Managing Soils to Address Global Challenges

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Opening Remarks: Mike Michener

Moderator: Robert Bertram

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Opening Remarks

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Speaker

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Soil Science and Global Challenges

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DOMESTIC ANIMALS VS. HUMAN POPULATION

Human

Year	Population (10^9)
2022	7.9
2050	9.8
2100	11.0

(UN 2020)

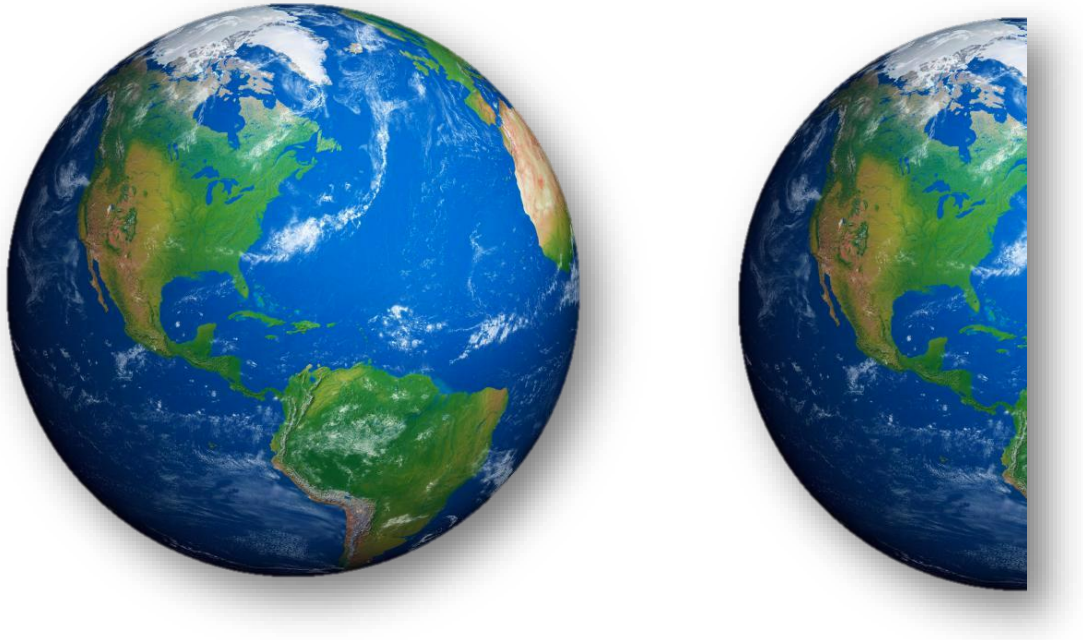
Domestic Animals

Species	Amount (10^9)
Cows	1.4
Pigs	1.0
Sheep and Goats	1.9
Chickens	20.0

Science 344(2014), 1067

HUMAN USE OF EARTH'S RESOURCES

Humanity is using one-and-a-half planets.



HUMANITY WATER FOOTPRINT

Green water : 6700 km^3/yr

Blue water : 1000-1700 km^3/yr

Grey water : 1400 km^3/yr

HUMANITY FOOTPRINT : ACTUAL VS SUSTAINABLE

Carbon : 46-55 vs. 18-25 Gt CO_2 Eq/yr

Ecological : 18.2 Bha vs. 12 Bha

Material : 70 Gt/yr (10.5t/cap. Vs. 8t/cap)

Hoekstra and Wiedma (2014)

HUMAN FOOTPRINT INCREASE IN THE PERIOD 1900 TO 2000

Parameter	Factor
Blue water	5.6
Reactive N	9.0
C Emissions	16.0

Historic Carbon Emission From Land Use and Fossil Fuel Emissions

(Friedlingstein et al., 2021)

Emissions	Pg C		
	1750 - 2020	1850 - 2021	1960 - 2020
Land Use Change	235 ± 75	200 ± 65	80 ± 45
Fossil Fuel	460 ± 25	465 ± 65	375 ± 20
Total	690 ± 80	660 ± 65	455 ± 45

Per Capita Food Waste CFP (FAO, 2014)

Region	Per Capita Kg CO_2 eq/Person - yr
North America and Oceania	860
Industrialized Asia	810
Europe	680
Latin America	540
North Africa/West Africa	350
South/SE Asia	350
Sub-Saharan Africa	210

CARBON STOCK IN THE ATMOSPHERE

Era	Pg C
Pre-Agriculture	360
Pre-Industrial Revolution	560
Present	880

Total Emission From LUC & Agric.=575 Gt

Total Emission From Fossil Fuel =445 Gt

Zimov et al. (2006), WMO (2018), Lal (2018)

GLOBAL SOIL DEGRADATION

Global Land Area Degraded
= One-third of Total Land Area

FAO (2015)

Comprising:

