Managing Soils of the Tropics to Meet Societal Demands of the 21st Century

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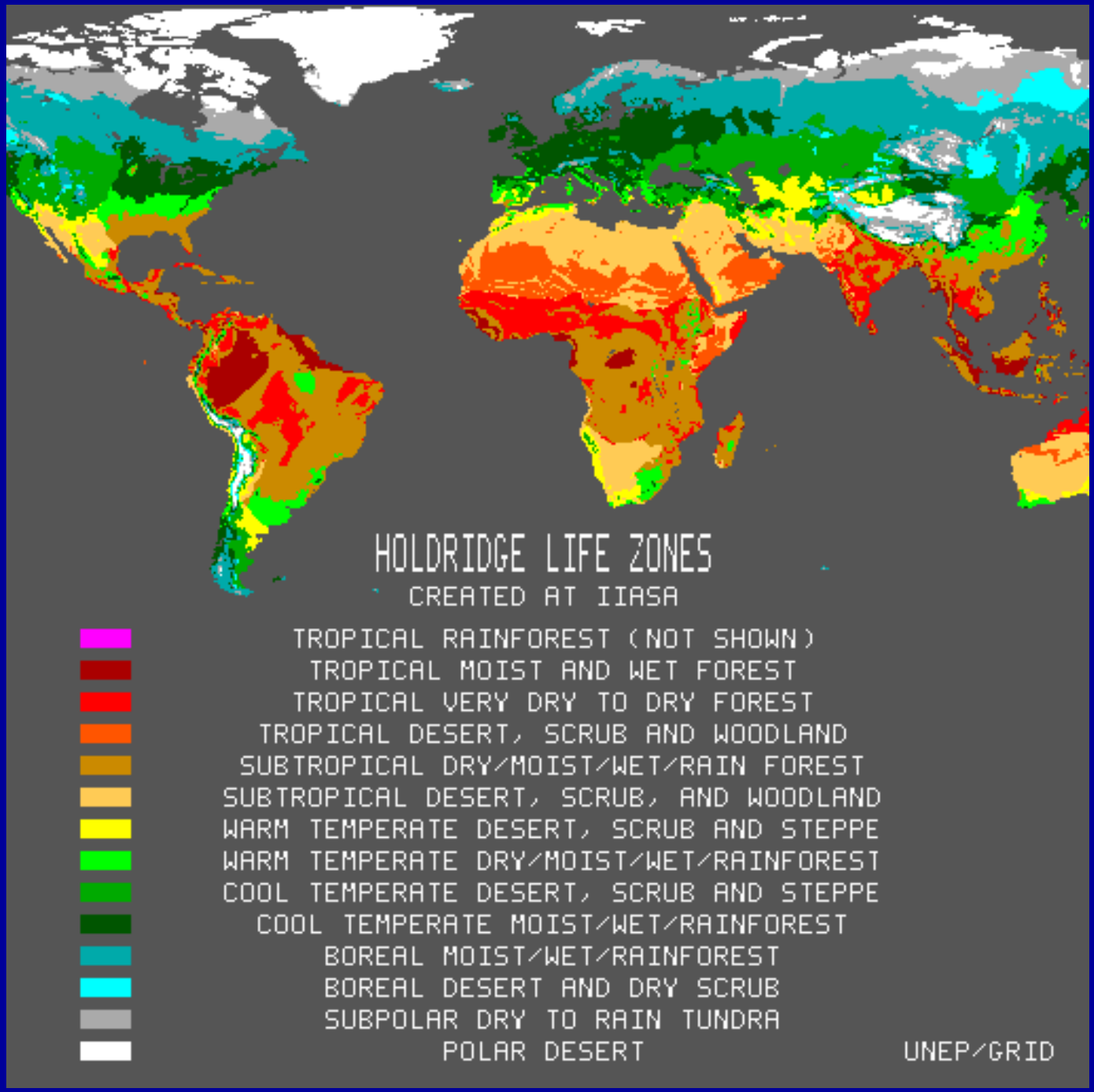

HOLDRIDGE LIFE ZONES
CREATED AT IIASA
TROPICAL RAINFOREST (NOT SHOWN)
TROPICAL MOIST AND WET FOREST
TROPICAL VERY DRY TO DRY FOREST
TROPICAL DESERT, SCRUB AND WOODLAND
SUBTROPICAL DRY/MOIST/WET/RAIN FOREST
SUBTROPICAL DESERT, SCRUB, AND WOODLAND
WARM TEMPERATE DESERT, SCRUB AND STEPPE
WARM TEMPERATE DRY/MOIST/WET/RAINFOREST
COOL TEMPERATE DESERT, SCRUB AND STEPPE
COOL TEMPERATE MOIST/WET/RAINFOREST
BOREAL MOIST/WET/RAINFOREST
BOREAL DESERT AND DRY SCRUB
SUBPOLAR DRY TO RAIN TUNDRA
POLAR DESERT
UNEP/GRID

Tropics

The land between 23ºN and S of the equator:

- **40% of the earth's surface**
- **5 billion hectares (Bha)**
- **50% of the world's rainfall**
- **53% of 3 Bha of the world's potentially arable land area**

Tropical Agroecosystems

Agroeco regions	LGP (days)	DMT (C°)
Warm humid tropics	275-365	>20
Warm seasonally dry tropics		
- sub-humid	180-275	>20
- semi-arid	75-118	>20
- arid	<75	>20
Cool tropics	--	5-20

