Eco-intensification of Agro –ecosystems, For Food Security & Mitigation of Climate Change

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Impressive Agronomic Production Since 1960s

The rapid increase in agricultural production since the 1960s has been caused by massive inputs of fertilizers ,pesticides, energy use in plowing and other farm operations, irrigation of about 350 M ha of land, and expansion of agriculture to about 5 G ha of land area.

This has led to a strong interaction between human and nature as is evidenced by numerous indicators.

DEGRADED LAND

(BAI et al., 2008)

Category	Quantity
Degrading Area	3.5 Gha
Territory	23.54 (%)

GLOBAL SOIL DEGRADATION OTHER THAN EROSION (Gha)

- **Salinization : 0.85 (FAO, 2005)**
- **SOC Loss :25-75% (Lal,2004)**

ANTHROPOGENIC EMISSIONS (Gt) BY THE CARBON CIVILIZATION (LE QUERE ET AL.2019;LAL,2018)

I. Land use

(i) Prehistoric : 320
(ii) 1750-2017 : 235
(iii) SOC loss : 135

II. Fossil Fuel combustion

(i) 1750-2017 : 430

III. Cumulative Emissions 1750-2018

(i) 625 Gt : 75% FF, 25% LUC

These emissions have and will affect the ecosystems from which we derive food, feed, fiber, fuel and shelter.

The Need for a Paradigm Shift

- There is a need for a paradigm shift in managing soils of agroecosystems so that human demands can be met while restoring the environment.
- Eco-intensification (EI), designed to restore soil organic carbon (SOC) and soil inorganic C (SIC) stocks of degraded soils, is an option to bring about the desired paradigm shift.
- Sustainable management of SOC, to maintain stocks above the threshold level of 1.5% to 2.0% in the root zone, is essential to sustaining productivity while restoring the environment.

THE LIVING SOIL

Soil is an organic-carbon mediated realm in which solid, liquid, gas and biology all interact from a scale of nanometer to landscape.

The weight of live organisms in arable land is 5 t/ha

ECO-VIOLENCE

Most of the post-Cold War violence is "eco-violence" because of eroded and degraded soil/land resource base or the "shrinking resource-pie" and deterioration of the environment in which people live.

People are mirror images of land they live on.

De Soysa (2002), Homer-Dixon ad Blitt (1998), Kaplann (1994), Renner (1996)

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 **pulses** and plant-based diet, and alternate source of protein,
- **Accepting** personal responsibility of not taking things for granted, and
- **Increasing** agronomic productivity from existing land, restoring degraded lands, enhancing BNF by legumes and converting some agricultural land for nature conservancy without any conversion of natural land to agro-ecosystems, through **sustainable eco-intensification and restoration of soil health.**

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We must reconcile the need of advancing food and nutritional security with the necessity of improving the environment.

Eco-Intensification(EI)

- EI is defined as intensification of biological processes supporting ecosystem services on medium-term (efficiency of management options) and long-term (sustainability of management options) basis

ECO- INTENSIFICATION

The strategy is to produce more food:

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.

SUSTAINABLE SOIL MANAGEMENT

- Replace what is removed,
- Respond wisely to what is changed,
- Predict what will happen from anthropogenic and natural perturbations, and
- Enhance soil resilience by sequestering SOC to 1.5-2.0% in the root zone

Comparison of Organic Farming, Sustainable Intensification, and Eco-Intensification(Lal,2019)

Parameter	Organic Farming	Sustainable Intensification	Eco-Intensification
Fertility management	Managing soil organic matter, enhancing soil biological activity, biological nitrogen fixation (BNF)	Using chemical fertilizers	Using INM based on a judicious combination of organic and inorganic sources, biomass recycling, and BNF
Disease and pest management	Crop rotations, natural predators, resistant varieties, diverse cropping systems	Chemical pest control: herbicides, fungicides, insecticides	IPM, creating disease suppressive soils, judicious chemical intervention, and enhancing biodiversity
Seedbed preparation	Mechanical tillage for weed control, residues incorporation, and manure management	No-till based on chemical weed control	CA based on a system approach
Water management	Soil-water conservation	Supplemental irrigation, drip-fertigation	Soil water conservation, minimal supplemental irrigation, resilience against drought-flood syndrome

