Climate Challenges: How to Reduce GHG Emissions

Minimize New Emissions

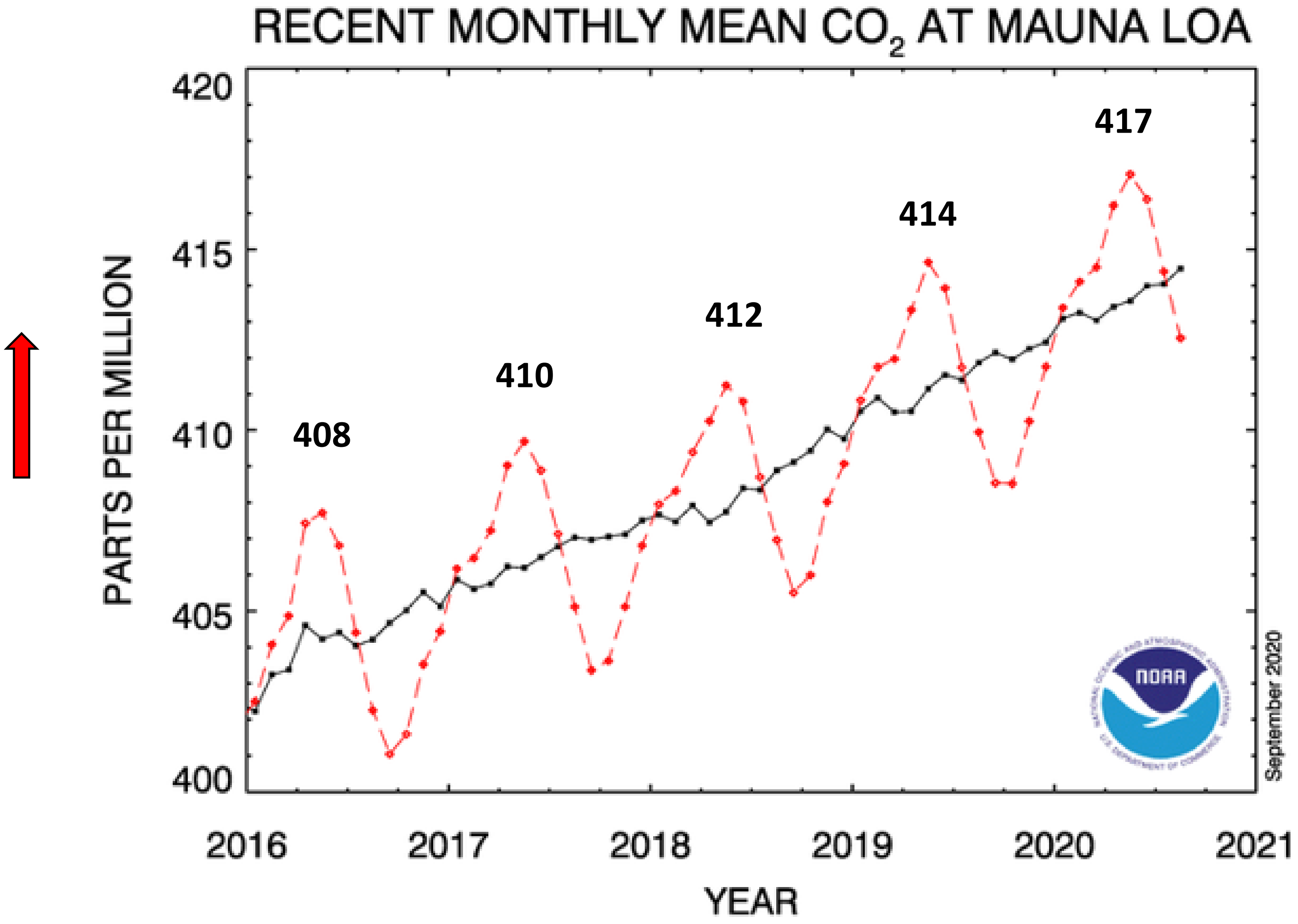
Remove CO_2 from Atmosphere

Adaptations Options

Reduce Population Demand
Consumption, Transport
& Change Behaviour
Reduce Meat Consumption

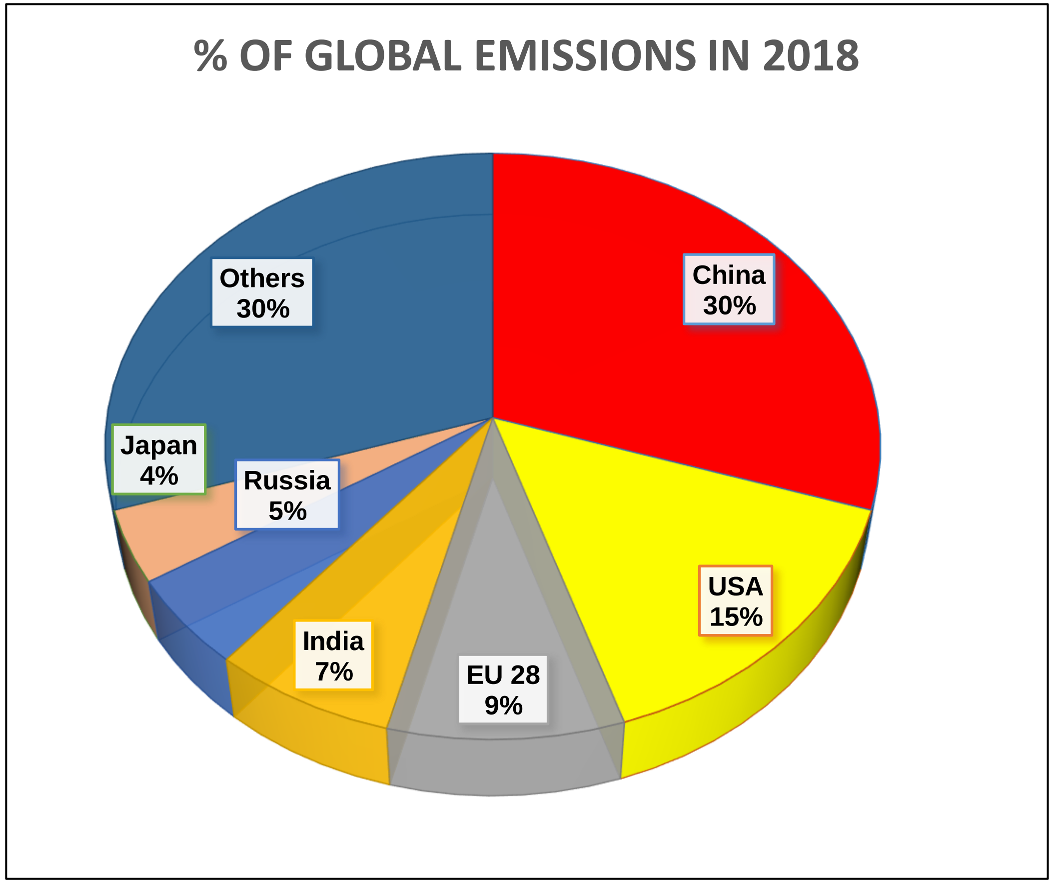
Technological Option
Land Use Changes
Enhancing Natural Processes

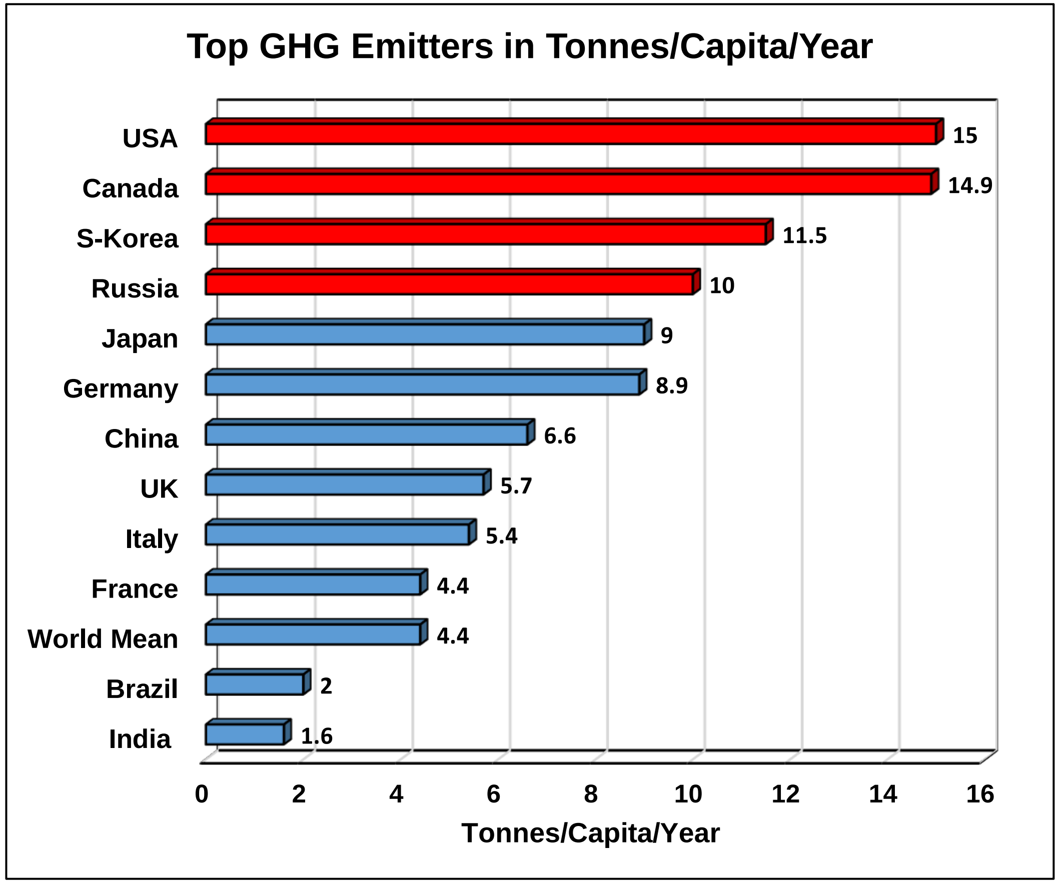
Greenhouse Gas Emissions (GHG)



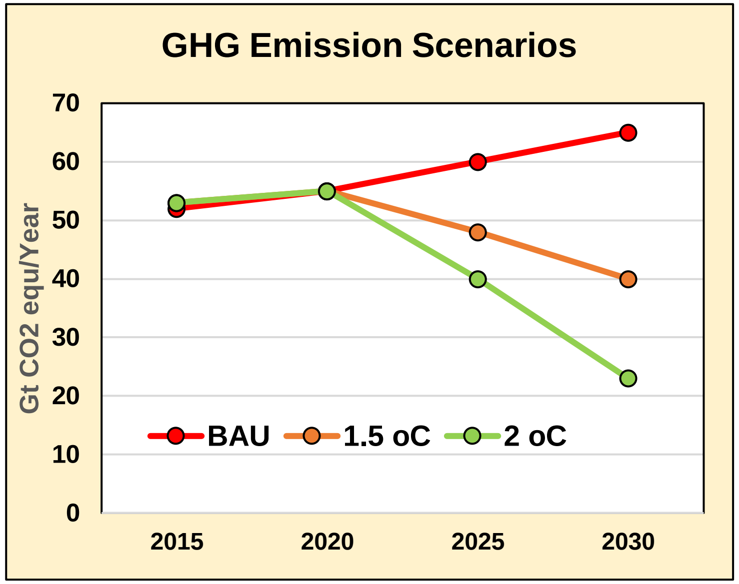
Data Source: NOAA 2020

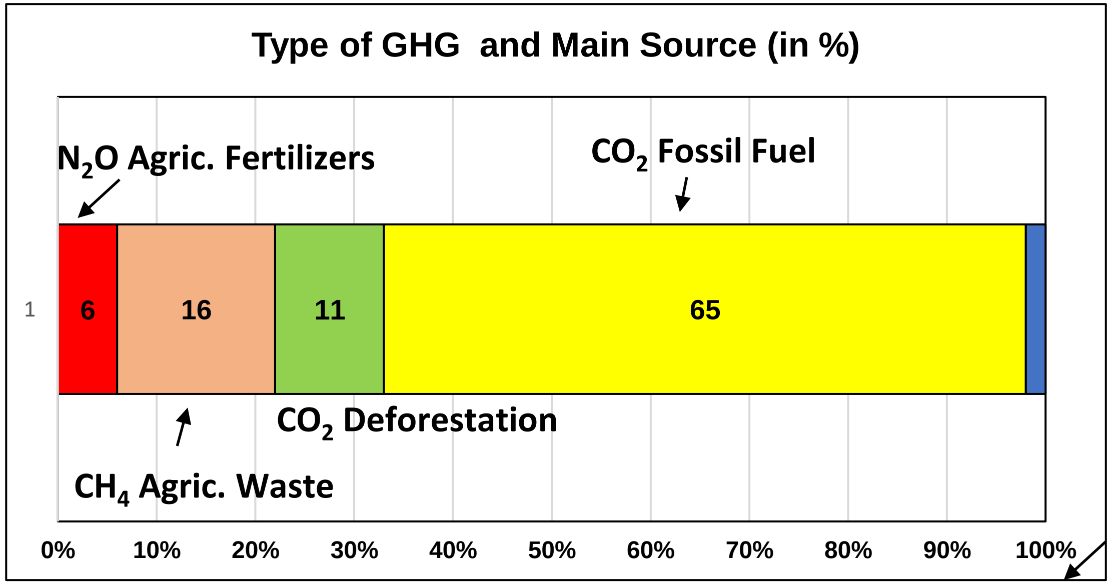
Total and Per Capita GHG Emissions





Greenhouse Gas Emissions Sources & Scenarios





1979-2000 = 1.3% increase in CO2
2000-2010 = 2.2% increase in CO2
2018 = 2.7% increase in CO2