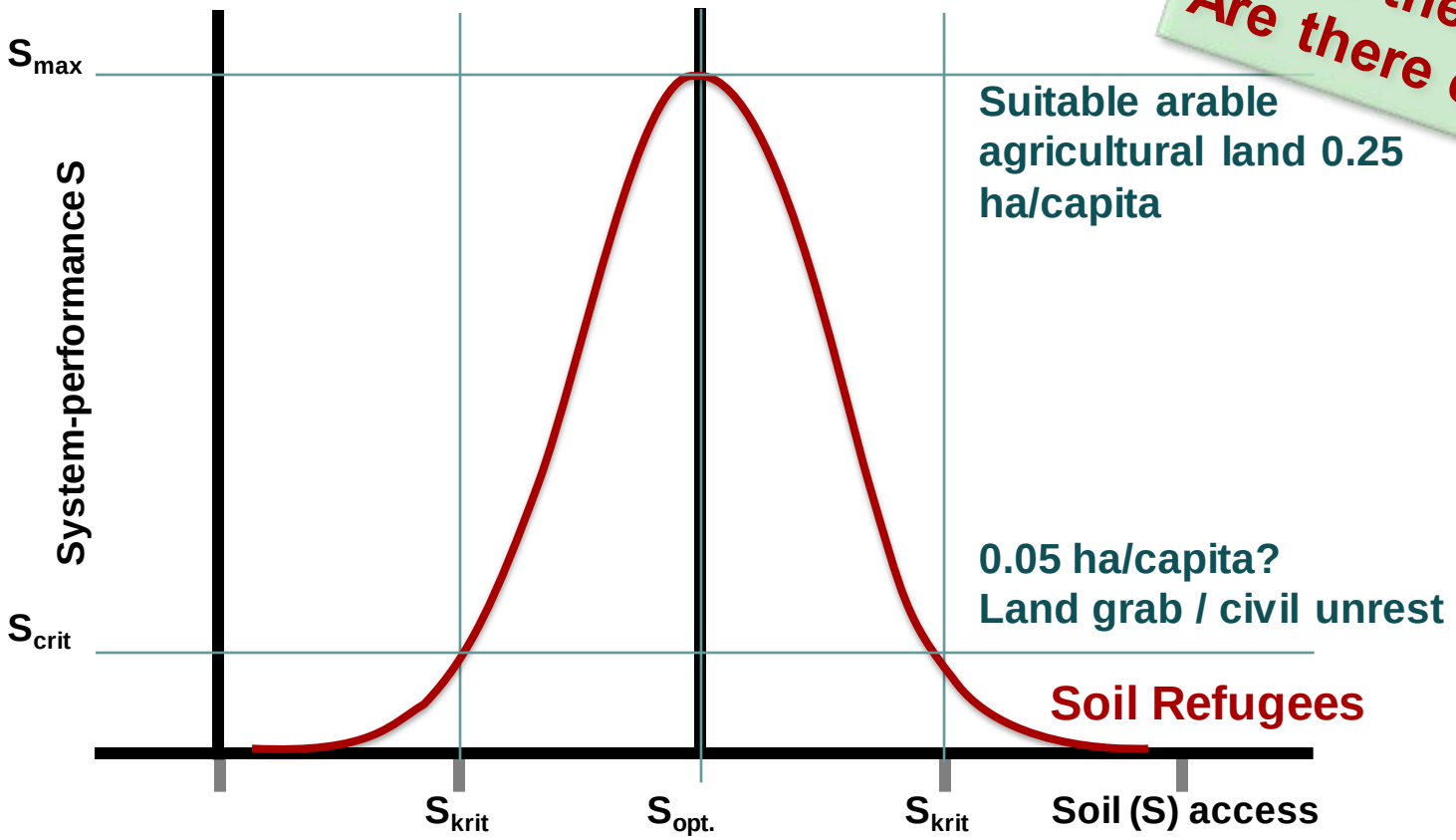
Forest	**= 47%**
Cropland	**= 18%**

} **2 B ha of degraded / degraded lands**

Bai et al. (2008)

HUBBERT CURVE FOR SOIL

Is there a peak soil?
Are there endangered soils?



NATURAL RESOURCES USED FOR AGRICULTURE

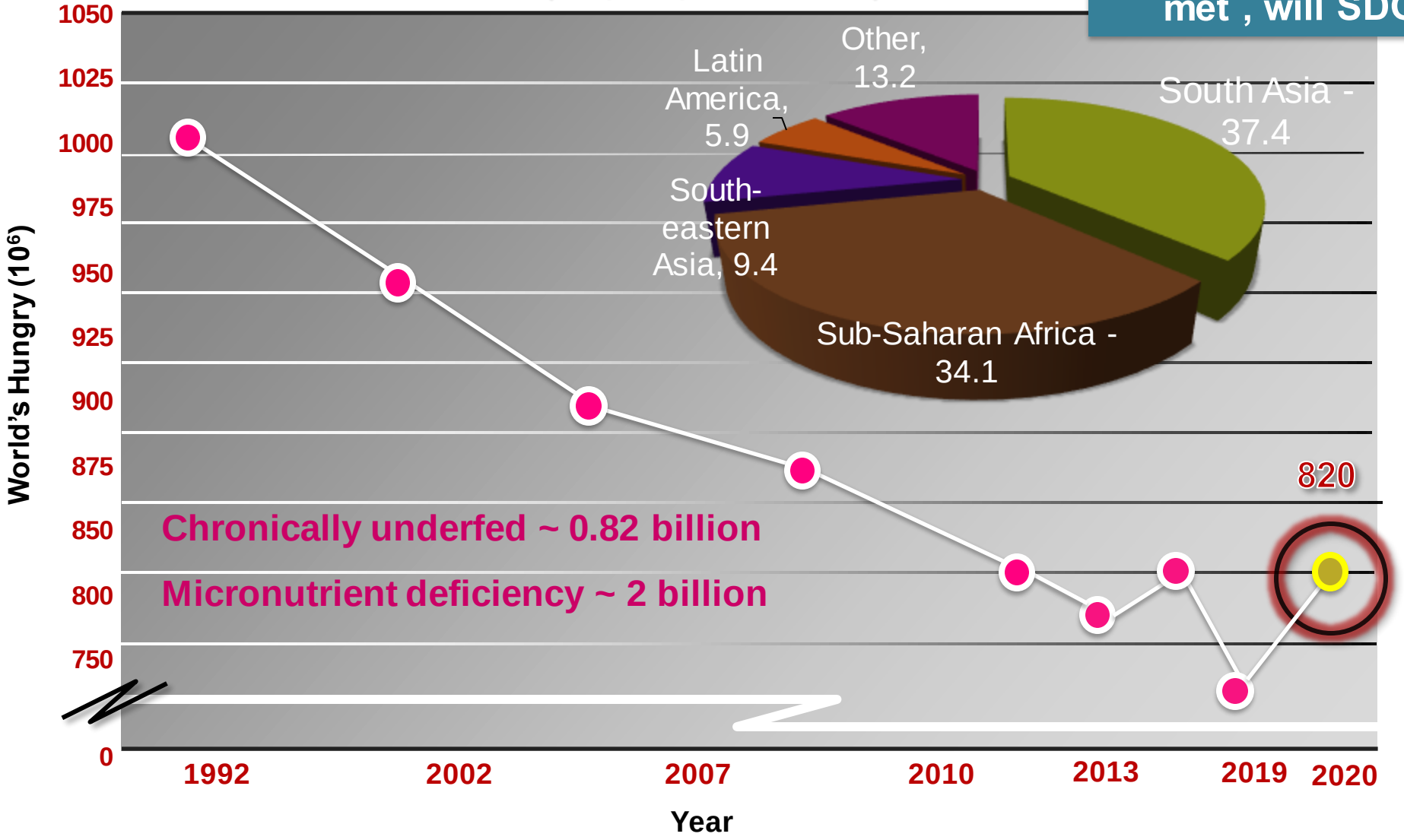
- 40% of the Earth's terrestrial surface is used for agriculture,
- 75% of agricultural land (3.73 Bha) is allocated to raising animals,
- 70% of the global freshwater withdrawals are used for irrigation,
- 30-35% of global greenhouse gas emissions are contributed by agriculture.

