THE OHIO STATE UNIVERSITY

Soil and Sustainability

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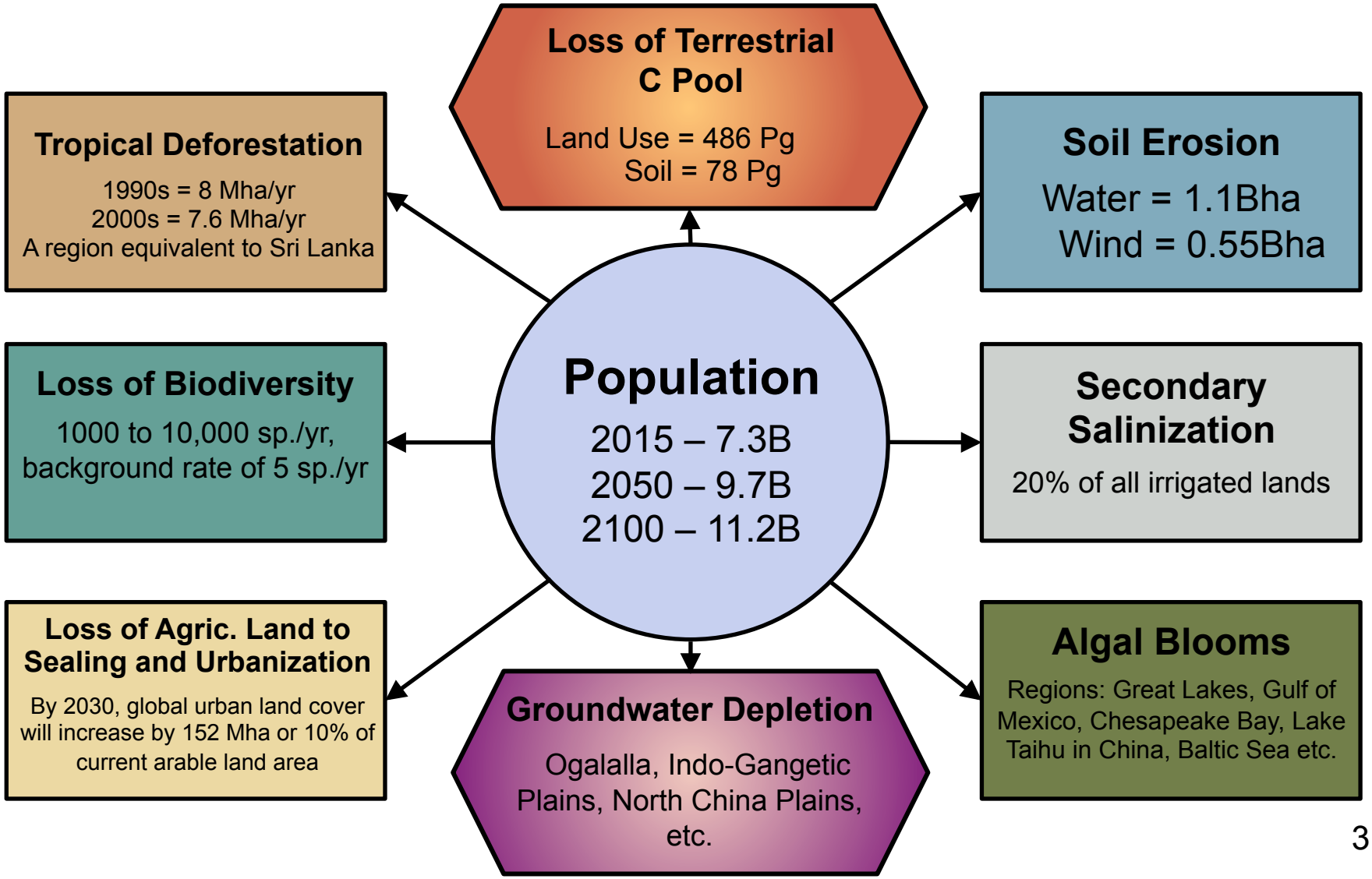
INTERNATIONAL YEAR OF SOILS 2015

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

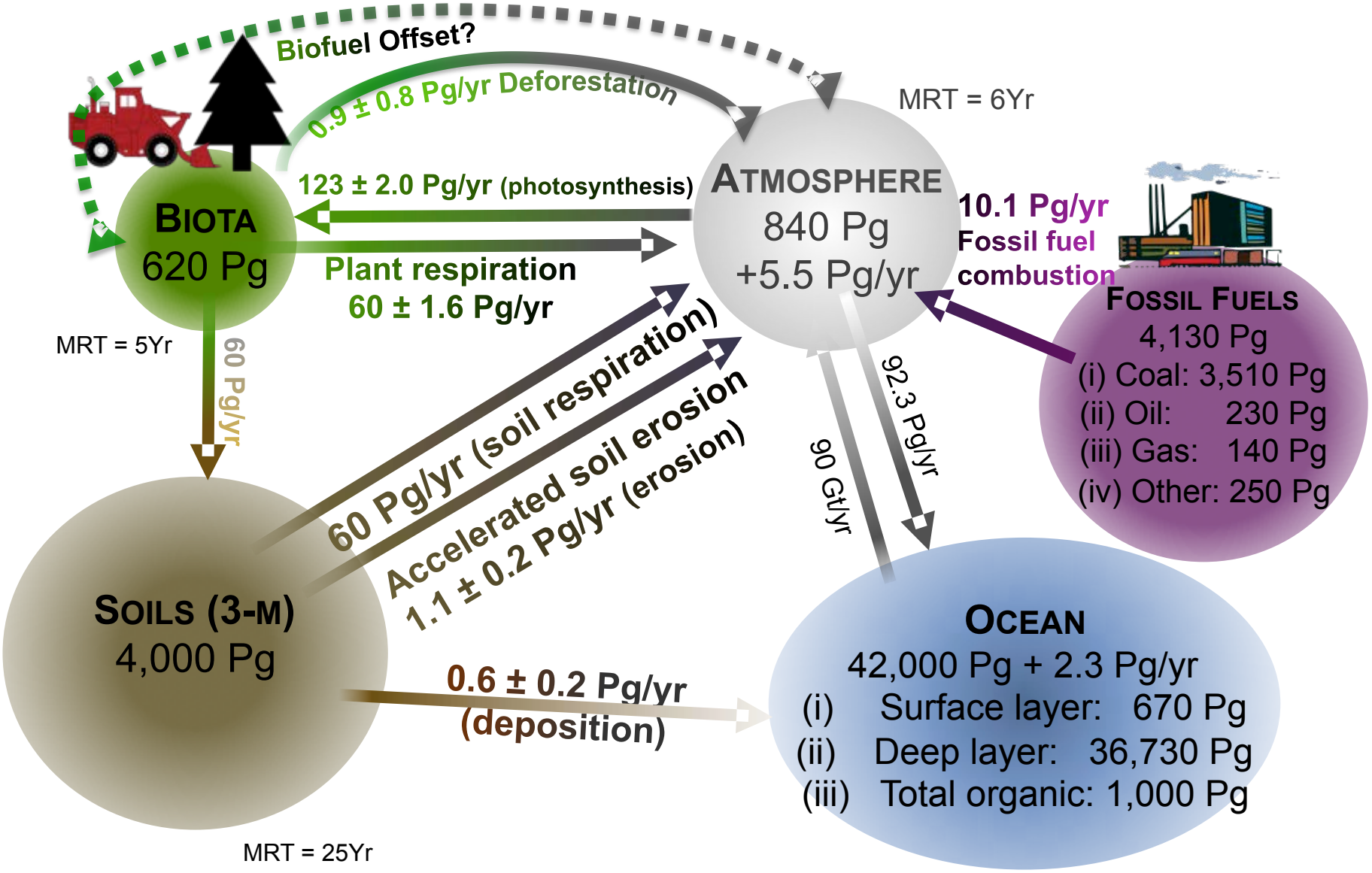
The Objectives of IYS are:

