大自然透過**光合作用**，

將空氣中的二氧化碳與**有機質**結合，成為**土壤碳**

光合作用利用光及二氧化碳來製造醣類（如葡萄糖）

光合作用基本公式：

$$6\,CO_{2(氣體)} + 6\,H_2O_{(液體)} + 光 \rightarrow$$

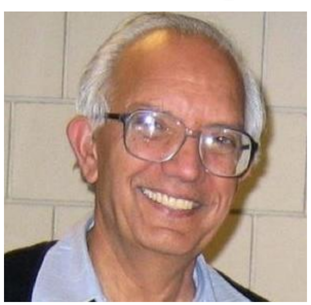
$$C_6H_{12}O_{6(液體)} + 6\,O_{2(氣體)}$$

(資料來源: wikipedia)

Dr. Christine Jones

Abe Collins

Dr. Elaine Ingham



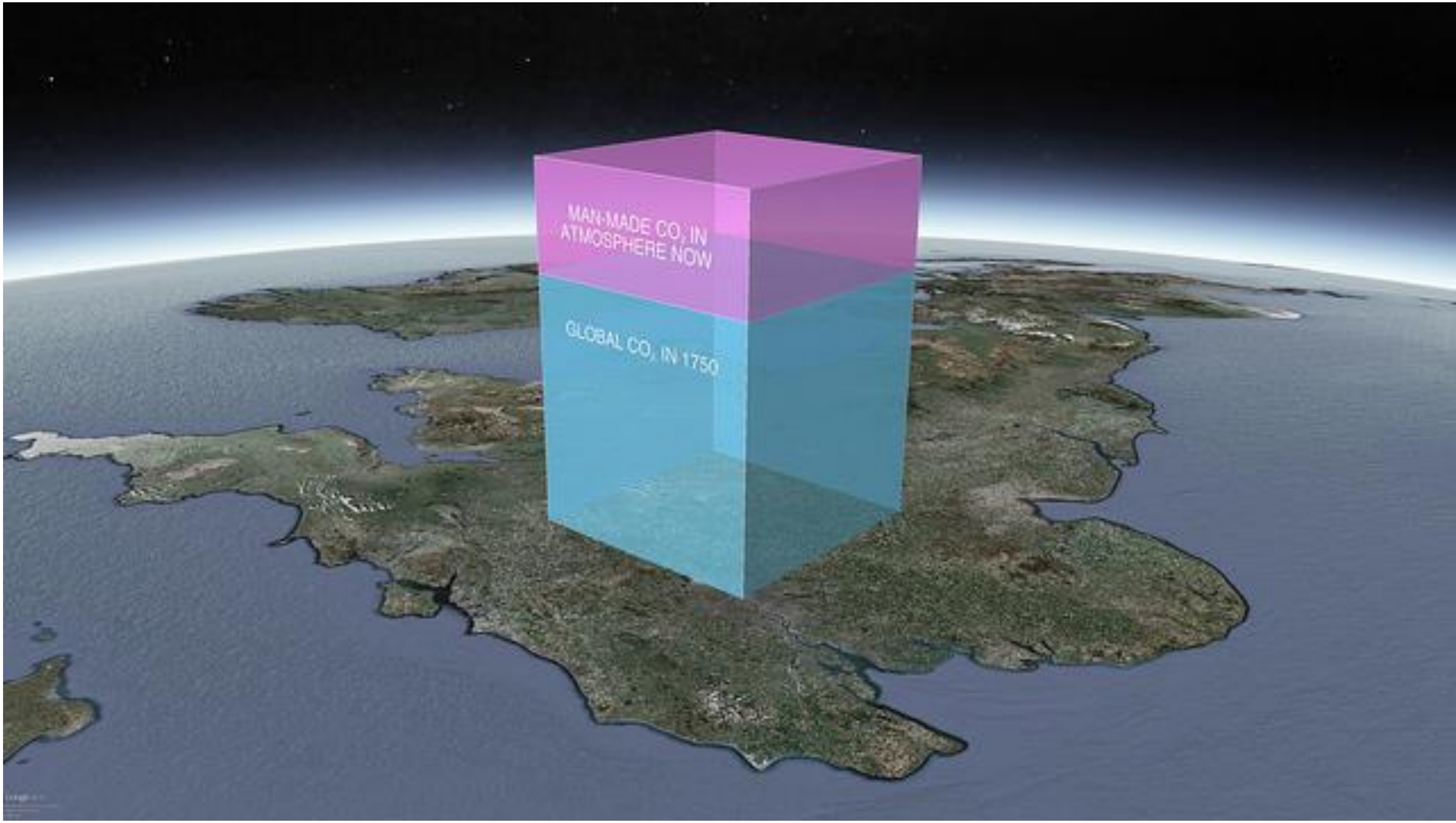
Prof. Rattan Lal

Carbon Farming

Carbon Farming as a term is fairly recent & has been popularised in response to the insights of people such as Allan Yeomans, Allan Savory, Professor Rattan Lal, Dr. Christine Jones & Abe Collins among others. The development of systems to increase soil carbon through the action of soil biota has been led by the work of Dr. Elaine Ingham & her colleagues at Soil Food Web Inc.