And yet 1 in 10 persons is food-insecure and 1 in 4 are malnourished.

MDG of reducing undernourishment were not met , will SDGs be met ?

GLOBAL FOOD INSECURITY

(FAO, IFAD, UNICEP 2020)



GLOBAL ISSUES OF THE 21ST CENTURY

1. Population of 7.9 billion and increasing at 1.1%/yr (7.25 million/month).
2. Per capita arable land area of 0.22 ha and decreasing to <0.07 ha for 30 countries by 2025.
3. Soil degradation of 2 billion ha and increasing at 5-10 Mha/yr.
4. Renewable fresh water supply of < 1000m^3 for 30 countries and increasing to 58 countries (4 billion people) by 2050.
5. Atmospheric CO_2 concentration of 412.5 ppm (2/22/22)and increasing at 0.5%/yr, or ~2ppmv/yr.
6. Energy use of 575 Quads in 2015 and increasing by 8 quads/yr (10^{15} BTU/yr, and increasing at 2.2%/yr between 2001 and 2025,and expected to be 736 quads by 2040).
7. Per capita grain consumption of 300 Kg/yr and decreasing.
8. Food-insecure population of 820 million(11 % of the population) and increasing.
9. Per capita CO_2 emission in the world is 4.48 Mg CO_2/ yr and in the U.S. is 17.56 Mg CO_2/ yr.
10. Humanities per capita water footprint at global level is 1385 m^3/yr and increasing.

U. N. Sustainable Development Goals are a Challenge.

Solutions lie in managing natural resources

LIMITATIONS OF THE PRESENT FOOD SYSTEMS

30% of all GHGs

- Failed to end hunger and malnutrition,
- Haven't provided adequate nutritious food, health diet, and safe food, and
- Have degraded soils, polluted water, aggravated global warming, dwindled biodiversity, and denuded landscapes.

THE WAY FOOD IS PRODUCED AND CONSUMED

- Affects the health of soil, plants, animals, people , ecosystems and the planet itself
- Above all the SDGs of the Agenda 2030 are not on the track

NATURE-POSITIVE PRODUCTION

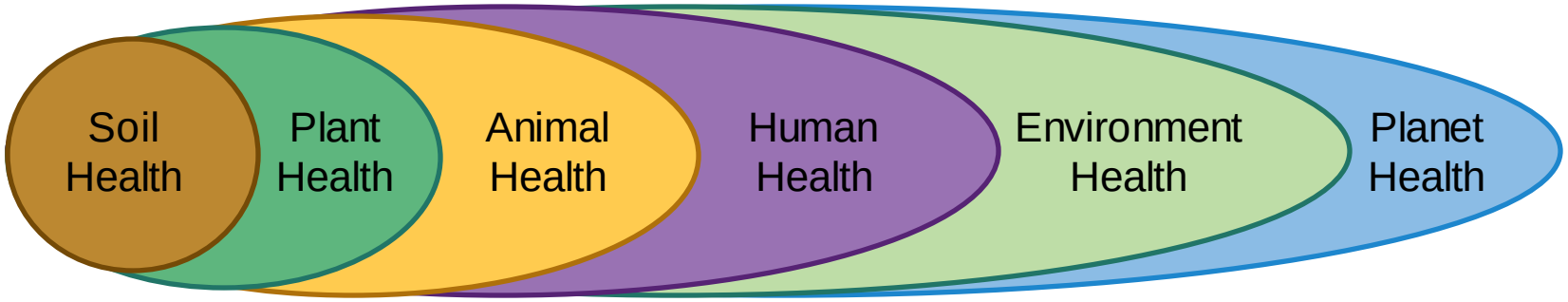
- Mitigating climate change,
- Reducing emissions and increasing carbon capture,
- Regenerating and protecting critical ecosystems,
- Reducing food waste and energy usage, and
- Returning half of the land back to nature.

MANAGING SOIL HEALTH

Drawdown of CO_2 from the Atmosphere

- Regenerative Agriculture (e.g., CA)
- Digital Agriculture: Precision Agriculture
- Artificial Intelligence: Robots, Drones
- Biofortification of crops to fight hidden hunger
- Soil-Water-Air-Energy Nexus
- Build New Soil
- Urban/Soilless Farming

Soil, Human, Planet-Health Nexus



"When we try to pick out anything by itself, we find it hitched to everything else in the Universe." (John Muir).

