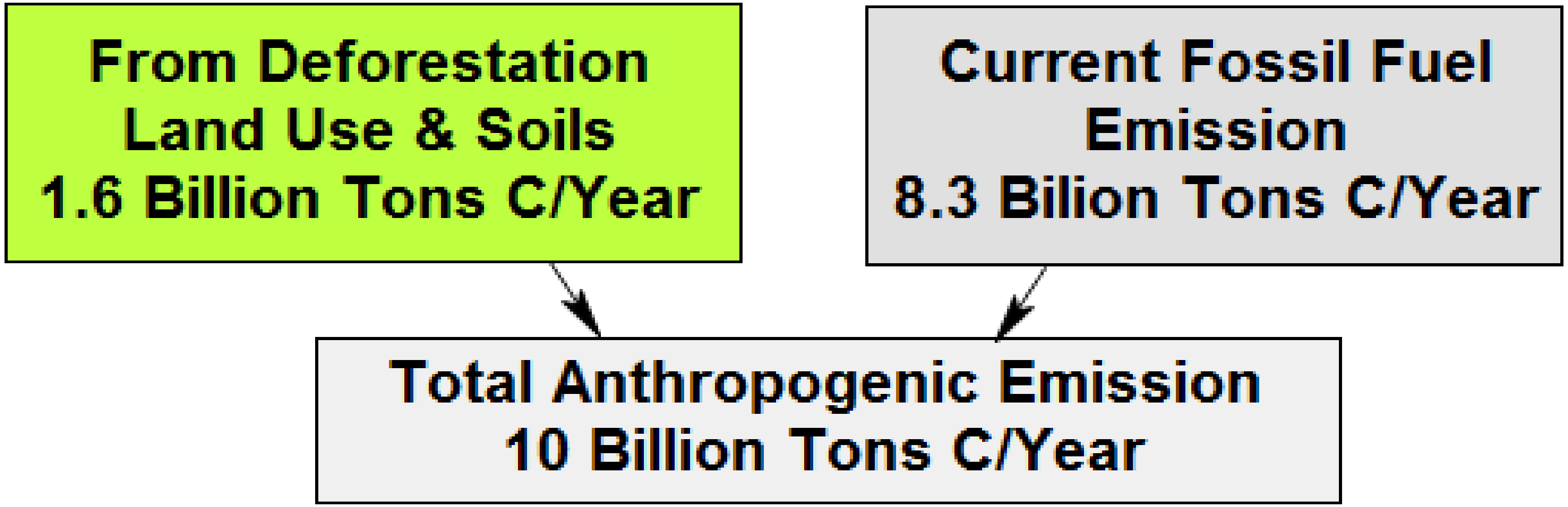
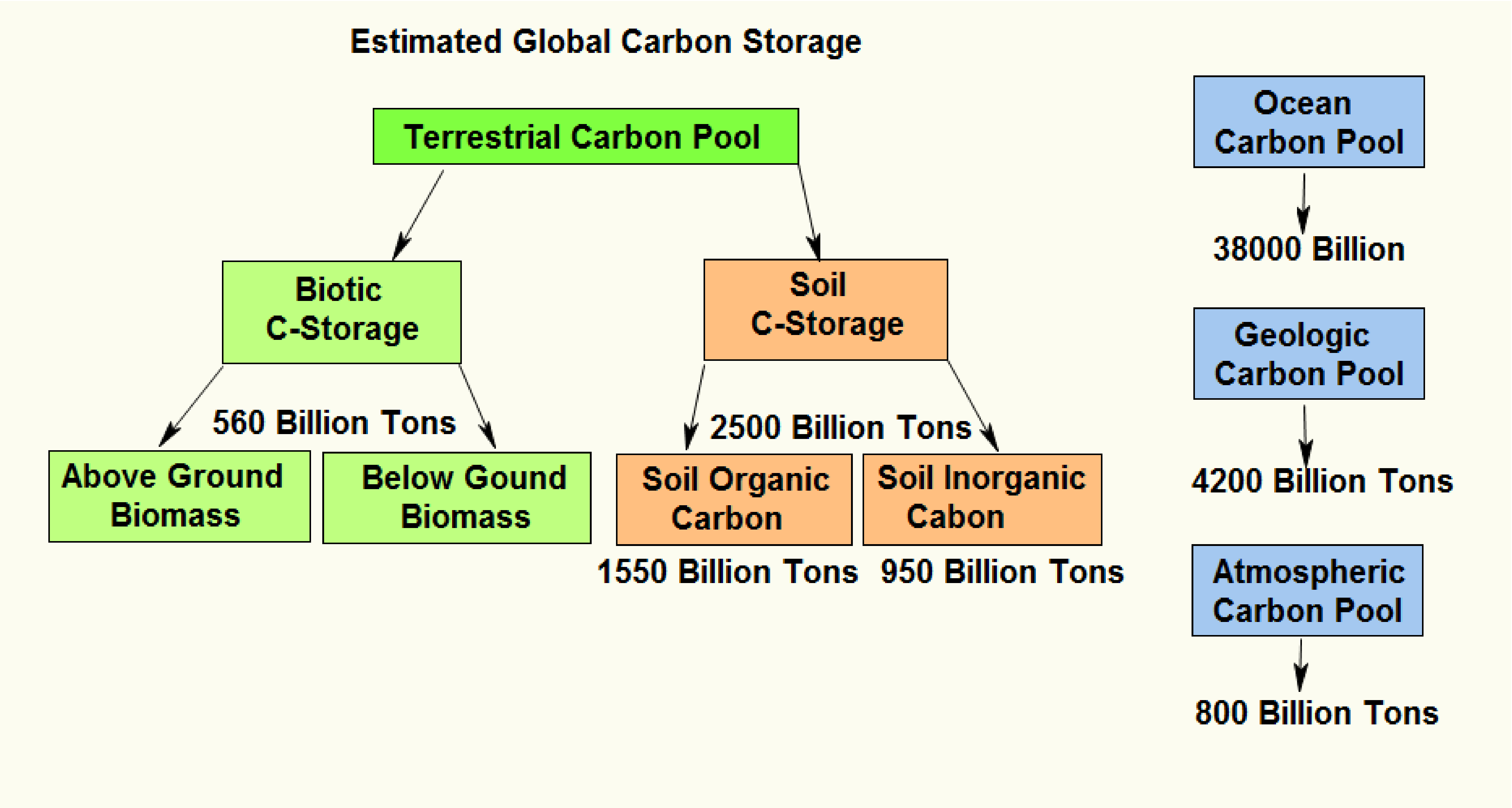
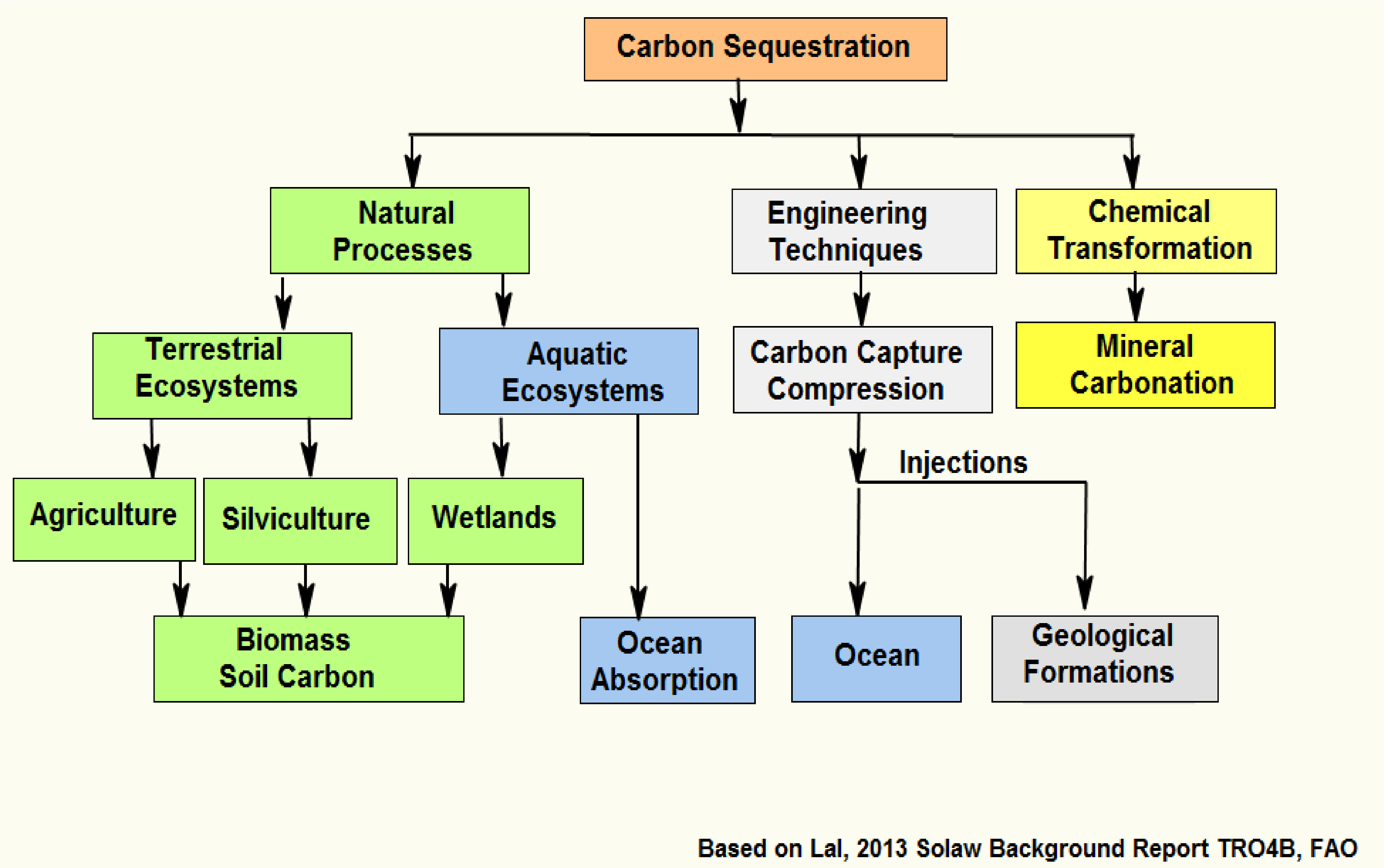
Estimated Current Annual Carbon Emissions