Several Techniques have been developed that are designed specifically to increase soil carbon:

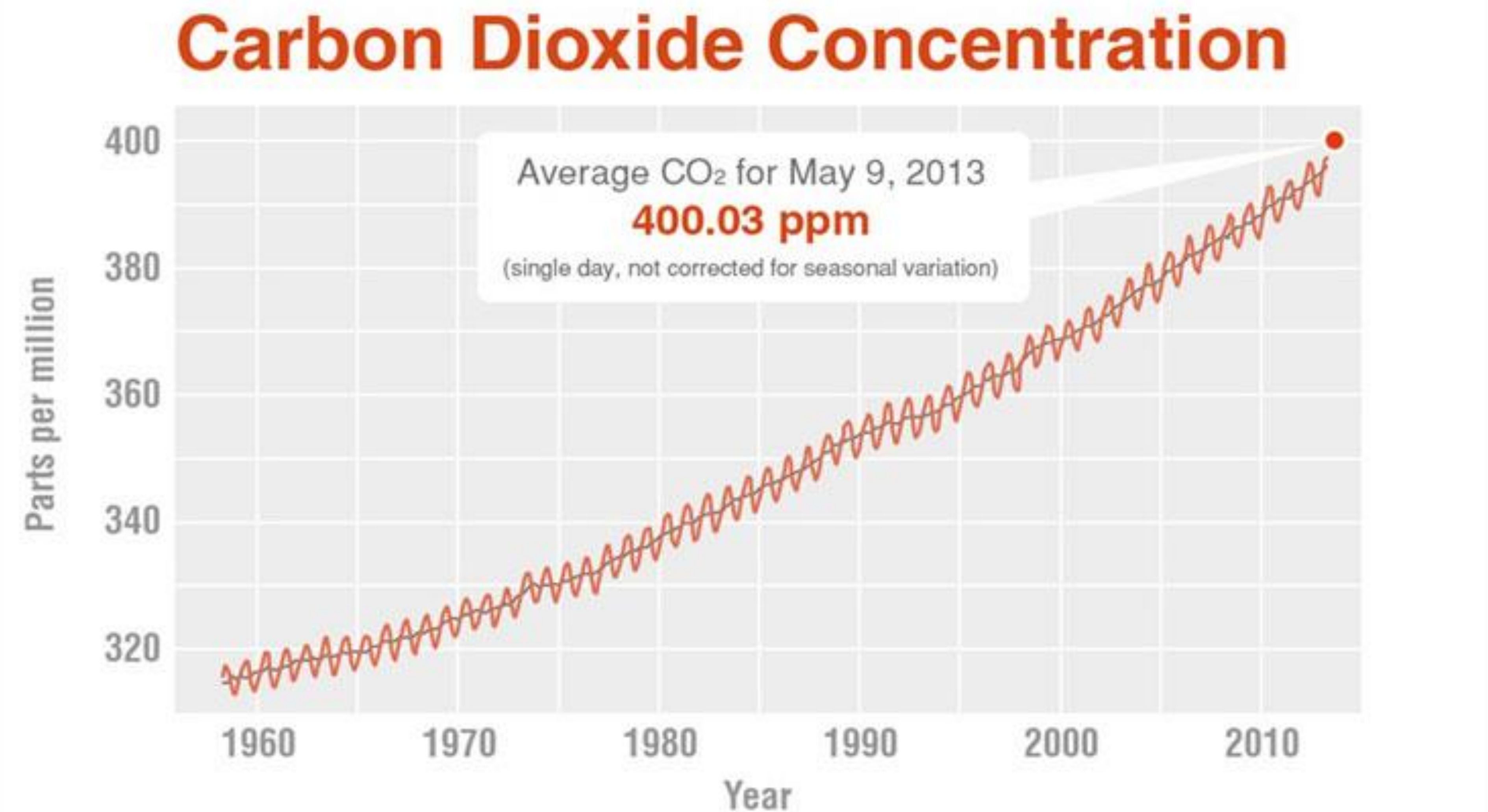
- **Holistic Management® Planned Grazing or 'Management Intensive Grazing'**
- **Yeomans Keyline Pattern Plowing or non-inversion sub-soiling**
- **Soil Food Web-designed Compost Tea application**
- **BioChar application**
- **Integrated Farm Planning using Permaculture, Keyline, ZERI & Holistic Management-inspired procedures & processes**