(Lal 2020)

https://www.researchgate.net/figure/Rendzina-or-humus-calcareous-soil-Bulgarian-classification-1976-Rendzic-Leptosol-WRB_fig2_312825283

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

Sequestering 12 Mg of C would need 1 Mg of N.

TRANSFORMATIVE STRATEGIES

Take Land From Nature — **5 Ds**

- Deplete
- Degrade
- Destroy
- Discard
- Dominate

Transformational Change

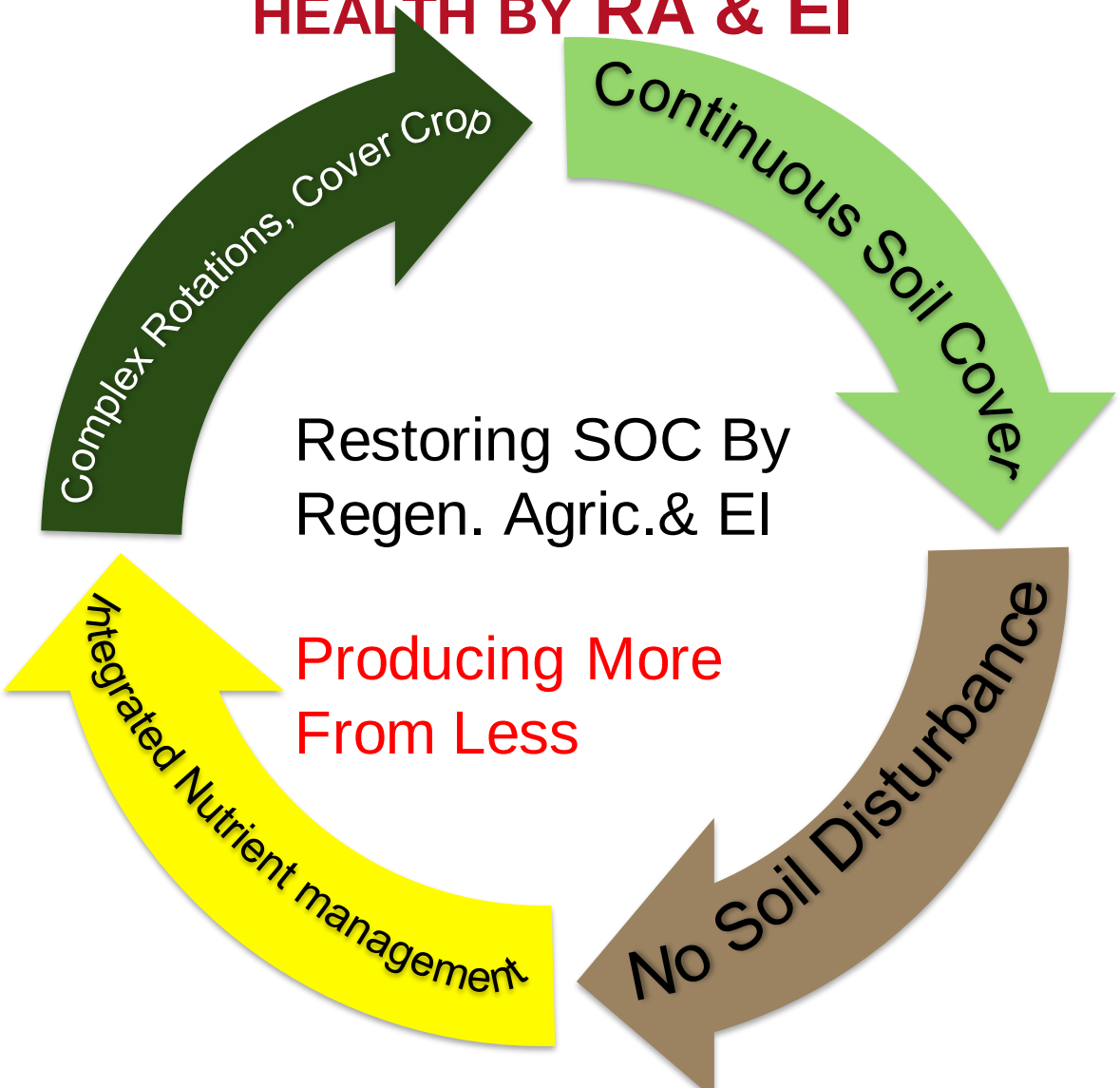
Return Land to Nature — **5 Rs**

- Reduce
- Reuse
- Recycle
- Regenerate
- Restore

REGENERATIVE AGRICULTURE

Inspired by eco-innovation, powered by non-carbon energy, driven by a circular economy and green infra-structure, and supported by the re-carbonization of the terrestrial biosphere as the bedrock of sustainable development.

MANAGING SOIL CARBON AND RESTORING SOIL HEALTH BY RA & EI



ZERO BUDGET NATURAL FARMING VS REGENERATIVE AGRICULTURE

RA is not to be confused with ZBNF. The latter is not an option to feed 8B people now and 11 B by 2100.