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


Carbon Sequestration
Natural Processes
Engineering Techniques
Chemical Transformation
Terrestrial Ecosystems
Aquatic Ecosystems
Carbon Capture Compression
Mineral Carbonation
Injections
Agriculture
Silviculture
Wetlands
Biomass Soil Carbon
Ocean Absorption
Ocean
Geological Formations
Based on Lal, 2013 Solaw Background Report TRO4B, FAO

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

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

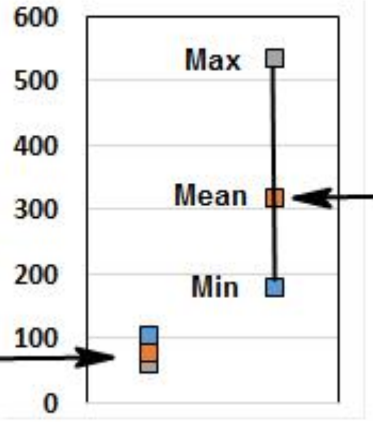
=

< 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%

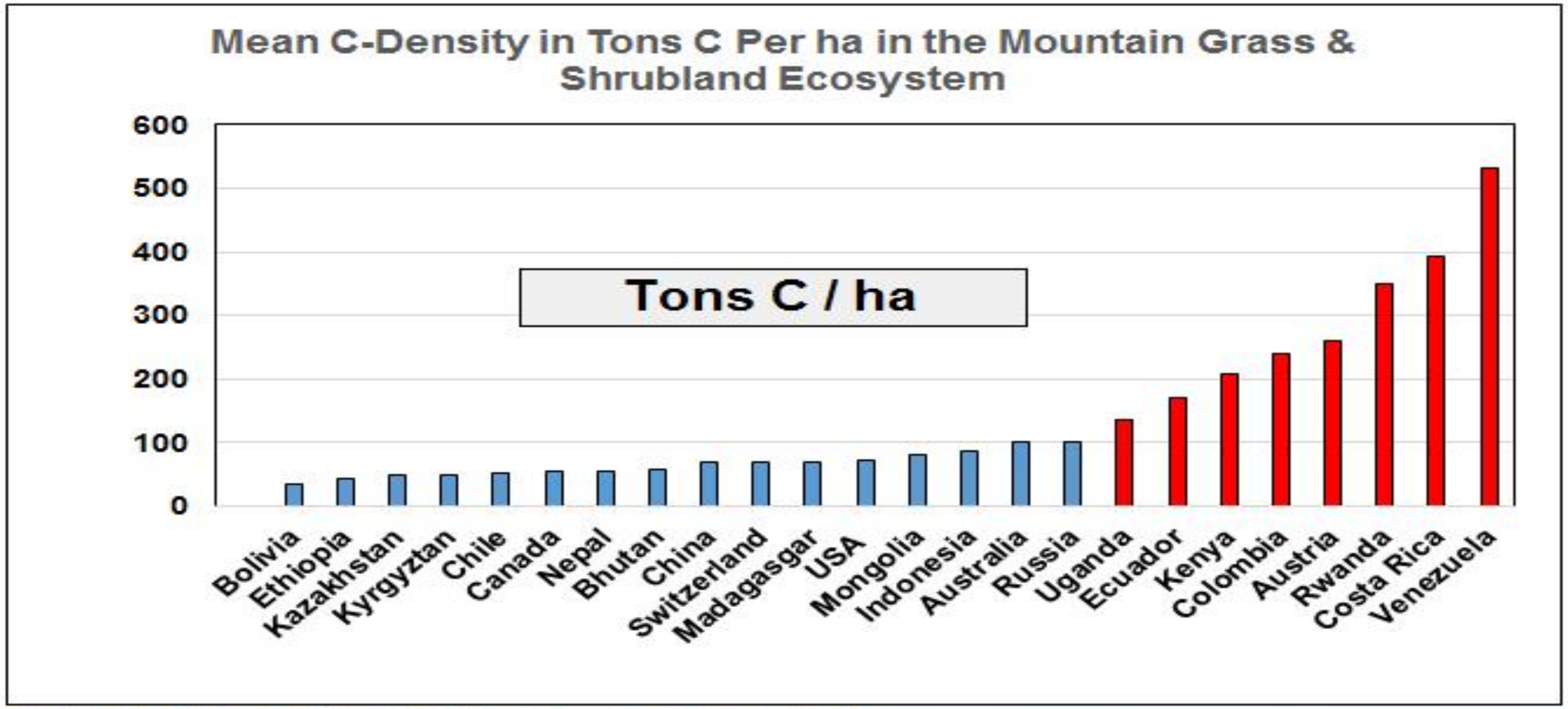
Countries	Area Million ha	Carbon-Stock Billion Tons
Ecuador	1.58	0.22-0.33
Colombia	1.53	0.31-0.43
Venezuela	0.31	0.13-0.20
3 Country Total	3.42	0.66-0.96
% of Global Total GSL	0.36%	1.10-1.16%