- 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.

INDICATORS OF HUMAN-ECOSYSTEM INTERACTIONS



THE SHORT-TERM GLOBAL CARBON CYCLE



Mean Residence Time (MRT) = 400Yr

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 7.2 billion and projected to be 10 billion, have to deal with it and increasingly so in the future
- Yet, there is no consensus as in Rio +20

GLOBAL SOIL ORGANIC CARBON POOL 0-30cm DEPTH

996)

0.

OFF-SETTING OIL BY SOIL C SEQUESTRATION

CARBON PIE

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

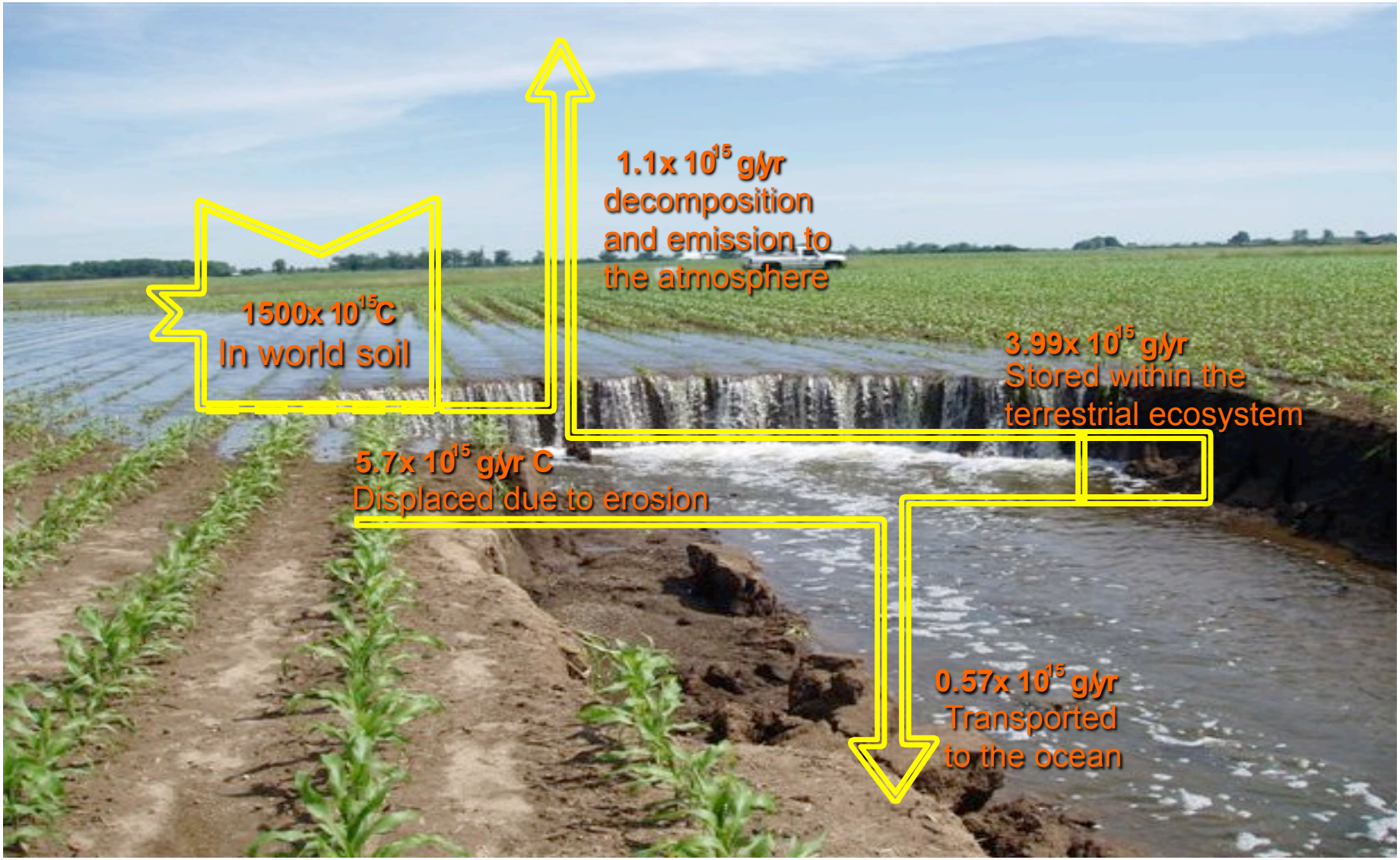
How do we divide the pie among nations?