LGP = Length of he growing period

DMT = Daily mean temperature

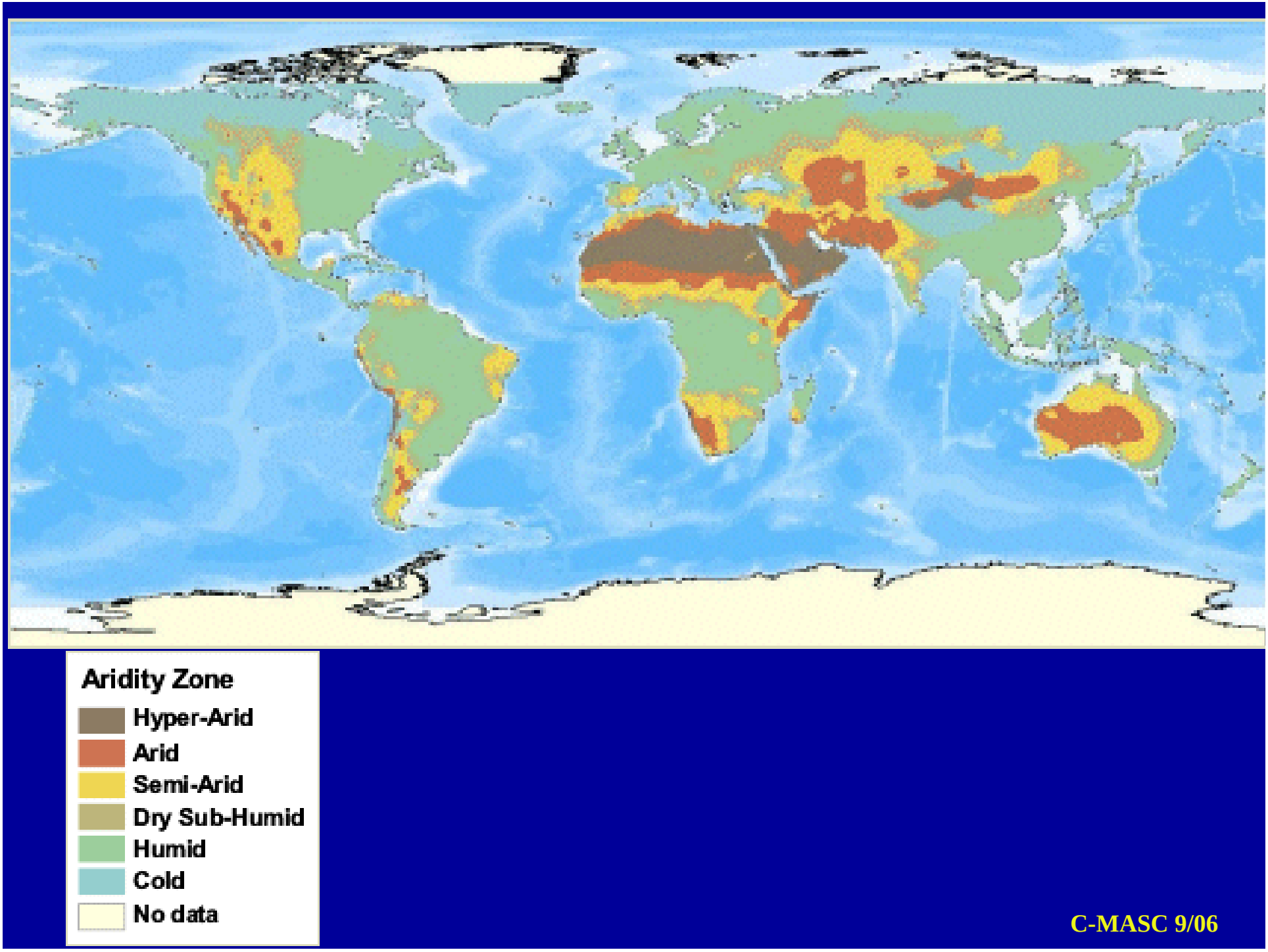
Principal Ecoregions of Drylands

Ecoregion	AI	Area (Bha)	% of earth's area
Sub-humid	0.50-0.65	1.29	9.9
Semi-arid	0.20-0.50	2.31	17.7
Arid	0.05-0.20	1.57	12.0
Hyper-arid	<0.05	0.98	7.5
Total		6.15	47.1

AI : Aridity Index

Global Distribution of World's Drylands

Region	Area (Bha)	% of earth's area
Africa	1.96	15.0
Asia	1.95	14.9
Australia	0.66	5.1
Europe	0.30	2.3
N. America	0.74	5.6
S. America	0.54	4.2
Total	6.15	47.1
U.S.	0.37	2.8


Aridity Zone
Hyper-Arid
Arid
Semi-Arid
Dry Sub-Humid
Humid
Cold
No data
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Land Use in Drylands