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

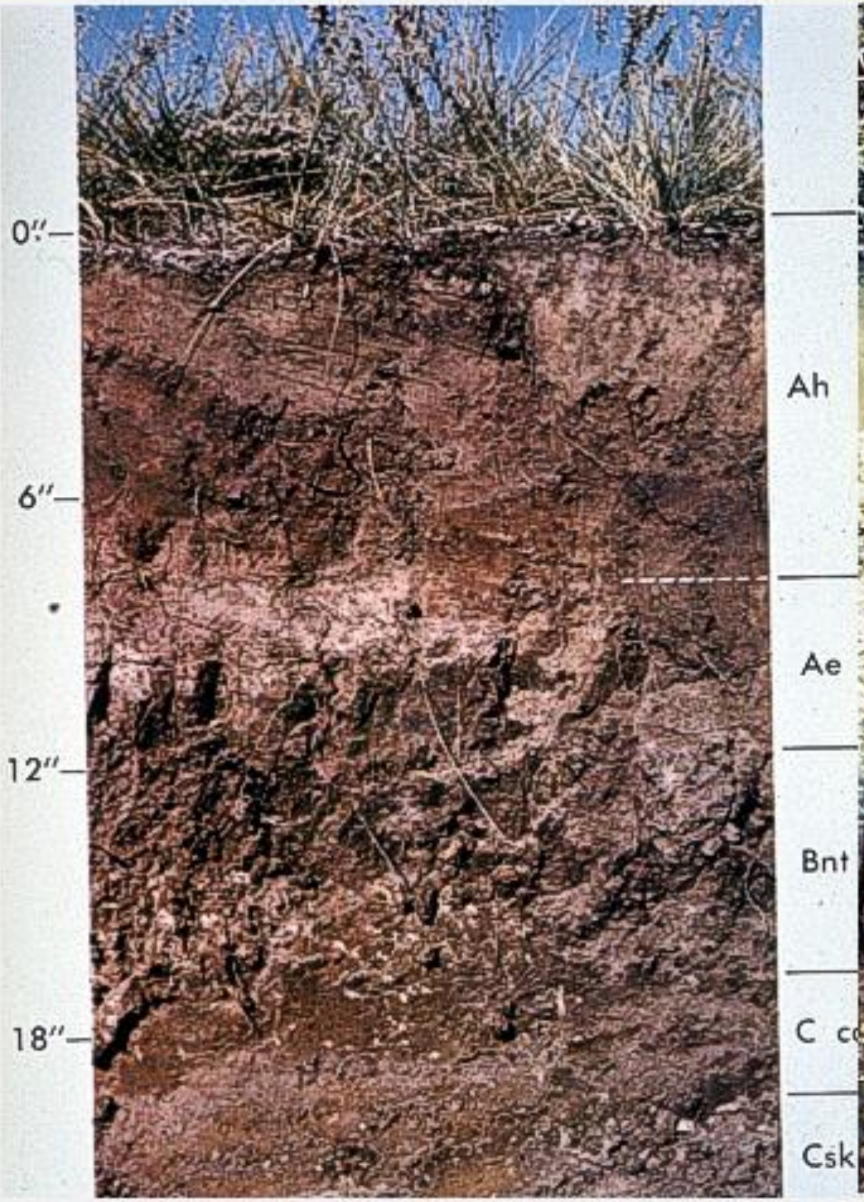

Mean C-Density in Tons C Per ha in the Mountain Grass & Shrubland Ecosystem
600
500
400
300
200
100
0
Tons C / ha
Bolivia
Ethiopia
Kazakhstan
Kyrgyztan
Chile
Canada
Nepal
Bhutan
China
Switzerland
Madagasgar
USA
Mongolia
Indonesia
Australia
Russia
Uganda
Ecuador
Kenya
Colombia
Austria
Rwanda
Costa Rica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

US $ 1.2-11.8 Billion
(Based On Carbon Price of $ 36 / t CO_2)

Sequestration Rate Between 2000-2015		Value
112 Million t CO_2 / Year	=	$ 1.2-11.8 Billion / Year
Total Stored CO_2 in Ecosystem = 250 GT	=	$ 2.5-26 Trillion

A. Ward 2016. The extent and value of carbon stored in the mountain grasslands & shrublands globally, and the prospect of using climate finance to address natural resource management issues. PhD thesis. University of Queensland, School of Geography, Planning and Environmental Management, Australia, 165 pp.