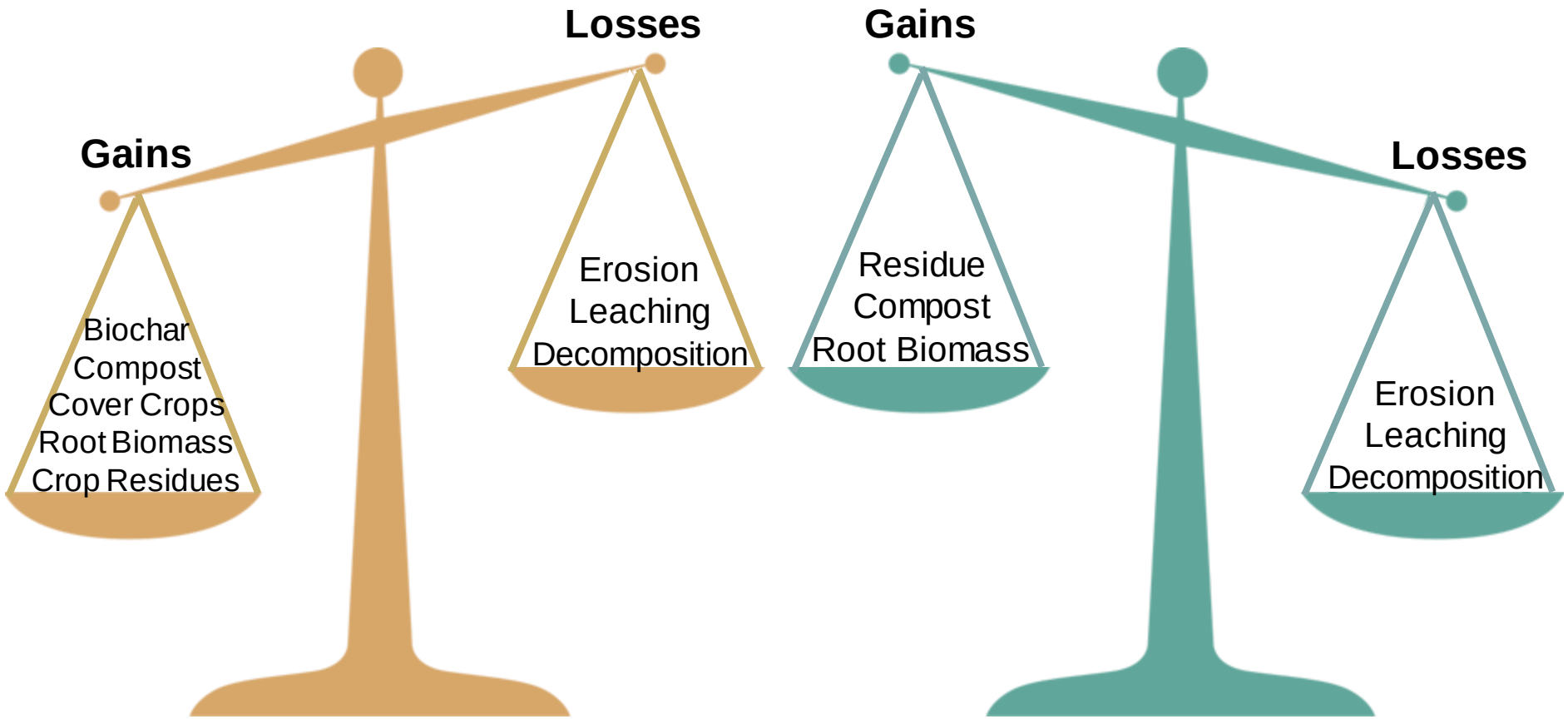
RA is based on the Law of Return by Sir Albert Howard "Anything taken from soil should be returned to it.

THE LAW OF RETURN

"The law states that substance we take from nature must be returned to the place from which it was taken."

— Sir Albert Howard

CREATING POSITIVE C BUDGET



Soil Carbon Sequestration **Soil Carbon Depletion**

INNOVATIVE AGRICULTURAL PRACTICES

- Conservation agriculture
- Regenerative agriculture
- Agroecology
- Agroforestry
- Integration of crops with trees and livestock
- Practices with positive soil/ Eco.C budget
- (CNPK) through ISFM
- Balanced use of plant nutrients
- Drip Fertigation
- Digital Agriculture & Precision Farming
- Artificial Intelligence, Drones, & Robotics

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)

SOCIETAL VALUE OF SOIL ORGANIC CARBON

- **Inherent value: $130/ton C (Nickel per lb) = $35/ton CO_2**
- **For 0. 5ton C/ha = $65/ha = $26/acre**
- **For 0.33ton C/ha = $43/ha = $17.5/acre**

Lal (2014)

GLOBAL FOOD PRODUCED BY SMALL FARMS

- Total Crop Production: 28-31%
- Food Supply: 30-34%
- Gross Agricultural Area: 24%
- Total Number of Farms: 570 Million
- Farm Size: <2ha
- Total population of Small Farms: 2.3-3.5 B

Riccardi et al.(2018)
Lowder et al. (2016)

DEMAND FOR FOOD PRODUCTION IN AFRICA

SSA will need to produce three times more cereals by 2050 relative to 2005-2007 to maintain the present level of self-sufficiency (about 80%) due to population growth and dietary change.

Alexandreatos and Bruinsma (2012)

SOIL DEGRADATION IN AFRICA

- 65% of arable land, 30% of grazing land, and 20% of forest in Africa are already degraded
- Serious land degradation accounts for about a quarter of the land area of SSA
- About 180 million people who are living on the land that is in some way or another degraded
- Increase in erosion risks between 1980s and 2090 in Africa are +36% and the world are +14%
- Soil degradation is the cause of food insecurity

Montpellier Panel (2105)

Managing Nutrient Depletion in Africa

- Global fertilizer use = 135 kg/ha
- Fertilizer use in SSA = 17 kg/ha
- SSA has 20% of world's arable land but it consumes only 2% of the world's fertilizer