2018 Emissions 55 Gt CO2

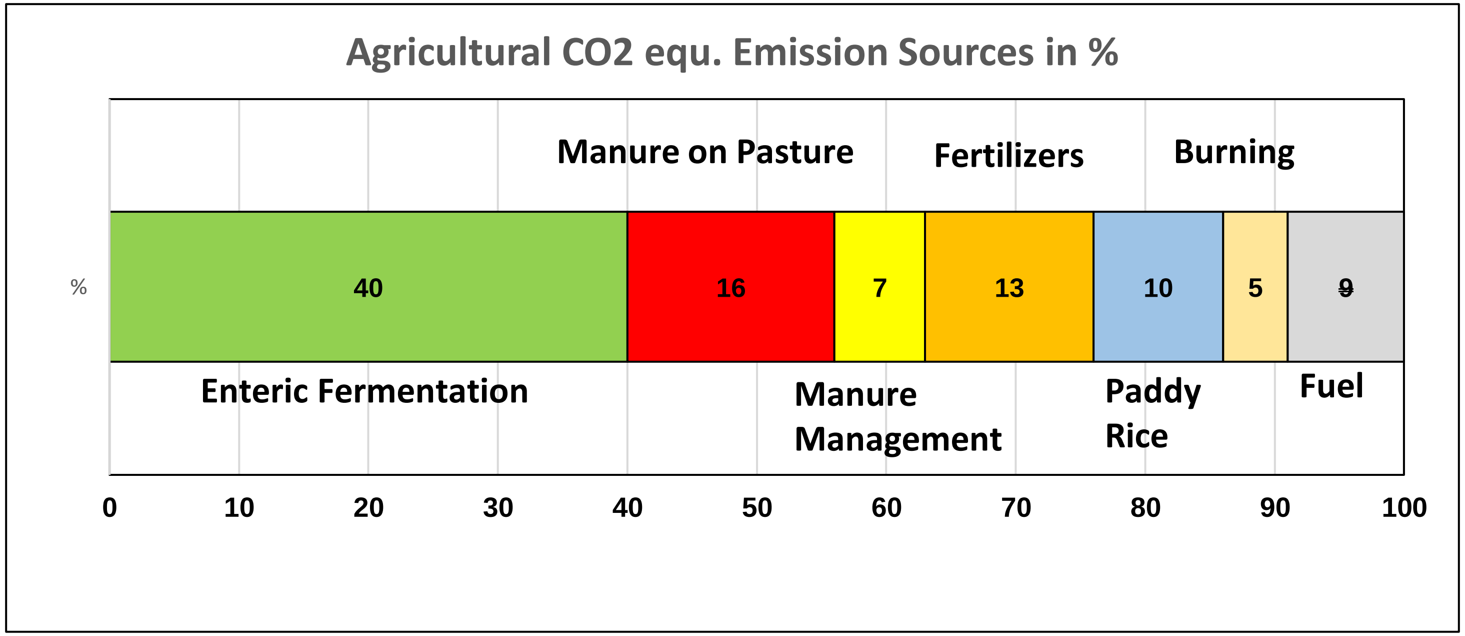
5 Gt from Land Use Changes

Adapted from: UN Environment, Emission Gap Report 2018

Required Reduction By 2030 (Based on 2017 Emissions)

25% to meet 1.5 °C Target
55% to meet 2.0 °C Target

CO2 Emission from Agriculture : 11-14% of Total CO2 equ. Emissions



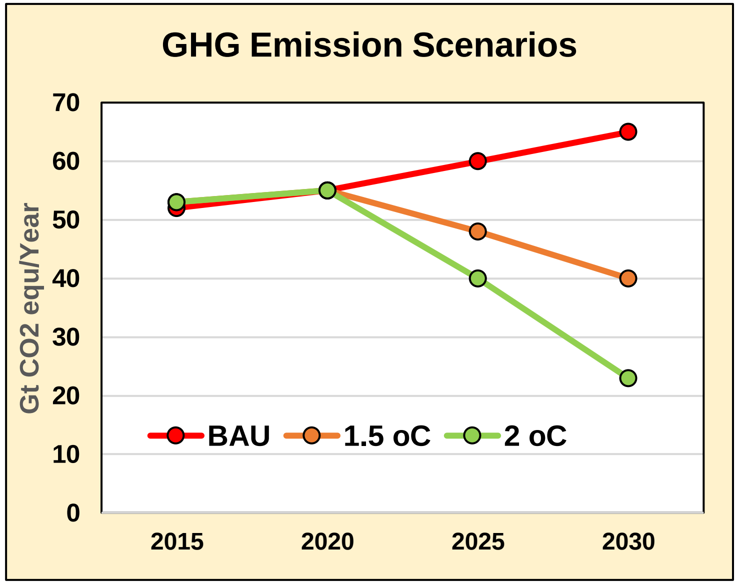
Reduce Emissions

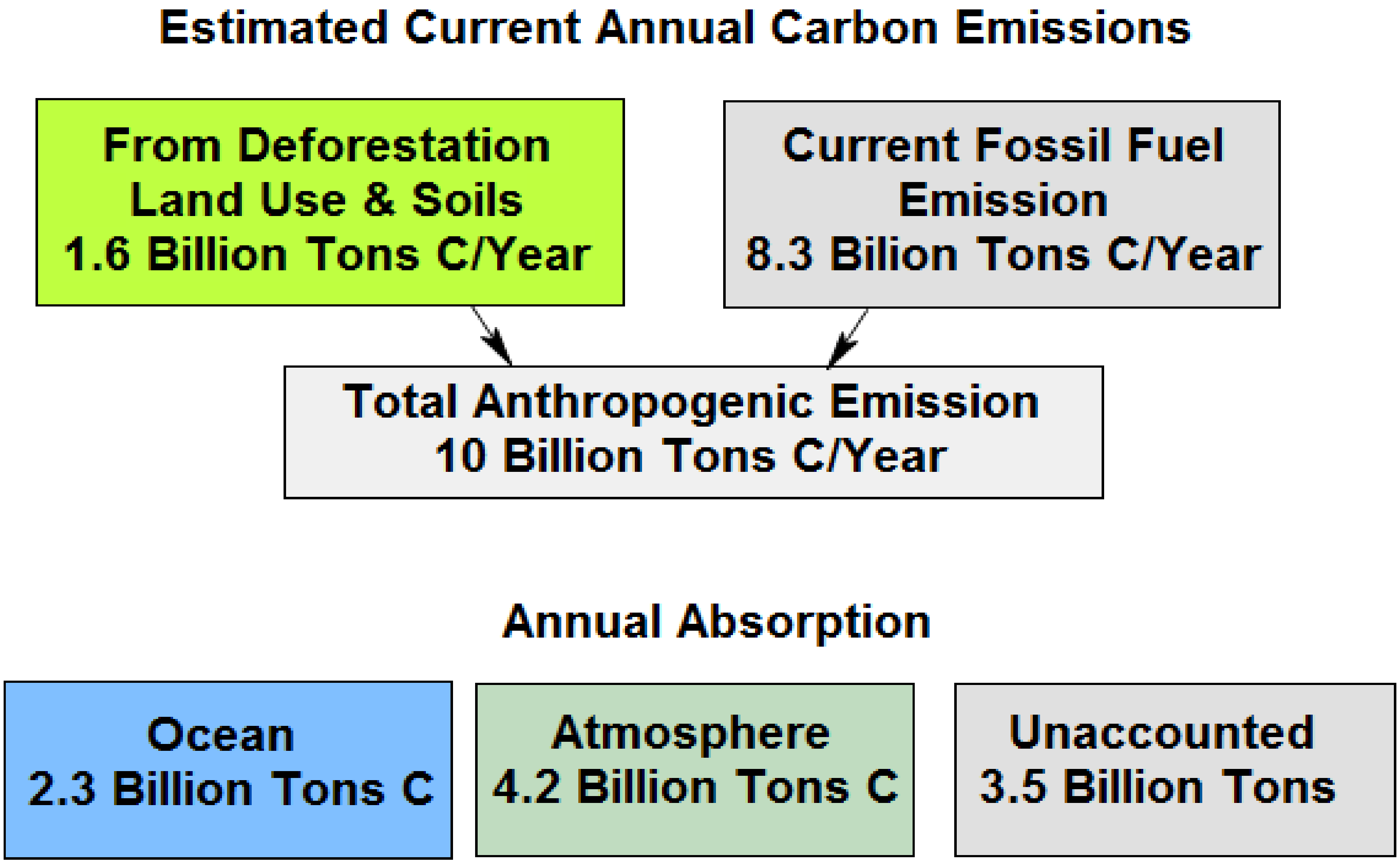
Reduce Fossil Fuel Use
Car Use & Air Travel
Change Heating & Cooling Systems
Change Diet, Less Meat
Change Consumption