Different Soils Have Different Soil Organic Matter Content



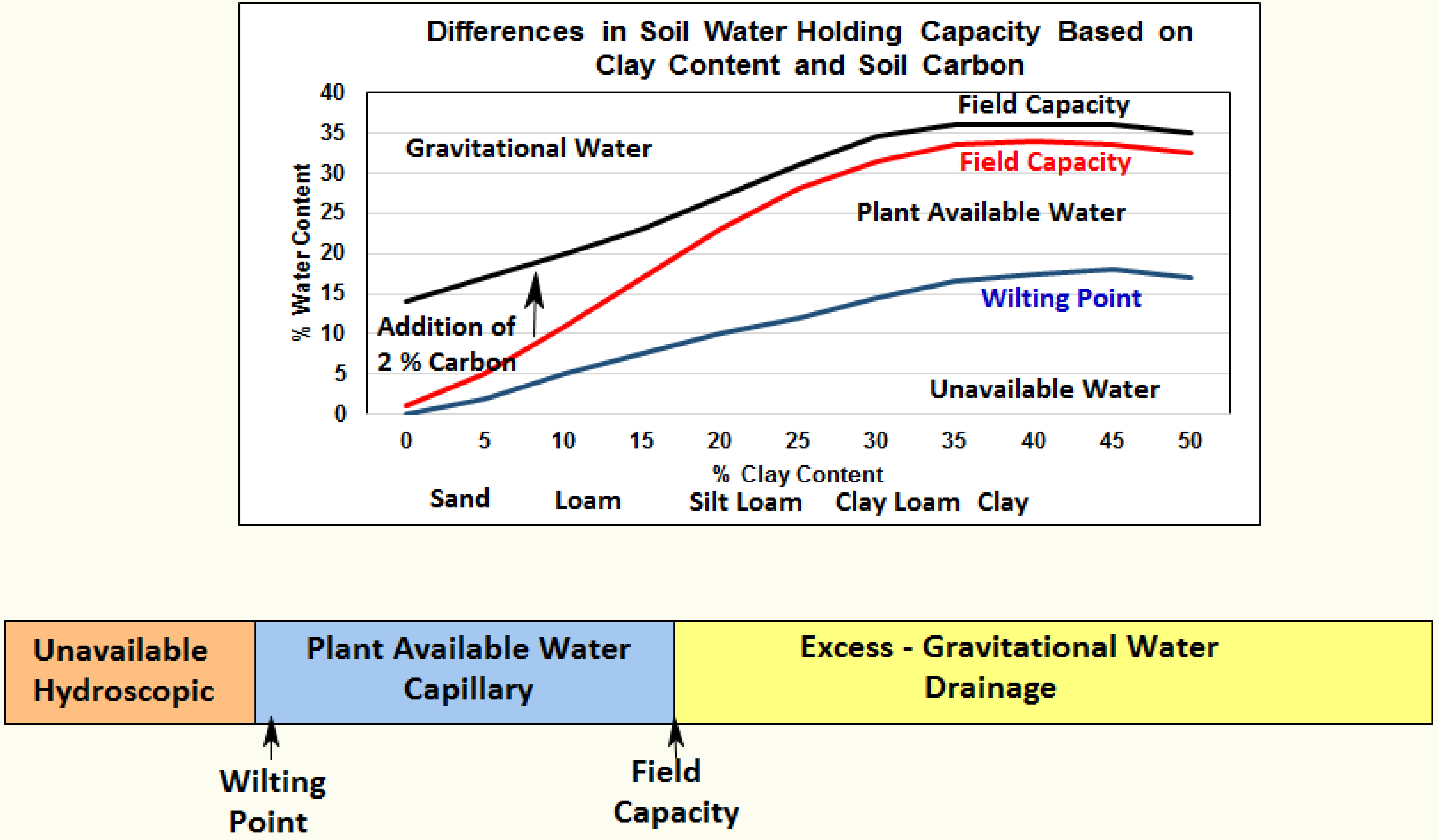
Benefits of Organic Carbon is Soils

Physical Functions	Chemical Functions	Biological Functions
Aggregate Stability Soil Structure Soil Stability	**Nutrient Exchange** Increases Cation Exchange Capacity	**Energy & Food** Provides Source of Energy & Food for Microbes
Hydrological Properties Water Holding Capacity, Infiltration, Hydraulic Conductivity	**Nutrient Availability** Slow release of Nutrients through Decomposition (e.g.Phosphorus)	**Decomposition** Releases Nutrients (N, P, S, etc) by recycling
Aeration Properties Improved Air Movement through the Soil	**Organic-Inorganic Interactions** Bilds Organo-Mineral Complexes	**Tranfer Functions** Transfers Nutrients with Water to other Plants (Micorrhizal Fungi)
Thermal Properties Improved Heat Transfer		**Disease Control** Biological Control of some Diseases

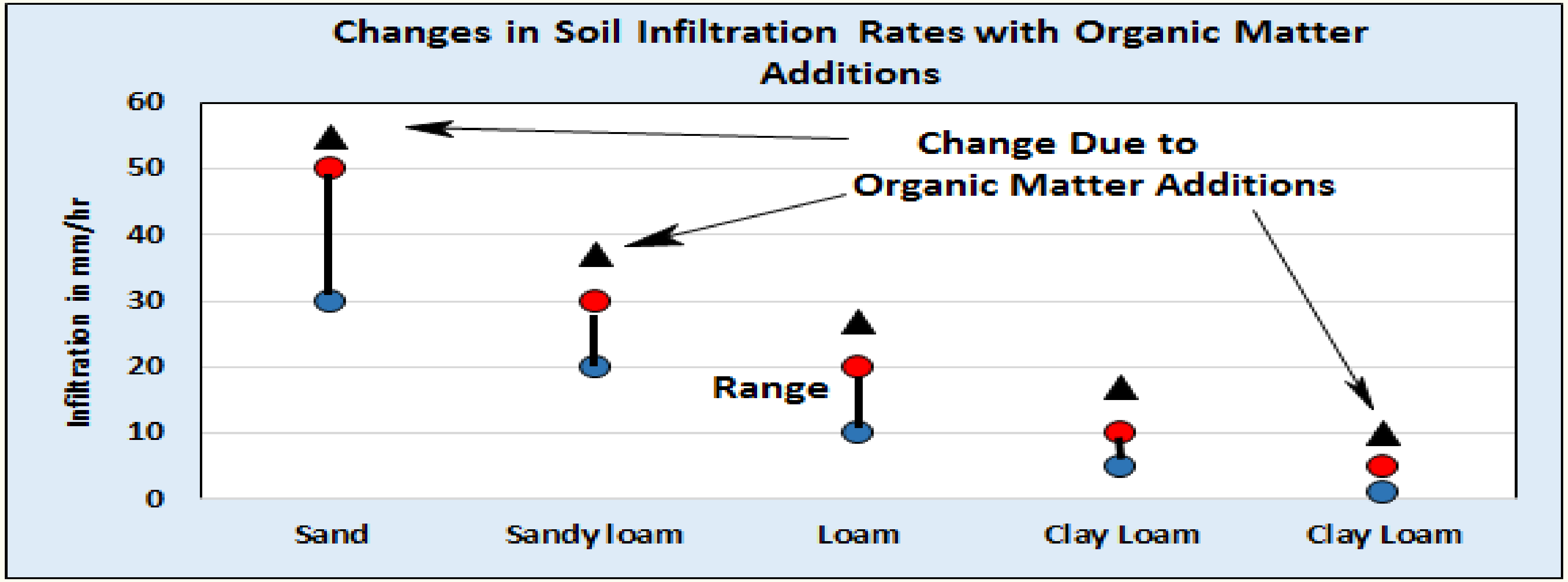
Benefits from Increasing Soil Carbon

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 that 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

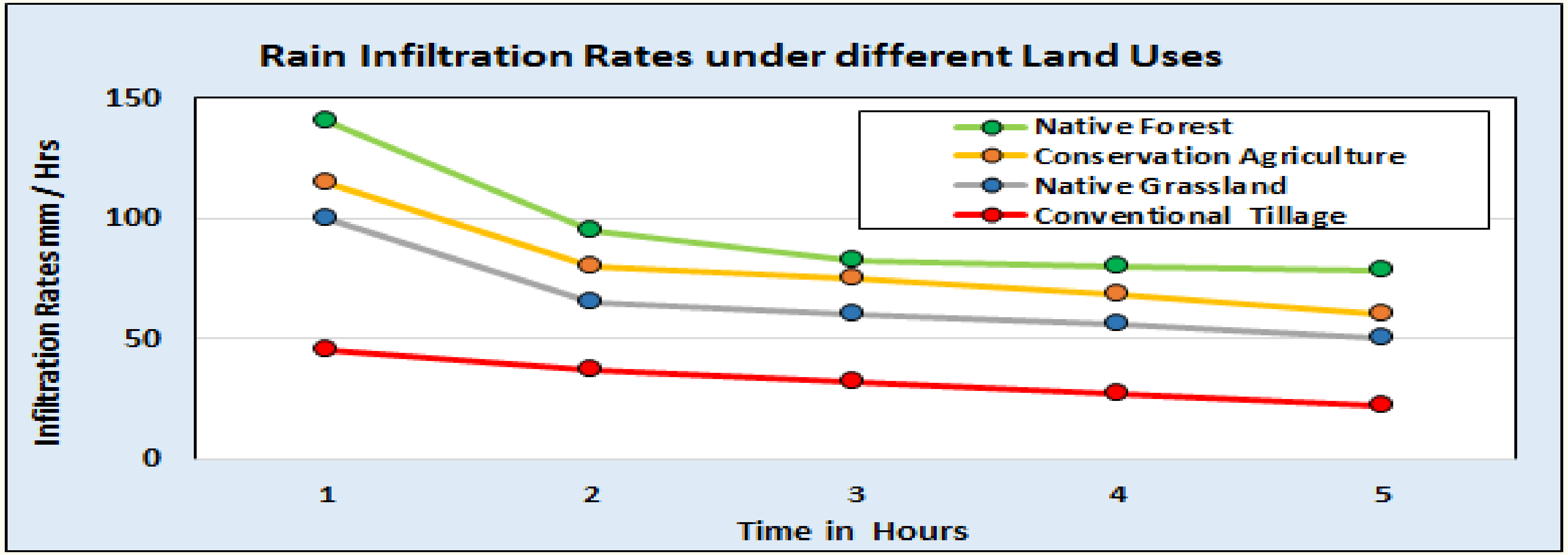
Soil Water Holding Capacity and Potential Increases with Organic Carbon Additions