MAN-MADE CO_2 IN
ATMOSPHERE NOW
GLOBAL CO_2 IN 1750

First time over 400ppm: 2013

Full time over 400ppm: 2016.3

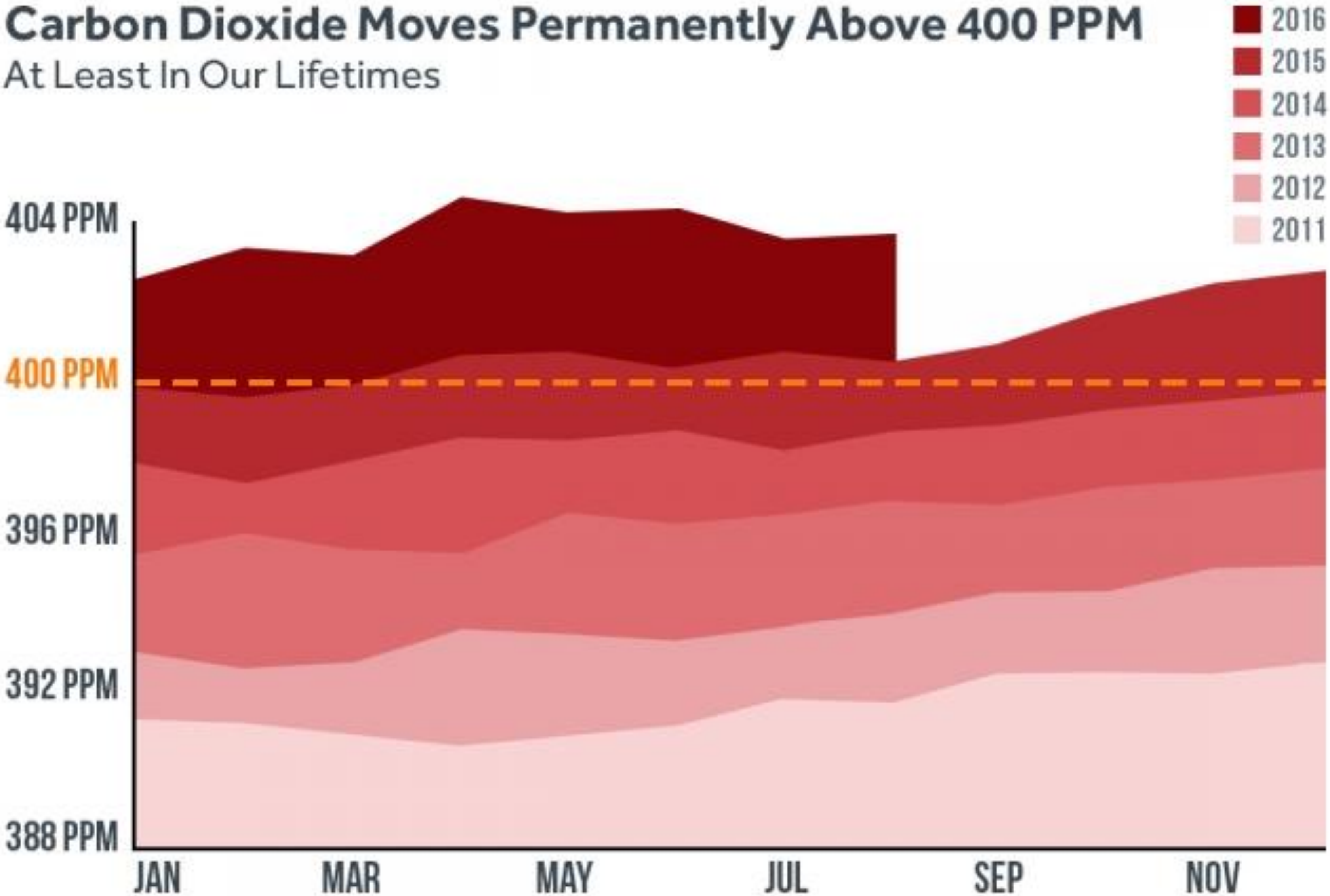
Safe level:350ppm



Credit: NOAA/Scripps Institution of Oceanography

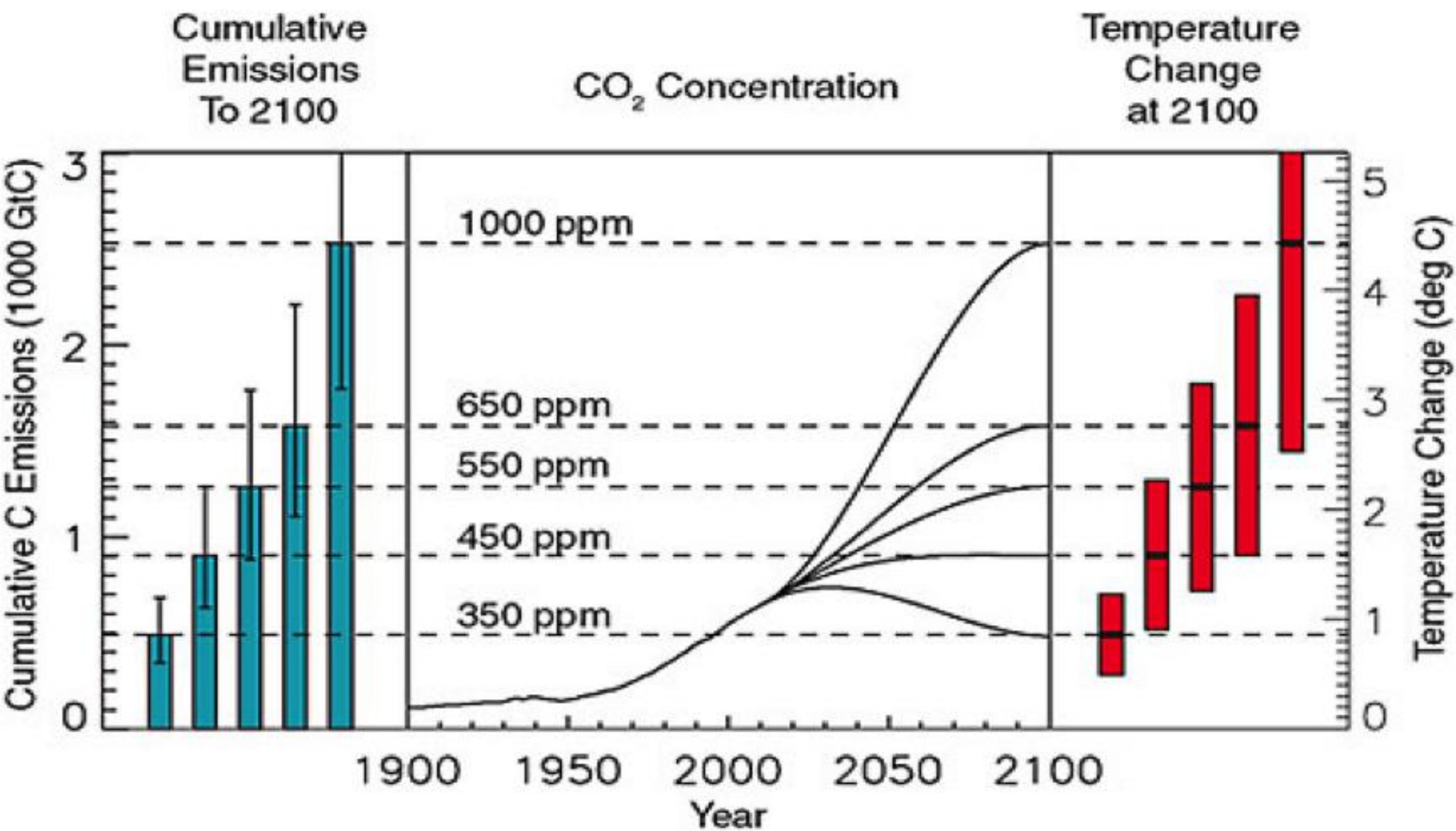
Carbon Dioxide Moves Permanently Above 400 PPM