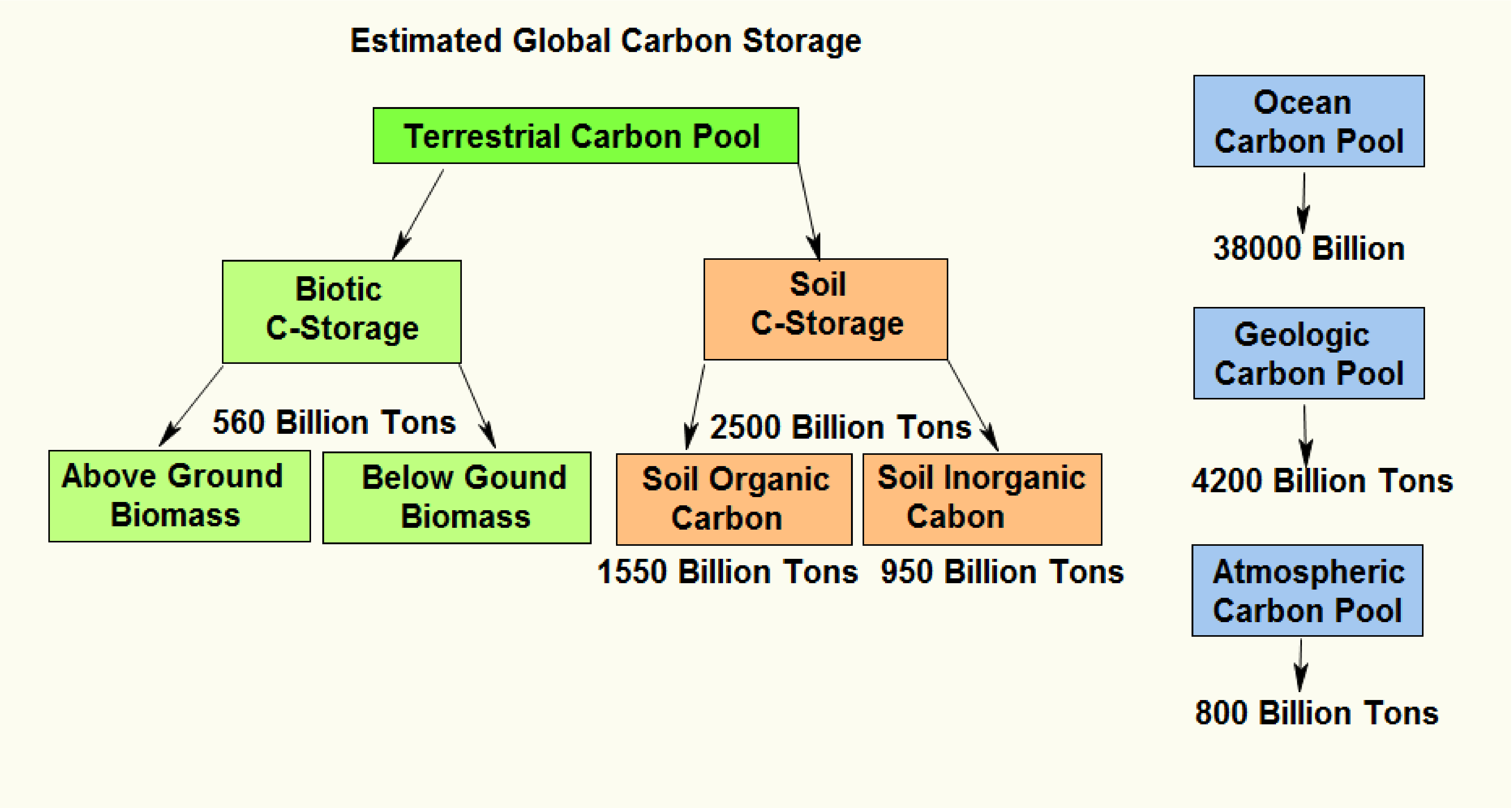
Remove CO2 from Atmosphere

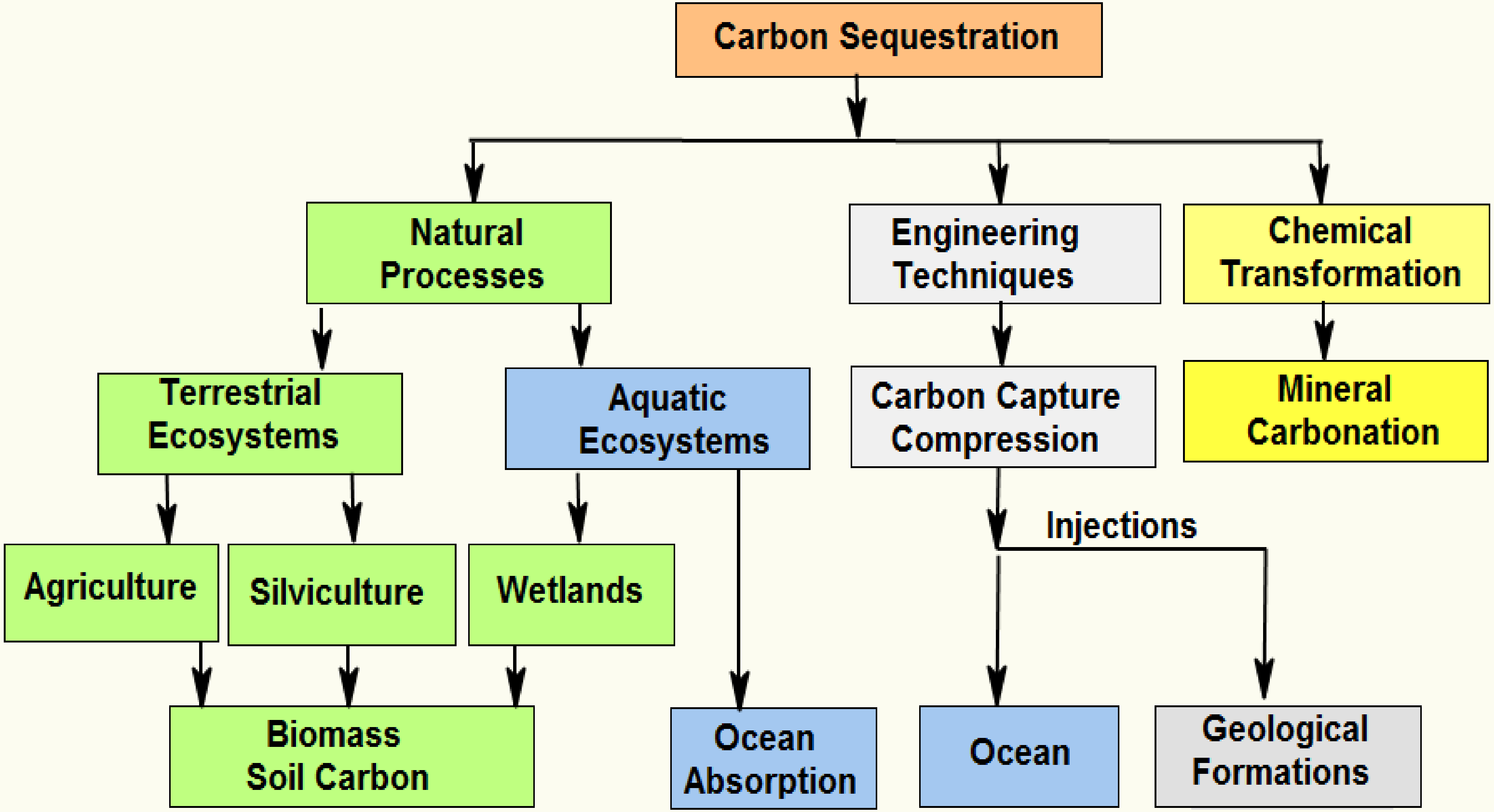
Current Emissions 55 GT CO2 equ./Year

Annual Reduction Requirement
1.3 Gt/Year to Reach 40 Gt by 2030 (1.5 oC)
3 Gt/Year to Reach 22 Gt by 2030 (2 oC)




Estimated Current Annual Carbon Emissions
From Deforestation Land Use & Soils 1.6 Billion Tons C/Year
Current Fossil Fuel Emission 8.3 Bilion Tons C/Year
Total Anthropogenic Emission 10 Billion Tons C/Year
Annual Absorption
Ocean 2.3 Billion Tons C
Atmosphere 4.2 Billion Tons C
Unaccounted 3.5 Billion Tons


Estimated Global Carbon Storage
Terrestrial Carbon Pool
Biotic C-Storage
560 Billion Tons
Above Ground Biomass
Below Gound Biomass
Soil C-Storage
2500 Billion Tons
Soil Organic Carbon
1550 Billion Tons
Soil Inorganic Cabon
950 Billion Tons
Ocean Carbon Pool
38000 Billion
Geologic Carbon Pool
4200 Billion Tons
Atmospheric Carbon Pool
800 Billion Tons



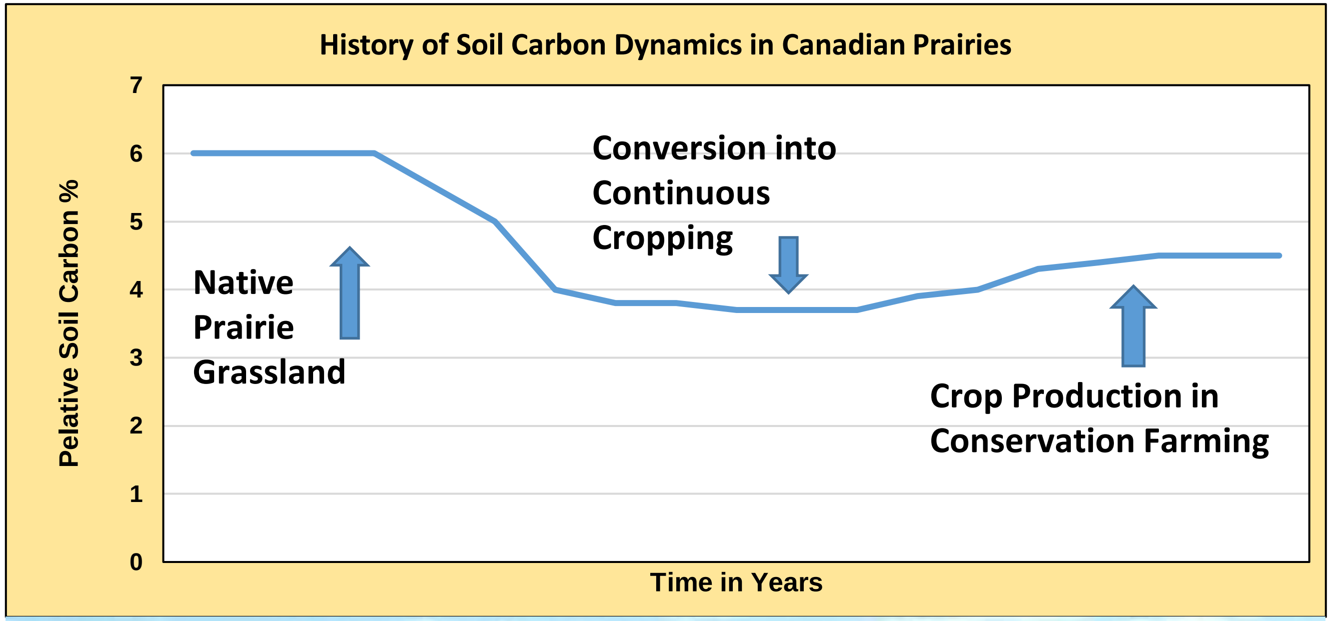
Based on Lal, 2013 Solaw Background Report TRO4B, FAO

Different Soils Have Different Soil Organic Matter Content

Some of the Best Soils are in the USA & Canadian Prairies ,Ukraine & Russia

The Conversion of these Grasslands into Conventional Agriculture resulted in 30-50% Losses of Soil Carbon

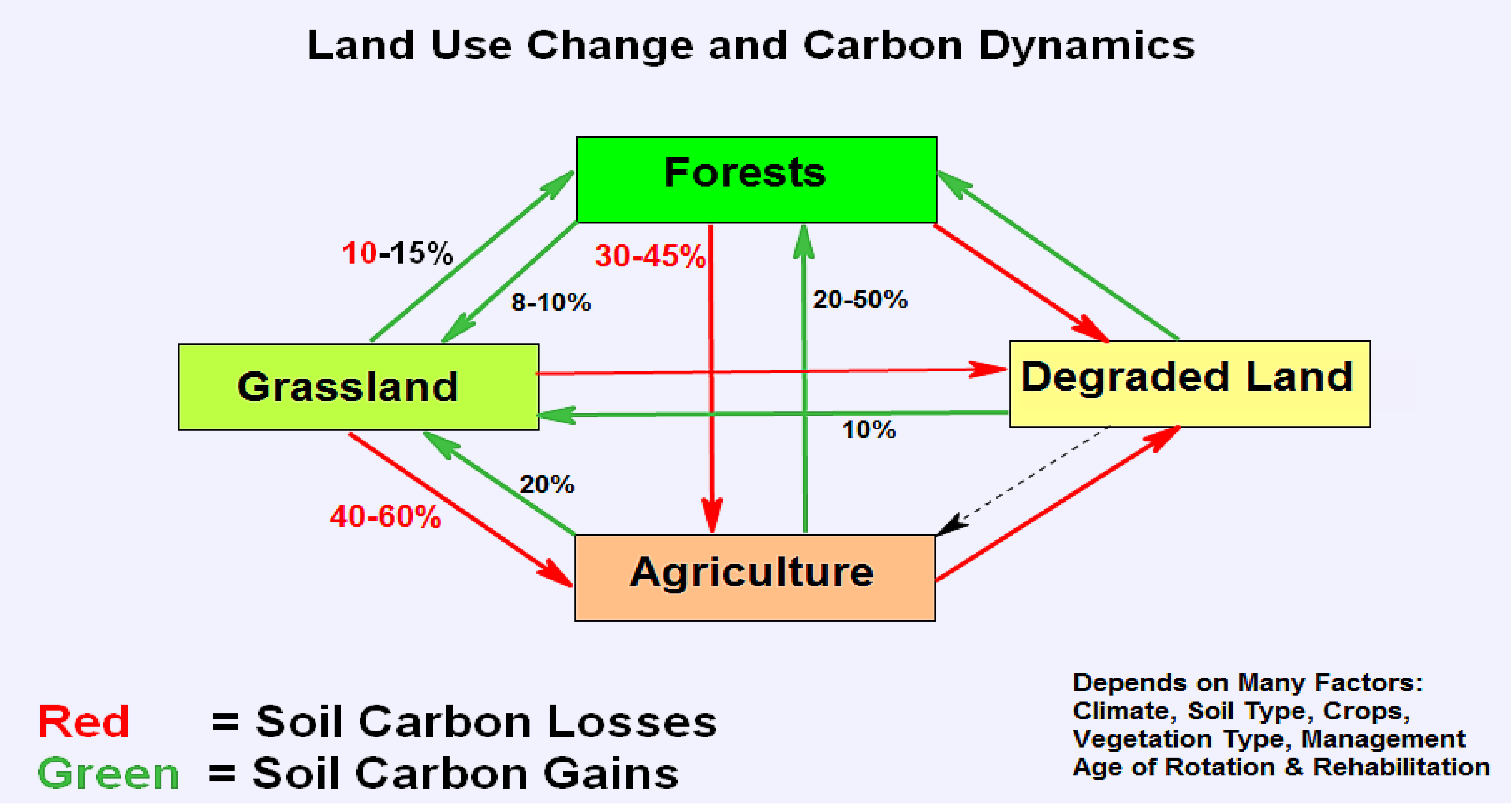
Carbonate Rich, Semi Arid Environment



Prairies = 80% of Canadian Farmland

Moving from Conventional Till to No Till
Over 5 Years would save
10% of Agric. CO_2 Emission
Would increase Soil C from
1.2-1.7 Million Mg C

Carbon Sequestration



Increase Soil Carbon

- Greater Biomass Production (Above & Below Ground)
- Fertilization, Irrigation, BMP
- Organic Matter Additions
- Plant & Crop Rotation
- Add Legumes & Diversify Species
- Green Manure & Agro-Forestry
- Improve Grazing Land Management

Decrease Losses & Erosions

- Reduce Tillage & Disturbance
- Maintain Vegetation Cover and Minimize Soil Compaction (Less Erosion, Better Soil Quality)
- Provide Favorable Conditions For Stable Carbon Formation
- Maintain Anaerobic Conditions in Wetlands & Peatland

Soil Carbon Gains

Crops - Grass	= 1.0 Mg C/ha/Year
Forest - Grass	= 0.68 Mg C/ha/Year
Crops - Forest	= 0.45 Mg C/ha/Year

Soil Carbon Losses

Grass - Crop	= 0.89 Mg C/ha/Year
Forest - Crops	= 1.74 Mg C/ha/Year
Forest - Plantation	= 0.62 Mg C/ha/Year

Decomposition is Determined by:

Temperature, Moisture, Drainage, pH, Bacterial Activity, Clay Mineralogy, Nutrients, C-Stabilizing Processes