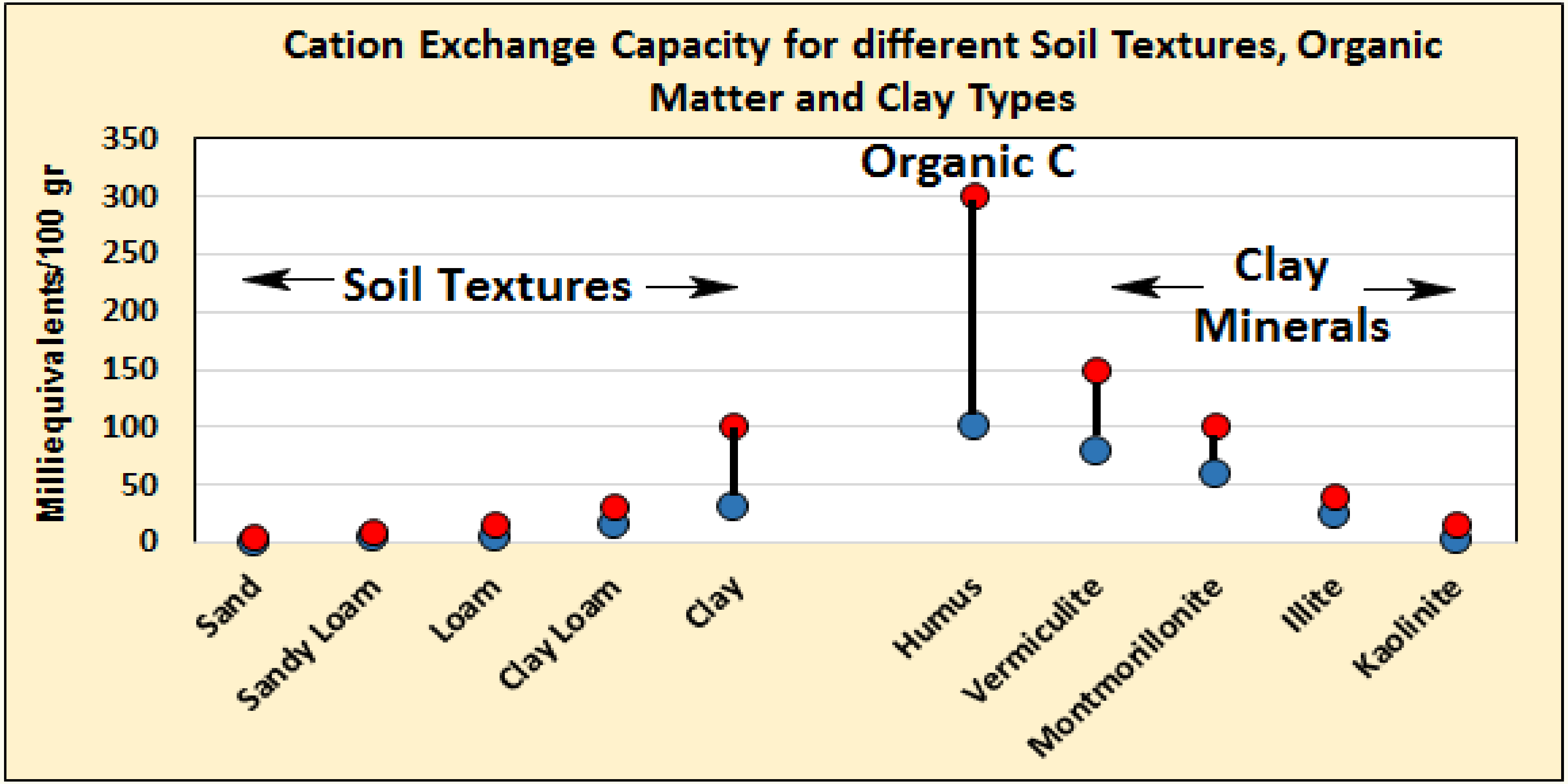
Soil Infiltration Rates and Potential Increases with Carbon Additions



The Role of Soils and Land Use & Cover



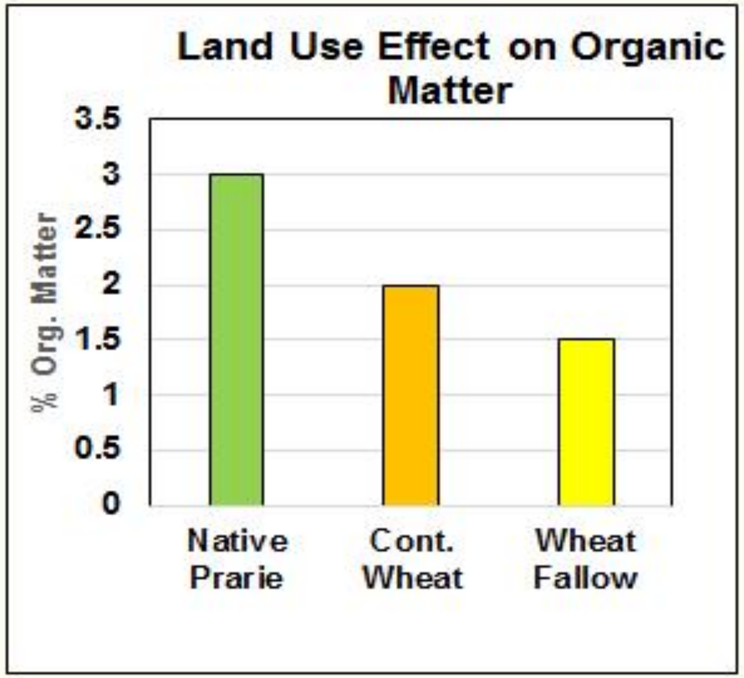
Nutrient Holding Capacity = Cation Exchange Capacity and Potential Increases with Organic Carbon Additions



Soil Organic Matter

Soils	Virgin	Cultivated
Brown	3-4%	2-4%
Dark Brown	4-5%	3-5%
Black	6-10%	4-6%
DarkGray	4-5%	2-3%
Gray	1-2%	1-2%

Source: Alberta Agriculture



Organic Matter Decline 30-50%
Lickacz & Penny 2001

How to increase Organic Matter

Add Manure
Reduce Tillage
Grow N-Fixing Trees and Crops
Lime The Soils

Benefits
Increases Water Holding Capacity
At 4% OM WHC increases 60%
Sequesters Carbon
Improves Nutrient Holding Capacity