320 Gt

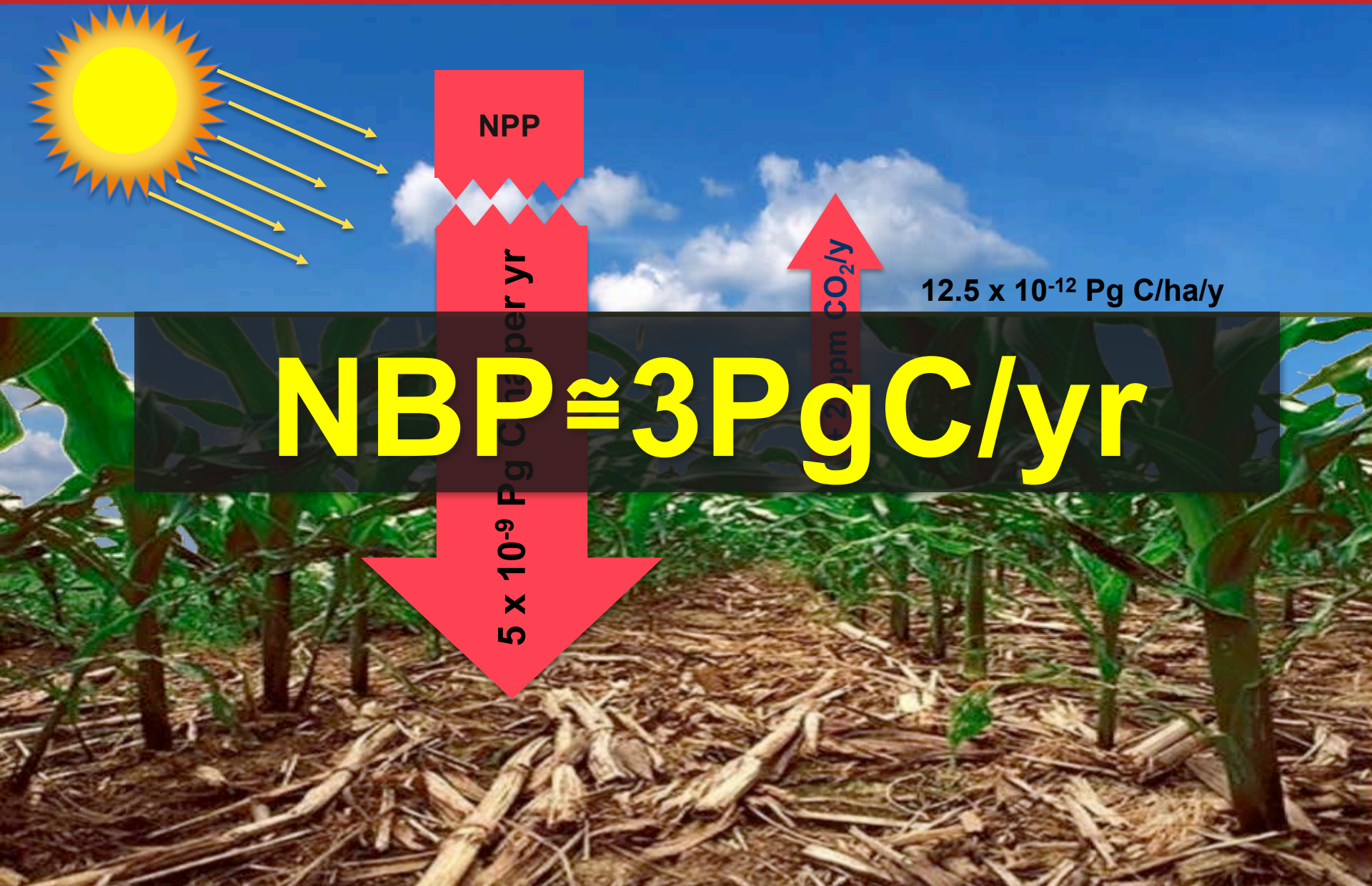
BIOFUELS?

(1 Billion ton cellulosic feedstock)

