MANAGING SOIL FOR ADVANCING FOOD SECURITY AND ADAPTING TO CLIMATE CHANGE

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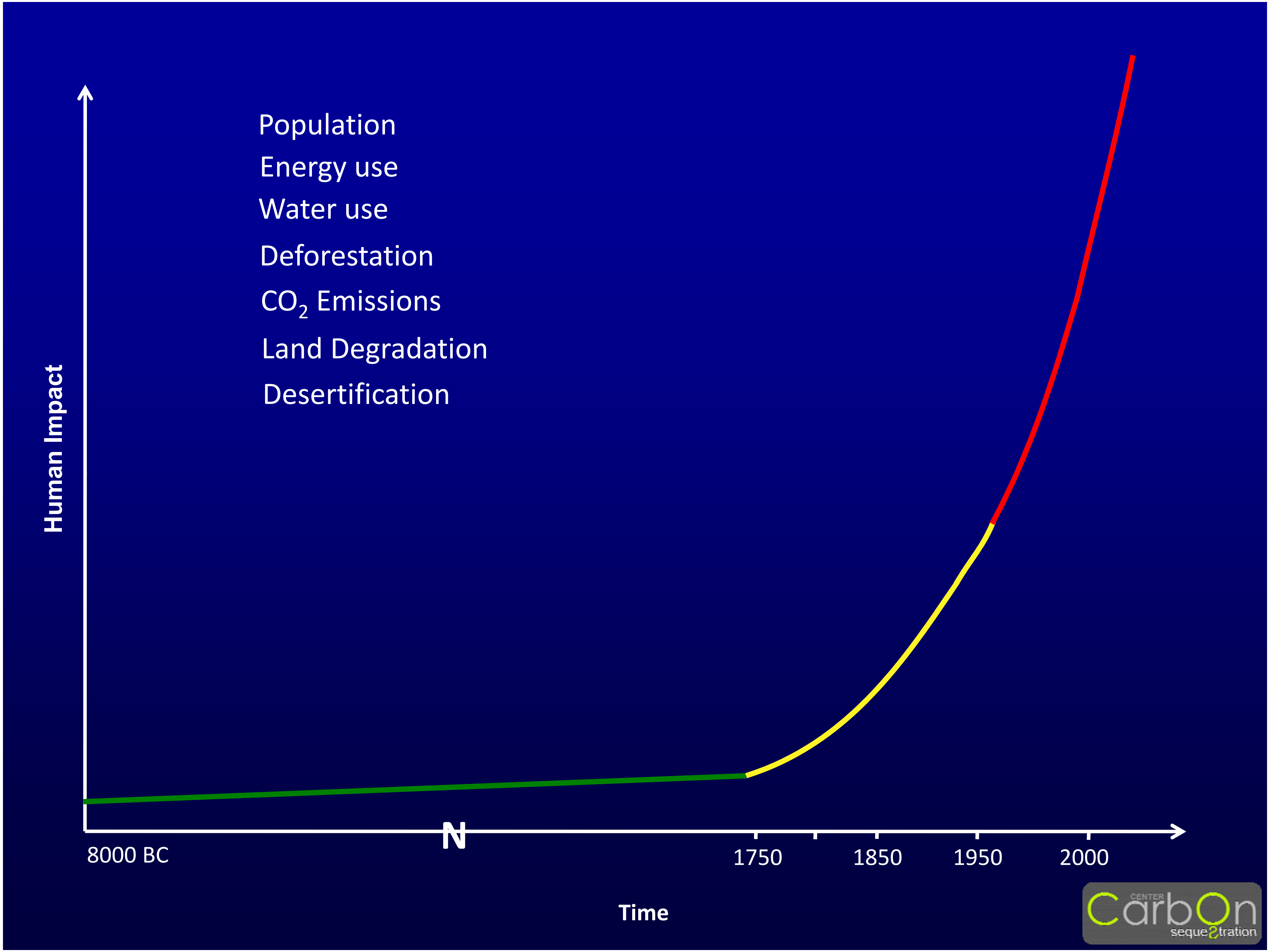

Population
Energy use
Water use
Deforestation
CO_2 Emissions
Land Degradation
Desertification
Human Impact
8000 BC
1750
1850
1950
2000
Time

PRODUCTIVITY INCREASE BETWEEN 1900 AND 2000 (PONTING, 2007)

Parameter	Increase Factor Between 1900-2000
Population	3.8
Urban Population	12.8
Industrial output	35
Energy Use	12.5
Oil Production	300
Water Use	9
Irrigated Area	6.8
Fertilizer Use	342
Fish Catch	65
Organic Chemicals	1000
Car Ownership	7750