Comparison of Organic Farming, Sustainable Intensification, and Eco-Intensification (cont.)(Lal,2019)

Parameter	Organic Farming	Sustainable Intensification	Eco-Intensification
Environment management	Strengthening biodiversity, minimizing chemical release	Minimal biodiversity	High soil biodiversity, good soil health, better environment quality
Risks of soil degradation and pollution	No soil pollution but high risks of soil erosion because of mechanical tillage	High risks of soil pollution by chemicals	Conservation-effective with minimal risks of soil degradation and environmental pollution
Agronomic yield	Low	High but not sustained	Optimal but sustained with creation of better environment and re-greening of landscape
Gaseous emission	Low	Very high	Moderate and often emission-negative
System approach	High diversity of crops, integrated with trees and livestock	Improved varieties grown with high input of fertilizers and supplemental irrigation	CA and sequestering carbon

Toward Making Soil of Agroecosystems A Carbon Sink

- Soils of agroecosystems, croplands and pasturelands combined, cover about 5 Gha (1.24×10^{10} ac) of manageable land area for soil C sequestration.
- Soils of these ecosystems can be sink for atmospheric CO_2 by judicious management and adopting the nexus approach such as conservation agriculture(CA).

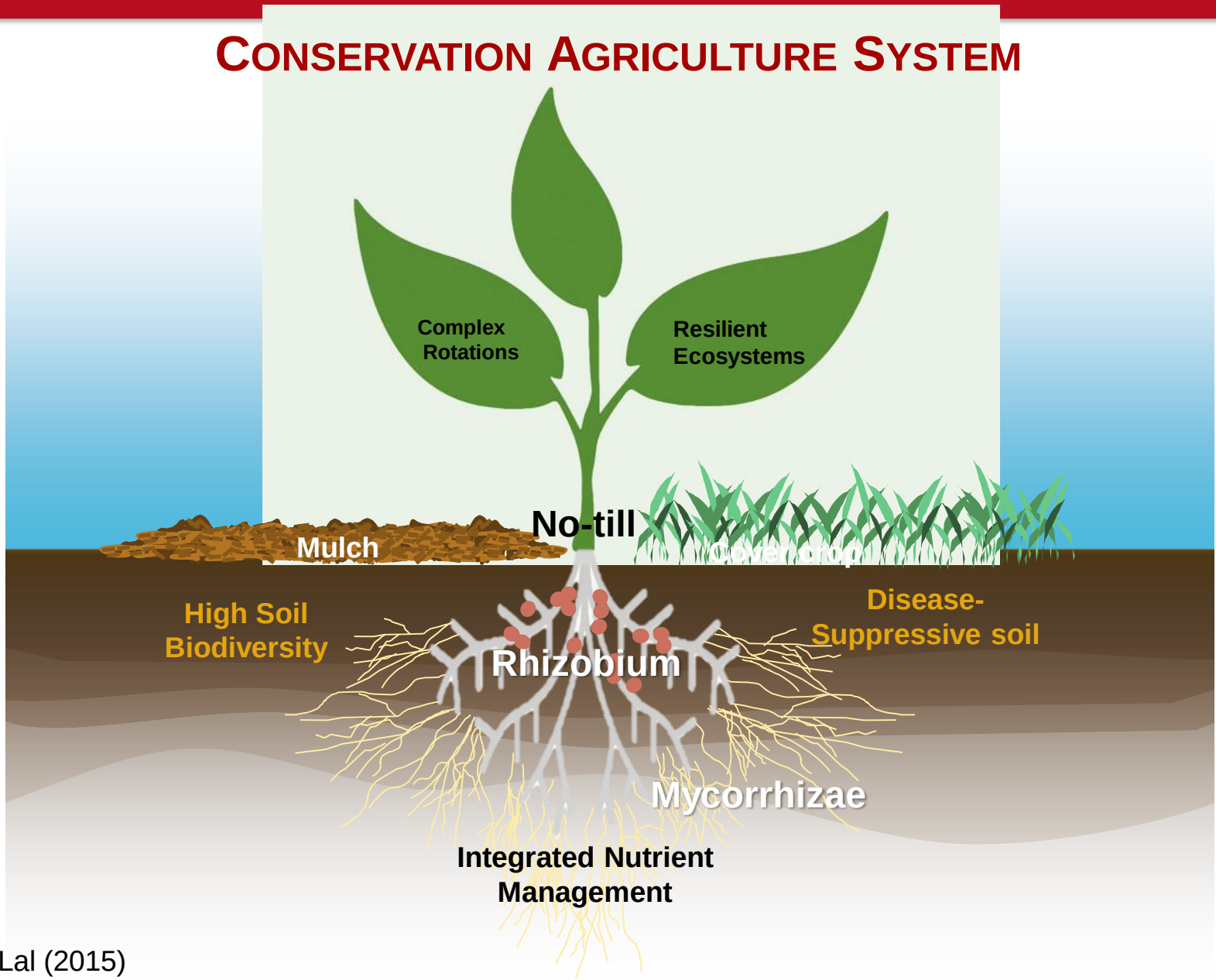
A System-Based Conservation Agriculture(CA)