At Least In Our Lifetimes



Source: Scripps Institute of Oceanography, Mauna Loa Observatory

CLIMATE CENTRAL



Cumulative Emissions To 2100
CO2 Concentration
Temperature Change at 2100
Cumulative C Emissions (1000 GtC)
Temperature Change (deg C)
1000 ppm
650 ppm
550 ppm
450 ppm
350 ppm
0
1
2
3
0
1
2
3
4
5
1900
1950
2000
2050
2100
Year

“Decade Zero”

- “The door to 2° C is about to close. In 2017 it will be closed forever.”
  - – Fatih Birol, chief economist for International Energy Agency

Climate Realities

- Climate change is real and is caused by human activity: 97% of climate scientists agree
- Greenhouse effect
- Arctic ice
- Climate uncertainties:
  - IPCC: +3.8° C to +4.8° C by 2100
  - Scientists: +2.5° C to +7.8° C by 2030 to 2100
  - Current status: +1.5° C already locked in (reality is continually more drastic than IPCC estimates)

+6° C is real possibility

+2° C will endanger 2.7 billion people in 46 countries by fueling conflict over resources and space

-6° C Last ice age

+6° C 55 million years ago when there was rainforest in Greenland

+6° C Great Permian extinction 251 million years ago (95% of life extinct within 100 years)

+6° C super-storms become regular and widespread

Tipping points臨界點
positive feedback loops正回饋環

- 北極因冰河融化而有更多融冰Arctic ice melt is causing more melting due to dark sea
- +2°C causes 15% of plants and soils to off-gas carbon to become net loss of stored carbon
- +4°C causes 40% of plants and soils to off-gas carbon
- +4°C將融化北極富含碳的土壤 (9000 億噸)(900,000,000,000)will melt Arctic carbon rich soils (900 billion tons)
- 海裡的甲烷Methane from sea

Part of problem is that we can't see the problem. Greatest effects are taking place far away.
How long have you already had a cold/cancer/been an alcoholic/been overweight before the symptoms get really bad?