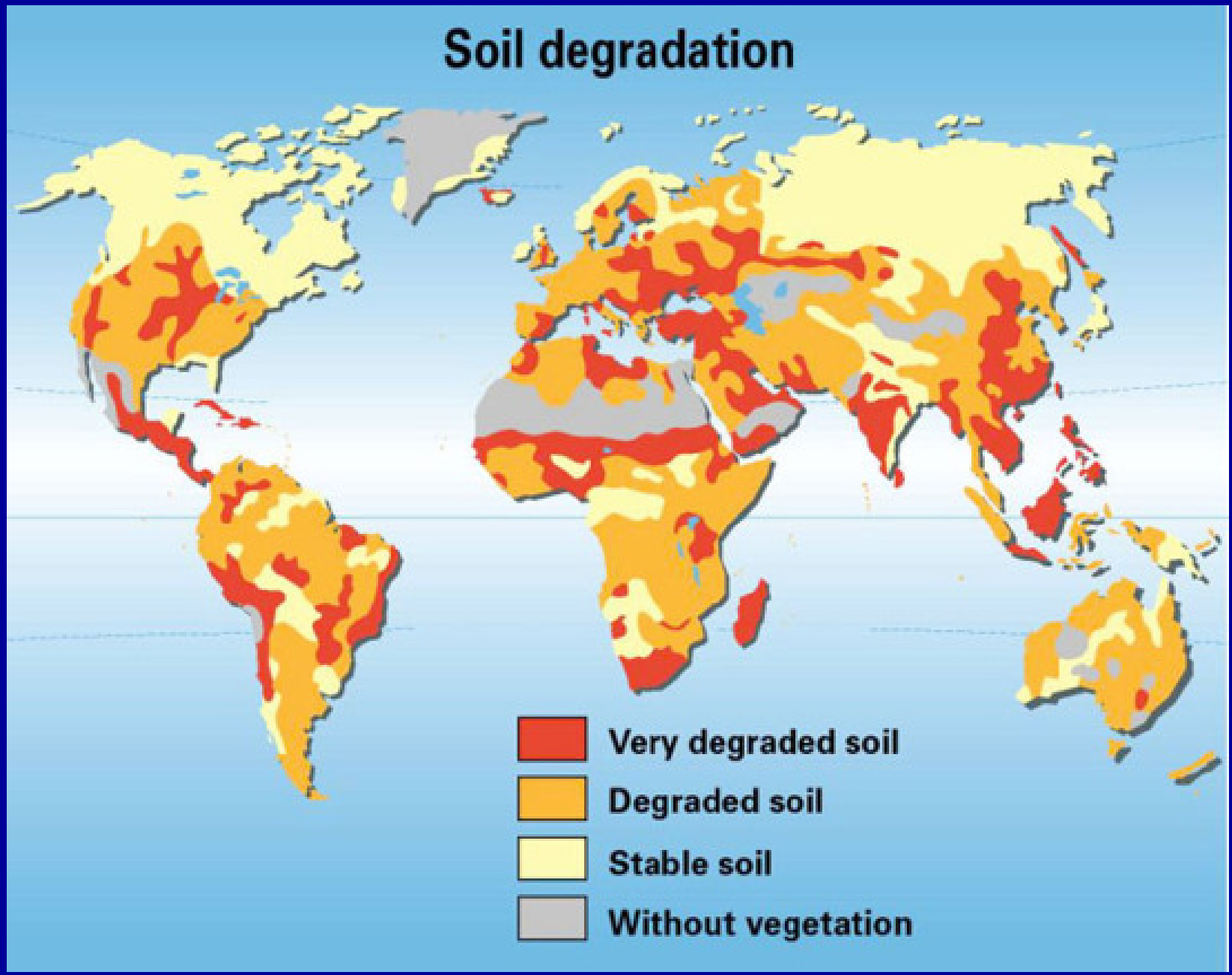
Land use	World	U.S.
	----------Mha----------	
Irrigated	145.5	15.2
Rainfed	457.7	30.1
Rangeland	4556.4	325.1
Hyper-arid	916.1	1.3
Total	6075.7	371.7

Dregne and Chou (1992)

Soil Degradation in Third World Countries

Region	Land area (10^6 ha)
Africa	494
Asia	747
C. America and Mexico	63
S. America	234
Total	1538
World	1964

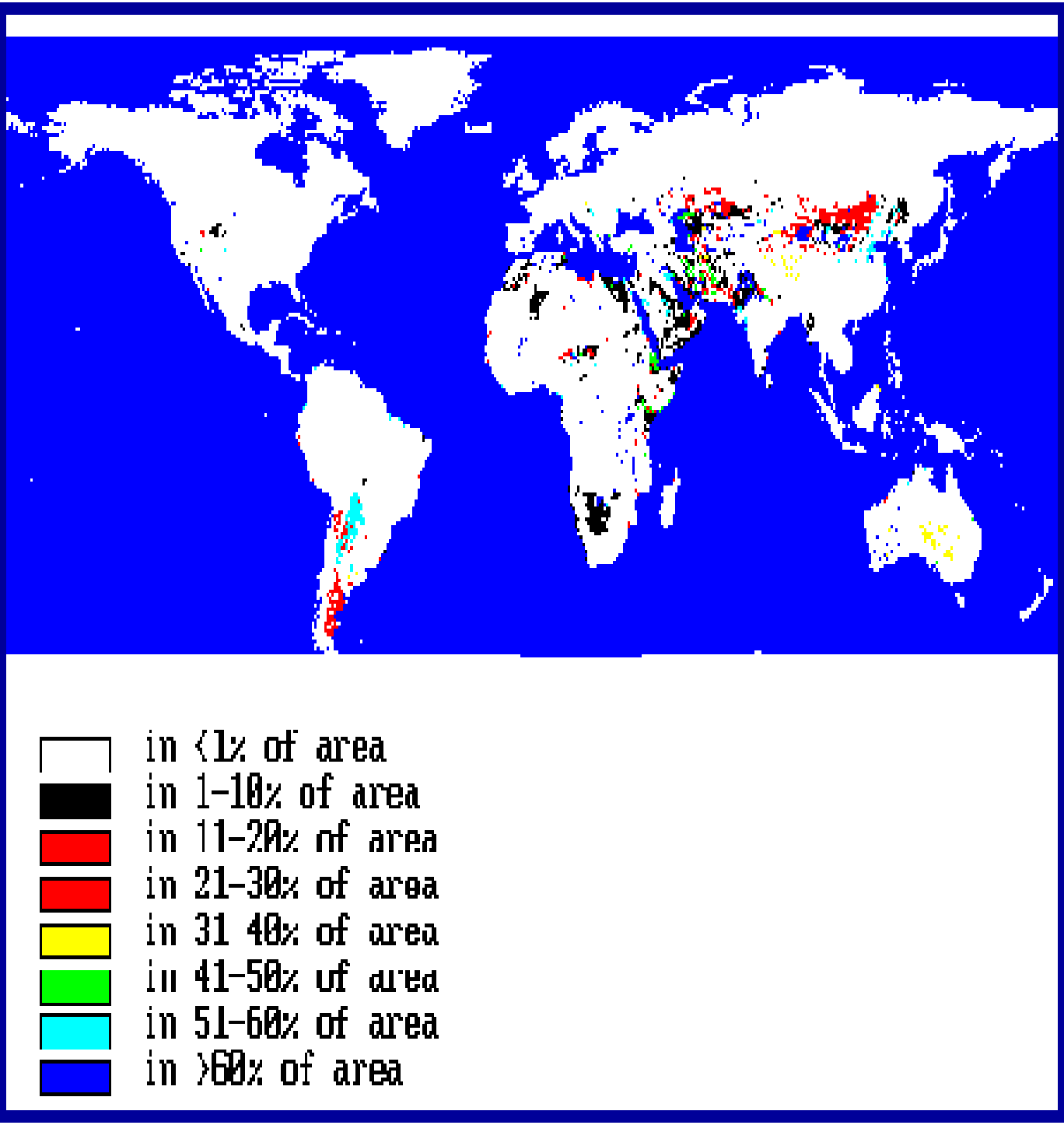
Oldeman, 1994


Soil degradation
Very degraded soil
Degraded soil
Stable soil
Without vegetation

Global Distribution of Salt-Affected Soils (10^6 ha)