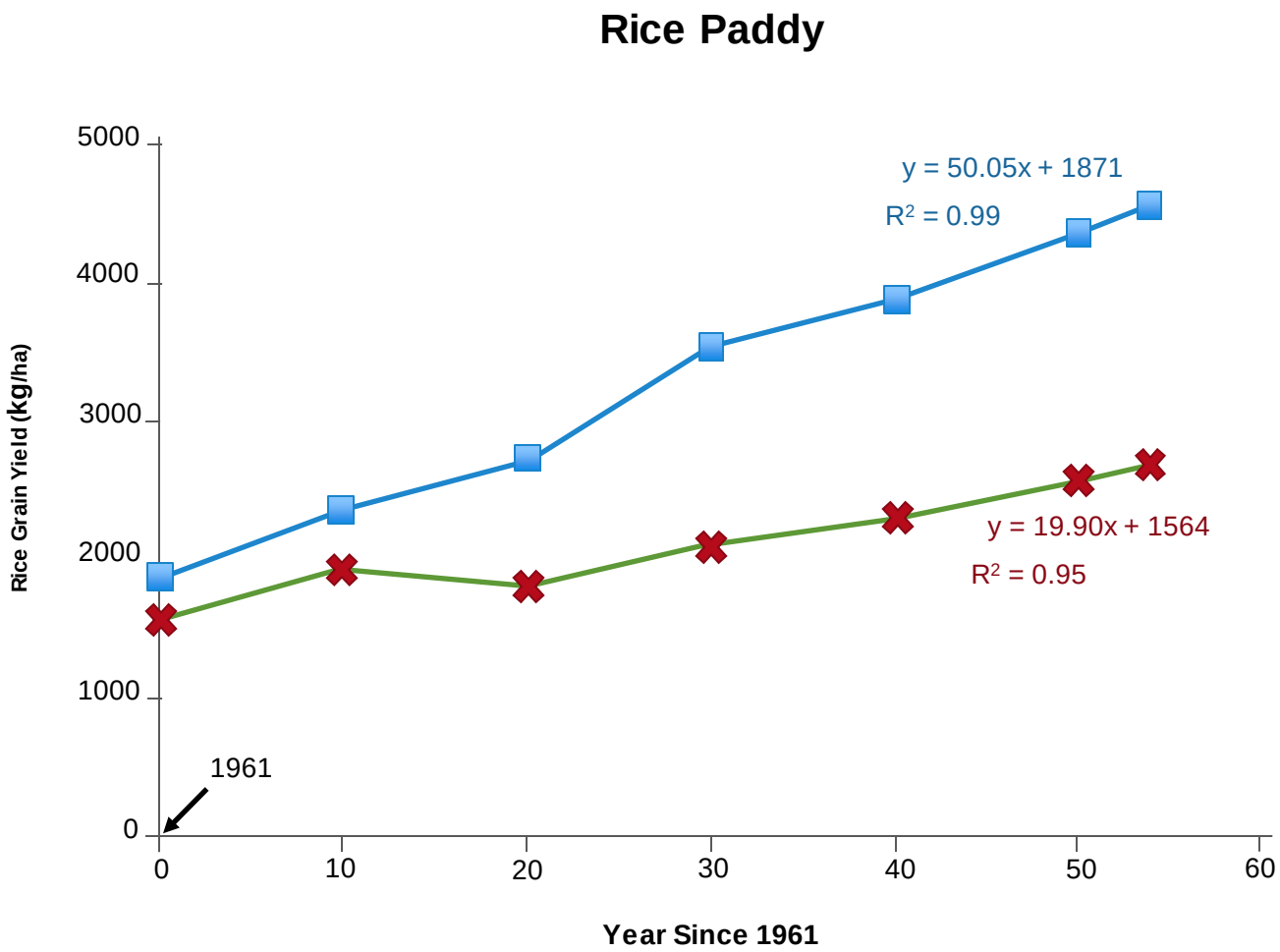
Irrigation in Africa

- Irrigation can alleviate drought and can double or more comparable rain fed crop yields

- Only 6-7% of cropland in Africa (13 Mha) is presently irrigated compared with 14% in Latin America and 37% in Asia

DSF that saves water, energy, and fertilizer must be promoted

TEMPORAL CHANGES IN AVERAGE GRAIN YIELD OF CEREALS IN THE WORLD AND AFRICA



(Lal 2017)