臨界點Tipping points

Denuded mountains in Greece

臨界點Tipping points

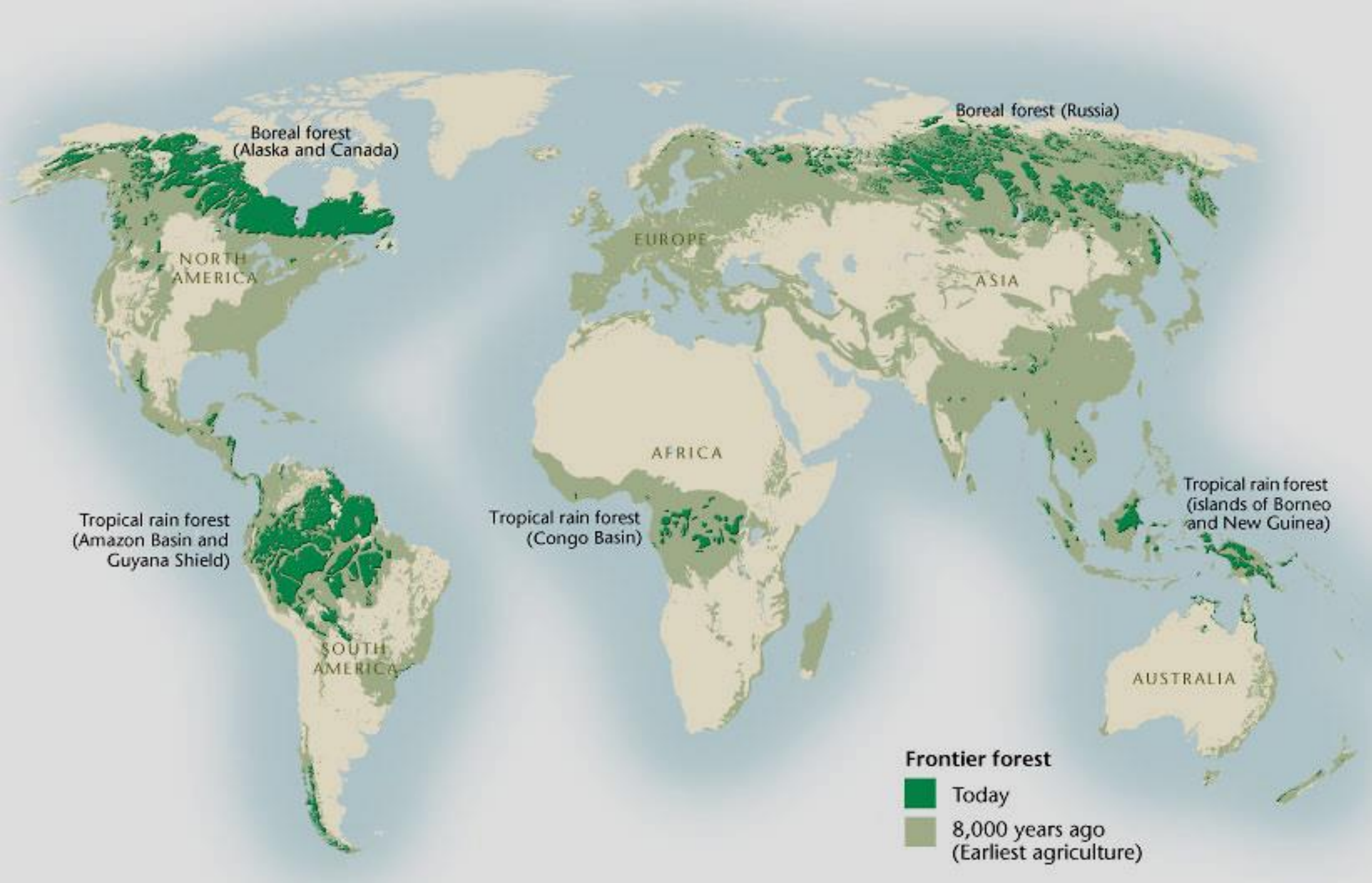
Anatolia, Turkey – thousands of years of human inhabitation


臨界點

臨界點

臨界點

8000年前的原始森林面積與現存森林面積 /8000年前，農業的起始



臨界點

Gastrotheca cornuta
This image was taken at the Omar Torrijos National Park study site in 2002, two years before epidemic. This species is now extinct in the region.

Made by Renée K

We are in the midst of a 6th mass extinction

Ordovician–Silurian extinction
450-440 million years ago

Late Devonian extinction
375-360 million years ago

Permian–Triassic extinction
251 million years ago

Triassic–Jurassic extinction
205 million years ago

Cretaceous–Paleogene extinction
65 million years ago

- Marine species that survived or aren't immediately threatened with extinction
- Terrestrial species that survived or aren't immediately threatened with extinction
- Species that went extinct
- Species threatened with extinction
- Species estimated to be extinct 100-500 years from now

A mass extinction is the extinction of a large number of species within a relatively short period of geological time.

The Earth has known five great mass extinctions in the past that each wiped off 50 to 85% of the species that were alive at that time. Some of these events were preceded by a huge disaster, such as a meteorite hitting the surface of the Earth or a supervolcano erupting, while others were caused by the shifting of the continents.

But the sixth mass extinction isn't like the ones that killed the dinosaurs; this one is entirely man-made. If we continue the precedent we have set up to this point, this exctinction event could be the fastest and one of the most devastating ones we have seen, yet.