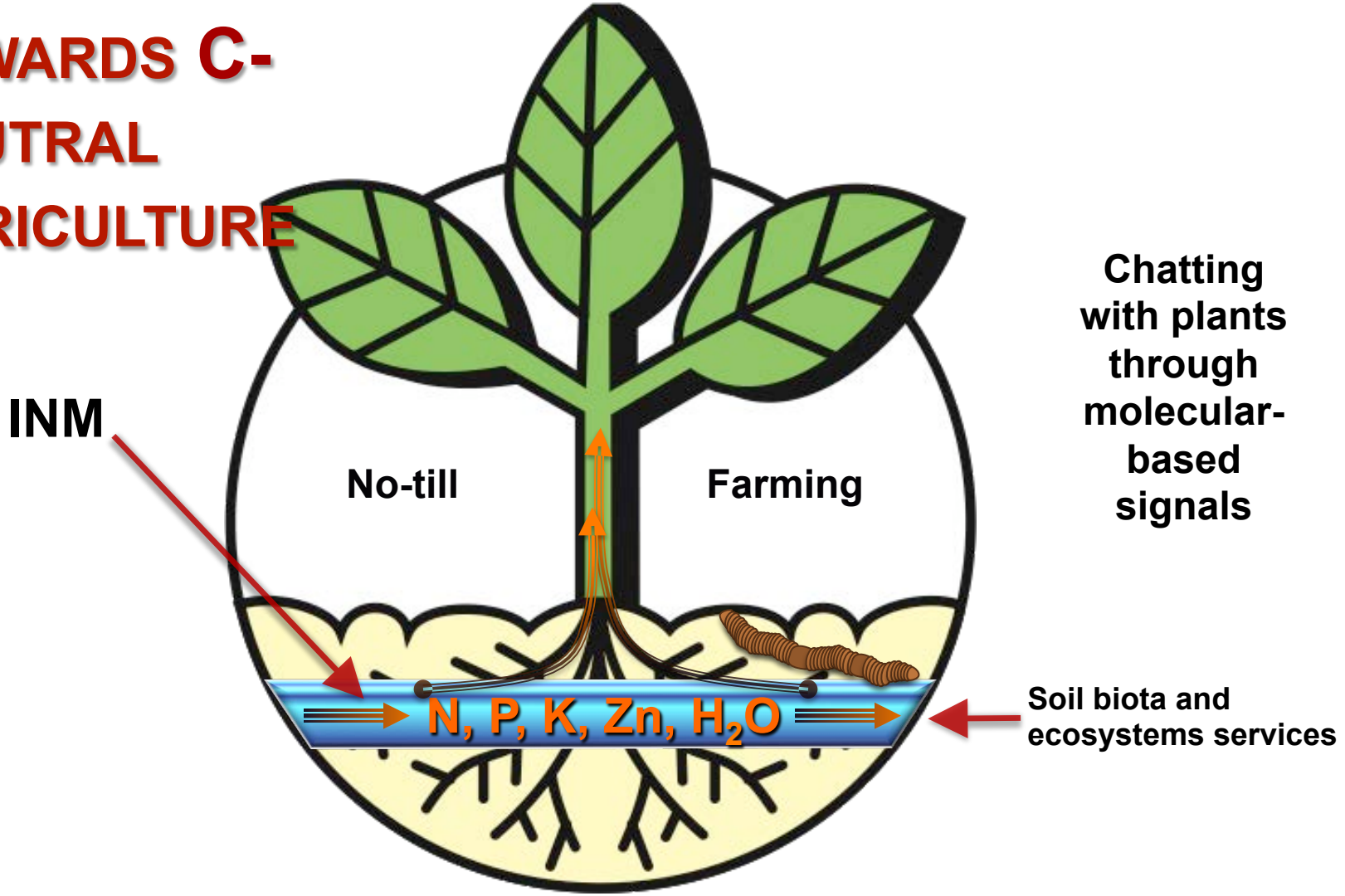
GLOBAL SOIL EROSION & DYNAMICS OF SOIL ORGANIC CARBON



The NPP of a Corn Field is 400 Times the Annual Increase in Atmospheric C pool



TOWARDS C-NEUTRAL AGRICULTURE



Chatting with plants through molecular-based signals

Delivering nutrients and water directly to plant's roots

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

SOCIETAL & MARKET VALUE OF SOC

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

GLOBAL 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

Lal (2010)

TOTAL POTENTIAL OF SIC SEQUESTRATION

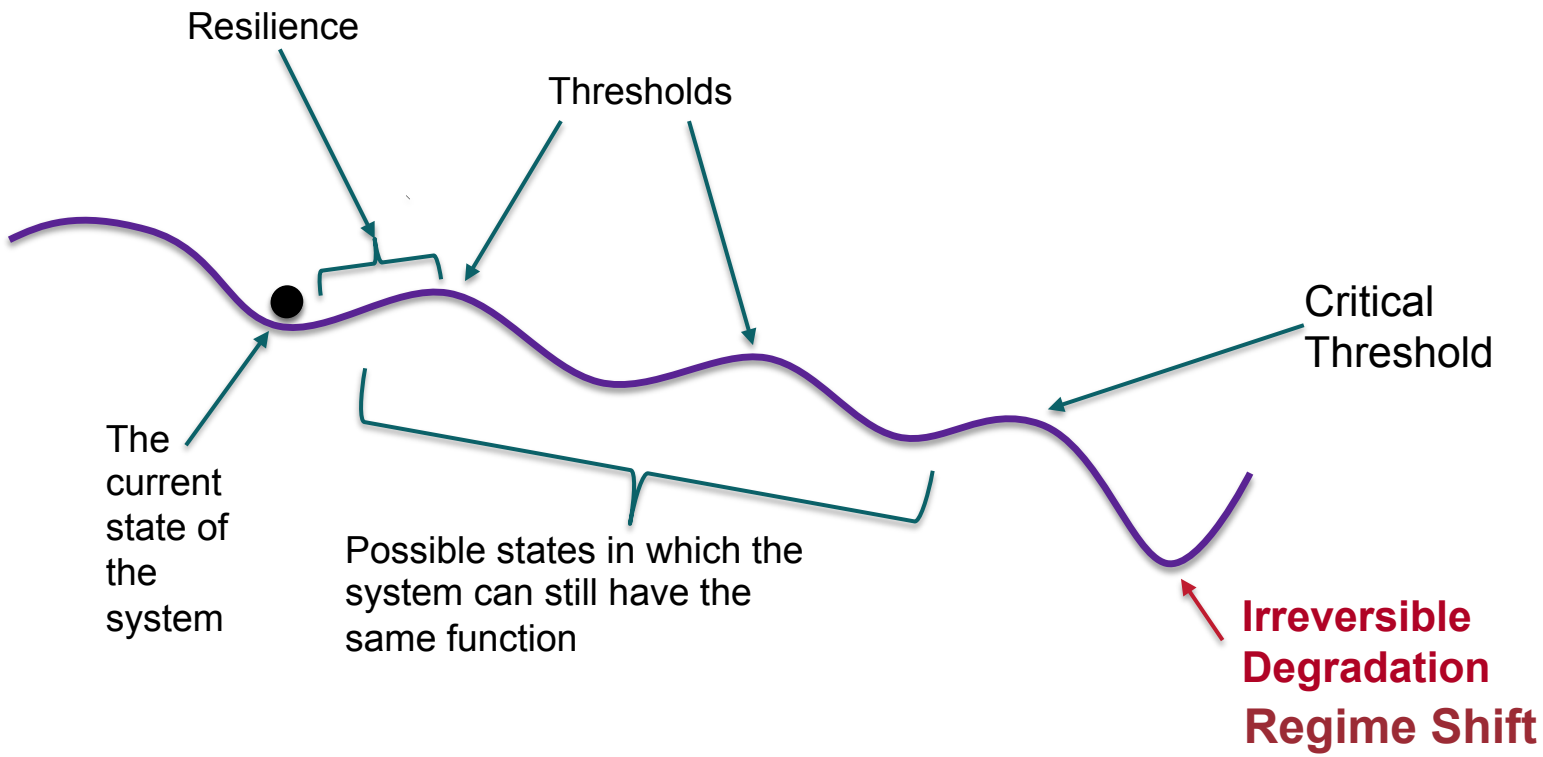
Process	Technical Potential (PgC/yr)
Secondary Carbonates	0.01-0.03
Leaching of Bicarbonates	0.20-0.36
Total	0.21-0.39