Region	Saline	Alkali	Total
Africa	53.5	26.9	80.4
Americas	77.6	69.2	146.8
Asia	194.9	121.9	316.8
Australia	17.4	340.0	357.4
Total	343.3	558.1	901.4

Szabolcs, 1979; Gupta and Abrol, 1990



Saline Soils of the World

Forest Cleared Between 1960-1990

Region	%
Asia	30
Africa	18
Latin America	18
World	20

Total area of TRF lost from 1980-2000 = 250 Mha or 12-15 Mha/yr

Biomass Burning in the Tropics

Region	C released	
	Biomass burning	Deforestation
	----------Tg C/yr----------	
Tropical America	780	665
Africa	1450	373
Asia	980	621
Oceania	200	--
Total	3410	1659


QUEMAS
VEREDA LA TOMA, CAUCA
Junio de 2005

Average Annual Rate of Tropical Deforestation and Afforestation

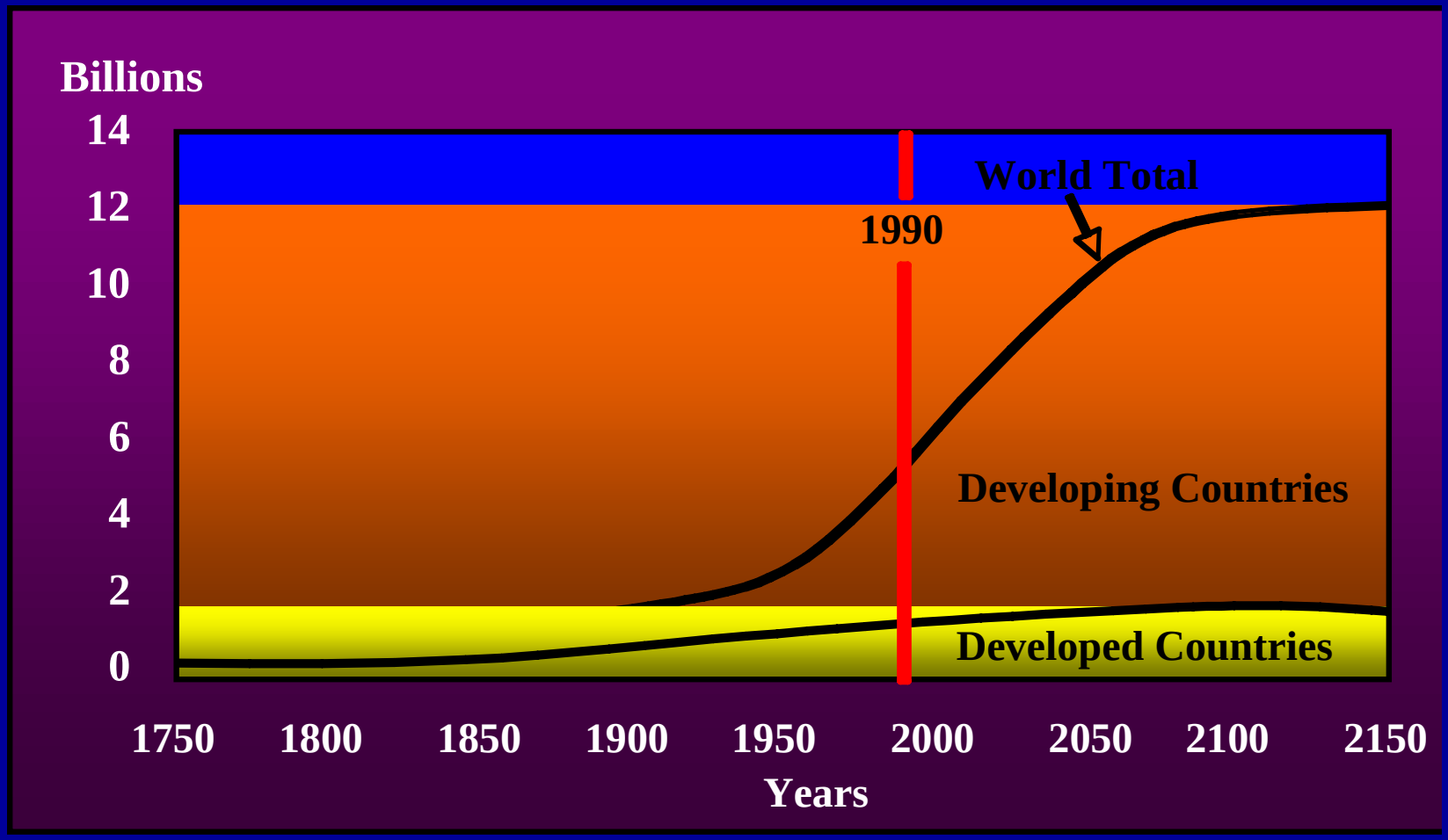
Region	1981 - 1990		1991 - 2000	
	Deforestation	Afforestation	Deforestation	Afforestation
	10^3			
Africa	-4,101	130	-5,524	250
Latin America	-7,407	373	-4,546	215
Asia	-3,922	22,104	-5,770	33,225
Total	-15, 430	2,607	-15,840	3,690

(Houghton 2003)

Deforestación

Sistemas agropastoriles

World Population Projections 1750 – 2150



Source: J. Bongaarts, The Population Council, 1994.