Renzina Soils Developed in Limestone

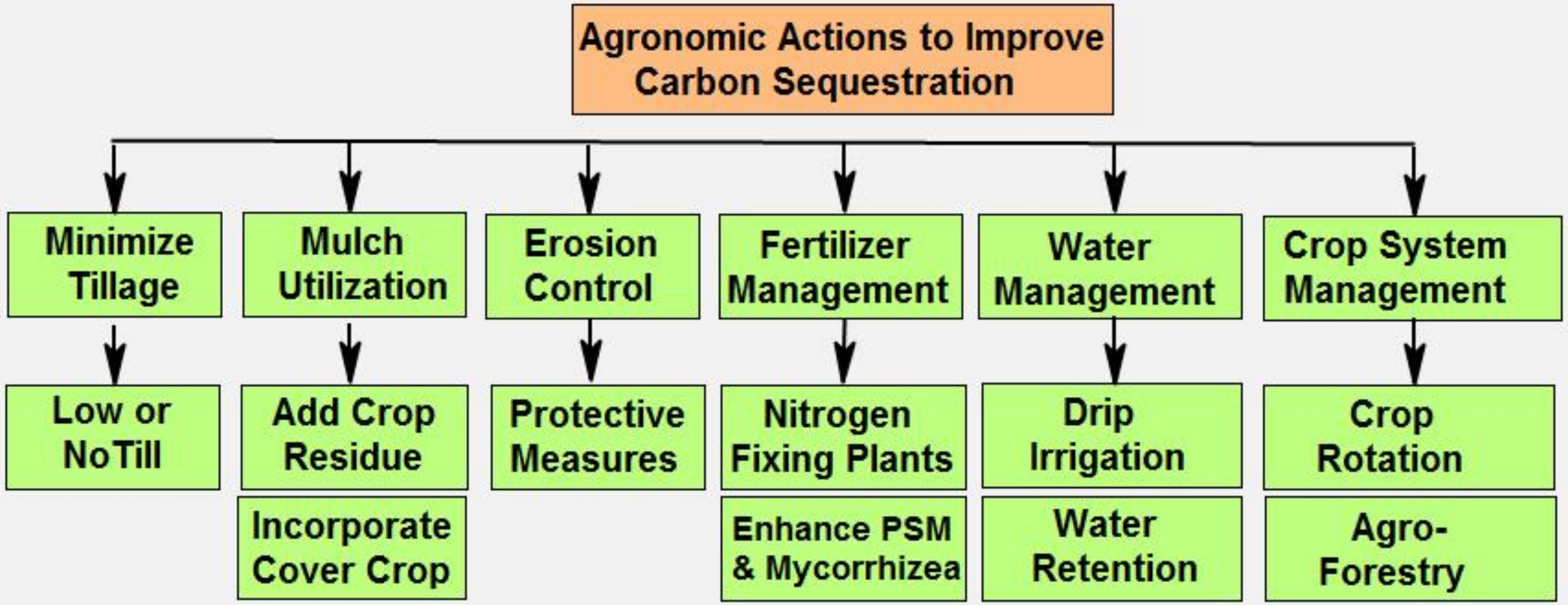

bog


swamp


marsh


fen

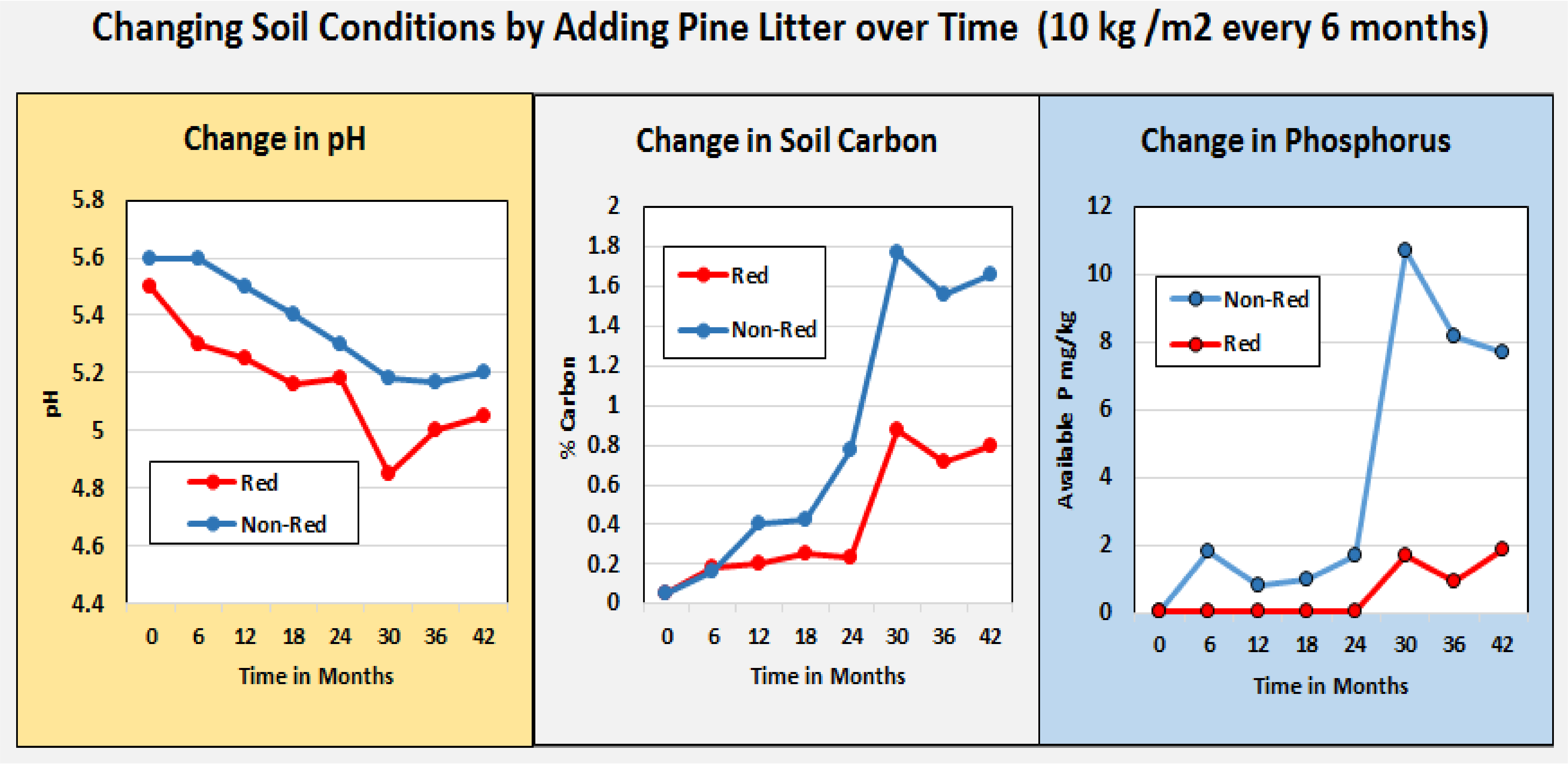

shallow water


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

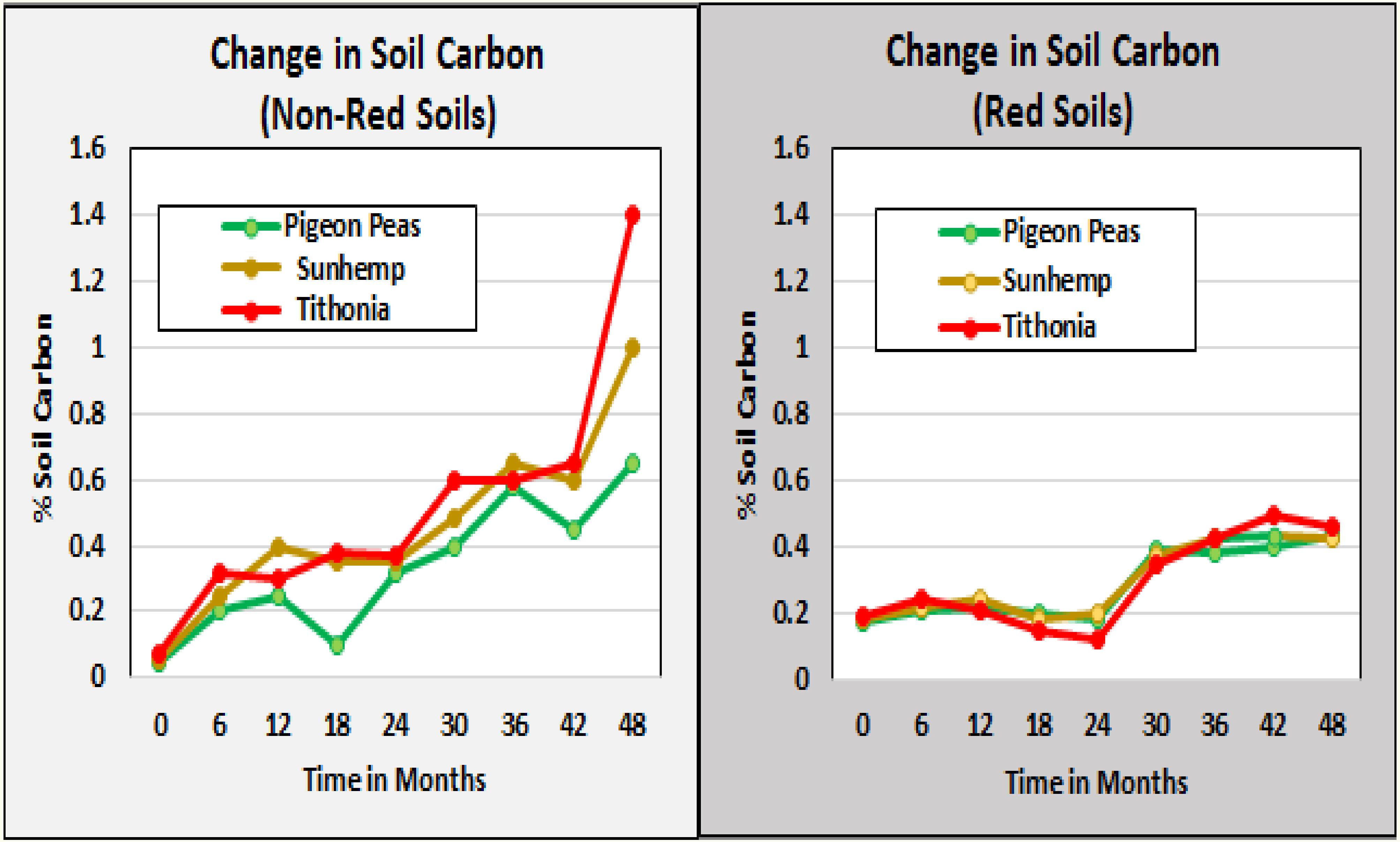
Carbon Transfer From Forests to Agriculture