SUSTAINABILITY

- A state in which demands placed on the environment can be met without reducing its capacity to allow all people to live well, now and in the future
- **Four pillars of sustainability**
  1. Environmental
  2. Economic
  3. Social
  4. Institutional
- Thus, "sustainability" is integration or balancing of environmental, social , institutional and economic issues.
- "Sustainable Development" is "making people better off in an ethically-sound way"… "stewardship."

Resilience of Soil-Ecological Systems

It has multiple regimes (stable states) which are separated by thresholds



SOIL QUALITY VS SOIL HEALTH

- The term ***soil quality*** is not synonymous with ***soil health***, and they should not be used interchangeably.

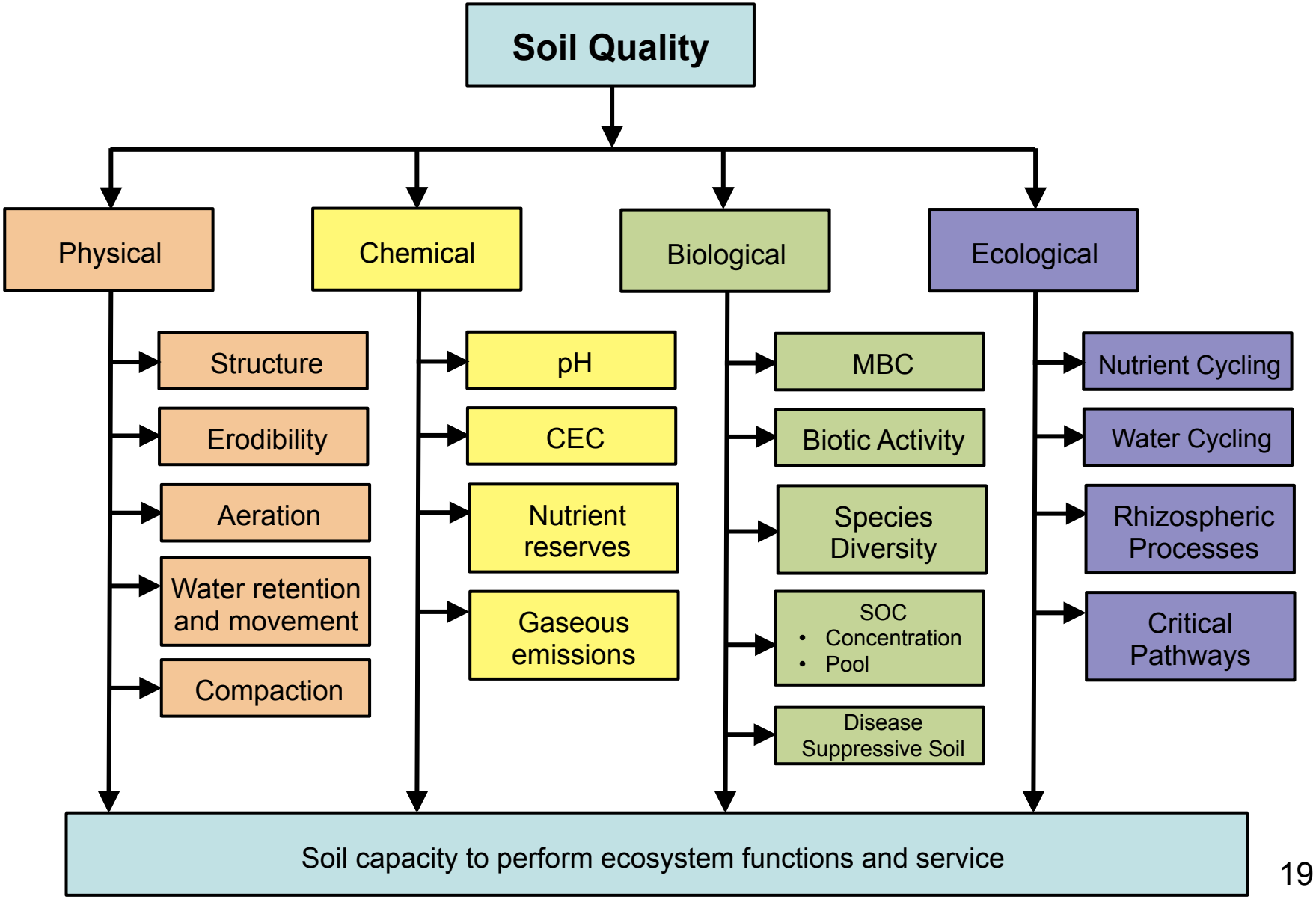
- Soil quality is related to soil functions or what it does, whereas soil health presents the soil as a finite and dynamic living resource. Soil health is directly related to plant health.