WORLD ENERGY CONSUMPTION

Year	EJ/y
1860	12
2005	463
2030	691
2050	850

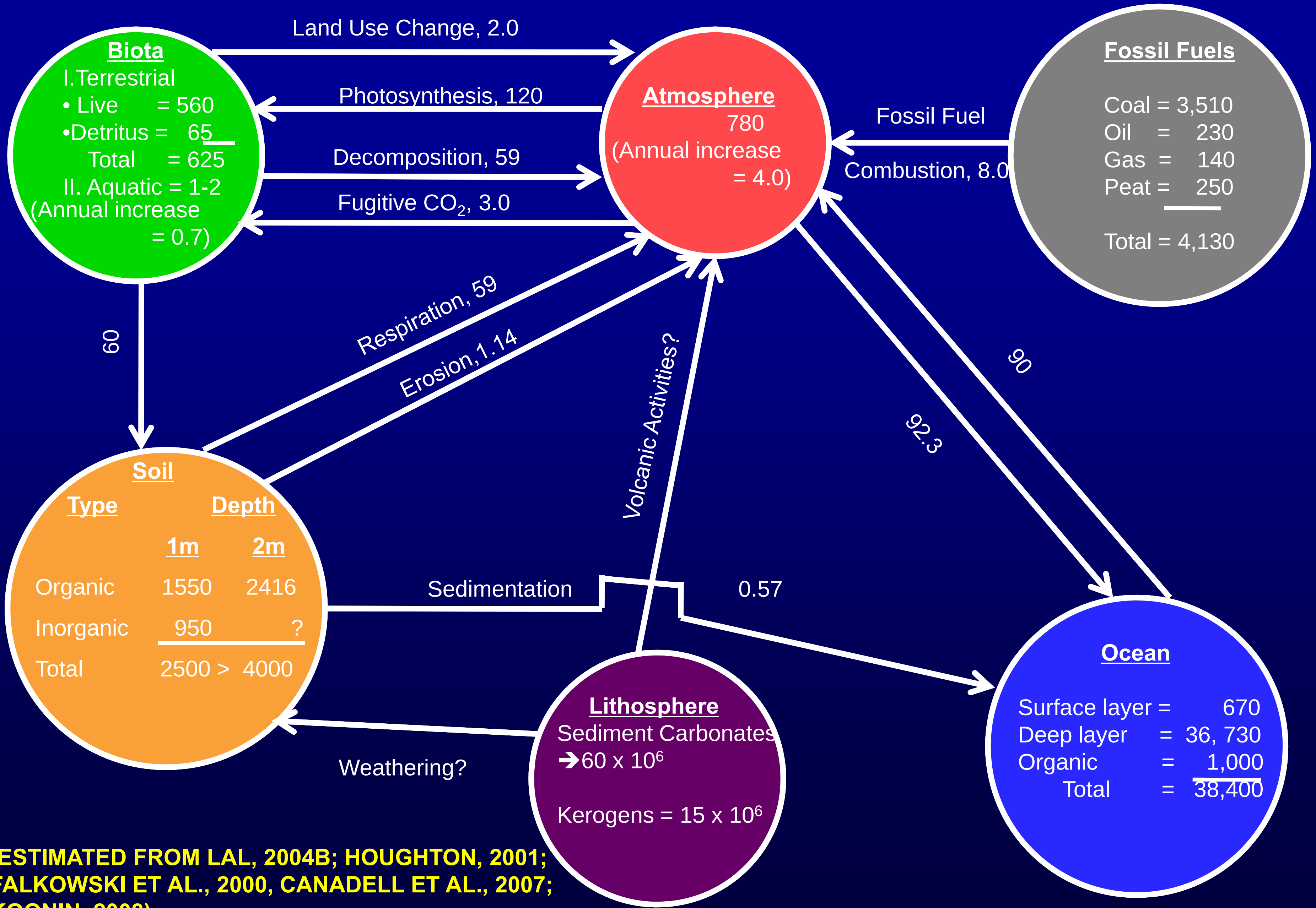
THE ADDICTION OF CARBON CIVILIZATION

1. Global Daily Oil Consumption	=	86 million barrels/day
	=	18.9 billion L/day
2. Per Capita Oil Consumption	=	2.8 L/person/day

PER CAPITA CO_2 EMISSION IN SELECTED COUNTRIES IN 2005

Country	Per Capita Emission (Mg C/y)
USA	5.32
Australia	4.95
Canada	4.54
Norway	3.11
Japan	2.63
Germany	2.60
U.K.	2.47
France	1.69
China	1.16
Brazil	0.48
India	0.35
Nigeria	0.23
Bangladesh	0.08
Ethiopia	0.03
Burundi	0.01
World	**1.23**

PRINCIPLE GLOBAL CARBON POOLS AND FLUXES AMONG THEM. ALL POOLS ARE IN GT AND FLUXES ARE IN GT/Y.



(ESTIMATED FROM LAL, 2004B; HOUGHTON, 2001; FALKOWSKI ET AL., 2000, CANADELL ET AL., 2007; KOONIN, 2008).

ATMOSPHERIC CHEMISTRY

CO_2 CONCENTRATION

Year	PPMV
1750	280
1950	315
2008	380 (+2 ppm/y)

SOIL DEGRADATION IMPLIES

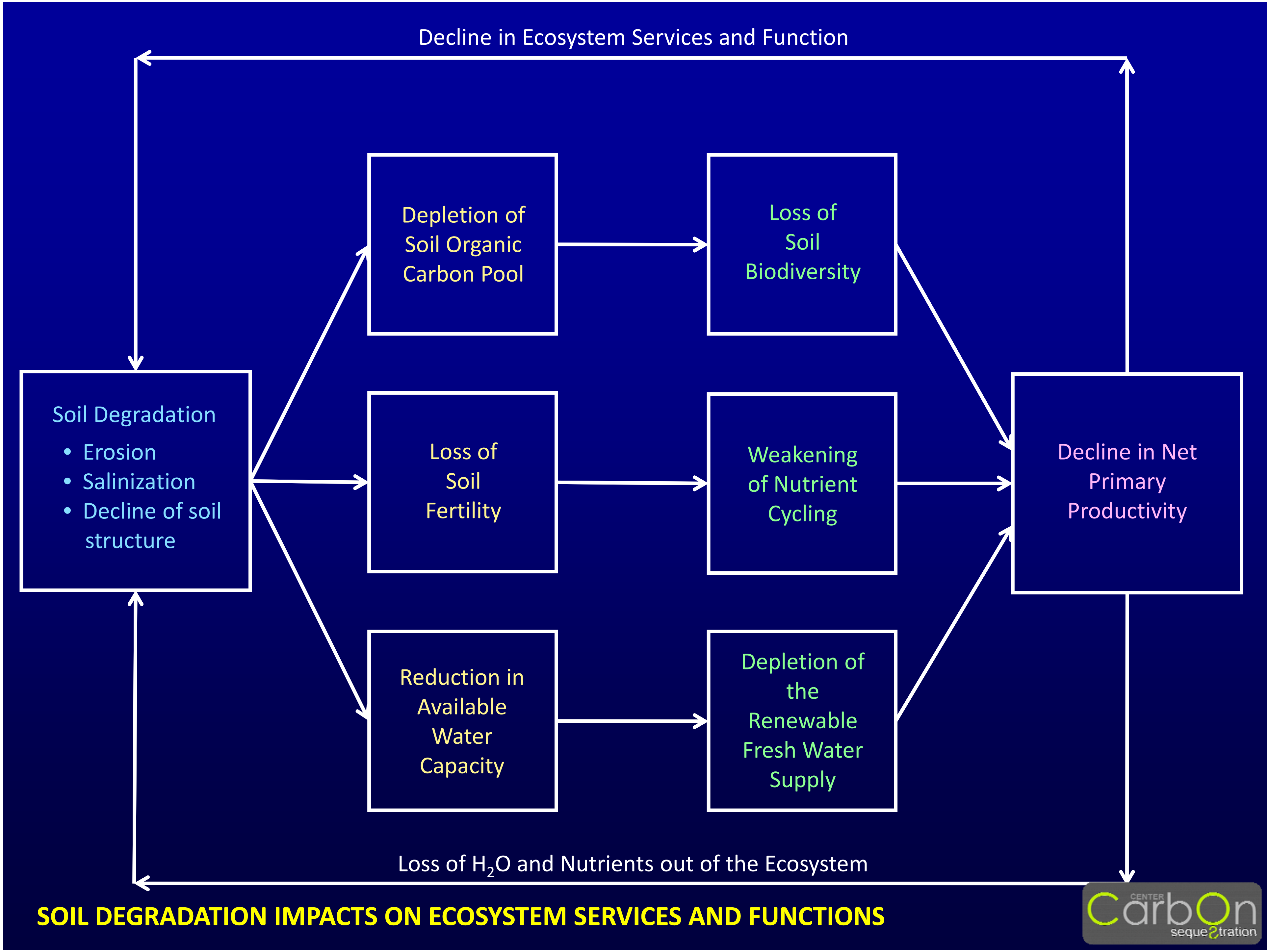
Decline in the quality and capacity of soil's productivity through its misuse