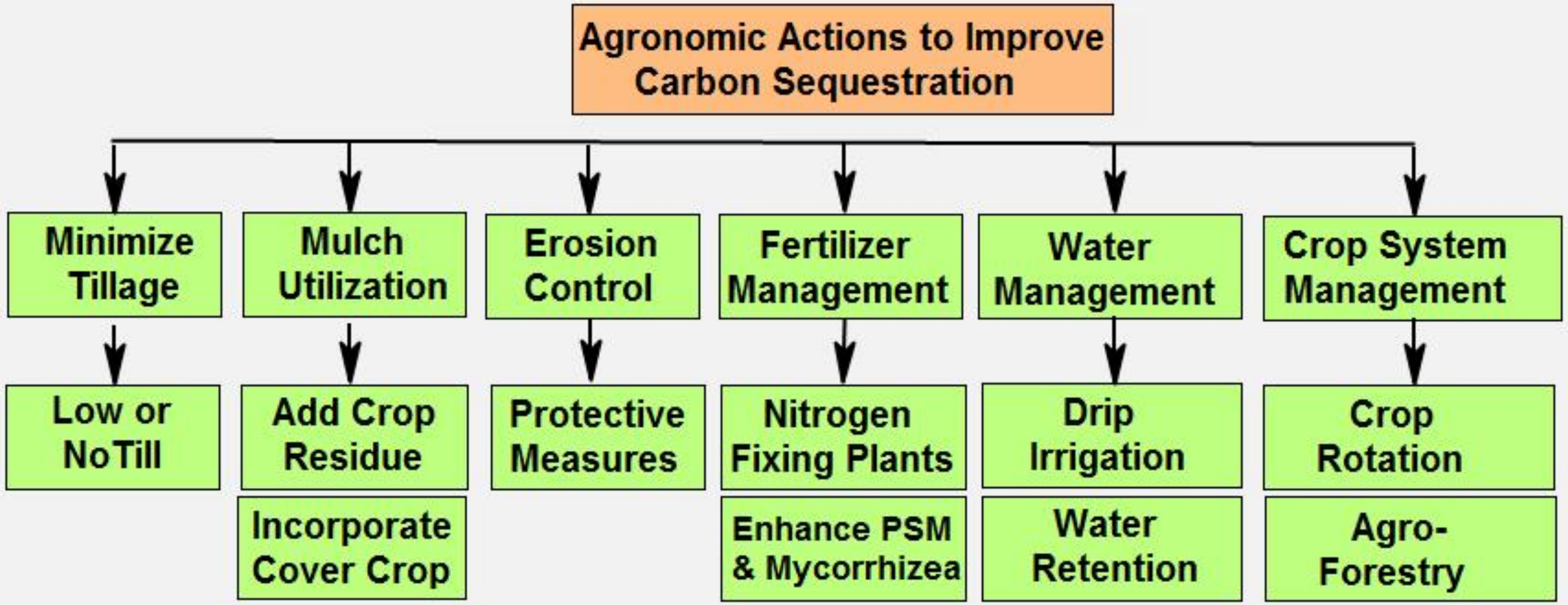
Example: Comparison of Soil C after 20 Year Corn vs. Poplar Plantation

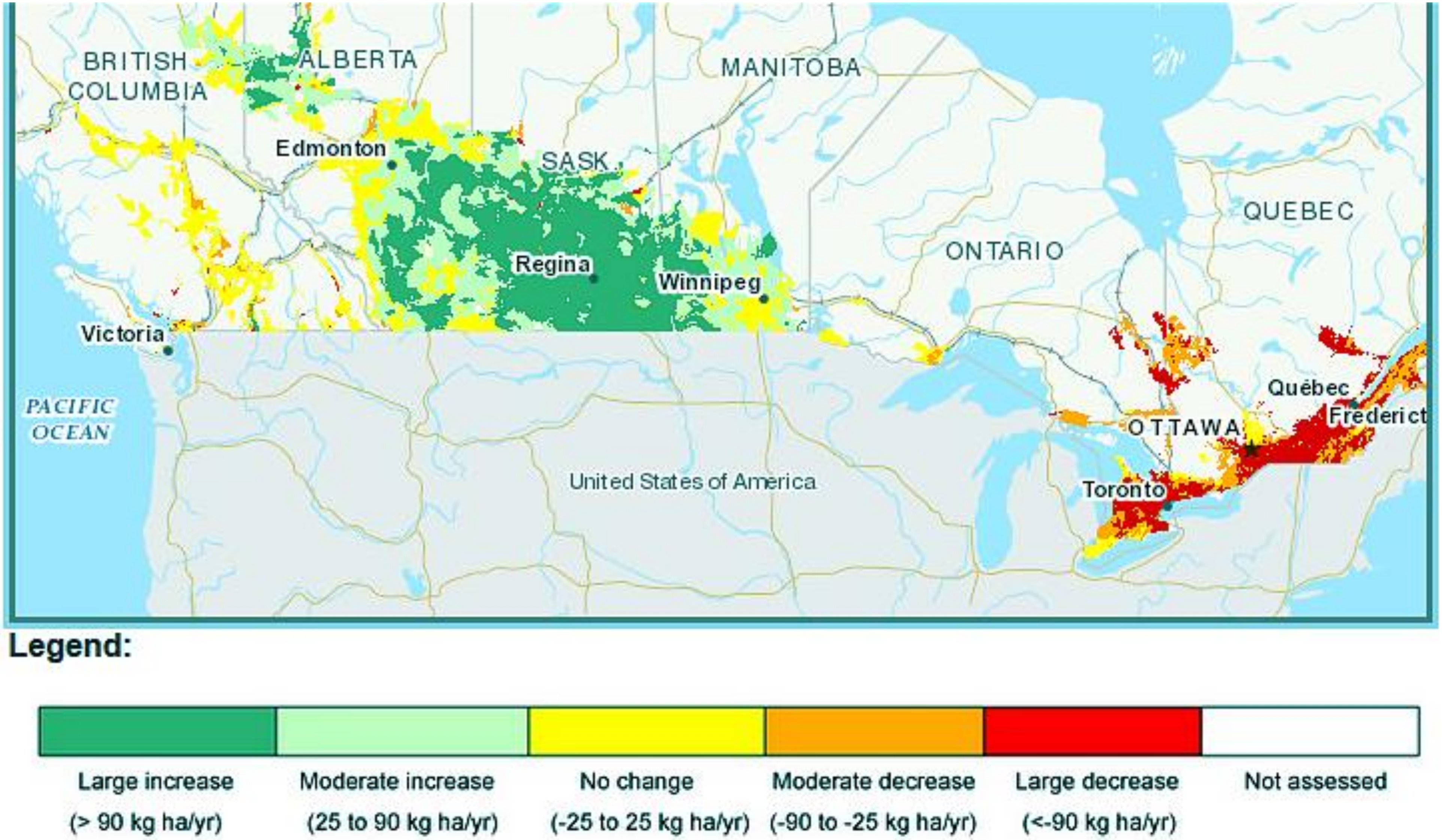
Soil Depth	Corn	Poplar
	g C / Kg Soil	
0-20cm	0.18	0.23
20-50cm	0.15	0.16
50-100cm	0.10	0.12

Soil Depth	Corn	Poplar
	Stable C in %	
0-20cm	24	34
20-50cm	30	38
50-100cm	40	47

Conservation Efforts (Carbon Farming) can reduce 0.5 ppm CO2 equ./Year = 50 ppm/100 Years

Best Options : Rehabilitate Degraded Grassland (high C- Sequestration)
Modest Option : Degraded Cropland (50% C Saturated)
Lower Option : Forest Rehabilitation (C-Saturated- Low Sequestration Potential)


Agronomic Actions to Improve Carbon Sequestration
Minimize Tillage
Mulch Utilization
Erosion Control
Fertilizer Management
Water Management
Crop System Management
Low or NoTill
Add Crop Residue
Incorporate Cover Crop
Protective Measures
Nitrogen Fixing Plants
Enhance PSM & Mycorrhizea
Drip Irrigation
Water Retention
Crop Rotation
Agro-Forestry



Data Source: Agriculture & Agri-Food Canada 2012 and Environment Canada. National Inventory Report 1990-2011, GHG Sources & Sinks in Canada

Conservation & Rehabilitation

Enhance Natural Processes
To Increase Soil Carbon
Reforestation,
Improving Grassland
Rehabilitate all Degraded Areas

Frontier Technologies

Biochar Additions
Perennial Grain Crop Breeding
More Root Forming Crops
Geological Absorption of CO_2
CO_2 Injection into Geo-Formation
Fe Additions to Oceans (uptake)

Potential: Could Sequester 4-5 Gt CO2/Year
Approximatly 10% of Annual Emissions

Potential: Problematic (Knowledge & Cost)
Consensus Fe Ocean Additions is not viable

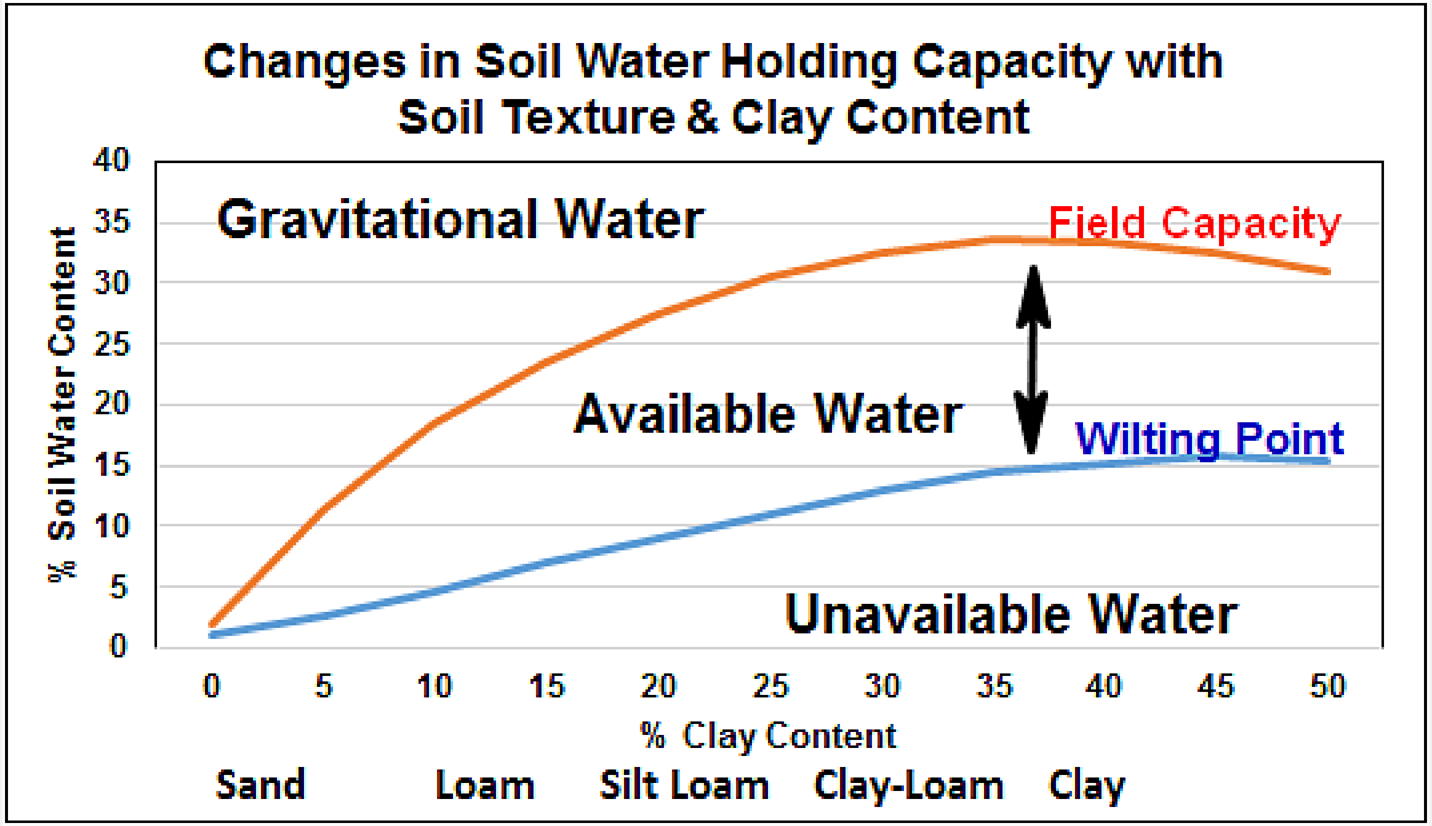
Benefits of Increasing Soil Carbon

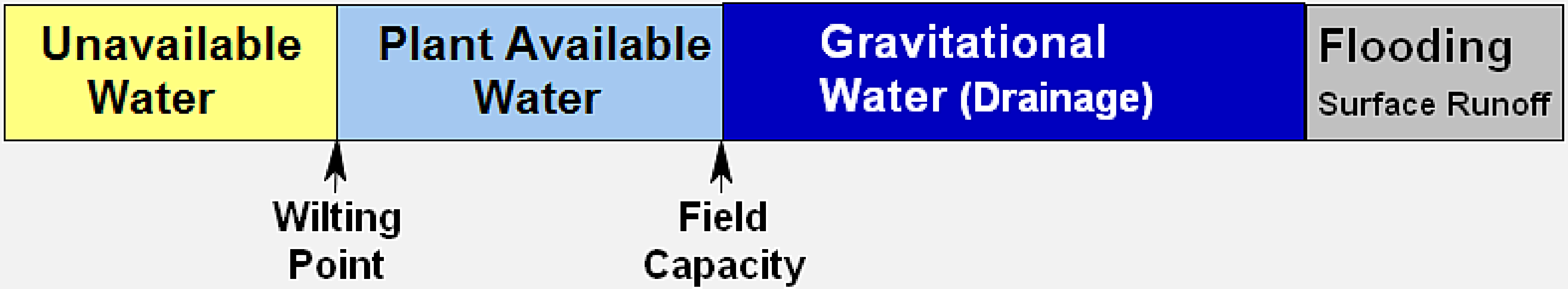
- Reduced CO_2 Emissions
- Improves Ecosystem Services
- Creates a more Diverse and Resilient Ecosystem
- Increases Biomass and Food Production
- Reduces Erosion Degradation and Pollution