Litter Experiment With
Chir Pine and Tithonia, Sunhep and Pigeonpea



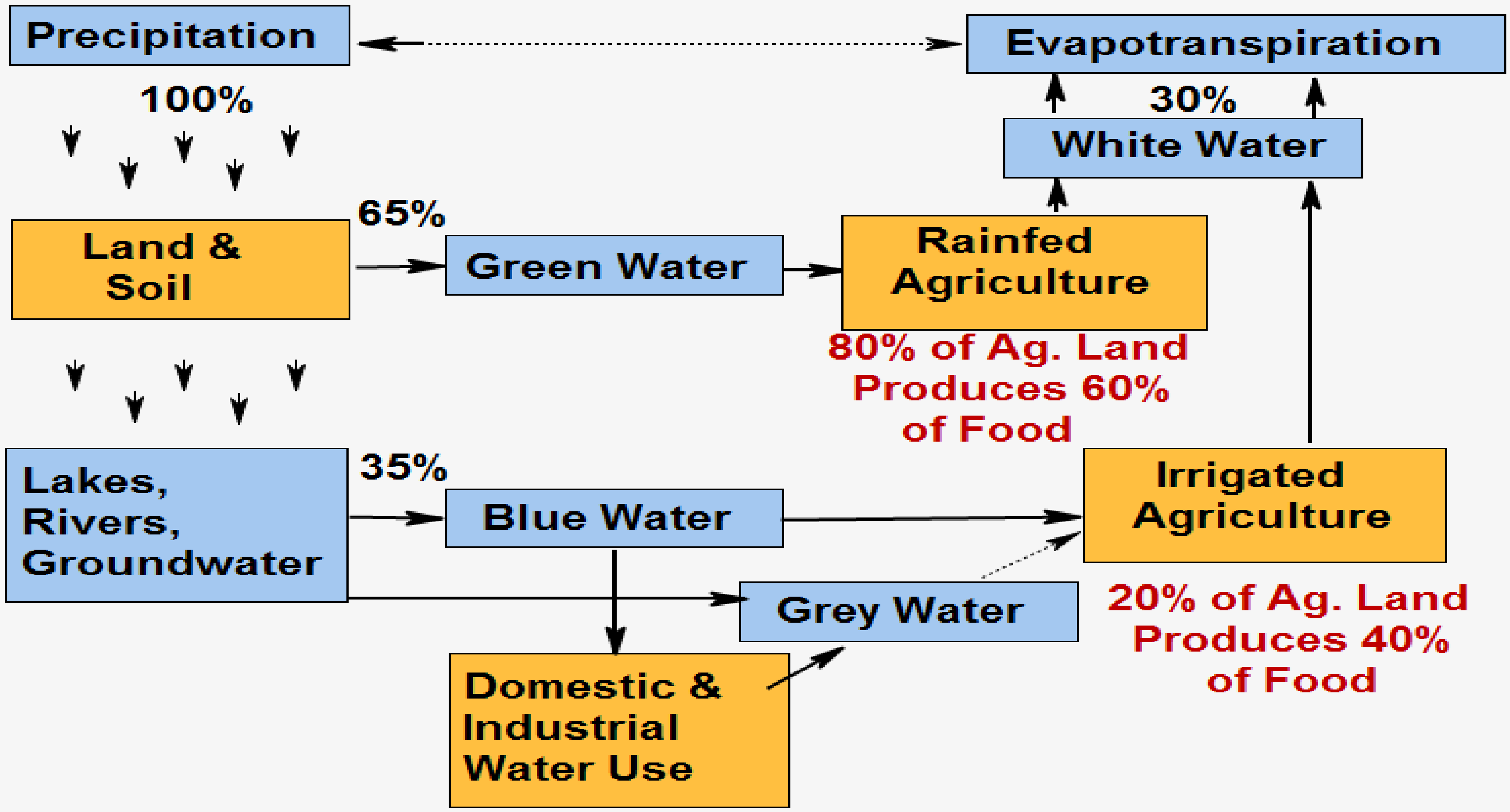
Changing Soil Conditions by Adding Pine Litter over Time (10 kg /m2 every 6 months)
Change in pH
pH
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
0 6 12 18 24 30 36 42
Time in Months
Red
Non-Red
Change in Soil Carbon
% Carbon
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 6 12 18 24 30 36 42
Time in Months
Red
Non-Red
Change in Phosphorus
Available P mg/kg
12
10
8
6
4
2
0
0 6 12 18 24 30 36 42
Time in Months
Non-Red
Red