Food Gap by Region

Region	Food Gap	
	2000	2010
	- - 10^6Mg yr^{-1}- - -	
Sub-Saharan Africa	10.7	17.5
Latin America	0.6	1.0
Asia	1.7	3.6
Others	0.2	0.2
Total (67 Countries)	13.2	22.3

(Shapouri, 2005)

Latin America

Population: 7% of the 2004 world population of 6.3 B.

Total Area: 15.3% of the world's total area of 13.4 Bha.

Arable Land: 9.7% of the world's cropland of 1.4 Bha.

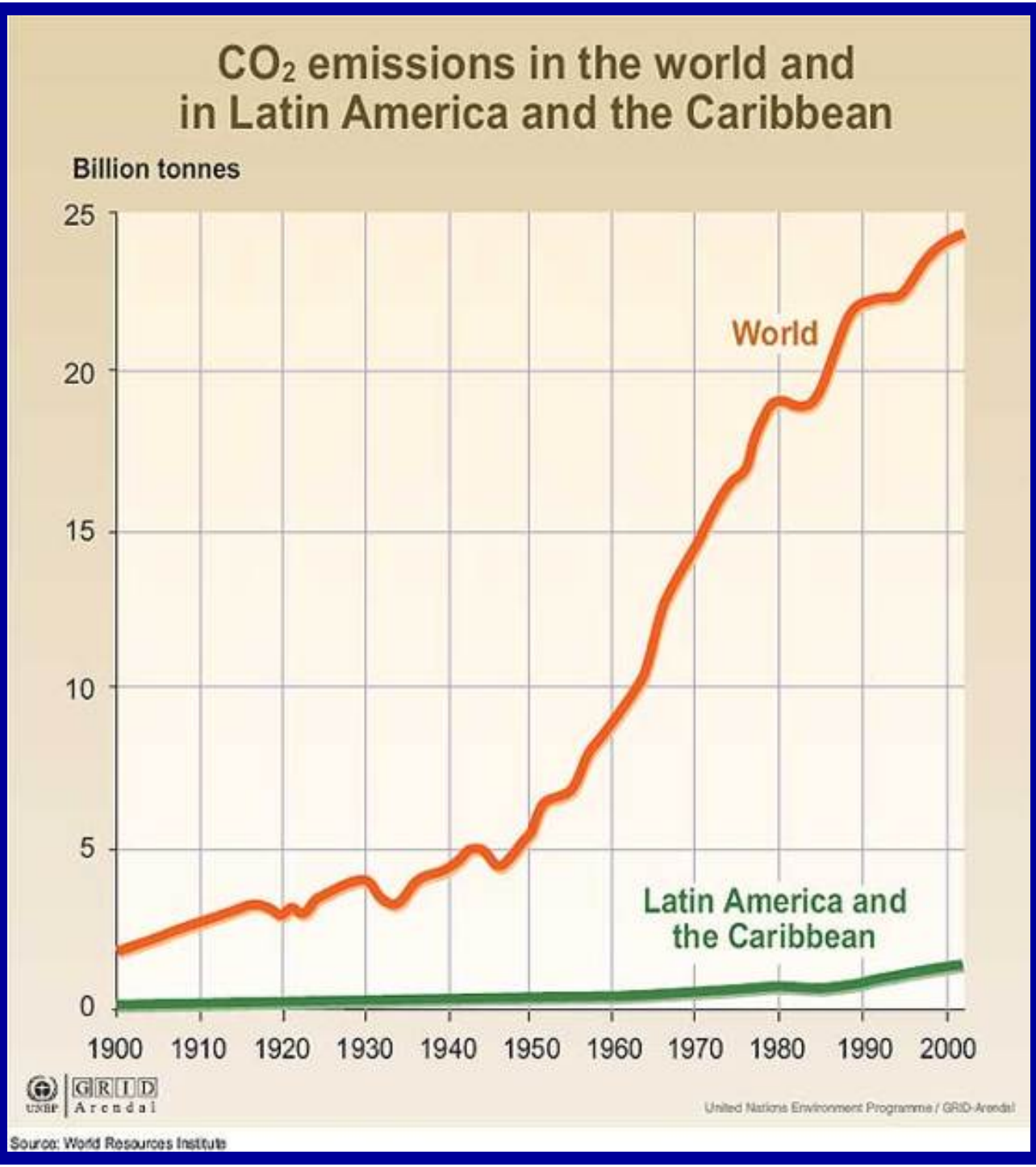
CO_2 emission in 2001: 4% of the world's emission 6.5 Pg.

World's TRF: 59% of world's TRF of 1.28 Bha.

CO_2-C Emissions in Latin America and the World

Year	CO_2 - C emissions (Tg C/yr)	
	Latin America	World
1990	192	5887
2001	263	6524
2010	326	7566
2025	504	10,135

(USDOE 2004)


CO_2 emissions in the world and in Latin America and the Caribbean
Billion tonnes
25
20
15
10
5
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
World
Latin America and the Caribbean
UNEP
GRID Arendal
United Nations Environment Programme / GRID-Arendal
Source: World Resources Institute