- A system-based CA encompasses a site-specific combination of:
  1. No-till (NT),
  2. Residue retention as surface mulch,
  3. Complex rotations including cover cropping during the off-season , and
  4. Integrated nutrient management(INM) based on a judicious use of organic and inorganic sources of plant nutrients.
- The strategy is to fine-tune a site-specific system that creates a positive soil/ecosystem C budget on a long-term basis while conserving soil and water and improving soil health.

Adoption of Conservation Agriculture

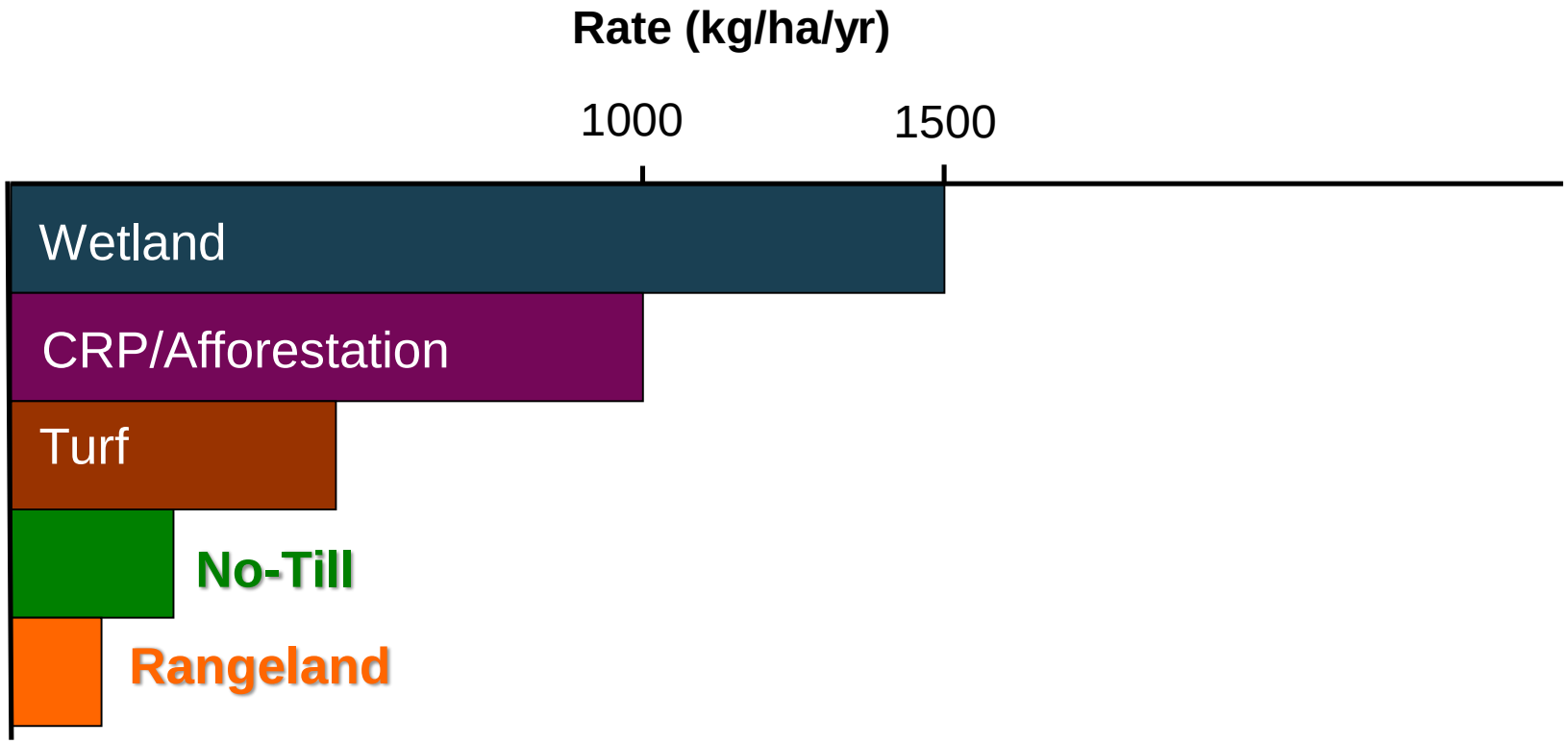
- Whereas the usefulness of CA has been recognized since the 1940s (Faulkner 1943), its adoption on about 180 M ha (4.45×10^8 ac) of cropland is primarily limited to large-scale commercial farms in North and South America, Australia, and New Zealand.