or

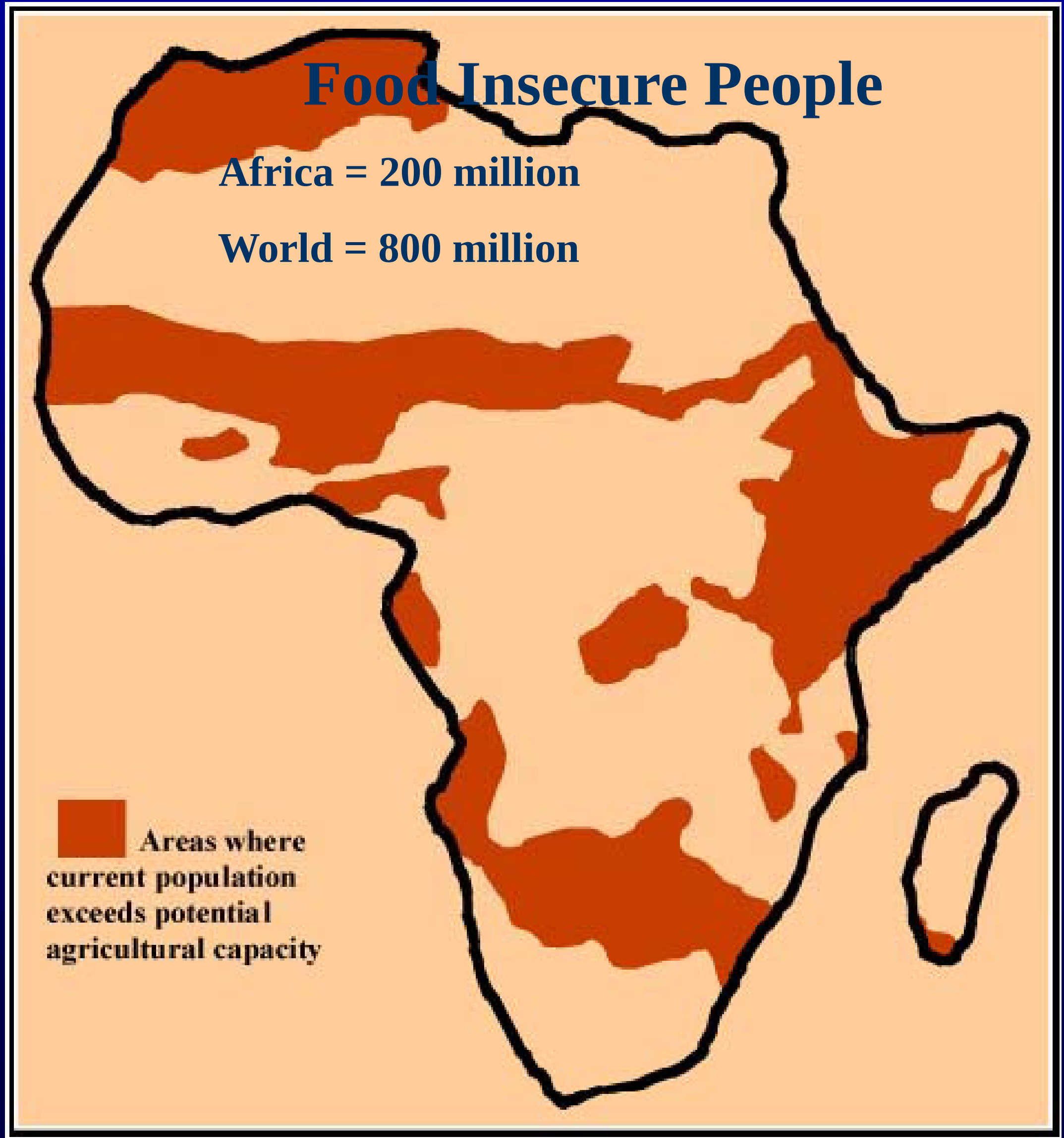
Diminution of the soil's current or potential capacity to produce food, feed and fiber as a result of one or more degradative processes.

LAND AREA AFFECTED BY DESERTIFICATION (Bai et al. 2008)

Parameter	Value
Area Affected (10^6 km^2)	35.06
% of the Land Area	23.54
Total NPP Loss (Tg C/yr)	955
% Total Population Affected	23.9
Total Population Affected (billions)	1.54


Decline in Ecosystem Services and Function
Depletion of Soil Organic Carbon Pool
Loss of Soil Biodiversity
Soil Degradation
• Erosion
• Salinization
• Decline of soil structure
Loss of Soil Fertility
Weakening of Nutrient Cycling
Decline in Net Primary Productivity
Reduction in Available Water Capacity
Depletion of the Renewable Fresh Water Supply
Loss of H_2O and Nutrients out of the Ecosystem
SOIL DEGRADATION IMPACTS ON ECOSYSTEM SERVICES AND FUNCTIONS

NUTRIENT DEPLETION IN AFRICA



EFFECTS OF DESERTIFICATION

1. Failing crops and grazing.
2. Declining quality and quantity of fresh water.
3. Loss of tree cover and biodiversity.
4. Drought stress

   (Monsoon failure in India, 2009).

SOIL DEGRADATION AFFECTS THREE TYPES OF DROUGHT

1. Meteorological	:	Long-term decline in precipitation
2. Hydrological	:	Decline in surface runoff and water table
3. Pedological	:	Decline in soil moisture availability

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EROSION-INDUCED CARBON EMISSIONS FROM WORLD'S DRYLANDS

Severity of erosion	Area affected by water and wind erosion	C emission (Pg C/yr)
Slight	372	0.08-0.10
Moderate	424	0.11-0.14
Strong	97	0.015-0.02
Extreme	7	0.0015-0.002
Total	900	0.21-0.26

(Lal, 2001)