MOST IMPORTANT THINGS CANNOT BE MEASURED BUT MUST BE MANAGED (Edward Demmings)

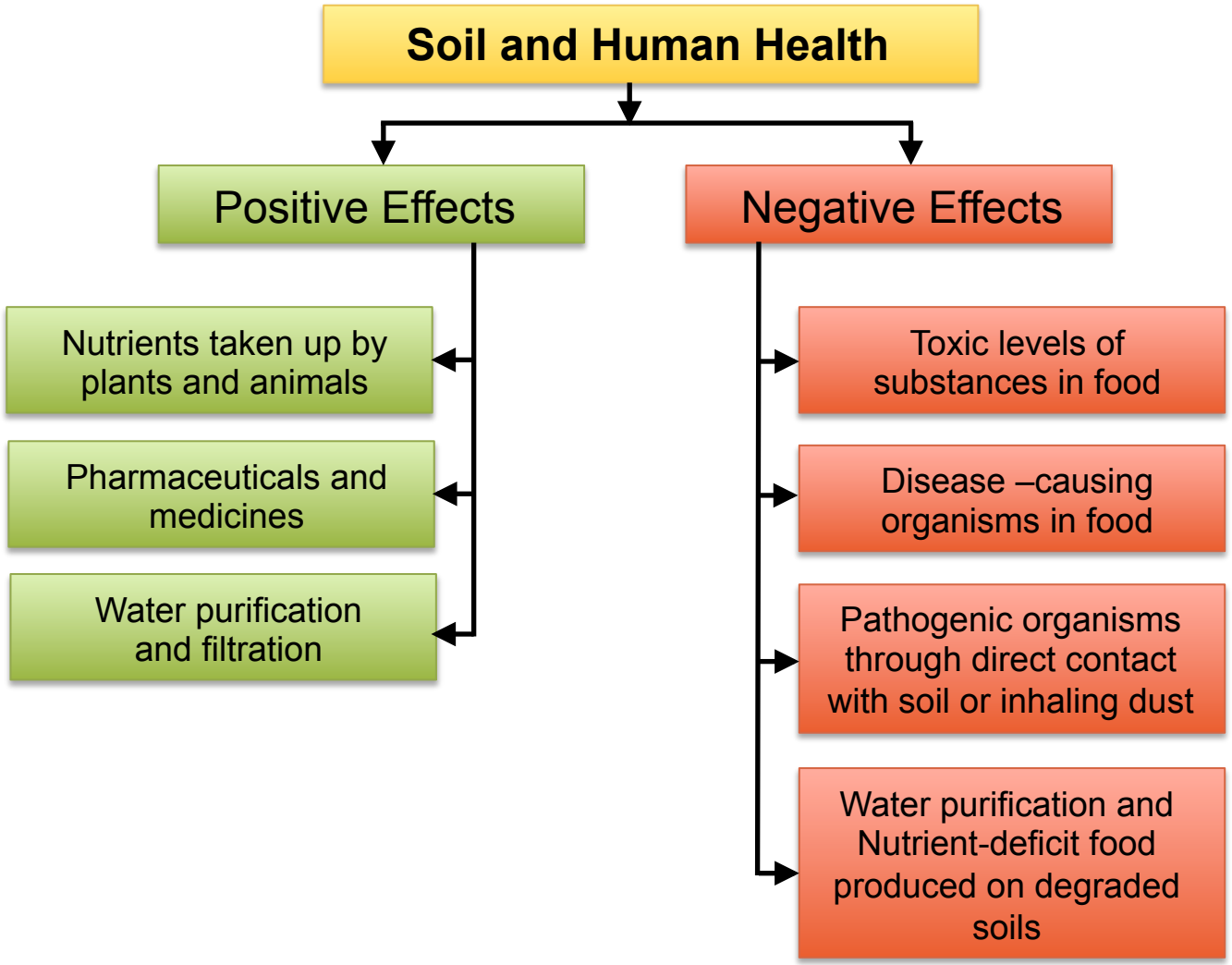
Therefore, question is not "What is there in the soil that can be measured, but what it does which must be managed "?

&

What it does is "soil quality".


Soil Quality
Physical
Chemical
Biological
Ecological
Structure
Erodibility
Aeration
Water retention and movement
Compaction
pH
CEC
Nutrient reserves
Gaseous emissions
MBC
Biotic Activity
Species Diversity
SOC
• Concentration
• Pool
Disease Suppressive Soil
Nutrient Cycling
Water Cycling
Rhizospheric Processes
Critical Pathways
Soil capacity to perform ecosystem functions and service

SOIL QUALITY AND HUMAN HEALTH



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.

ESSENTIAL ELEMENTS IN HUMAN BODY

Major Elements:(i) H, O, C, and N (99% atoms in the body)
(ii) Na, P, Ca, Mg, S, and Cl (0.9% of atoms in the body)

Minor/ Trace Elements: Li, V, Ca, Mn, Fe, Co, Ni, Cu, Zn, V, Mo, Si, Se, F, I, As, Br and Sn

Combs (2005), Brevik (2011)

ELEMENTAL DEFICIENCY IN SOIL AND HUMAN HEALTH

Element	Symptoms/Disease Caused by Deficiency	Population Affected (10^{9})
Fe	Anemia: exacerbated by soil-borne infections (e.g., hookworms)	2
I	Goitre: with neuro and psychological disorders	-
Se	Keshan (a heart disease called osteoarthrosis), cancer, stunted growth, immune system, reproductive problems	-
Zn	Stunted growth, anorexia, skin lesions, diarrhea, impaired immune and cognitive functions (Calcareous leached and acidic soils	-

Combs (2005), Brevik (2011)

ELEMENTAL TOXICITY IN SOIL AND HUMAN HEALTH

Element	Symptoms/Disease Caused by Toxicity	Country/Region
Cd	Itai-Itai (weak brittle bones), pain in legs and spine, anemia, kidney failure	Japan
Se	Brittle hair and nails, hair loss, tooth decay, skin rash, weakness, lack of mental alertness, diarrhea	-

Brevik (2011)