CONSERVATION AGRICULTURE SYSTEM



Source: Lal (2015)

RATE OF CARBON SEQUESTRATION



TECHNICAL POTENTIAL OF C SEQUESTRATION

I. Soils ……. 1.45 – 3.44 Pg C/yr (2.45 Pg C/yr)

Lal (2018)

II. Terrestrial Biosphere by 2100

- Soils …….. 178 Pg
- Vegetation …… 155 Pg

Total 333 Pg (157 ppm CO_2)

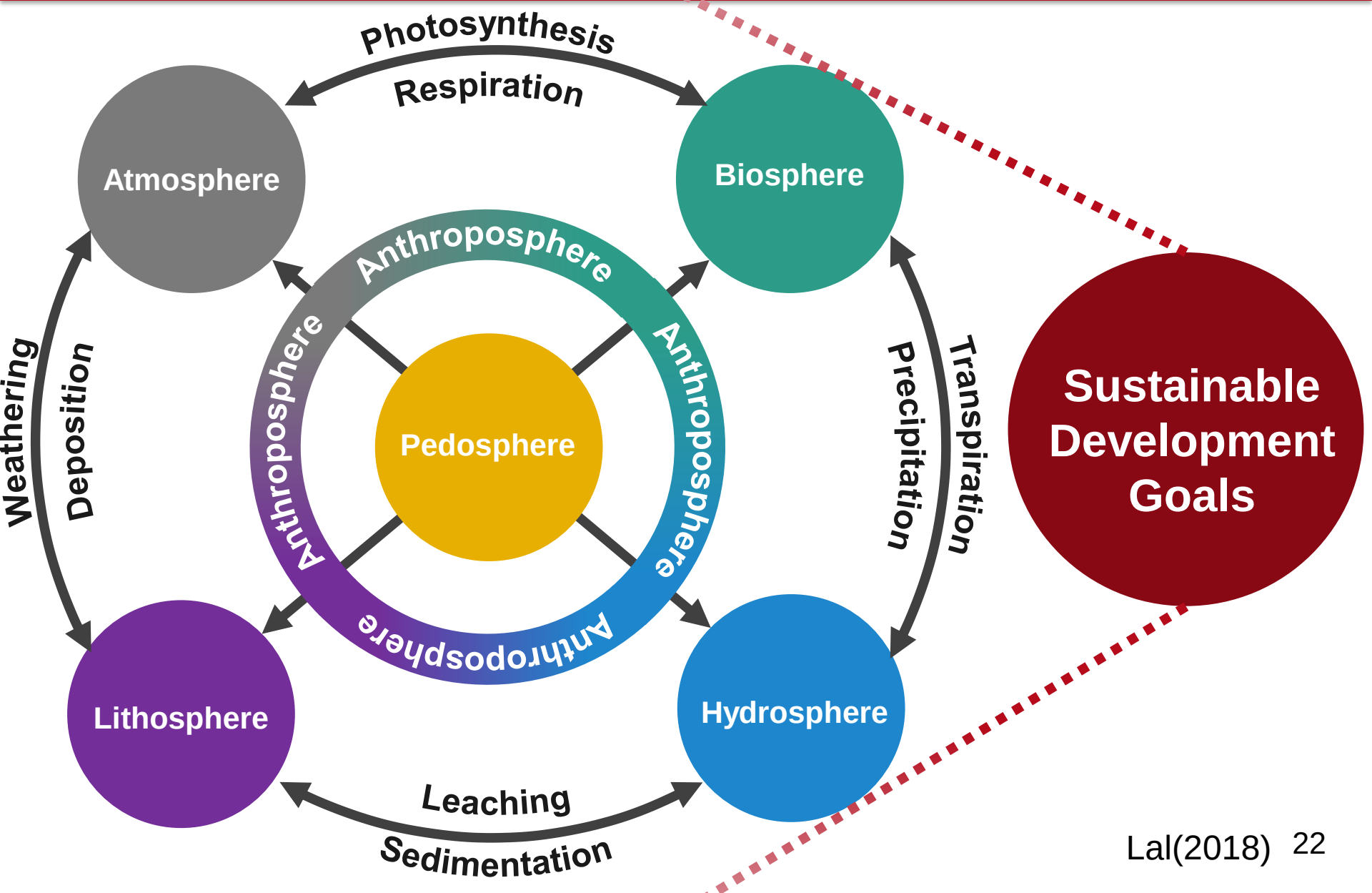
Lal et al. (2018)