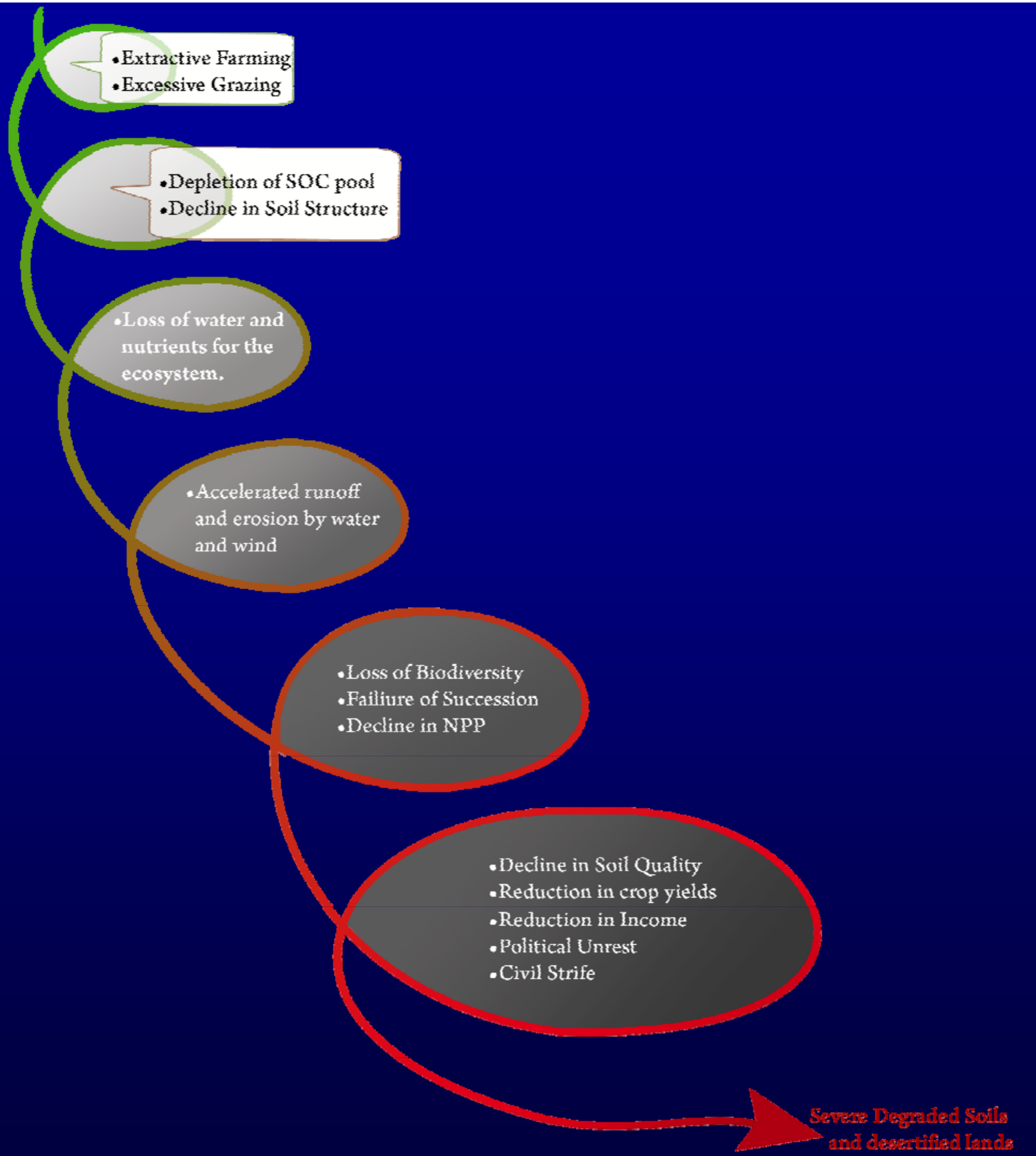


Fig. 1. Soil and ecosystem degradation caused by depletion of SOC pool.

CENTER Carbon sequestration

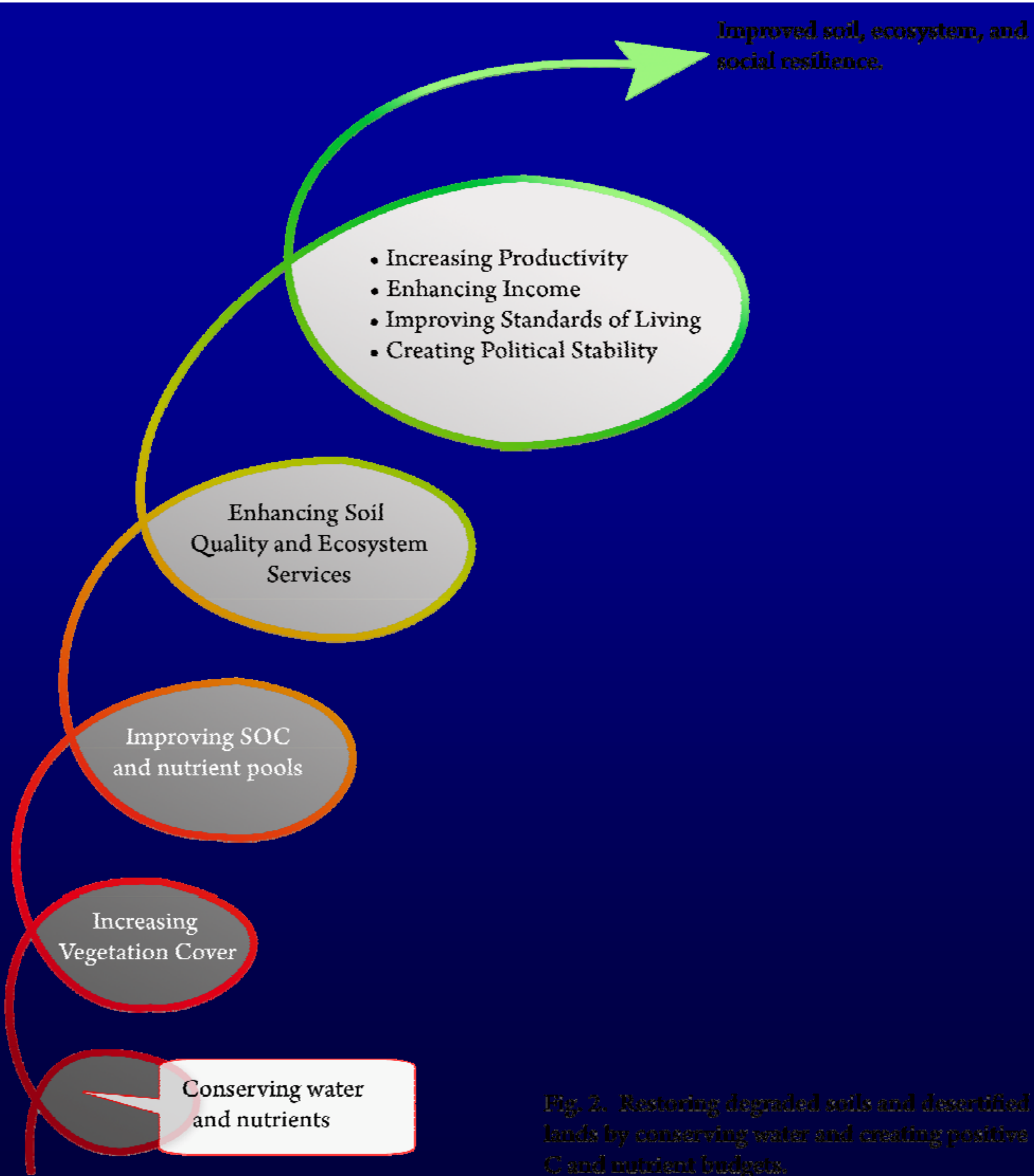


Fig. 2. Restoring degraded soils and desertified lands by conserving water and creating positive C and nutrient budgets.