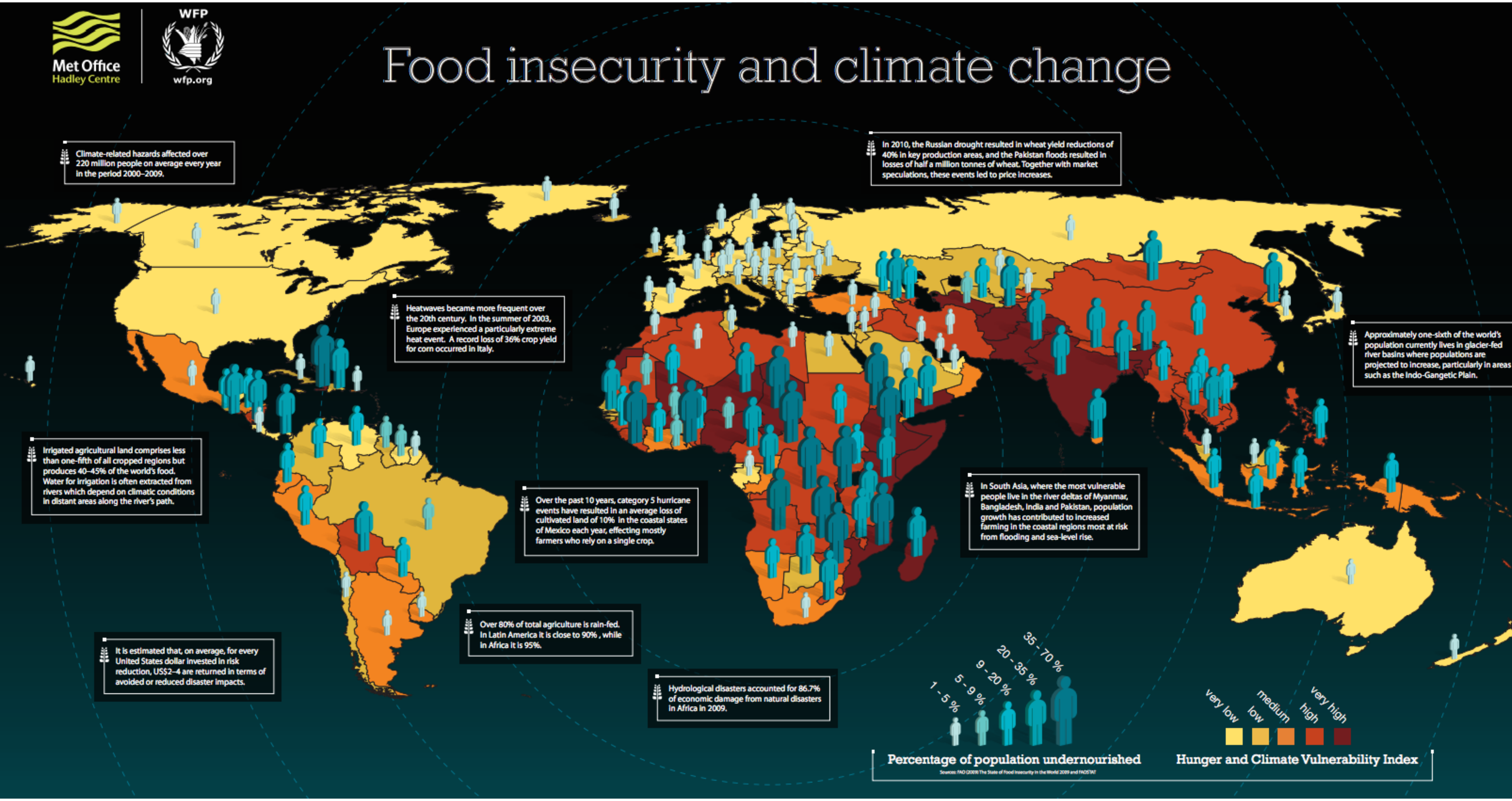
Why does this matter?

Ecosystems are fragile. Every animal, insect and plant species fulfills one or more invaluable roles to sustain the ecosystem it lives in. If one of those species goes extinct, the ecosystem needs time to adjust and restore. If several species go extinct in rapid succession, the consequences could be dire.

Ecosystems are valuable, and they provide us with resources and "services" free of charge. For instance, the total economic value of pollination by insects worldwide was estimated to be $200 billion in 2005.

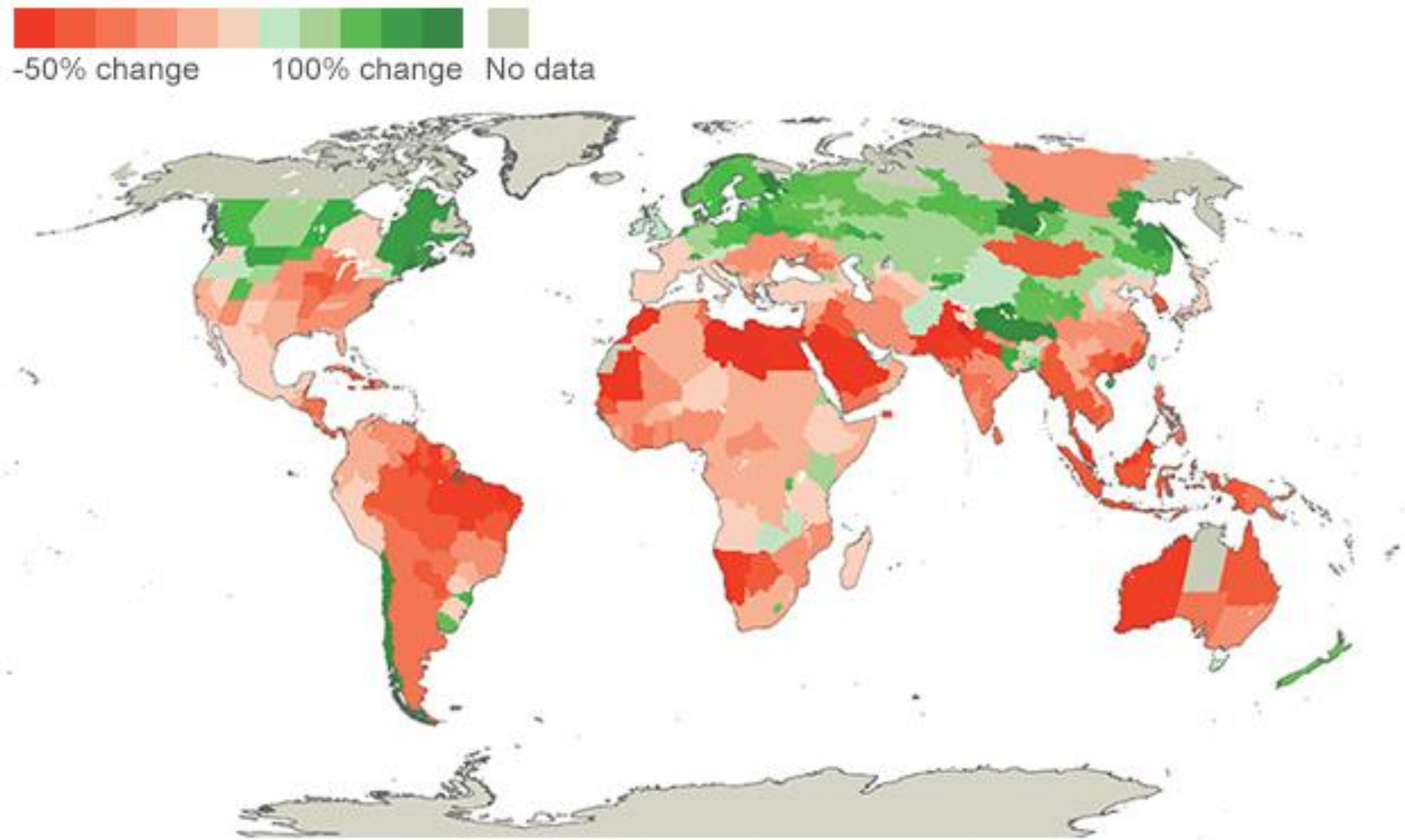
We depend on ecosystems to survive. The environment provides us with clean air, fresh water, ores and fuel. It provides us with the fertile soil we need to build our crops. It regulates climates and functions as a natural buffer against floods and storms.