REDUCING LAND AREA UNDER CEREALS IN THE 21ST CENTURY SAVING LAND FOR NATURE CONSERVANCY

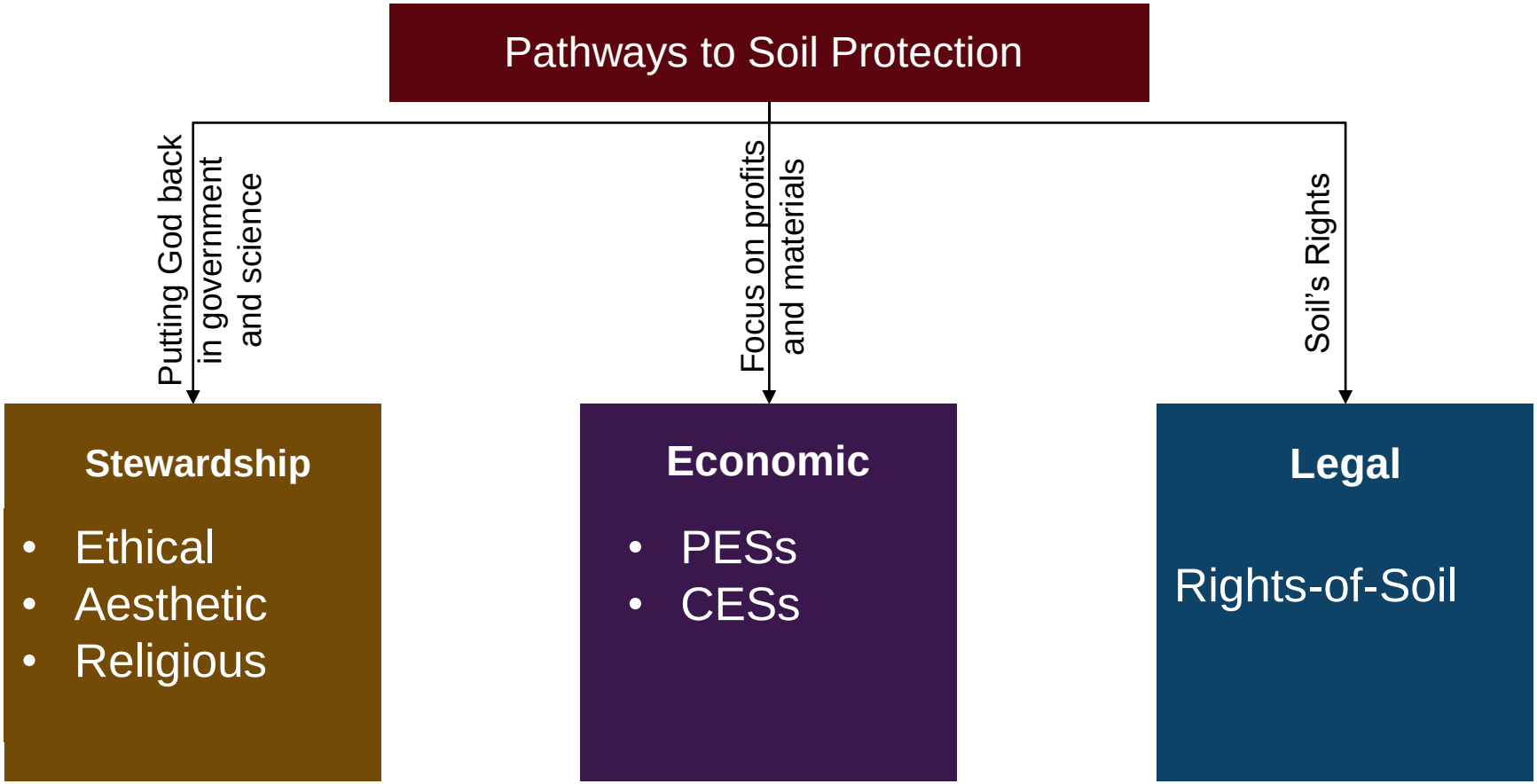
Parameter	Year			
	2005–07	2050	2080	2100
Population (10^9)	6.4	9.7	10.6	11.2
Per capita food consumption (kcal)	2772	3070	3200	3300
Cereal production (10^6 Mg)	2012	3012	3350	3540
Land area needed for intensive agriculture (Mha)	682	600	560	500
Total fertilizer demand (10^6 Mg)	200	160	120	100
The desired global average cereal yield (kg ha^{-1})	3280	5000	6000	7000