GLOBAL GRAIN PRODUCTION AND PER CAPITA CONSUMPTION 1950 - 2000

Year	Production (106 Mg)	Per Capita Consumption (Kg)
1950	631	267
1955	759	273
1960	824	271
1965	905	270
1970	1079	291
1975	1237	303
1980	1430	321
1985	1647	339
1990	1769	335
1995	1713	301
2000	1840	303

(Kondratyev et al., 2003)

CHRONICALLY UNDERNOURISHED/FOOD INSECURE PEOPLE IN THE WORLD

Year	Global Population Affected (10^6)
1970	960
1980	938
1990	831
2000	790
2005	730
2007	850
2008	950
2009	1020

GLOBAL CEREAL PRODUCTION

Year	Area (Mha)	Yield (Mg/ha)	Total Production (10^6Mg)
1970	676	1.77	1,192
1980	717	2.16	1,550
1990	708	2.75	1,952
2000	674	3.06	2,060
2005	686	3.27	2,240

FAO (2006)

FUTURE CEREAL YIELD AND PRODUCTION
(REVISED FROM WILD, 2003)

Year	Cereal Yield (Mg/ha)	Production (10^6 Mg)
2005	3.27	2,240
2025 a.	3.60	2,780
b.	4.40	3,629
2050 a.	4.30	3,255
b.	6.00	4,553

a = without dietary change

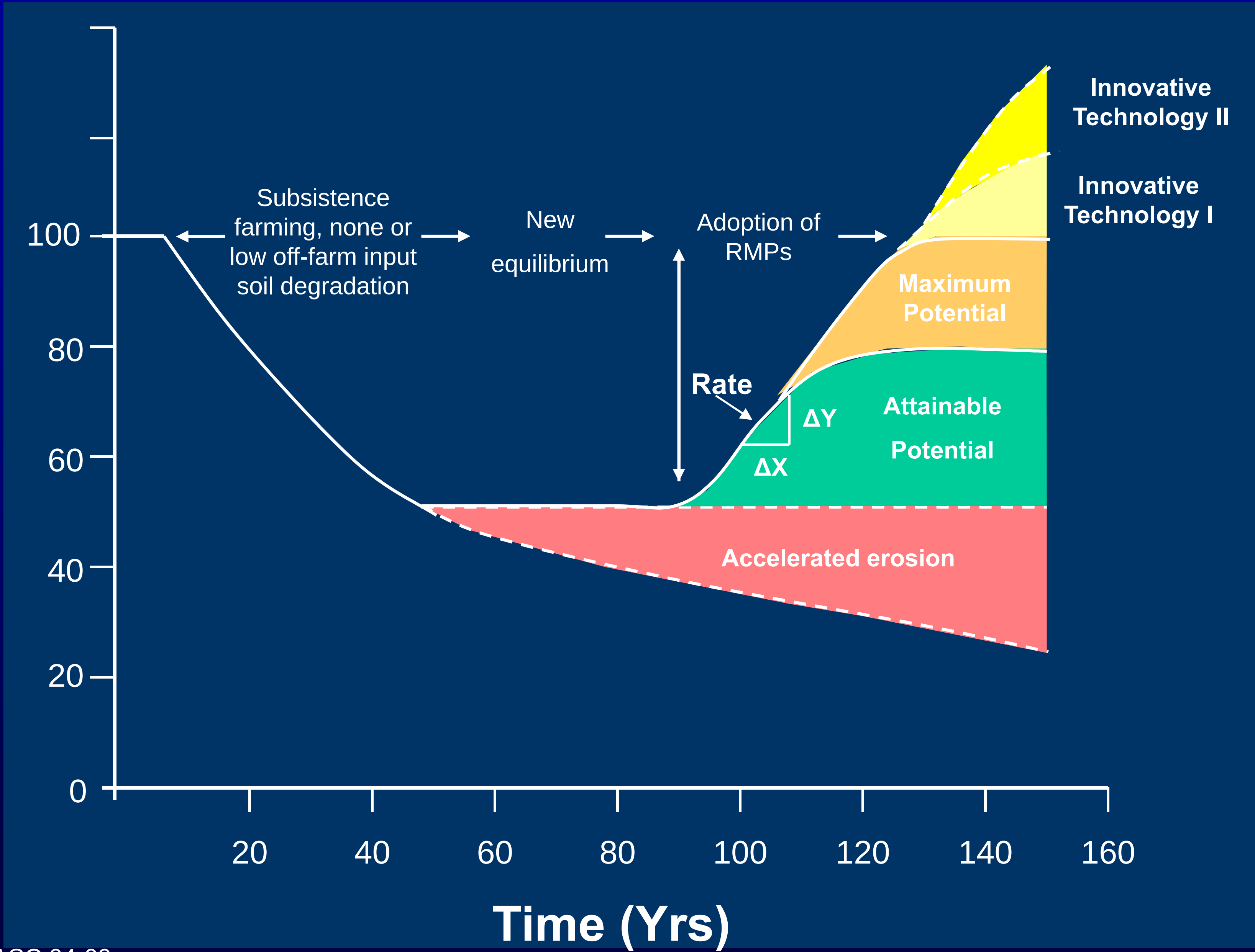
b = with dietary change

SOIL CARBON SEQUESTRATION

Transfer of atmospheric CO_2 into soil C pool as:

- Soil organic carbon (SOC)
- Pedogenic carbonates

Center Carbon Sequestration



Innovative Technology II
Innovative Technology I
100
80
60
40
20
0
Subsistence farming, none or low off-farm input soil degradation
New equilibrium
Adoption of RMPs
Maximum Potential
Rate
ΔY
ΔX
Attainable Potential
Accelerated erosion
20
40
60
80
100
120
140
160
Time (Yrs)