The Importance of Soil Carbon

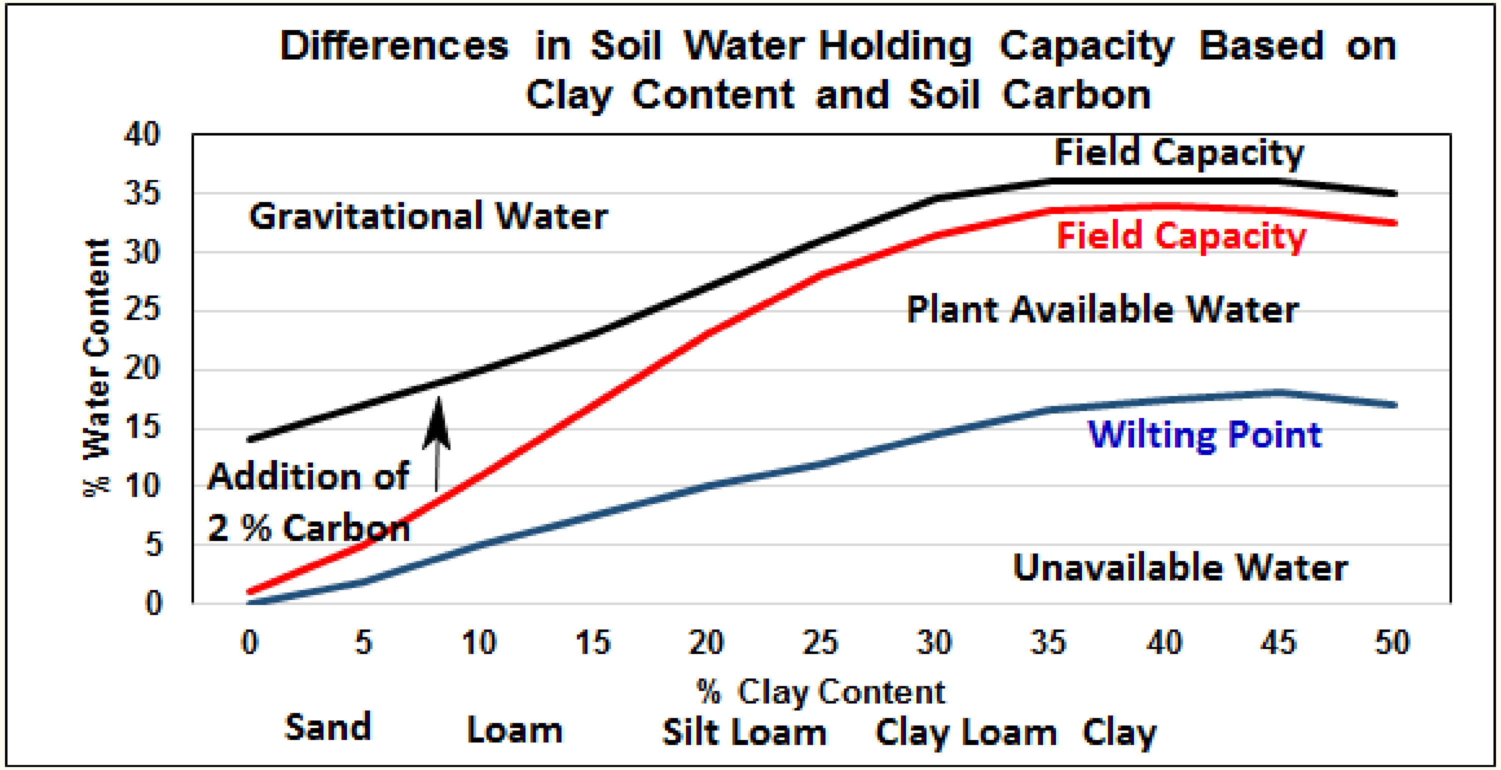
Benefits from Increasing Soil Carbon

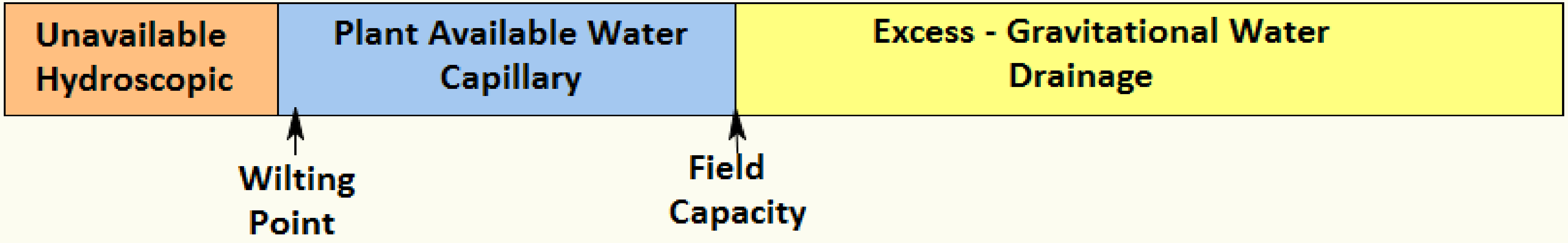
Increases Soil Water Holding Capacity	• Improves Water Availability to Plants • Reduces Plant Stress During Drought • Increases Biomass Production
Increases Soil Nutrient Holding Capacity	• Improves Biomass Production • Makes more N, P, S, Ca, Mg, K, Zn available to Plants • Reduces Leaching and Water Pollution
Increases Microbial Activity	• Enriches Species Diversity • Improves Decomposition and C-Conversion • Provides Nutrients to Plants & Increases Mychorrhizal • Fungi Feeds Water & Nutrients to Adjacent Plants
Improves Water Infiltration Capacity	• Minimizes Surface Runoff, • Reduces Erosion and Suspended Sediments • Reduces Water Logging and Flooding
Converting CO_2 into Soil Storage	• Impoves Biomass Production • Reduces CO_2 Emissions • Converts CO_2 into long term storage


Changes in Soil Water Holding Capacity with
Soil Texture & Clay Content
Gravitational Water
Field Capacity
Available Water
Wilting Point
Unavailable Water
% Soil Water Content
0
5
10
15
20
25
30
35
40
0
5
10
15
20
25
30
35
40
45
50
% Clay Content
Sand
Loam
Silt Loam
Clay-Loam
Clay

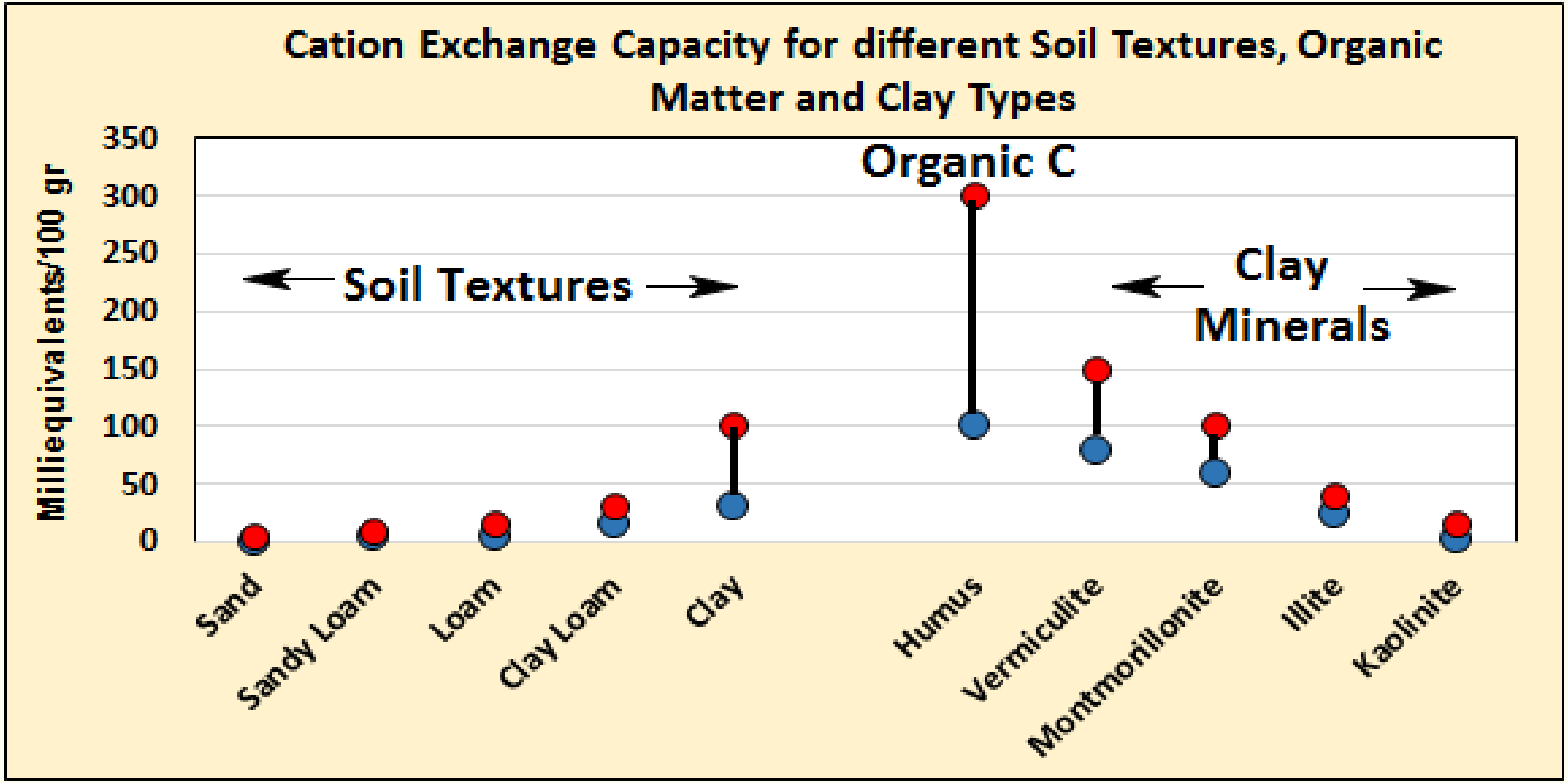

Unavailable Water
Plant Available Water
Gravitational Water (Drainage)
Flooding
Surface Runoff
Wilting Point
Field Capacity

Soil Water Holding Capacity and Potential Increases with Organic Carbon Additions





Nutrient Holding Capacity = Cation Exchange Capacity and Potential Increases with Organic Carbon Additions




bog


fen


swamp


marsh


shallow water

Carbon Stock in Grassland-Shrubland Mountain Ecosystem

Based on A. Ward's PhD Thesis- University of Queensland 2016

60.5-82.8 Billion Tons C
98% in Soil

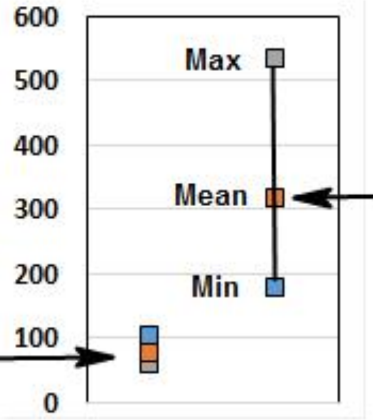
=

< 3% of Global C in Soils

Countries	Area Million ha	Carbon-Stock Billion Tons
China	299	17.5-23.6
Russia	151	12.9-17.8
USA	94	10.5-13.8
Canada	119	5.5-7.6
4 Country Total	663	46.4-62.8
% of Global Total GSL	71%	76%