"Use the best, save the rest"

Lal (2016)


Photosynthesis
Respiration
Atmosphere
Biosphere
Anthroposphere
Anthroposphere
Anthroposphere
Pedosphere
Weathering
Deposition
Precipitation
Transpiration
Sustainable Development Goals
Lithosphere
Hydrosphere
Leaching
Sedimentation

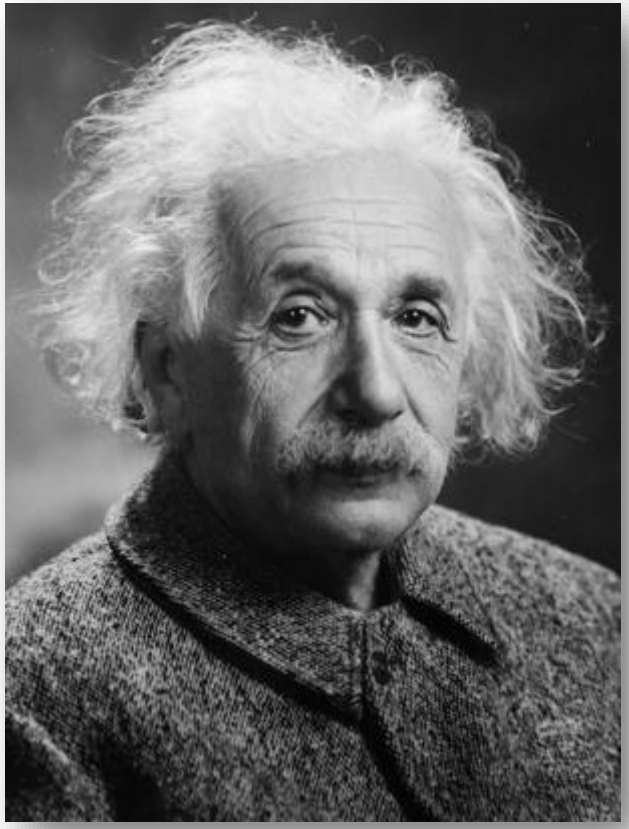
Lal(2018)



Paradigm Shift from Revolution to Evolution

Lal 2019)

MUTUAL INTER-DEPENDENCE OF SCIENCE AND RELIGION



"Science without religion is lame,
Religion without science is blind."

