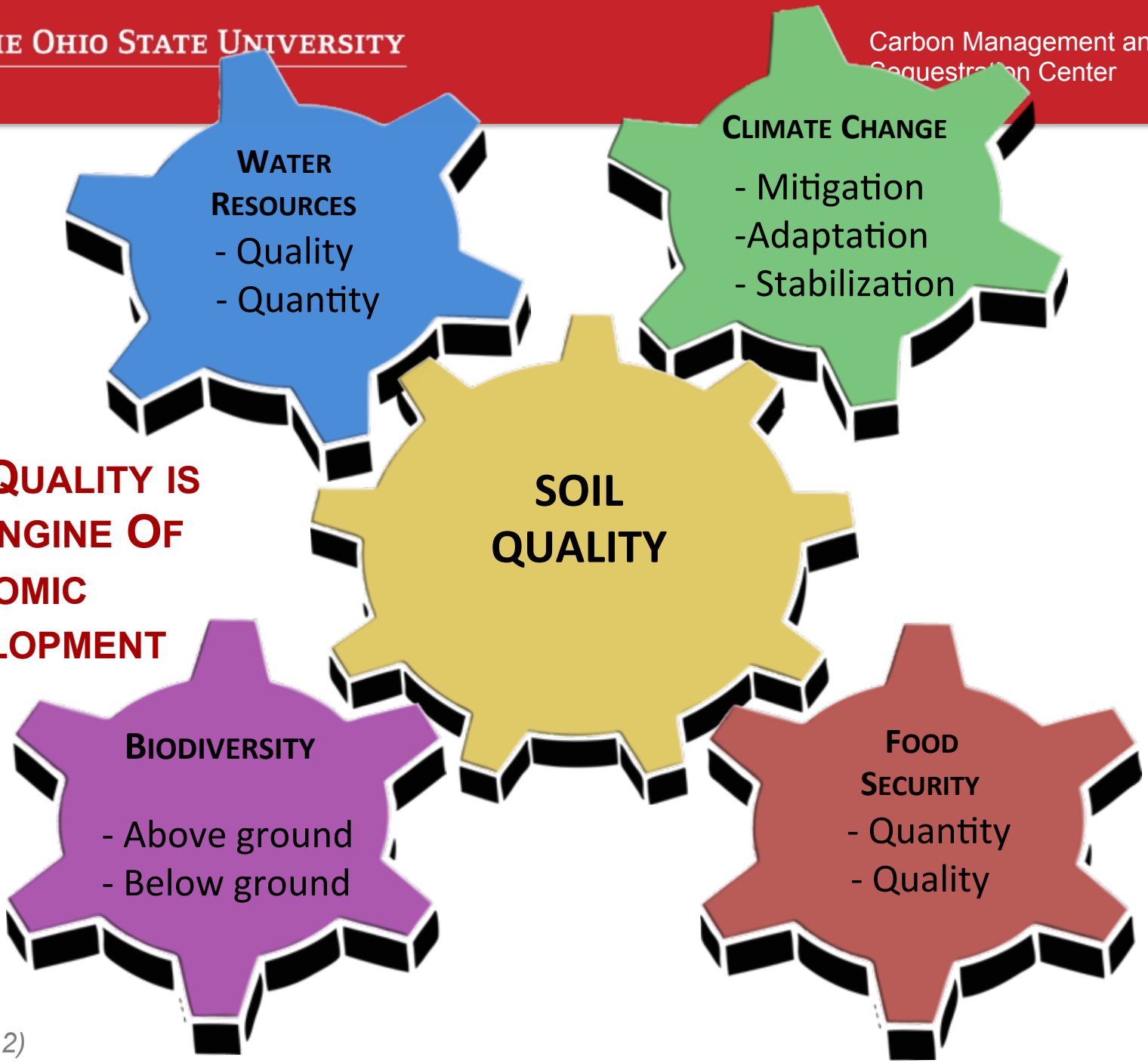
CHARACTERISTICS OF DISEASE-SUPPRESSIVE SOILS

Soils in which disease development is minimal even in the presence of a virulent pathogen and a susceptible host.

(i.) General Suppression : Related to total amount of microbial activity

(ii.) Specific Suppression : Through a specific micro-organism or group of micro-organisms

SOIL QUALITY IS THE ENGINE OF ECONOMIC DEVELOPMENT



Lal (2012)

INTERNATIONAL YEAR OF SOILS 2015

The 68th UN General Assembly (A/RES/68/232) declared 2015 the "International Year of Soils"

The Objectives of IYS are:

- To create full awareness of civil society and decision makers about the fundamental roles of soils for human's life
- To advance full recognition of the prominent contributions of soils to food security, climate change, adaptation and mitigation, essential ecosystem services, poverty alleviation and sustainable development.
- To promote effective policies and actions for the sustainable management and protection of soil resources.

SOIL: THE GLOBAL ICON

Soil is Life and Life is Soil

Lal (2014)

HANDOUT / Reuters

www.seeturtles.org

www.worldwildlife.org

en.wikipedia.org