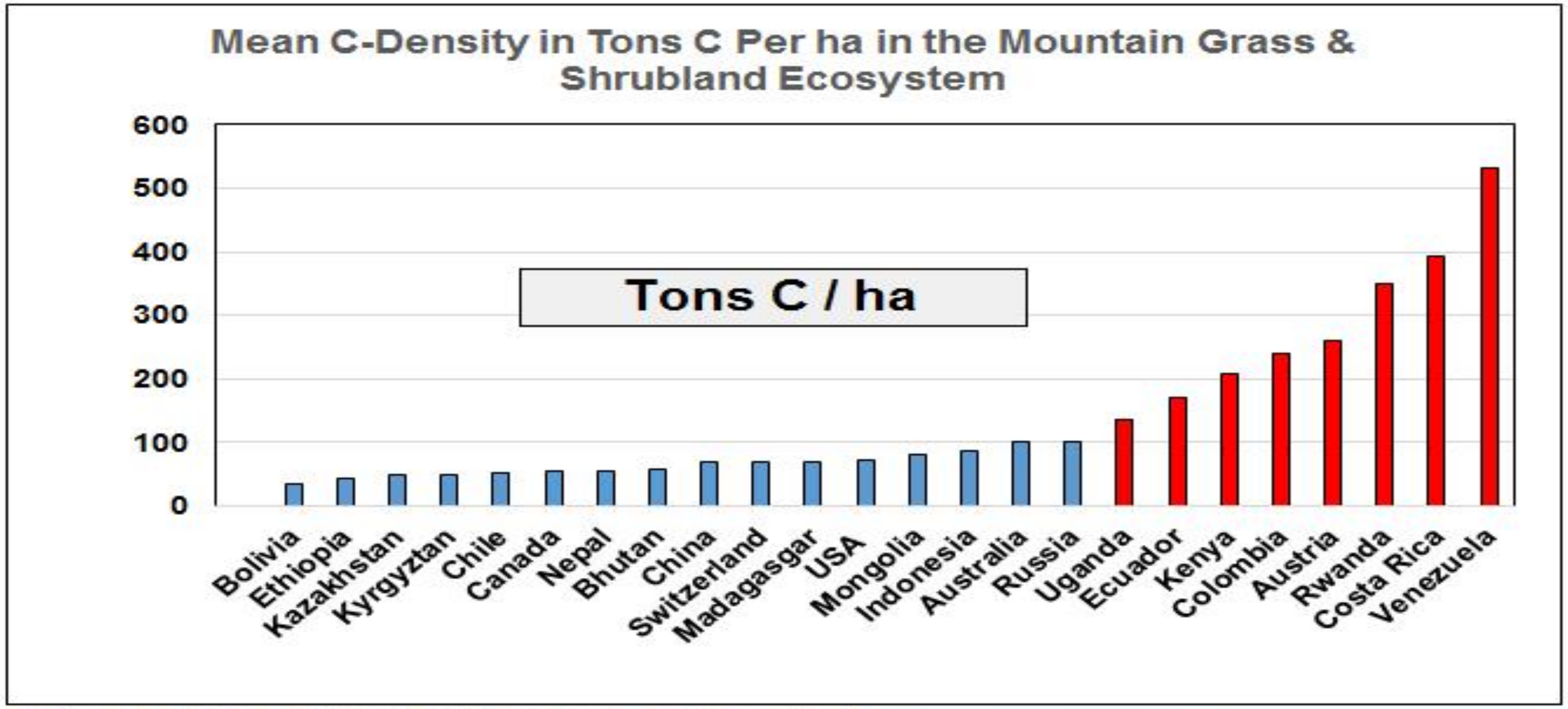
Countries	Area Million ha	Carbon-Stock Billion Tons
Ecuador	1.58	0.22-0.33
Colombia	1.53	0.31-0.43
Venezuela	0.31	0.13-0.20
3 Country Total	3.42	0.66-0.96
% of Global Total GSL	0.36%	1.10-1.16%

Countries	Mean C-Density t C / ha
China	68.7
Russia	101.7
USA	70.6
Canada	58.6



Countries	Mean C-Density t C / ha
Ecuador	171.6
Colombia	239.7
Venezuela	530.2

Global Average	60 t C / ha

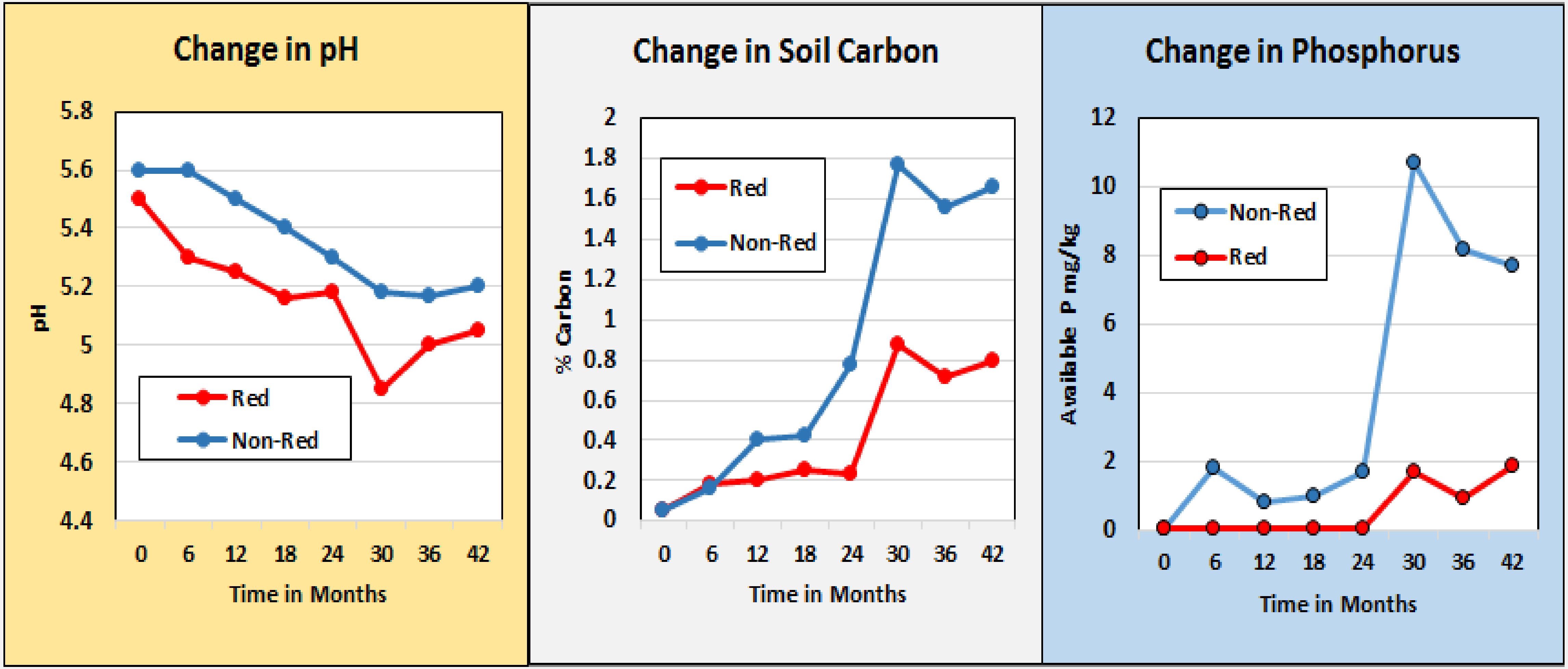

Mean C-Density in Tons C Per ha in the Mountain Grass & Shrubland Ecosystem
Tons C / ha
600
500
400
300
200
100
0
Bolivia
Ethiopia
Kazakhstan
Kyrgyztan
Chile
Canada
Nepal
Bhutan
China
Switzerland
Madagasgar
USA
Mongolia
Indonesia
Australia
Russia
Uganda
Ecuador
Kenya
Colombia
Austria
Rwanda
Costa Rica
Venezuela

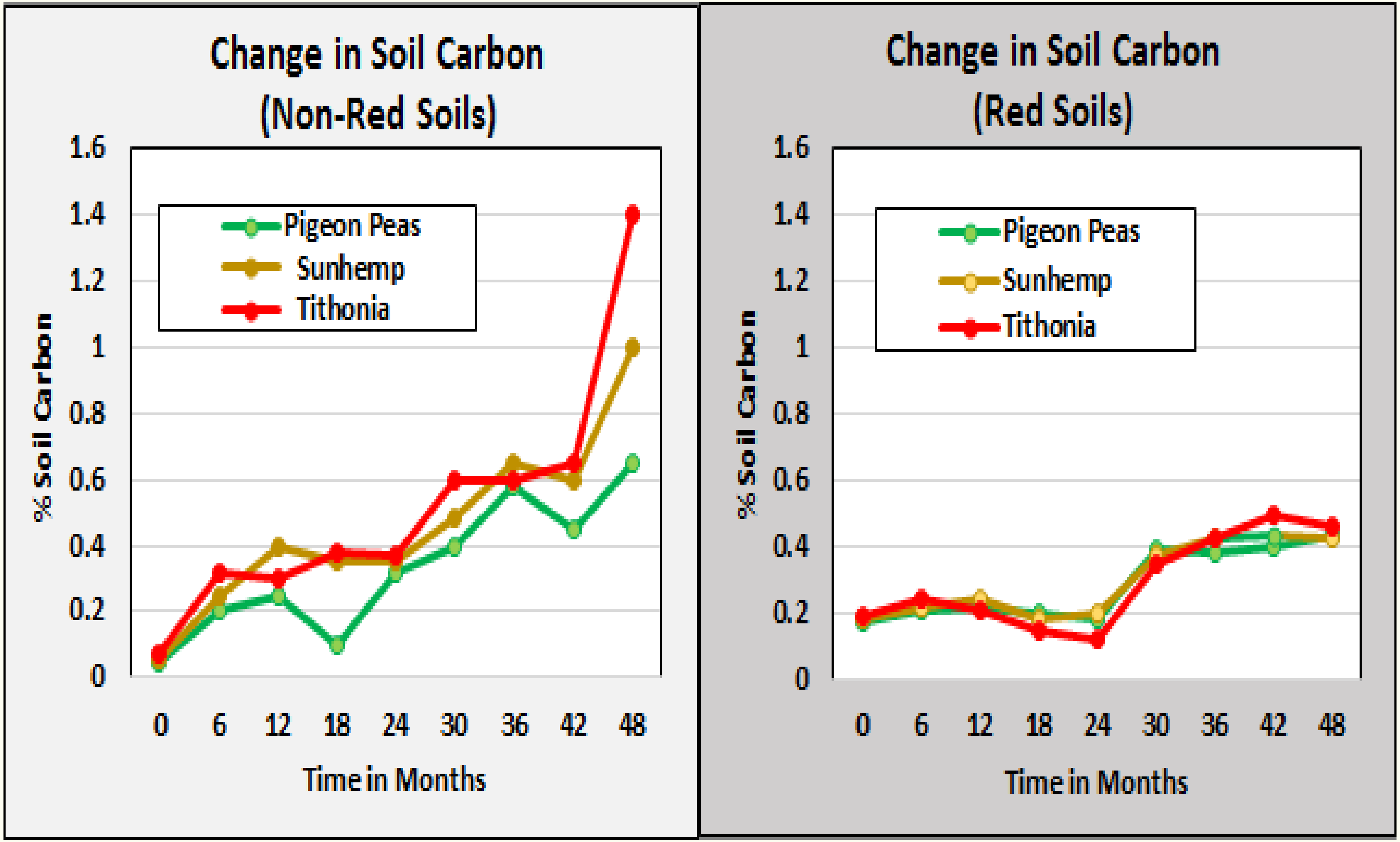

Carbon Transfer From Forests to Agriculture




Litter Experiment With
Chir Pine and Tithonia, Sunhep and Pigeonpeas

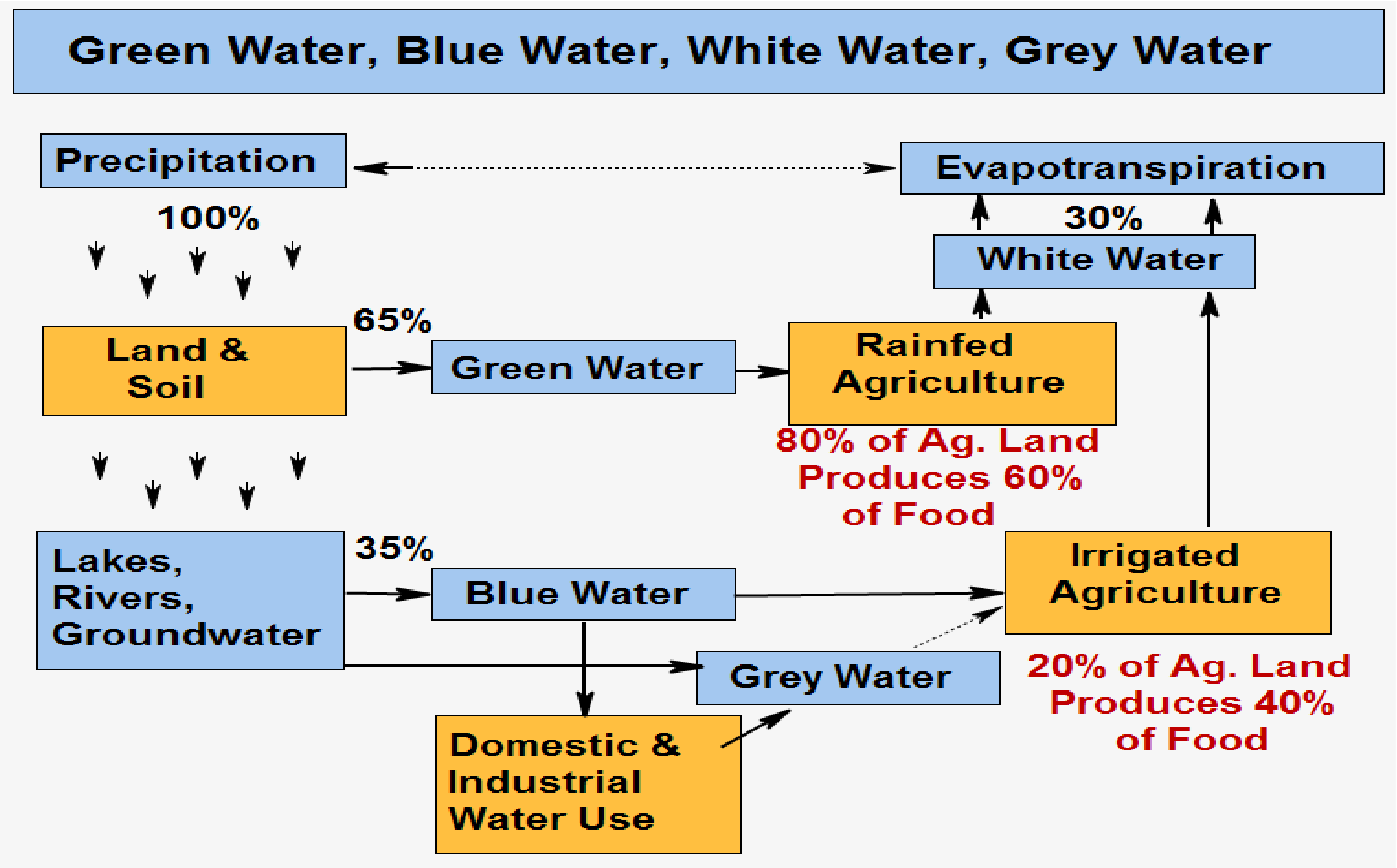
Changing Soil Conditions by Adding Pine Litter over Time (10 kg /m2 every 6 months)