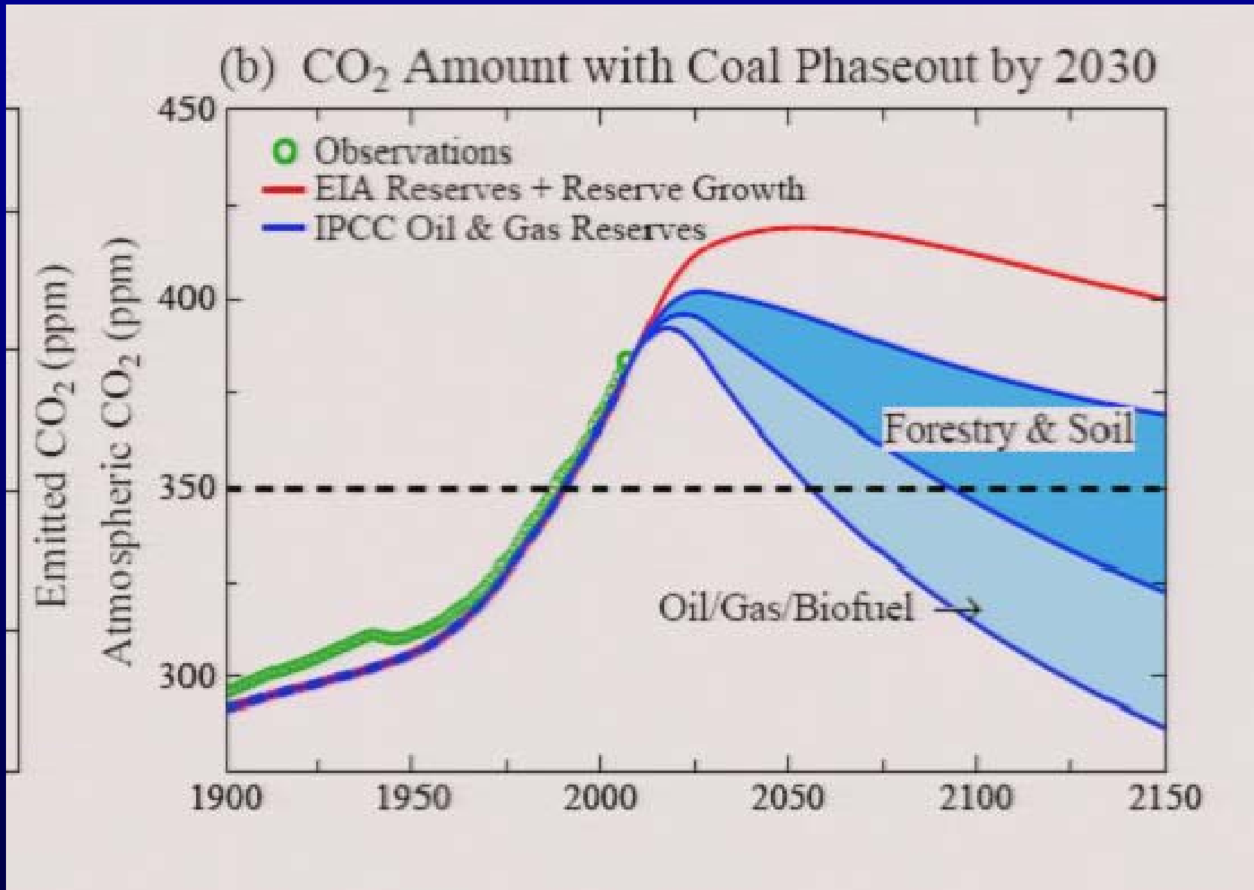
Lal, 2004

CAPACITY OF TERRESTRIAL CARBON SINK

- Historic Loss from Terrestrial Biosphere =
  456 Gt with 4 Gt of C emission = 1 ppm of CO_2
- The Potential Sink of Terrestrial Biospheres = 114 ppm
- Assuming that up to 50% can be resequestered = 45 – 55 ppm

- Cropland Soils: 1 Gt/yr
- Rangeland Soils: 1 Gt/yr
- Restoration of Degraded/Desertified: 1 Gt/yr
- Drawdown: 50 ppm of CO_2 over 50 years

POTENTIAL OF MITIGATING ATMOSPHERIC CO_2



(Hansen, 2008)

FOOD GAP BY REGIONS

Region	Food Gap 2000	Food Gap 2010
	- - - - - - - - - - 10^6 Mg/yr	- - - - - - - - - -
Sub-Saharan Africa	10.7	17.50
Latin America	0.63	0.99
Asia	1.70	3.63
Others	0.17	0.18
Total of 67 countries	13.20	22.30

(Shapouri, 2005)

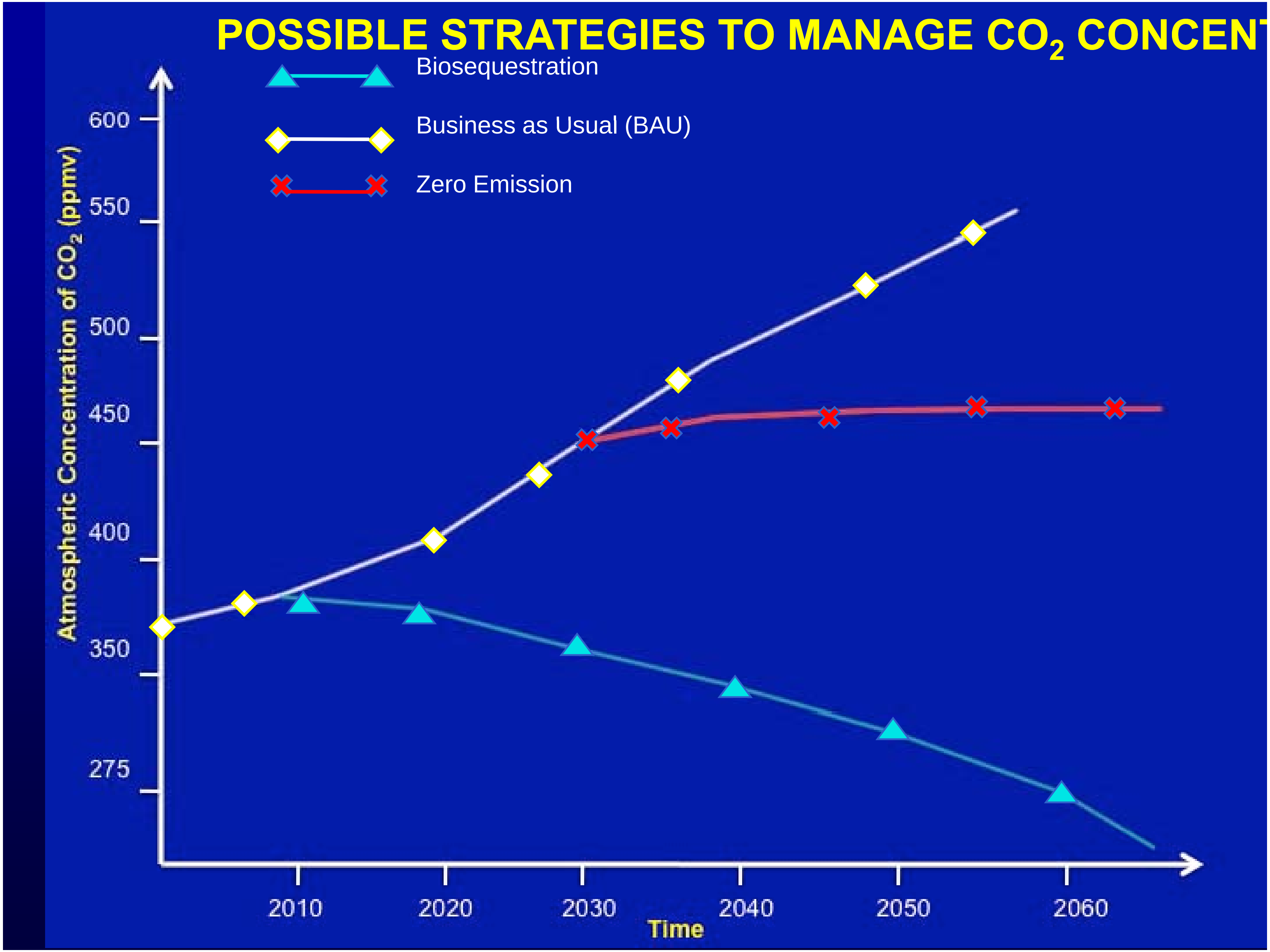
INCREASE IN FOOD PRODUCTION IN LDCS BY INCREASING SOC POOL BY 1 Mg C ha^{-1} yr^{-1}