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

Green Water, Blue Water, White Water, Grey Water



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

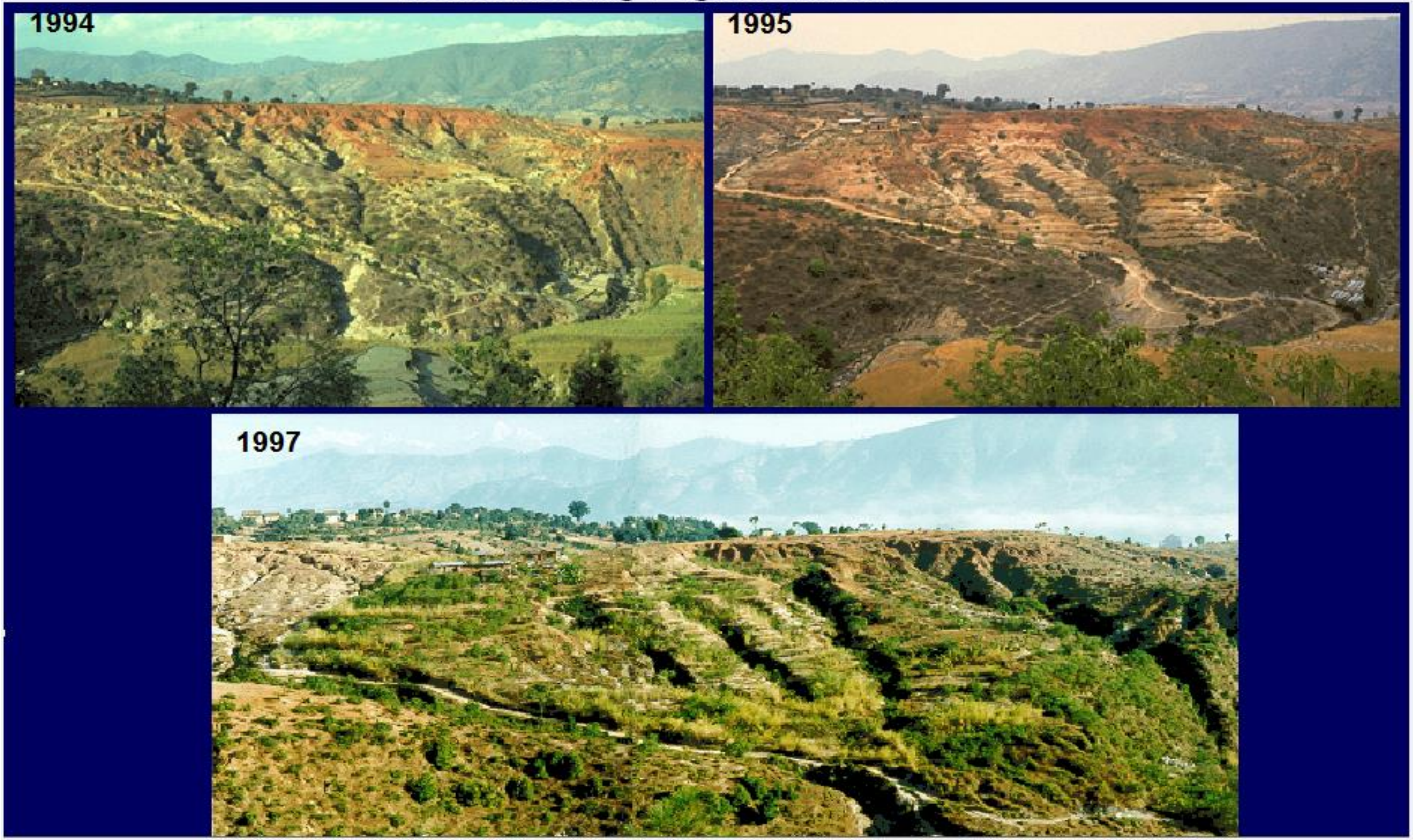

The idea is not to create forests but to plant fodder trees on private land
A nursery was established to supply native nitrogen fixing fodder trees for hedgerows, distribution to farmers and to maintain seed supplies

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

Forestry Factors to Consider to Adapt to Increased Climatic Variability

Increased Temperatures leads to:

Increases Drought
Increased Fire Hazards
Increases Diseases
Shift in Plant Communities (Altitude & Latitude)
Warmer Stream Temperatures

Increased Rainfall Variability leads to:

Increases Terrain Instability
Increased Erosion & Sediment Transport
Shift in Peakflow Events (Earlier Snow-melt)
Longer Dry Periods and Low Flow Problems
Rain on Snow Events

Vegetation Management Strategies

Plant a Wide Variety of Different Tree Species
Select Species that can be converted to Biofuel
Include Nitrogen Fixing Trees
Select Trees that tolerate Mycorrhizal Fungi
Select Native Trees & Plant them at Higher Elevation to enhance survival
Promote Biodiversity

Water Management Strategies

Minimize Tree and Soil Disturbance
Maintain effective Riparian Buffer Zones
Consider Water Demand for different Tree Species to be planted
Maintain good Soil Conditions (organic matter and high infiltration rates)
Enhance & Protect Wetlands
Improve Green Water Management

Direct Interventions to Improve Ecosystem Services

Regulatory

- Streamline Regulations
Amend Water Rights
Regulate Pollution
- Regulate Minimum Flow
Arrange Flow Releases
- Endangered Species Protection
- Conservation Initiatives

Economic

- Water Market & Trade Impacts
- Payment for Rehabilitation
- Fees for Point Sources
- Fines and Taxes
- Payment for Watershed Services

Governance

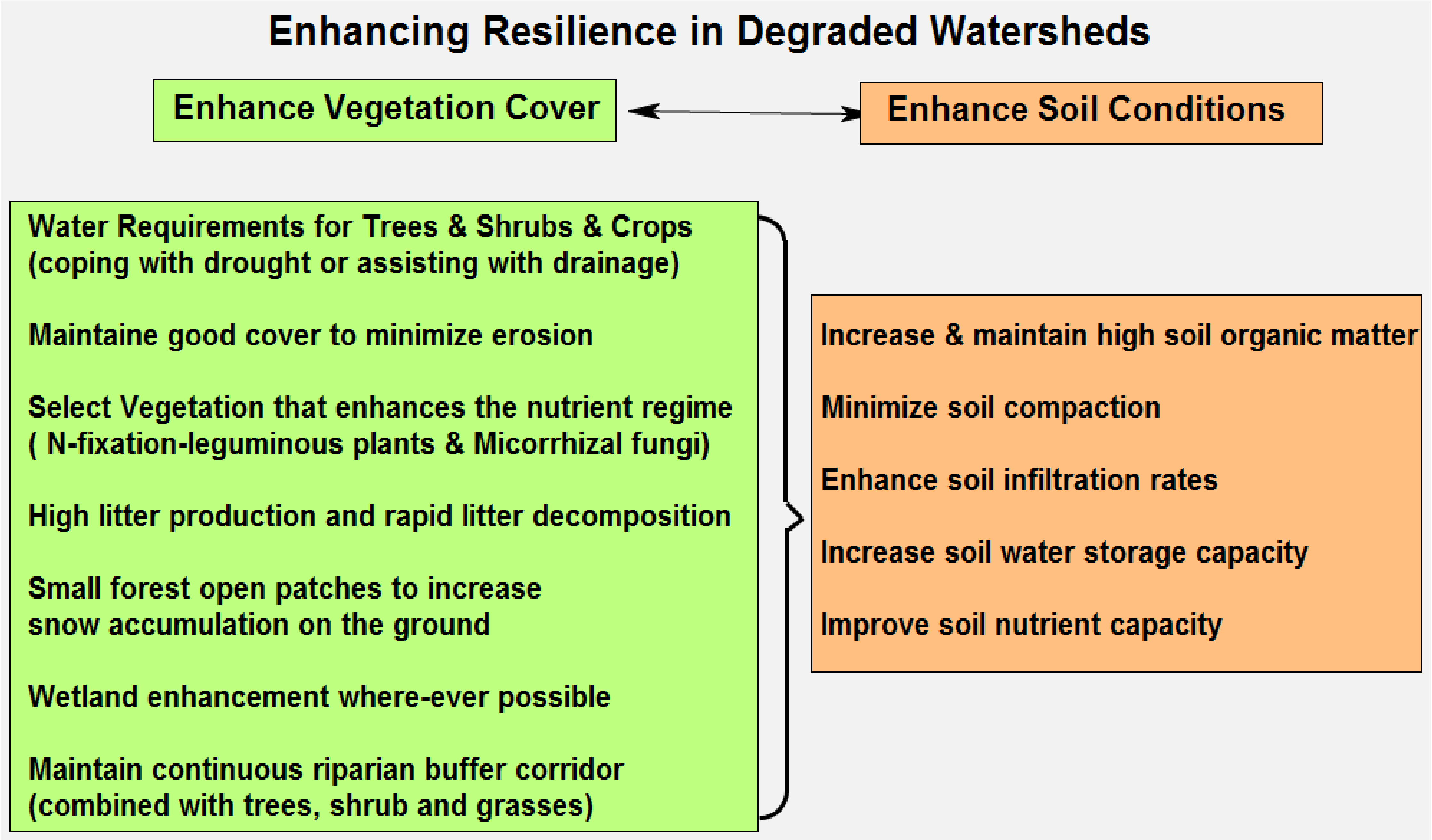
- Promote Participatory Mechanisms
- Assist River Basin Authorities & Councils
- Promote Integrated Watershed Management
- Initiate Capacity Building Programs

Technical

- Infrastucture Design
- Initiate Soil & Water Conservation
- Irrigation Efficiency
- Demand Management
- Water Saving Techn.
- Water Efficient Crops

Social/Cultural

- Create Awareness
- Education Programs
- Value Services Provided by Nature
- Consider Land- Water Interactions


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