Change in Soil Carbon
(Non-Red Soils)
Pigeon Peas
Sunhemp
Tithonia
% Soil Carbon
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
6
12
18
24
30
36
42
48
Time in Months
Change in Soil Carbon
(Red Soils)
Pigeon Peas
Sunhemp
Tithonia
% Soil Carbon
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
6
12
18
24
30
36
42
48
Time in Months

	Lemon grass	Setaria	Stylo	Koduz	Golden Botton
Control no planting					
Lime 1x					
Lime 2x					
Manure 1x					
Manure 2x					
Lime & Manure 1x					
Lime & Manure 2x					
Control planted					

Lemon grass


Green Water, Blue Water, White Water, Grey Water
Precipitation
Evapotranspiration
100%
30%
White Water
65%
Land & Soil
Green Water
Rainfed Agriculture
80% of Ag. Land Produces 60% of Food
Lakes, Rivers, Groundwater
35%
Blue Water
Irrigated Agriculture
Grey Water
20% of Ag. Land Produces 40% of Food
Domestic & Industrial Water Use

Simple bunds can retain runoff water during winter rains for a few hours. This is sufficient to recharge soil moisture and allows farmers to produce a crop of barley during the dry season (NW-Coast of Egypt - 250mm annual rainfall, rainfall only between Nov. and Feb)

Restoring a Degraded Site

Restoration Experiment


▪ The idea is not to create forests but to plant fodder trees on private land
▪ A nursery was established to supply native nitrogen fixing fodder trees for hedgerows, distribution to farmers and to maintain seed supplies

Focus on N-Fixation

Agroforestry; Fodder Trees in Hedgerows along Contour Lines

Innocculation of Mycorrhizal Fungi (P-Fixation)

Rehabilitating Degraded Land


1997


1999


2001

Native, nitrogen fixing fodder trees:

Latin name	Nepali
Albezia lebec	Kalo siris
Albezia procora	Rato siris
Dalbergi sissoo	Sissoo
Litsea monopetala	Kutmiro
Bauhinia purpurea	Tanke
Melia azedaiach	Bakaino
Acacia catechu	Khayes

☑ most successful species

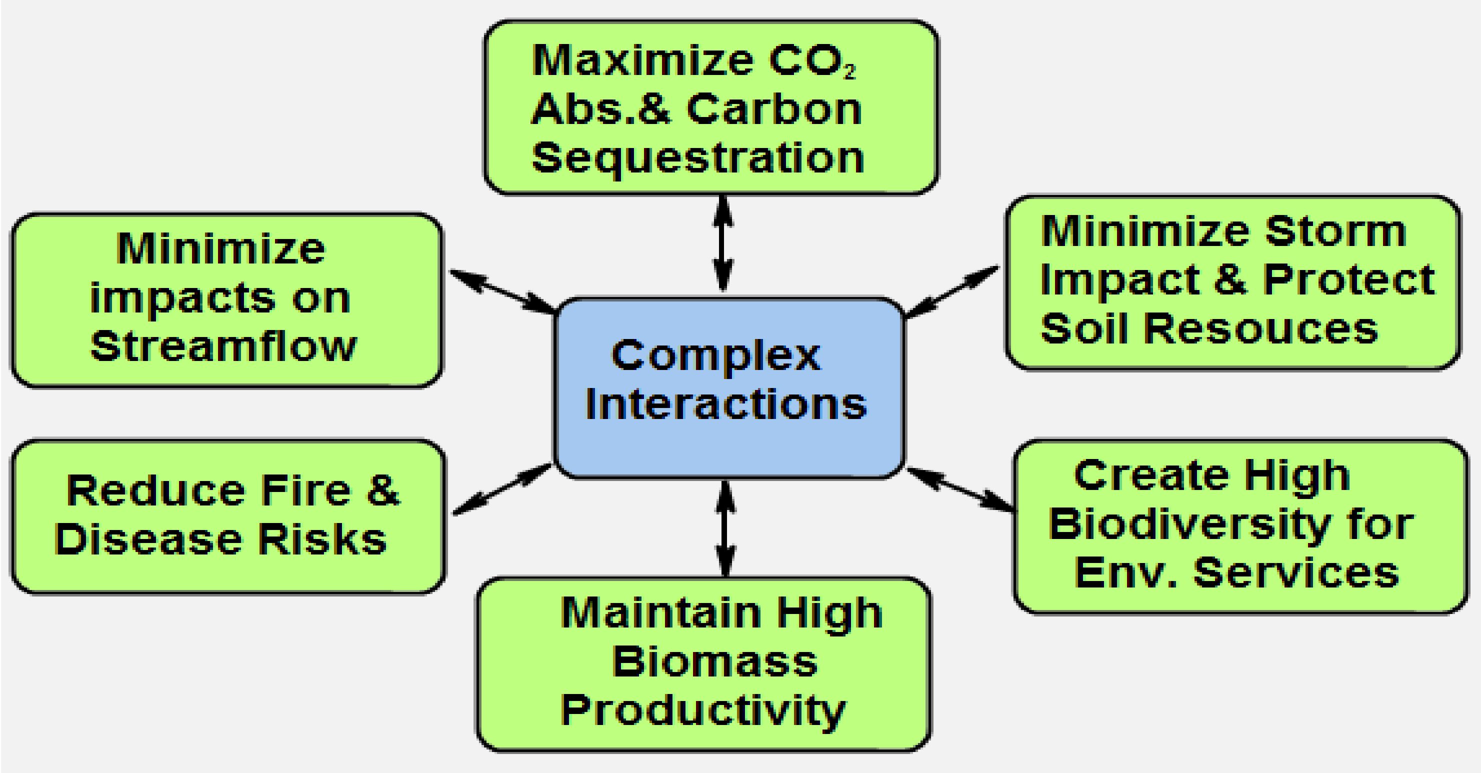
☑ unsuccessful species

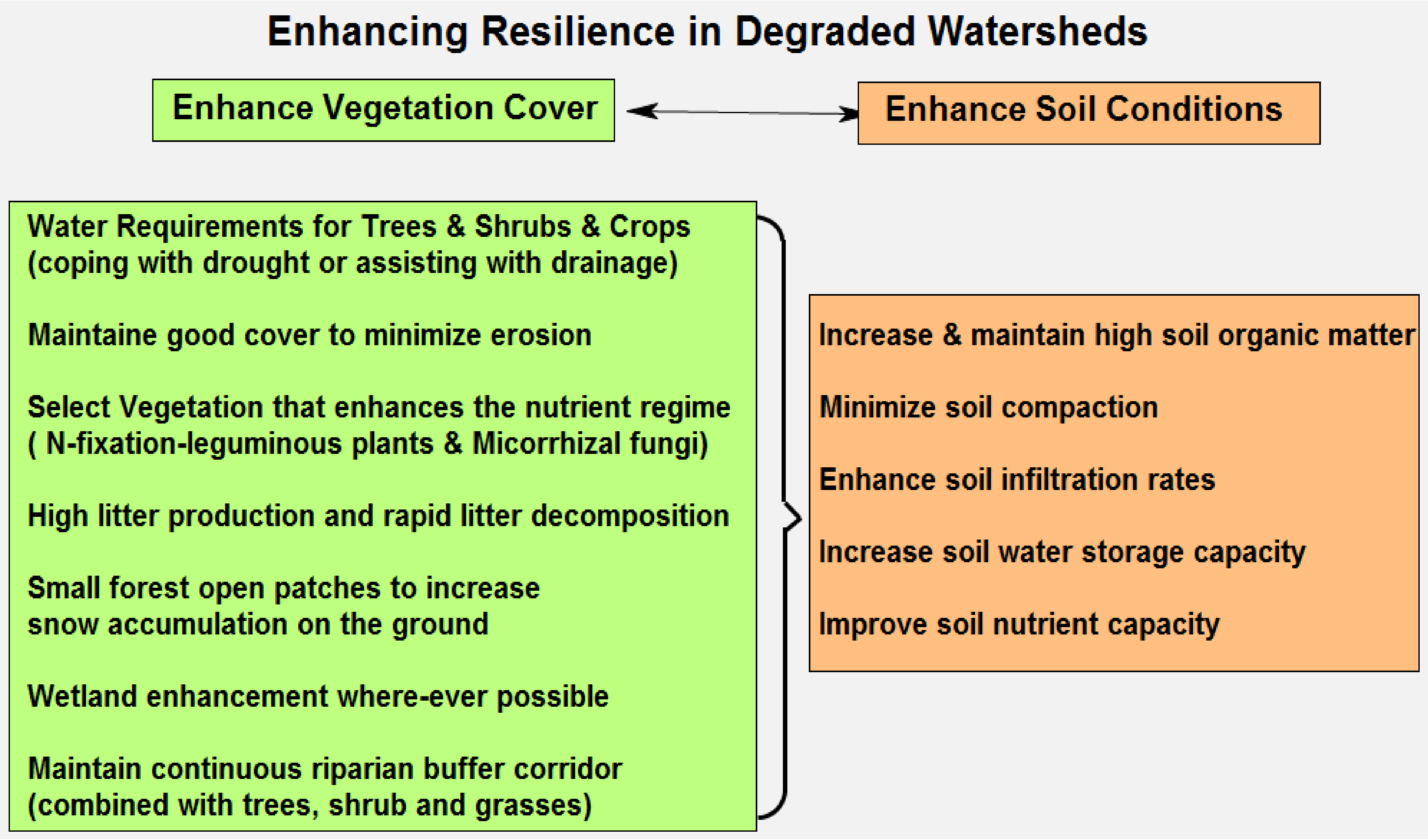
A Strategy for Maximizing Carbon Sequestration in Degraded Headwaters

Mixed Forest
Conifer & Broadleaf
Shrubs & Grasses
High Biodiversity

Soil Enhancement
Incorporate
Litter & Compost
Add Lime (Stabilizes C)

Agro-Forestry
Enhancement of
Grass & Perennial Crops
Shrubs & Trees




Enhancing Resilience in Degraded Watersheds
Enhance Vegetation Cover
Enhance Soil Conditions
Water Requirements for Trees & Shrubs & Crops (coping with drought or assisting with drainage)
Maintaine good cover to minimize erosion
Select Vegetation that enhances the nutrient regime (N-fixation-leguminous plants & Micorrhizal fungi)
High litter production and rapid litter decomposition
Small forest open patches to increase snow accumulation on the ground
Wetland enhancement where-ever possible
Maintain continuous riparian buffer corridor (combined with trees, shrub and grasses)
Increase & maintain high soil organic matter
Minimize soil compaction
Enhance soil infiltration rates
Increase soil water storage capacity
Improve soil nutrient capacity


Thank You

Strategies to Increase Soil Carbon in Agriculture

Focus on Degraded Cropland and Pasture Land

Cropland C-Restoration

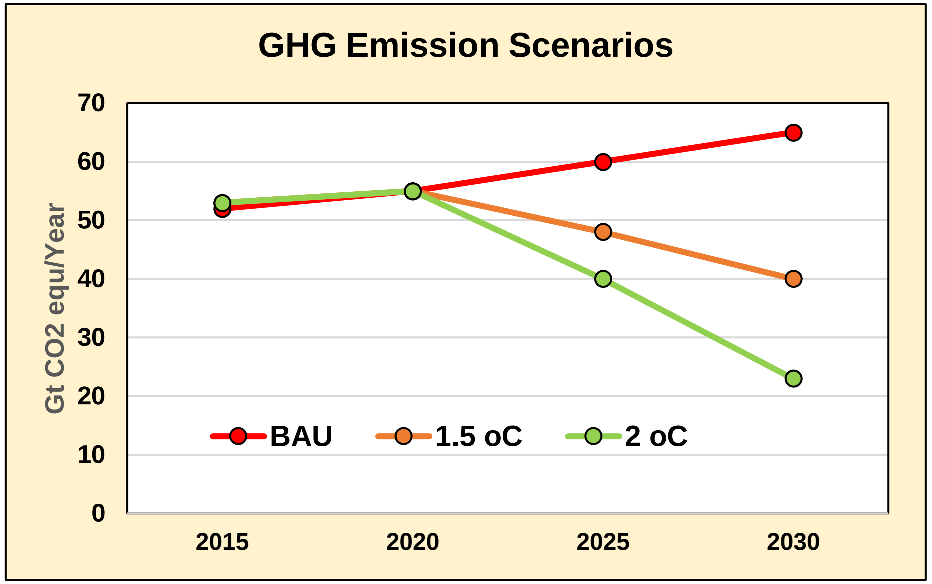
Increase Biomass Production
Include Cover Crops
Include Legumes in Crop Rotation
Modify Tillage to No-Till
Addition of Manure & Compost