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

Carbon Center sequestration

ESTIMATED INCREASE IN FOOD PRODUCTION IN AFRICA BY INCREASE IN SOC POOL BY 1 mg/ha/yr

Type	Total Annual Increase (10^6 Mg/yr)
Grains	3.3-5.4
Roots and Tubers	3.0-6.2
Total	6.3-11.6
Total in Developing Countries	24-62


POSSIBLE STRATEGIES TO MANAGE CO2 CONCENT
Biosequestration
Business as Usual (BAU)
Zero Emission
Atmospheric Concentration of CO2 (ppmv)
600
550
500
450
400
350
275
2010
2020
2030
2040
2050
2060
Time

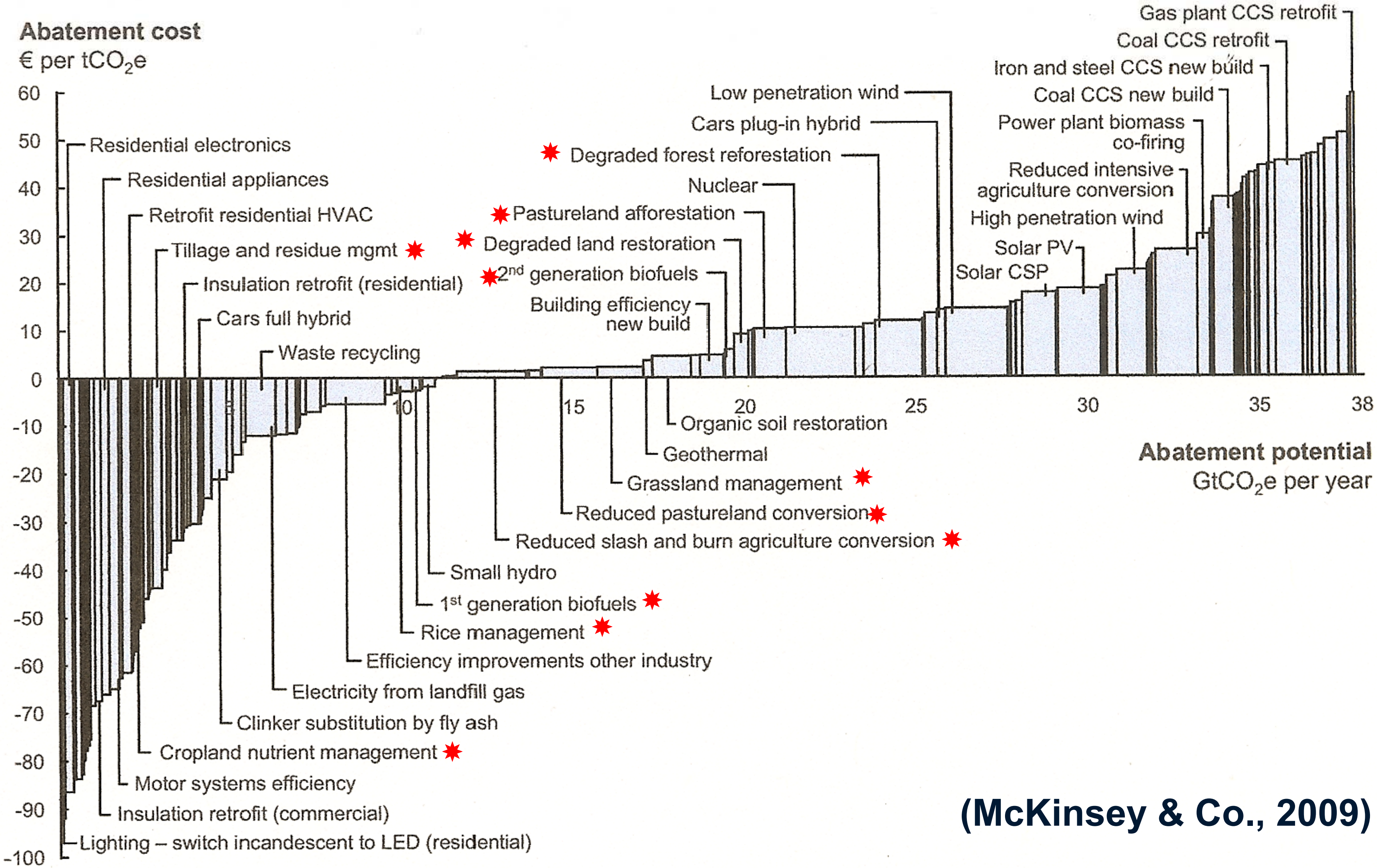
COMMODITIZATION OF SOIL C

How can soil C be made a commodity that can be traded like any other farm product?

TRADING C CREDITS

The C market may reach $ trillion by 2020. We need to make this market accessible to land managers.

Global GHG abatement cost curve beyond business-as-usual – 2030



(McKinsey & Co., 2009)

Price of CCS = \$100-150/t CO_2 (Harvard Kennedy School, 2009)

Total C Pool in World Soils (Janzen, 2005)

Ecosystem	Organic C Pool (Pg C to 1-m depth)			
	Range	Mean	% of Total	Flux (Gt C/yr)
Total in world soils	1395-2011	1580	100	60
Cropland soils	128-168	152	9.6	3
Grassland/Savannas	279-559	425	26.9	26
Plantations	-	90	5.7	5
Forests	-	704	44.5	17

57%

Farmers and the Environment

Farmers have custody of more environment than does any other group.

Farmers can address more global issues than any other group

CLIMATE CHANGE
- Mitigation
- Adaptation
FOOD SECURITY
- Quantity
- Quality
SOIL QUALITY & PROCESSES
WATER RESOURCES
- Quantity
- Quality
ENERGY DEMAND
- Use efficiency
- Biofuels

SOIL C AS AN INDICATOR OF CLIMATE CHANGE

There are numerous advantages:

1. It is a familiar property,
2. It involves direct measurement,
3. It can be measured in 4 dimensions (length, width, depth, time),
4. It lends itself to repeated measurements over the same site,

SOIL C AS AN INDICATOR OF CLIMATE CHANGE (Contd.)