DIGGING UP ANTIBIOTICS FROM SOIL

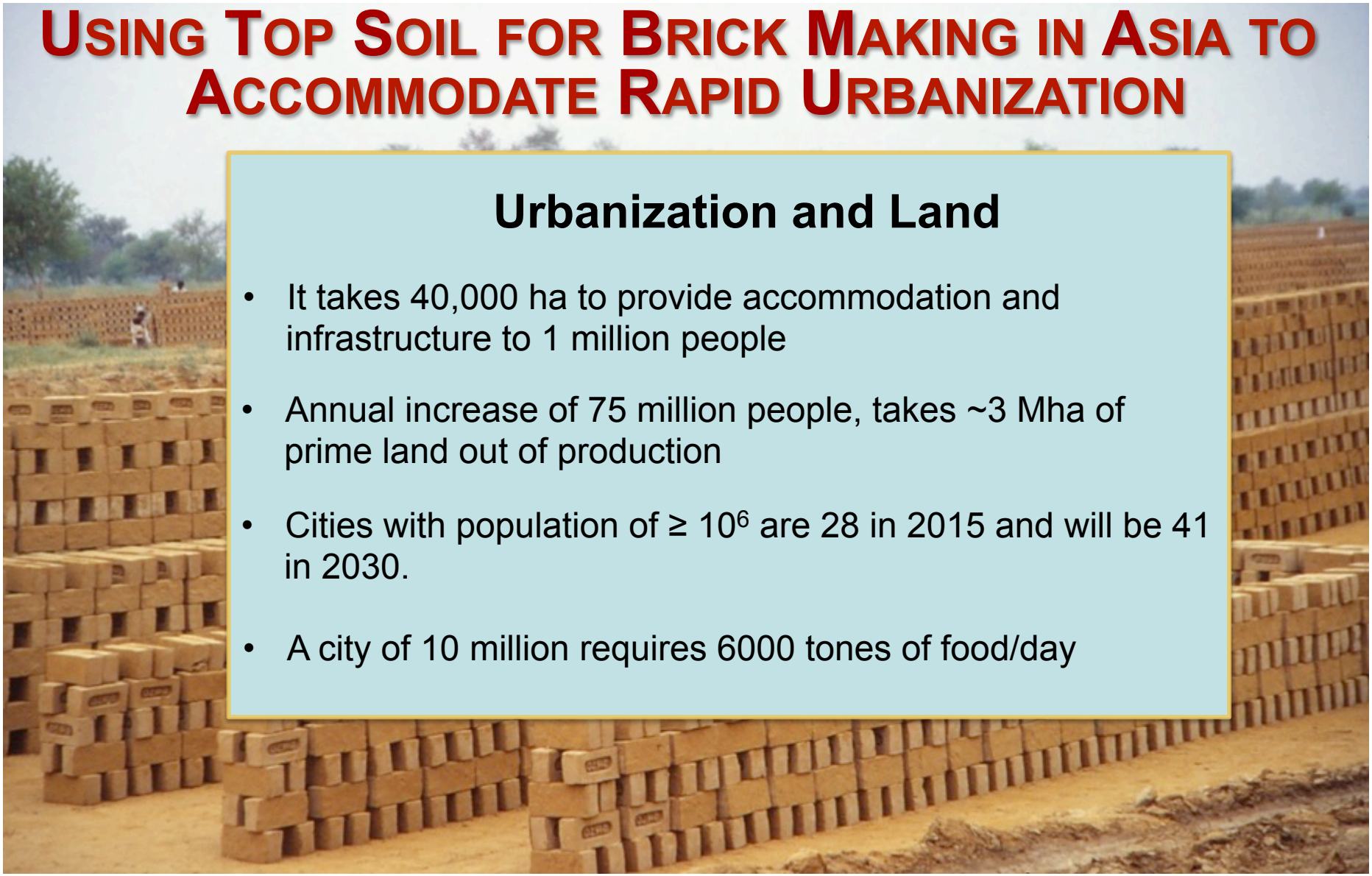
- Most antibiotic are produced by screening soil microorganisms.
- Penicillin came from *Penicilliium*, Streptomycin from *Streptomyces*, and Vanomycin from *Amycolatopsis orientalis*.
- Uncultured bacteria make up ~99% or all species in external environments, and are an untapped sources of antibiotics (Lewis, 2015. Nature)
- An antibiotic discovered from soil in Maine can kill *Mycibaterium tuberculosis* (Ling et al., 2015. Nature)
- A new antibiotic "Teixbactin" from soil can kill the bacteria that cause pneumonia, staph, and blood infections (Fink, 2015. Nature)
- Almost 50% of Actinomycetes isolated from soil are capable of synthesizing antibiotics. There are a lost of unanticipated surprises still lurking in soil

DISEASE-SUPPRESSIVE SOILS

These are soils in which disease severity or incidence remains low, in spite of the presence of a pathogen, a susceptible host plant, and climatic conditions favorable for disease development.

Baker and Cook (1974)