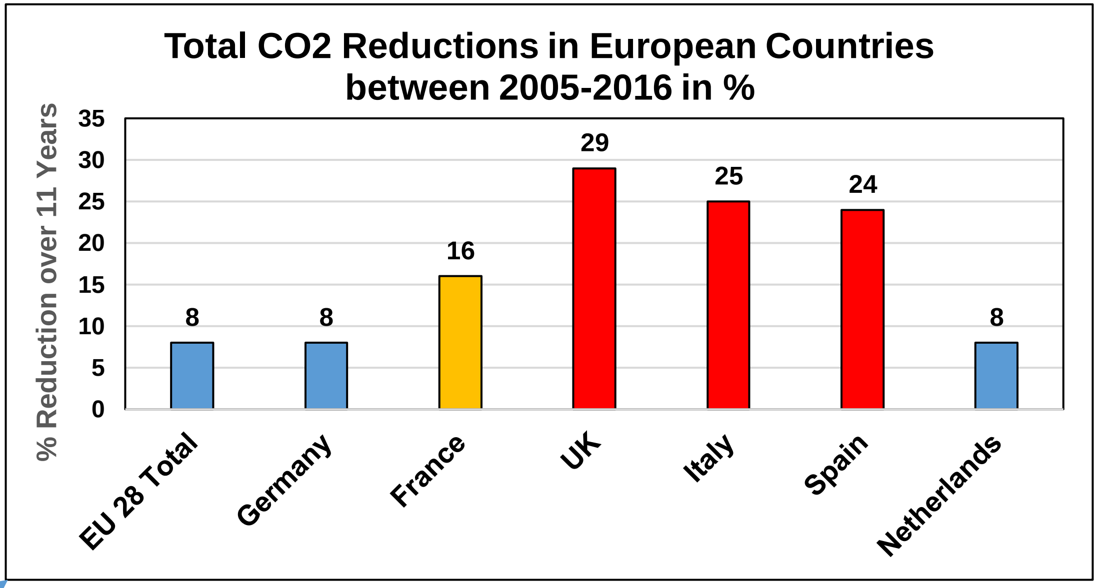
Grassland C-Restoration

Change Pasture Management
Increase Biodiversity in Plants
(Perennials, C3 & C4 Plants)
Include Legumes in Grasses
Addition of Manure

Protect Wetlands

Maintain Anaerobic Conditions
(Secure Water Supplies, Rewetting)
Discourage Peat Extraction
Restore and Create New Wetlands

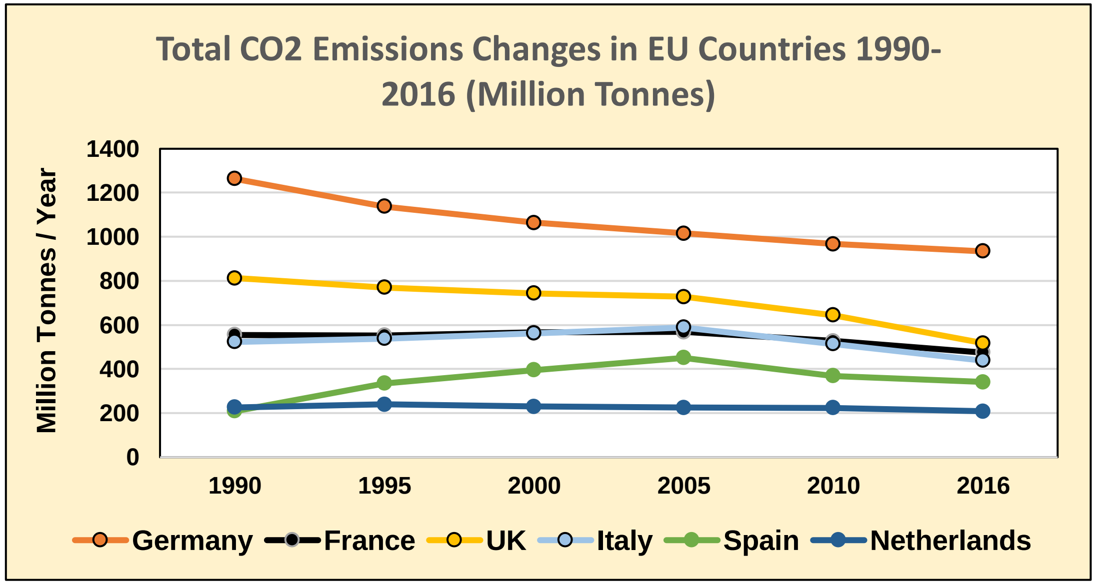




Change over 11 Years

Required CO2 Reduction Between 2019-2030

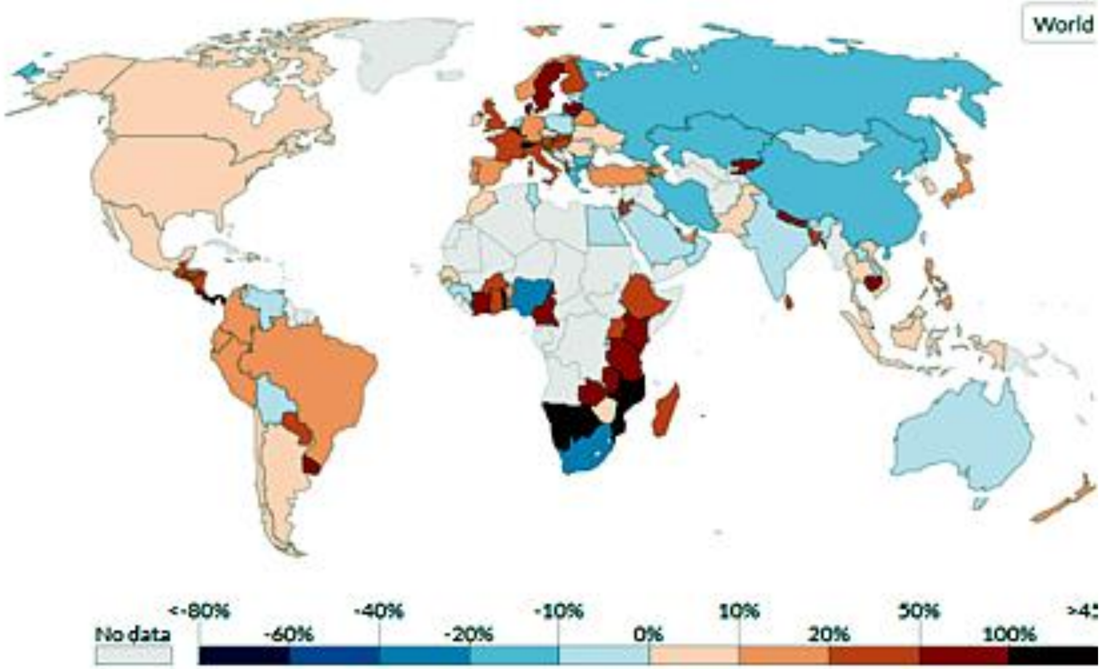
25% for 1.5 Degree C Target
55% for 2 Degree C Target



Data Source: Eurostat 2018

CO_2 emissions embedded in trade, 2017

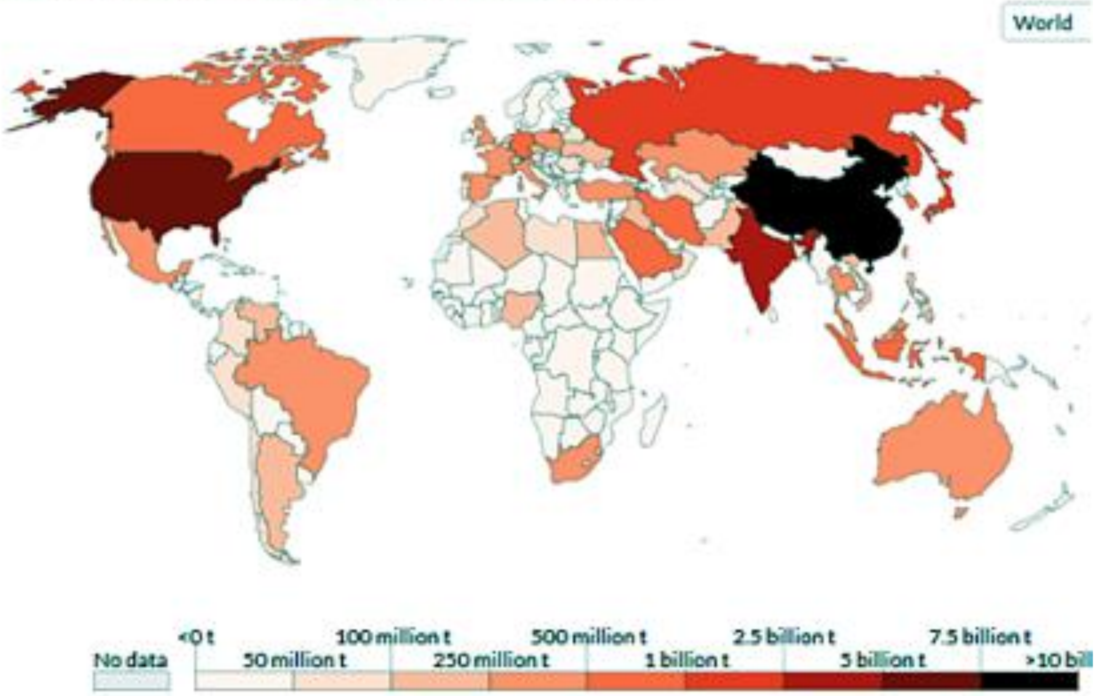
Share of carbon dioxide (CO_2) emissions embedded in trade, measured as emissions exported or imported as the percentage of domestic production emissions. Positive values (red) represent net importers of CO_2 (i.e. "20%" would mean a country imported emissions equivalent to 20% of its domestic emissions). Negative values (blue) represent net exporters of CO_2.



Source: Peters et al. (2012 updated); Global Carbon Project (2018)

Annual CO_2 emissions, 2018

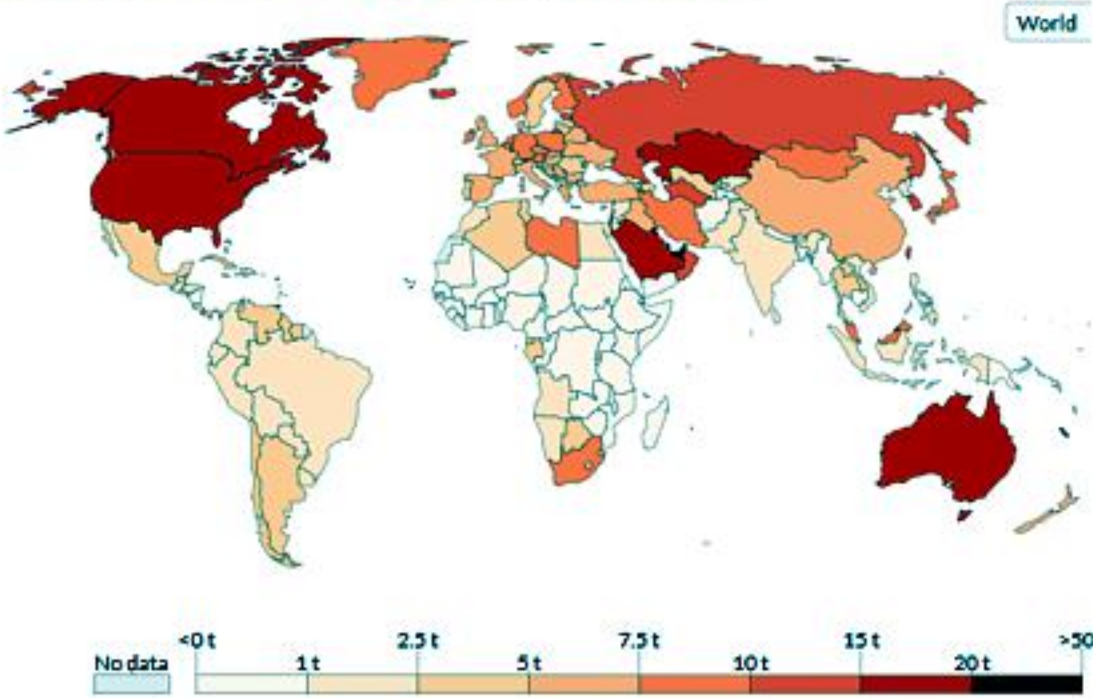
Annual carbon dioxide (CO_2) emissions, measured in tonnes per year.



Source: Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC)

Per capita CO_2 emissions, 2018

Average carbon dioxide (CO_2) emissions per capita measured in tonnes per year.



Source: OWID based on CDIAC; Global Carbon Project; Gapminder & UN