CO_2 Intensity in Latin America

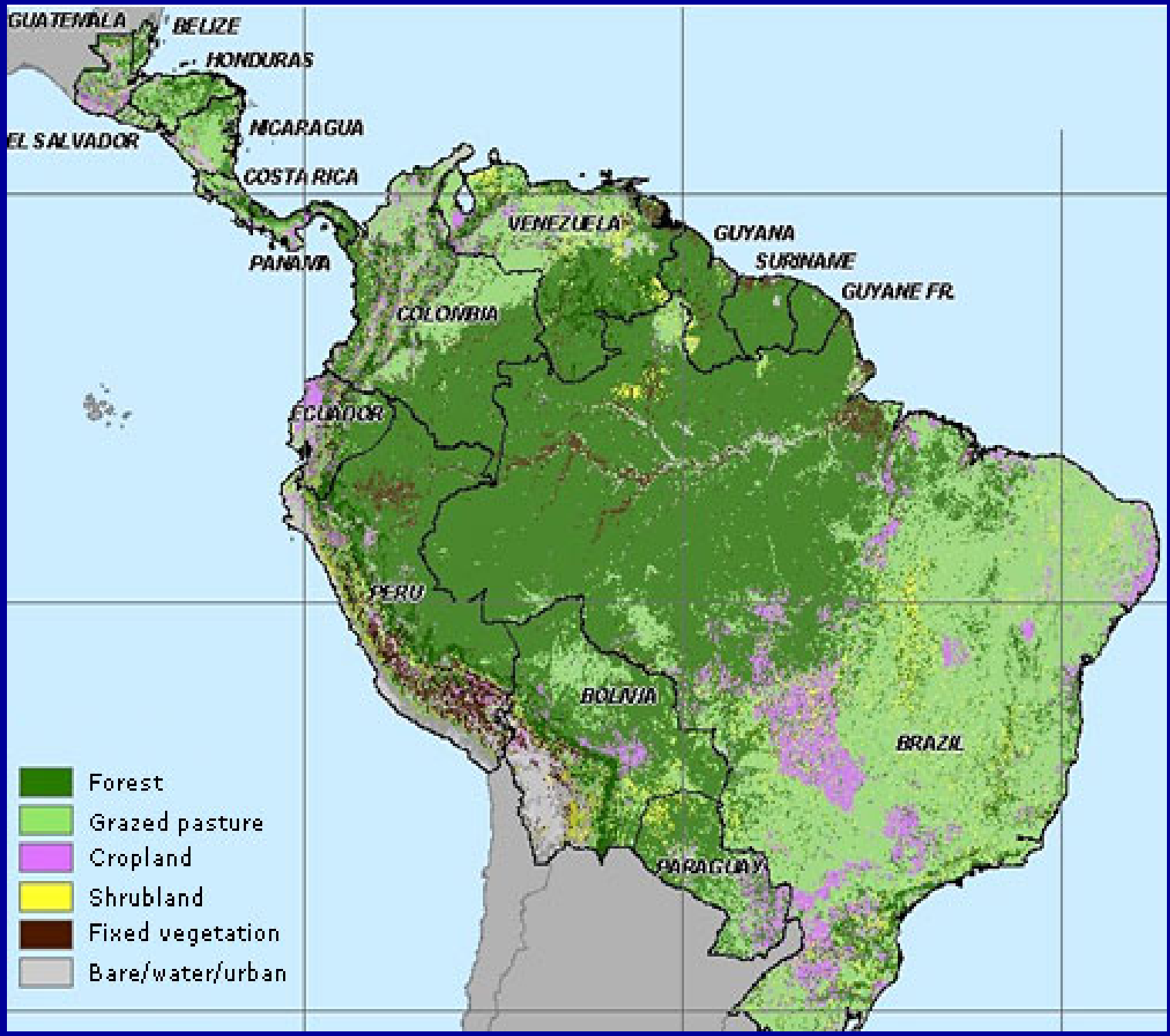
Relation between energy consumption and the gross domestic product metric ton of CO_2/USS million

Year	CO_2 Intensity
2001	615 Mg
2025	462 Mg

Land Use in South America

Land Use	Area (10^6 Ha)		
	Central America & Caribbean	South America	Total
Total area	271	1787	2058
Land area	255	1753	2008
Arable land	37	96	133
Permanent crops	6	20	26
Forest and woodland	?	?	1282

(FAO 2001)


GUATEMALA
BELIZE
HONDURAS
EL SALVADOR
NICARAGUA
COSTA RICA
PANAMA
VENEZUELA
GUYANA
SURINAME
GUYANE FR
COLOMBIA
ECUADOR
PERU
BOLIVIA
BRAZIL
PARAGUAY
Forest
Grazed pasture
Cropland
Shrubland
Fixed vegetation
Bare/water/urban

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Estimates of Rates of Deforestation in Some Countries of Latin America

Country	Rate of deforestation (10^3 ha/yr)
Bolivia	100 - 625
Brazil	1120 - 3671
Costa Rica	45 - 50
Mexico	3370 - 858
Venezuela	517 - 599

(Houghton 2003)

Global Issues of Soil Quality

1. Food security,
2. Availability of high quality water,
3. Air quality, and concentration of GHGs,
4. Waste disposal,
5. Urbanization and industrialization.

Soil Quality in the Context of 21st Century

It refers to soil's capacity to:

Maximize long-term productivity per unit input of non-renewable resources.

Minimize risks of environmental (water, air) pollution.

Moderate fluctuations in components of the water and energy budget due to change in land use and land cover, and

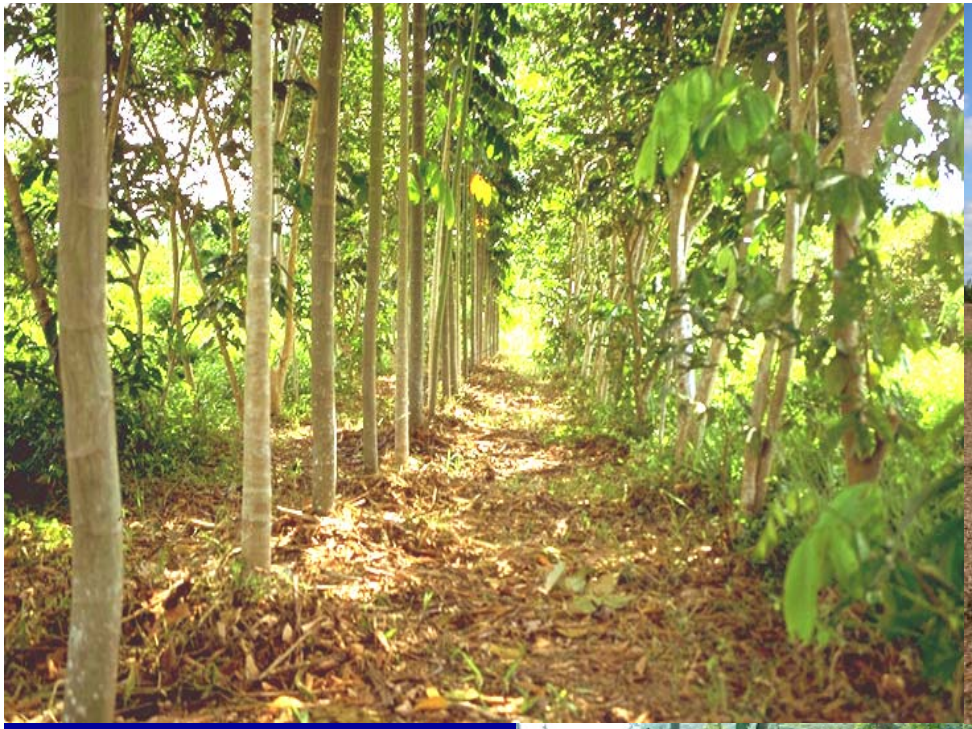
Proxy interpretations of past, and predict future global climate changes.