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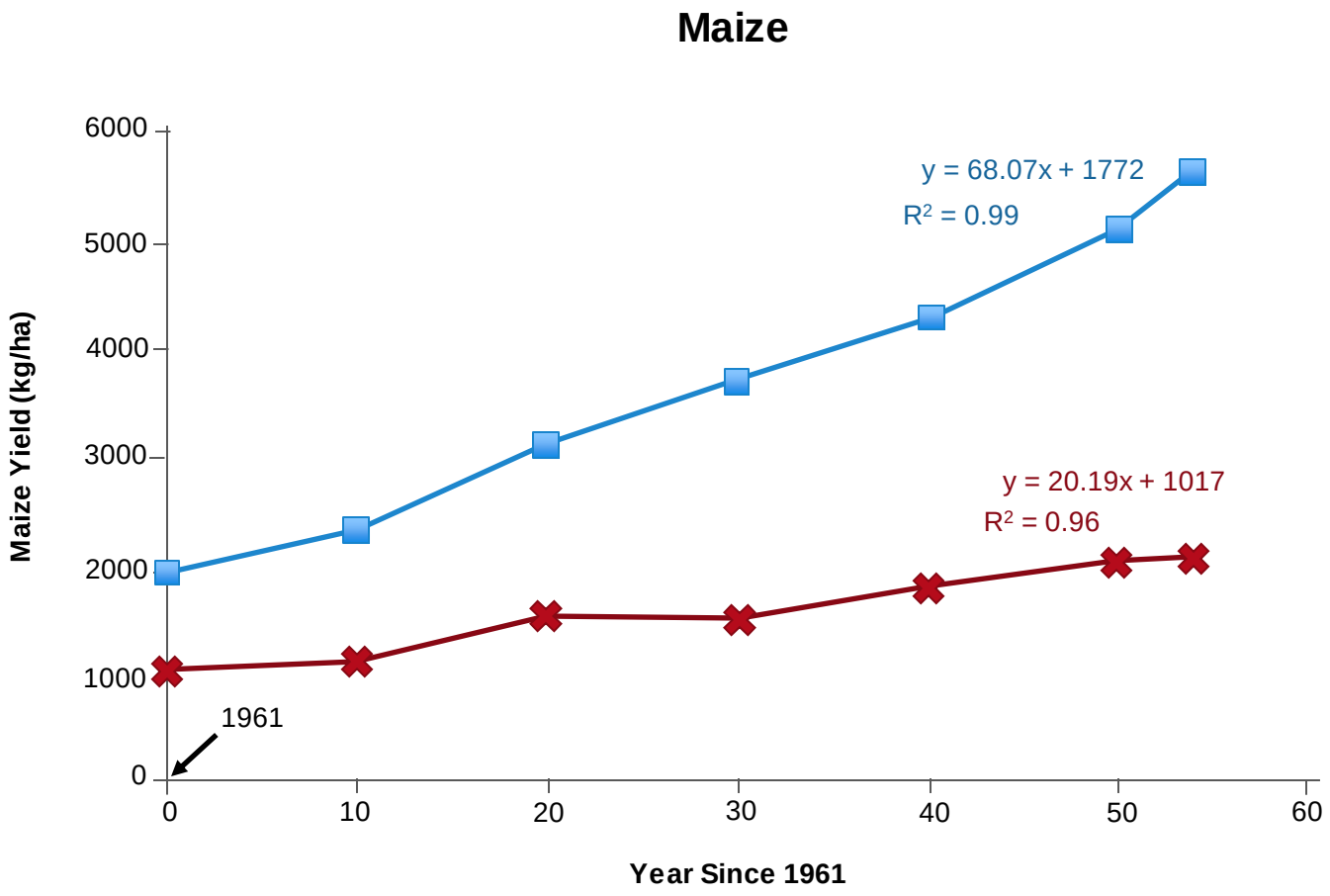


(Lal 2017)

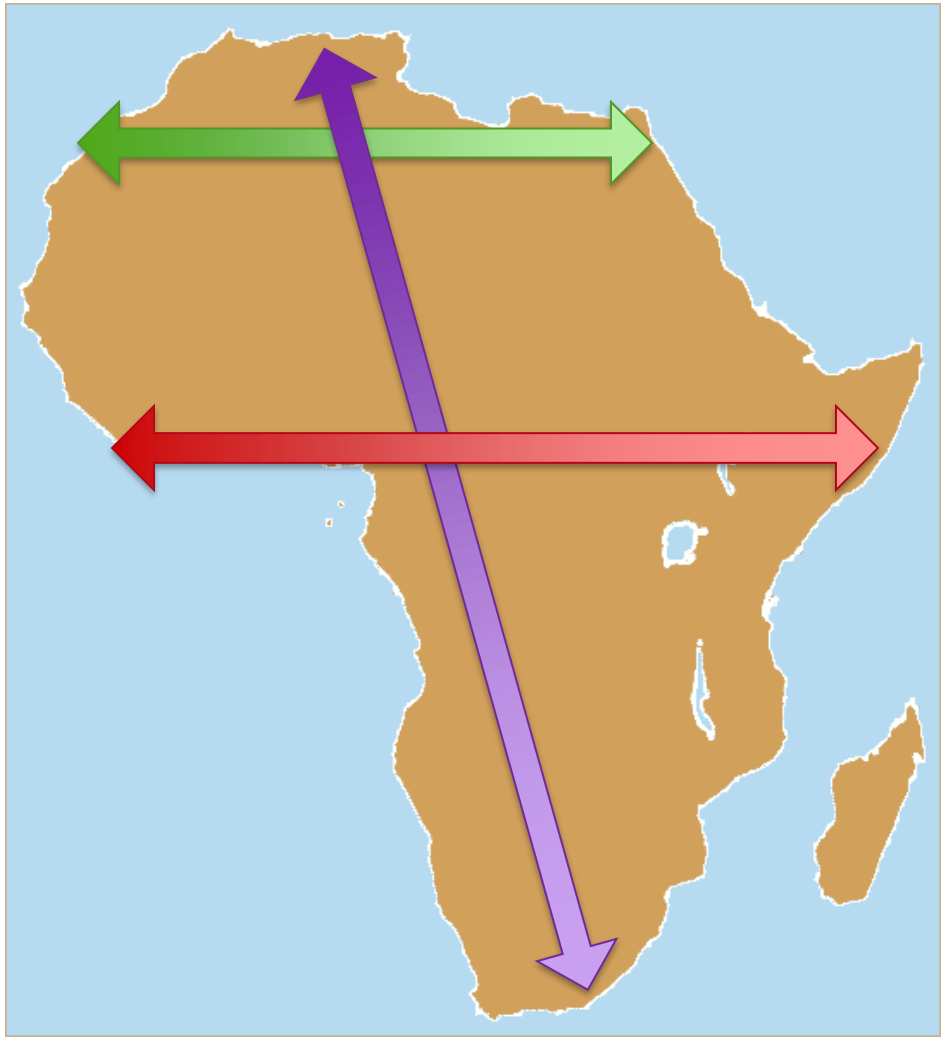
A ROAD MAP FOR FEEDING SSAFRICA

Technological Options	2020	2025	2030
Fertilizer Use (kg/ha)	17	30	60
Irrigated Cropland (%)	6	10	20
Conservation Agriculture (M ha)	1.5	10	50
Agroforestry (% of tree cover on agric. land)	10	15	20

Cropland Area = 242 M ha

AF = Zomer et al. (2009)
CA = Kasam et al. (2019)