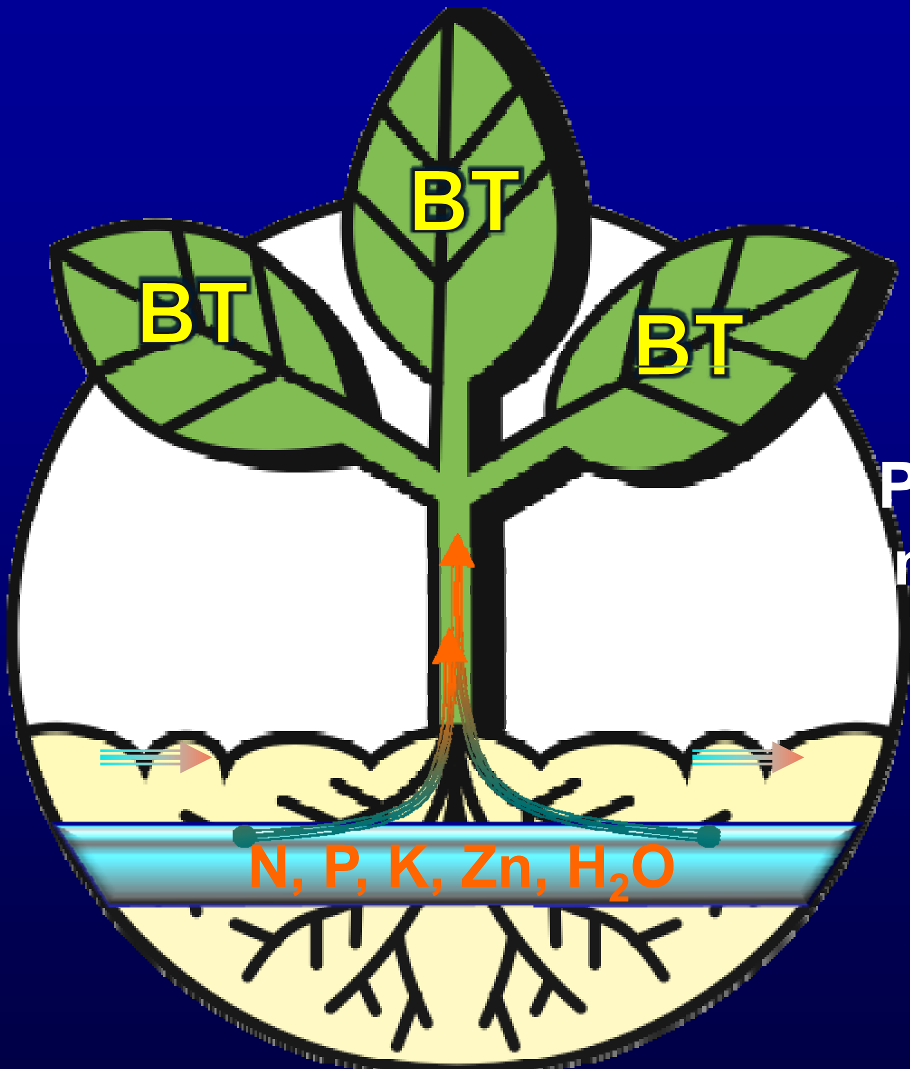
5. It is linked to ecosystem performance and services,
6. It is a key driver of soil formation,
7. It is important to soil fertility,
8. It has memory,
9. It has well defined properties,

SOIL C AS AN INDICATOR OF CLIMATE CHANGE (Contd.)

10. It can be used in synergism with other indicators,
11. Its uncertainty can be quantified,
12. Its pathways across the landscape can be followed,
13. It is an important archive of paleo-environmental conditions.

AGRICULTURAL INTENSIFICATION

Nano-enhanced Materials



Plants which emit molecular-based signals

Delivering nutrients of improved and water directly to roots plants

AGRONOMIC KNOWLEDGE TO PRODUCE FOOD

- We know how to double the production in South Asia, and quadruple in the SSA.

- It is a question of social, cultural and political issues and how to address them.

- Observe basic laws of soil management

SUGGESTIONS FOR POLICY MAKERS (SHORT-TERM 30 YRS)

If the objective to mitigate CO_2 and global warming policy makers may be better advised to focus on the following:

(i) Increase the efficiency of fossil fuel use,

(ii) Conserve the existing forest and savannahs,

(iii) Restore natural forests and grasslands or croplands that is not needed,

(iv) Restore soil C pool, and

(v) Trade C credits.

SUGGESTIONS FOR POLICY MAKERS (LONG-TERM >50 YRS)

Non-C Fuel Technology

(H_2)

LAW #1

CAUSES OF SOIL DEGRADATION

- The biophysical process of soil degradation is driven by economic, social and political forces.

- Vulnerability to degradation depends on “how” rather than “what” is grown.

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LAW #2
SOIL STEWARDSHIP AND HUMAN SUFFERING

- When people are poverty stricken, desperate and starving, they pass on their sufferings to the land.

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Law #3
NUTRIENT, CARBON AND WATER BANK

- It is not possible to take more out of a soil than what is put in it without degrading its quality.

- Only by replacing what is taken can a soil be kept fertile, productive, and responsive to inputs.

LAW #4

MARGINALITY PRINCIPLE

- Marginal soils cultivated with marginal inputs produce marginal yields and support marginal living.

- Recycling is a good strategy especially when there is something to recycle.

LAW #5

ORGANIC VERSUS INORGANIC SOURCE OF NUTRIENTS

- Plants cannot differentiate the nutrients supplied through inorganic fertilizers or organic amendments.

LAW #6
SOIL CARBON AND GREENHOUSE EFFECT

- Mining C has the same effect on global warming whether it is through mineralization of soil organic matter and extractive farming or burning fossil fuels or draining peat soils.

- Soil can be a source or sink of GHGs depending on land use and management.

LAW #7
SOIL VERSUS GERMPLASM

- The potential of elite varieties can be realized only if grown under optimal soil conditions.

- Even the elite varieties cannot extract water and nutrients from any soil where they do not exist.

Law #8

SOIL AS A SINK FOR ATMOSPHERIC CO_2

- Soil are integral to any strategy of mitigating global warming and improving the environment.

LAW #9
ENGINE OF ECONOMIC DEVELOPMENT

- Sustainable management of soils is the engine of economic development, political stability and transformation of rural communities in developing countries.

Law #10

TRADITIONAL KNOWLEDGE AND MODERN INNOVATIONS

- Sustainable management of soil implies the use of modern innovations built upon the traditional knowledge.

- Those who refuse to use modern science to address urgent global issues must be prepared to endure more suffering.

GANDHI'S 7 SINS OF HUMANITY.

1. Wealth without work
2. Pleasure without conscience
3. Knowledge without character
4. Commerce without morality
5. Politics without principle
6. Religion without sacrifice
7. Science without humanity

SINS OF HUMANITY CONTINUED…

8. Technology without wisdom

9. Education without relevance

10. Humanity without conscience