Issues of Soil Quality in Developed and Developing Countries

Developed countries	Developing countries
1. Optimizing crop yields per unit input	1. Maximizing crop yields per unit area, time
2. Minimizing input of chemicals and energy	2. Optimizing the use of off-farm input
3. Maximizing farm profit	3. Increasing household income
4. Reducing risks of pollution/ eutrophication of surface and ground waters	4. Ensuring adequate supply of water for human and animal consumption
5. Sustaining productivity on a long-term basis	5. Providing food for the family before the next harvest
6. Addressing issues of regional, national and global importance (e.g., global climate change)	6. Addressing concerns of the family

The Challenge of Soil Restoration in the Tropics

- Mulch farming
- No-till agriculture
- Agroforestry
- Integrated nutrient management



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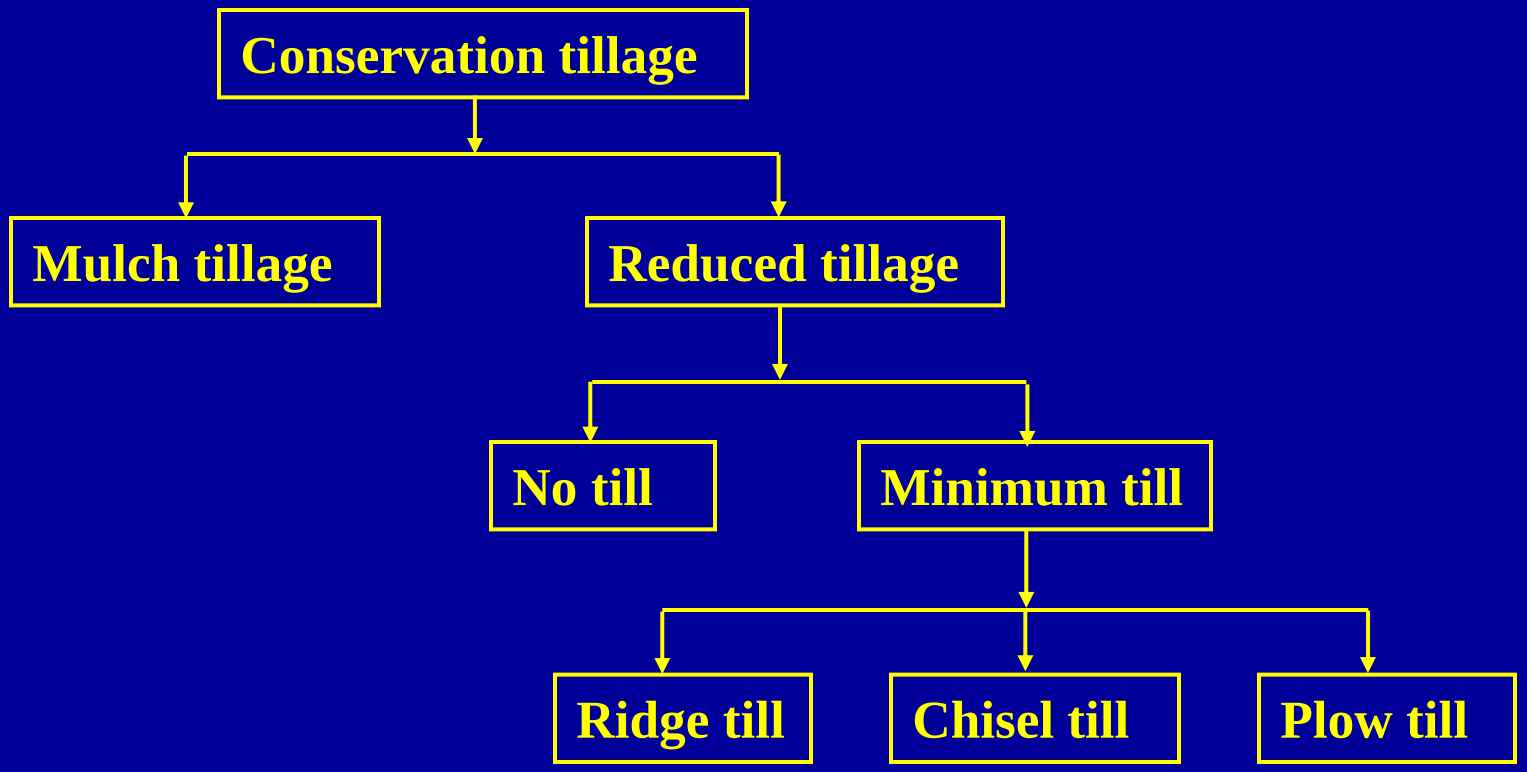
Mulch Farming

It is the strategy to ensure high soil productivity, reduce erosion and sedimentation, improve water quality, enhance SOC content, and sequester C to mitigate the greenhouse effect.

Mulch farming is the “life blood” of soils.