SELF-RELIANCE IN AFRICA



Goals for 21st Century

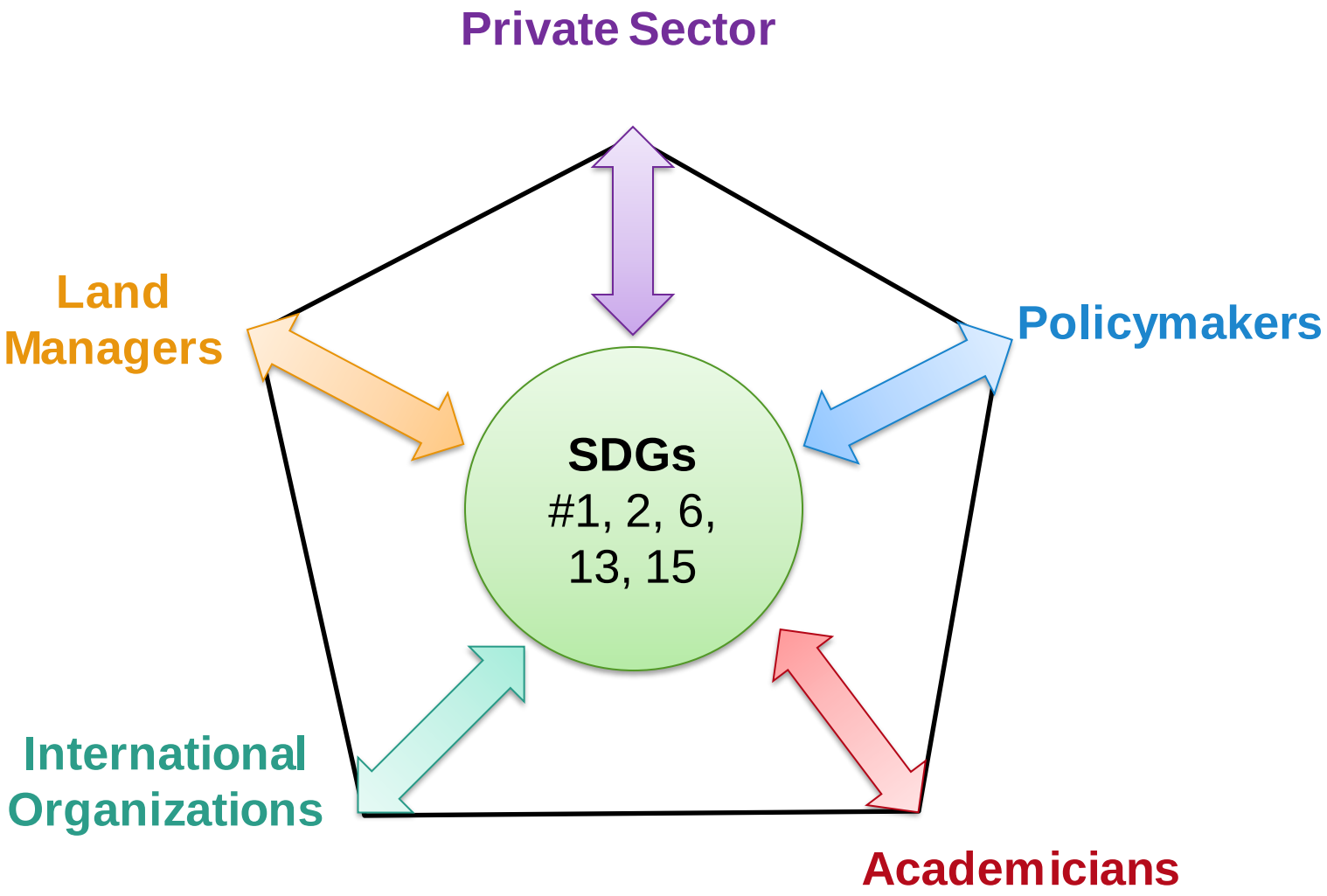
- Return Land to Nature : 10% per Decade
- Restore Degraded Land: 2 B Ha
- Protect all natural ecosystems
- Reconcile need to grow health food with the necessity of improving the environment
- No farmer left behind

THE ROLE OF PRIVATE SECTOR

Private sector can play a critical role in translating science into action by :

- **Promoting nature positive agriculture,**
- **Increasing access to inputs,**
- **Improving investment in agric. research and development**

COOPERATION WITH THE PRIVATE SECTOR



LiSAM for Making Soils and Agriculture a Carbon Sink: IICA/C-MASC

- Soils of managed ecosystems(crops, pastures , forests and urban) have a large C sink capacity, and it must be harnessed for adaptation and mitigation of ACC.

- Soil is a living entity,and its life-support processes must be enhanced

- Soils of these ecosystems can be sink for atmospheric CO_2 by judicious management and adopting the science-based options.

LONG-TERM OBJECTIVES OF CA4SH

- Enhancing cooperation among multiple stakeholders
- Promoting on-the-ground adoption of BMPs
- Developing tools for MMV of soil health & its indicators
- Advocating a system-based soil health agenda
- Implementing an action plan for restoring soil health
- Developing a protocol for payments of ESs
- Empowering farmers/land managers to adopt BMPs
- Strengthening human resource capital
- Enhancing respectability of soil health profession
- Alleviating drudgery of farming operations

Lal(2021)

EDUCATION OF THE NEXT GENERATION

- In addition to 3Rs,goal of the education is to prepare the next generations to address global issues:
- Food and nutrition,
- Environment :Soil , water, air , global warming
- Personal responsibility : culprit and victim
- Ethics
- Integrity
- Respect for nature

CONNECTING CHILDREN WITH NATURE

S es para Suelo

THE MANTRA

"Healthy Soil = Healthy Diet = Healthy People = Healthy Ecosystems = Healthy Planetary Processes"

Q&A

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