USING TOP SOIL FOR BRICK MAKING IN ASIA TO ACCOMMODATE RAPID URBANIZATION



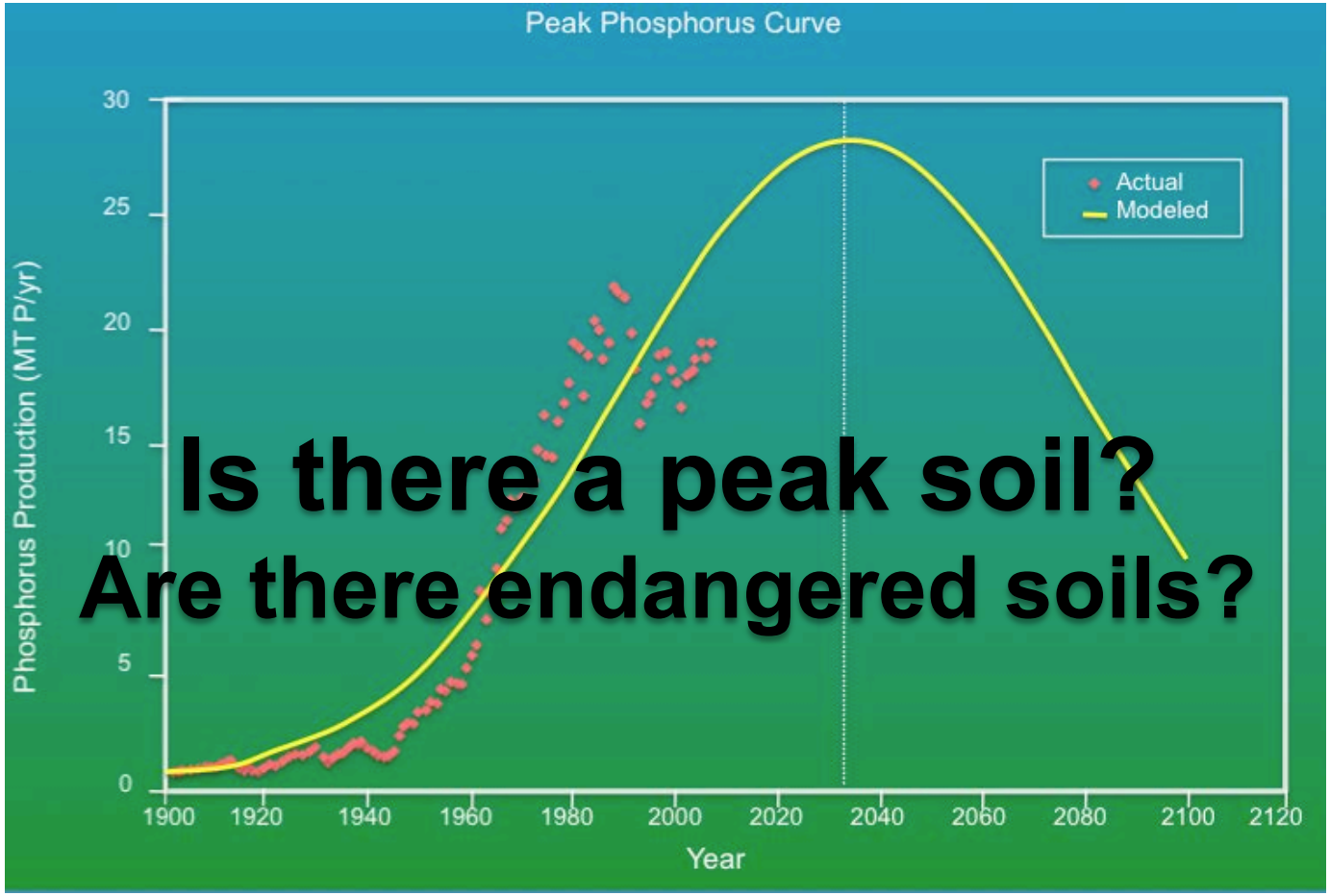
Urbanization and Land

- It takes 40,000 ha to provide accommodation and infrastructure to 1 million people
- Annual increase of 75 million people, takes ~3 Mha of prime land out of production
- Cities with population of $\geq 10^6$ are 28 in 2015 and will be 41 in 2030.
- A city of 10 million requires 6000 tones of food/day

POPULATION OF SOME MEGA CITIES

Mega City	Population (10^6)
Tokyo	38
Shanghai	23
Mexico	21
Mumbai	21
Sao Paulo	21
Osaka	20

HUBERT CURVE



- **Five countries (Morocco, China, SA, USA and Jordan) control 90% of the P reserves**
- **High P causes anoxia in coastal ecosystems**

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

SKY FARMING OR VERTICAL FARMING

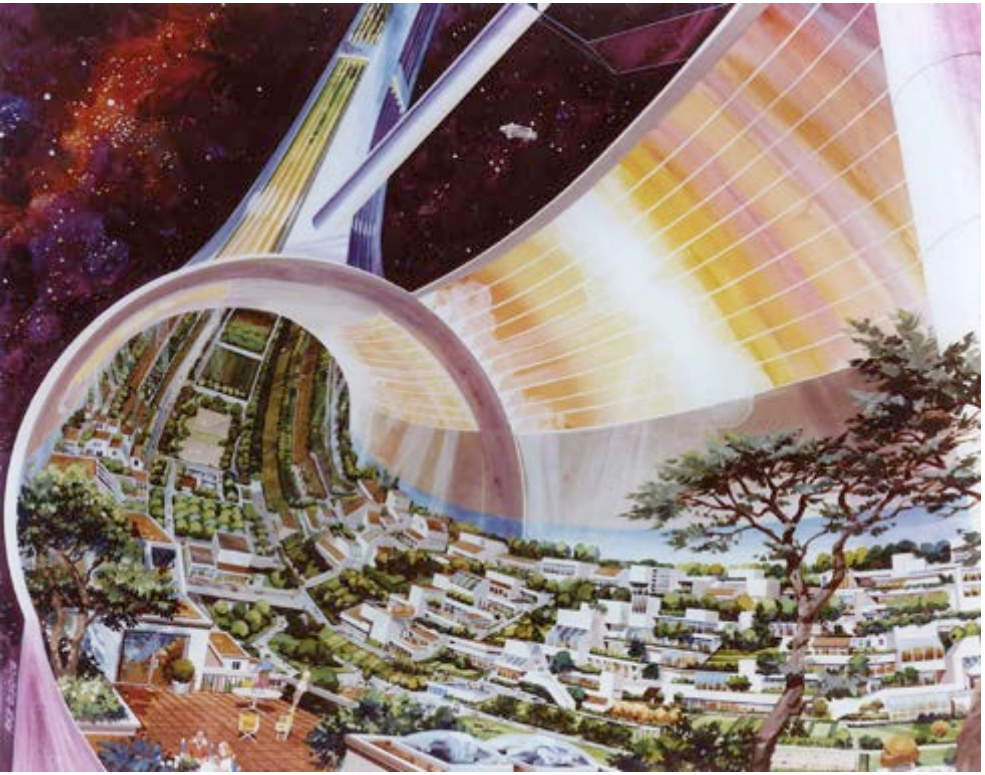
- Growing crops in a totally transparent building
- Capturing passive energy (wind, solar, geo, tidal)
- Recovering energy from inedible parts of crops to create zero energy building
- Returning land to perform ecosystem functions and services (nature conservancy)
- Reducing the ecological footprint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

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

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)

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.

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)

SOIL: THE ESSENCE OF LIFE

"Hello there folks. Do you know who
geomembrane of the Earth. I am yo
your mediator of energy, water
am your sustainer of pr
elements, and the ha
supports you, t
you will re

ces of
ndation that
dust from which

- Soil matters
- It is the answer to important global issues
- Food production must be soil-centric
- Soil management is essential to saving energy

Richard Arnold (2005)
Senior Soil Scientist

SOIL: THE GLOBAL ICON

Soil is Life and Life is Soil

Lal (2014)