Types of Conservation Tillage Systems



Factors Affecting Choice of Tillage Systems

- Climate
- Soil
- Terrain
- Cropping systems
- Social, economic & cultural factors

Benefits of Conservation Tillage Systems in the Tropics

- Erosion control
- Water conservation
- Reducing maximum soil temperature
- Improving soil structure
- Decreasing fuel
- Increasing profit
- Improving SOC content and C sequestration

Soil and Ecological Conditions Favorable for No-Till Farming

Factor	Favorable conditions
• Terrain	Flat to undulating, less than 20%
• Soil drainage	Good internal drainage
• Texture	Light to medium texture
• Soil structure	Structurally active soils
• Soil biodiversity	High biodiversity
• Rainfall regime	Sub-humid to humid climate
• Crop residue	Availablity at 4 Mg/ha
• Perennial weeds	Minimal

Soil and Ecoregions Where Conservation Tillage Is Not Readily Applicable

Degraded antecedent soil physical conditions

- **Crusted**
- **Compacted**
- **Uneven micro-relief**
- **Biologically inert soil**

Sellamiento

Suelo endurecido

Soil and Ecoregions Where Conservation Tillage Is Not Readily Applicable

Inherent soil properties

- **Structurally inert soils with LACs**
- **Heavy texture**
- **Slow/impeded internal drainage**

Soil and Ecoregions Where Conservation Tillage Is Not Readily Applicable

Lack of crop residue mulch due to:

- **Biomass burning**
- **Uncontrolled/excessive grazing**
- **Residue removal for other purposes**

Soil and Ecoregions Where Conservation Tillage Is Not Readily Applicable

Incidence of Pests

- **Perennial weeds**
- **Rhizomatous weeds**
- **Lack of effective and economic herbicides**
- **Crop damage by insects, rodents, pathogens**

Soil and Ecoregions Where Conservation Tillage Is Not Readily Applicable

Lack of appropriate seeding equipment

Alternative Conservation Tillage Systems

- Tied ridges
- Broadbeds
- Paraplow
- Application of biosolids
- Soil amendments
- Cover crops
- Agroforestry

Cropland Under No-Till in Key Countries 2003/2004

Country	Area (million hectares)	Country	Area (million hectares)
United States	23.7	South Africa	0.3
Brazil	21.9	Spain	0.3
Argentina	16.0	Venezuela	0.3
Canada	13.4	Uruguay	0.3
Australia	9.0	France	0.2
Paraguay	1.5	Chile	0.1
Pakistan/Northern India	1.5	Others	1.2
Bolivia	0.4	Total	90.1

(From Brown, 2005)

Expanding Conservation Tillage in the Tropics

- There is a strong need to adopt conservation tillage throughout the tropics.
- It is a “quiet revolution”.

Conservation Tillage in Marginal Soils of Harsh Tropical Climates

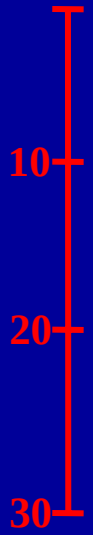
In areas of fragile soils and harsh climate, the benefits among tillage systems are to be sought in long-term sustainability of soil and water resources rather than in short-term yields.

- **Erosion control**
- **Water conservation**
- **C sequestration**


FORMACIÓN
DE
CARCAVAS


EROSIÓN POR
CAMINOS Y
COBERTURA
DEGRADADA
VEREDA LA TOMA, CAUCA
Junio de 2005

Desarrollo de raíces en pastos



Maíz labranza cero
T8 (Maíz – Soya A.V.)

Maíz cincel
T10 (*P. maximum*)

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Scope for Conservation Tillage in the Tropics

Soils and enviornment situations in the tropics necessitate researchers to look for ways to introduce conservation tillage in "feasible ecosystems." Such feasible ecosystems must be well-defined in terms of:

- **Soils, climate, drainage, irrigation**
- **Economic and social factors, and**
- **Institutional support**

Restoring SOC Pool by 1 Mg C ha^{-1} yr^{-1} and Food Production in LDCs

Crop	Area (10^6 ha)	Production Increase (10^6 Mg yr^{-1})
Cereals	430	21.8 - 26.3
Legumes	68	2.0 - 3.2
Tubers	34	6.6 - 11.3
Total	532	30.4 - 50.8

Observed Rates of C Sequestration in the Tropics

Strategy	SOC	SIC
	-------kg C/ha/yr------	
Conservation tillage systems	100-200	50-100
Restoration of degraded soils	50-250	50-100
Improving grazing lands	100-200	50-100

Potential of Soil C Sequestration

Region	Potential (Pg C yr^{-1})
World	0.6 - 1.2
Brazil	0.04 - 0.06
Tropics	0.29 - 0.54

Estimates of Carbon Sequestration and Carbon Sequestration Potential in Developing Countries Over 2003 - 2012

Region	Forest restoration	Sustainable agriculture	Avoided deforestation	Total C from all activities	Total net present value of all activities
	- 10^6 Mg C -				
Latin America	177.9	93.1	1097.3	1368.3	10,237.8
Africa	41.7	69.7	167.8	279.2	2,048.9
Asia	96.2	227.3	300.5	624.0	4,528.5
Total	315.8	390.1	1565.6	2271.5	16,815.2

(Modified from Niles et al., 2002)

Soil Carbon is Also a Farm Product

- **The Chicago Climate Exchange started trading C on 1 November 2003.**
- **The opening price was low at \$1/ton of CO_2 equivalent (\$3.67/ton of C).**
- **The present price is about \$1.90/ton of CO_2 equivalent (\$7.00/ton of C).**
- **The price in the E.U. countries is \$20/ton pf CO_2 equivalent (\$73.30/ton of C).**

The difference in price between the U.S. and European market is due to the mandatory cap imposed by E.U. countries on industrial emissions of CO_2.


Sustainable Management
of Soils of the Tropics
Sustainability
(SOC Sequestration)
Productivity
Soil Quality
Environmental Quality
Is a win - win situation