-Einstein

SOIL STEWARDSHIP

Soil stewardship and care must be embedded in every fruit and vegetable eaten, in each grain ground into the bread consumed, in every cup of water used, in every breath of air inhaled, and in every scenic landscape cherished.

Lal (2008)

SOIL STEWARDSHIP

Soil stewardship and ca
embedded in ev
vegetable
gr
ld in every
be cherished.

Should the food price reflect any degradation of these entities?

Lal (2008)

Soil Stewardship & Human Suffering

- **When people are poverty stricken, desperate and starving, they pass on their sufferings to the land. People are mirror image of the land & vice versa.**

- **Love and business and family and religion and art and patriotism are nothing but shadows of words when a man's starving.**

(O. Henry)

PROFITABLE TO WHO?

Because humanity belongs to nature, everything that it does must be profitable to nature. If humanity profits over a short-time and nature loses on a long-time basis, the lose-lose situation must be banned.

PAYMENTS FOR ESS

Payments to farmers for provisioning of ES s through restoration of soil health by SOC sequestration @ $40/ha·y is essential to protecting soils and ,and sequestering C in soil(2.5 Gt C/Yr).

(Lal, 2014;2018)

RIGHTS-OF-SOIL

Just as Universal Rights of Human, Rights of animals , there must also be Rights-of- Soil , and Rights-of-Nature. Being the essence of all life, soils must also have rights to be protected, restored, thrive and managed judiciously.

The violator of basic soil rights ought to have legal and binding implications.

RIGHTS-OF-SOIL (RoS)

- It implies that soil degradation, pollution, and depletion is a moral and ethical wrong that must be stopped by legal interventions.
- Soil as a living entity, sustains life, and has a right to thrive, flourish and be protected.
- RoS is not based on economic benefits, but on protecting and restoring the soil for the greater good of the planet rather than just for the humanity.
- **Therefore, communities should be authorized to bring litigation on behalf of soil against those who pollute, erode, deplete, or degrade soil health.**

THE FUTURE AGRICULTURE

- This is an exciting era, especially for agriculture and systems of food production
  - More change will happen between now and 2050 than during the past 10-12 millennia since the onset of agriculture

- With automation and full integration with the industrial sector, the global farmer population will decrease to < 1% of the 9.8 billion by 2050 or 11.2 billion by 2100

- The high tech 3-dimensional vertical farms can efficiently produce clean organic food within the urban centers

SEIZE THE OPPORTUNITY

- Soil and soil C sequestration are on a global agenda
- World policy makers are translating soil science into action
- Soil scientists must seize the opportunity to implement what we know while keep advancing the scientific knowledge.

SOIL HEALTH FOR CLIMATE AND FOOD

To answer the question what would I suggest to mitigate global warming , purify air and water and end global hunger and malnutrition, the logical response would be to change the ways soils are taken for granted and abused to produce, transport, process, and consume food ; and misused to procure feed, fiber , fuel , bricks and other ecosystem services.

A prudent strategy would imply making soil, water and agriculture an integral part of the solution, and empowering farmers and land managers to produce more and more from less and less by reducing waste ,enhancing the eco-efficiency restoring degraded soils , afforesting the denuded lands , and saving soil and water for nature conservancy.

Rattan Lal
10th April 2019
Tokyo,Japan

BUILDING BRIDGES ACROSS NATIONS : THROUGH RESTORING SOIL HEALTH AND LAND RESTORATION

An old man going down a lone highway, came at the evening cold and grey, to a chasm vast and wide and steep, with waters running cold and deep.

The old man crossed in the twilight dim, for the sullen stream held no fear for him. But he paused when safe on the other side, and built a bridge to span the tide.

Old man - said a friendly pilgrim near – you're wasting your time in a building here, your journey will end with the ending day, and you never again shall pass this way, you've crossed the chasm deep and wide, why build this bridge at even-tide?
(The old man replied)
Good friend, on the path I've trod today, comes a fair haired youth who must pass this way, this chasm that meant naught to me, to the fair haired youth might a pitfall be, he too must cross in the twilight dim, good friend, I'm building a bridge for him.
(Anonymous)