糧食安全和氣候變遷

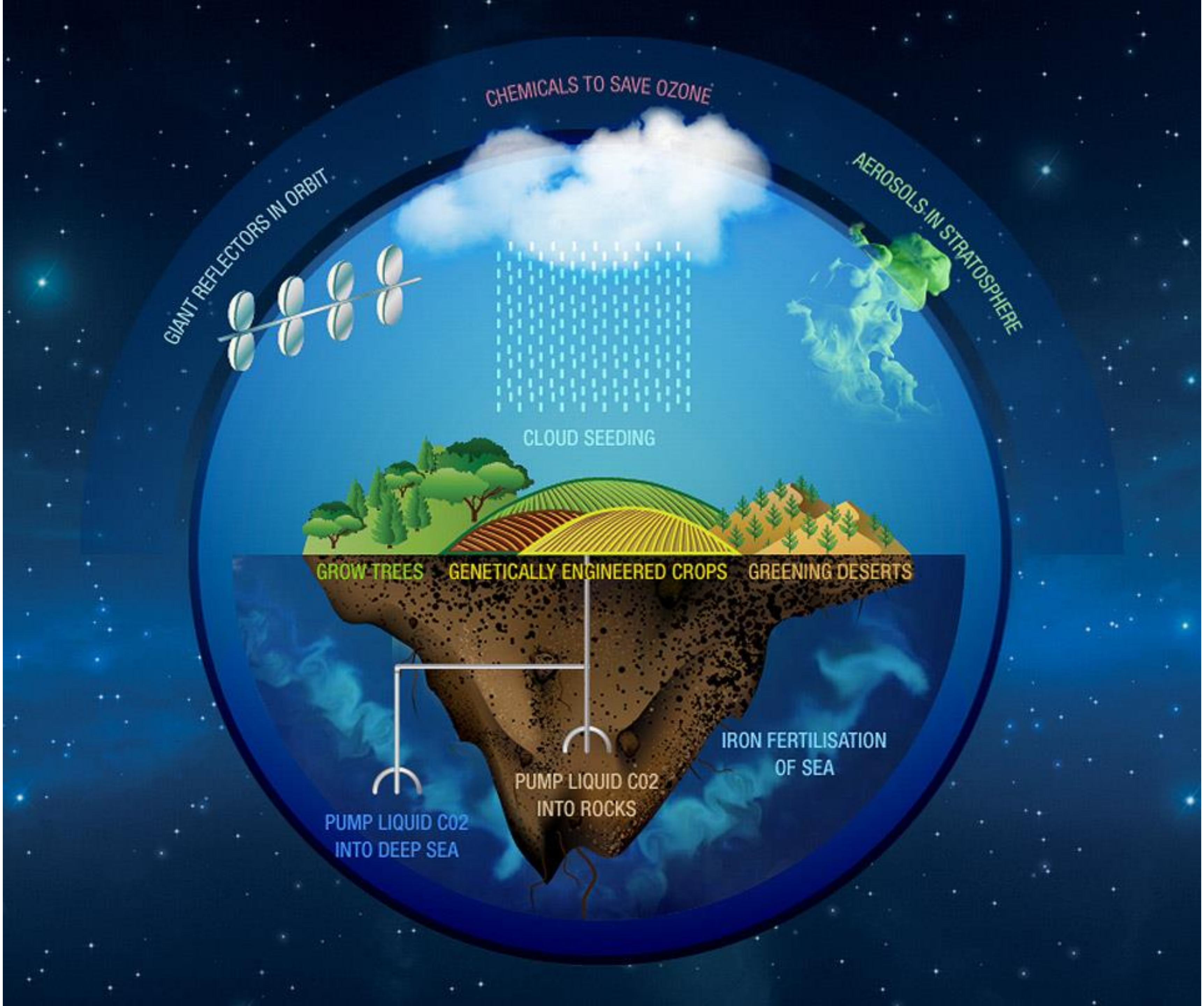


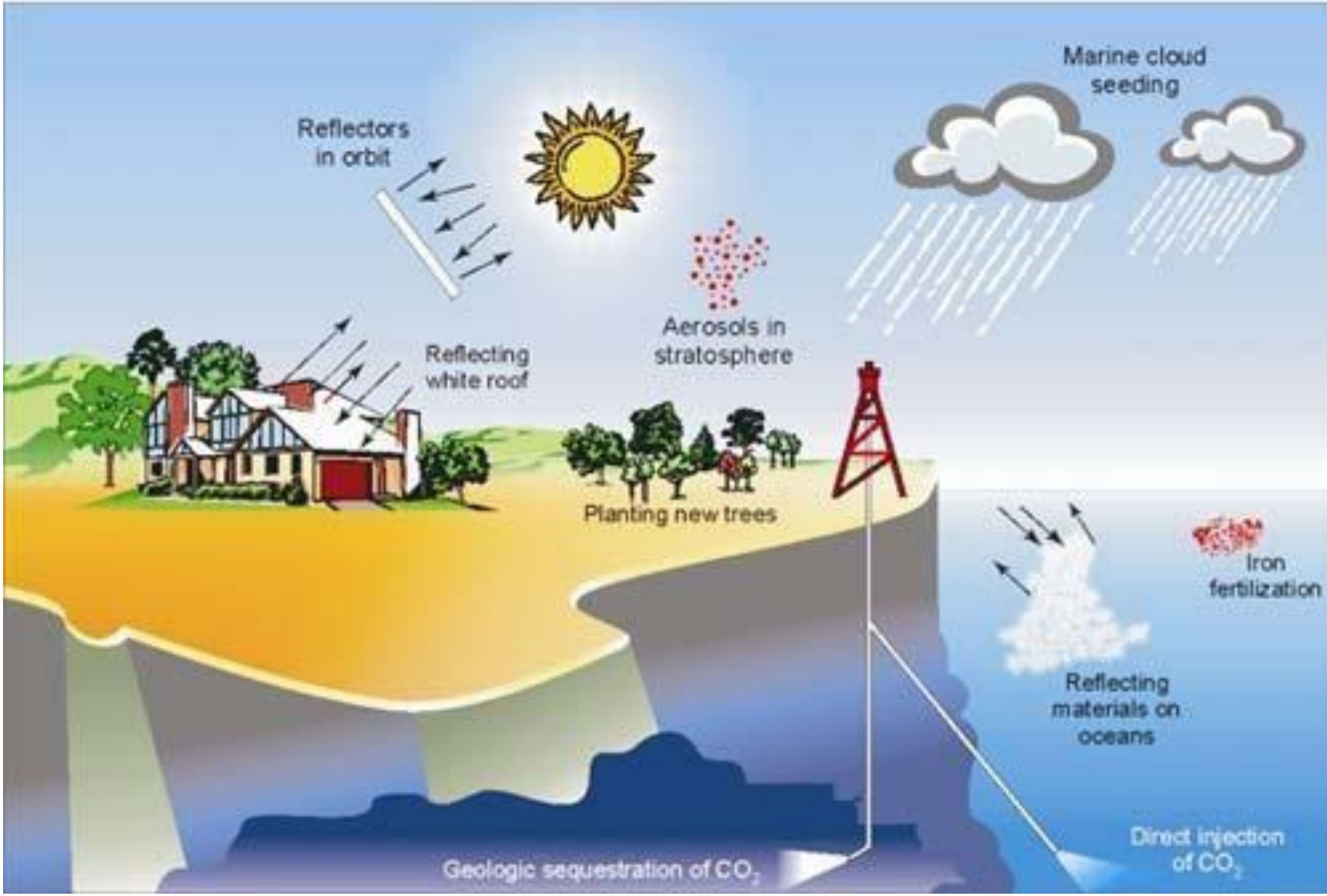
Met Office
Hadley Centre
WFP
wfp.org
Food insecurity and climate change
Climate-related hazards affected over 220 million people on average every year in the period 2000–2009.
In 2010, the Russian drought resulted in wheat yield reductions of 40% in key production areas, and the Pakistan floods resulted in losses of half a million tonnes of wheat. Together with market speculations, these events led to price increases.
Heatwaves became more frequent over the 20th century. In the summer of 2003, Europe experienced a particularly extreme heat event. A record loss of 36% crop yield for corn occurred in Italy.
Approximately one-sixth of the world's population currently lives in glacier-fed river basins where populations are projected to increase, particularly in areas such as the Indo-Gangetic Plain.
Irrigated agricultural land comprises less than one-fifth of all cropped regions but produces 40–45% of the world's food. Water for irrigation is often extracted from rivers which depend on climatic conditions in distant areas along the river's path.
Over the past 10 years, category 5 hurricane events have resulted in an average loss of cultivated land of 10% in the coastal states of Mexico each year, effecting mostly farmers who rely on a single crop.
In South Asia, where the most vulnerable people live in the river deltas of Myanmar, Bangladesh, India and Pakistan, population growth has contributed to increased farming in the coastal regions most at risk from flooding and sea-level rise.
Over 80% of total agriculture is rain-fed. In Latin America it is close to 90%, while in Africa it is 95%.
It is estimated that, on average, for every United States dollar invested in risk reduction, US$2–4 are returned in terms of avoided or reduced disaster impacts.
Hydrological disasters accounted for 86.7% of economic damage from natural disasters in Africa in 2009.
1 - 5 %
5 - 9 %
9 - 20 %
20 - 35 %
35 - 70 %
Percentage of population undernourished
Sources: FAO (2009) The State of Food Insecurity in the World 2009 and FAOSTAT
very low
low
medium
high
very high
Hunger and Climate Vulnerability Index

Estimated impact of +3 degrees C change on crop yields by 2050

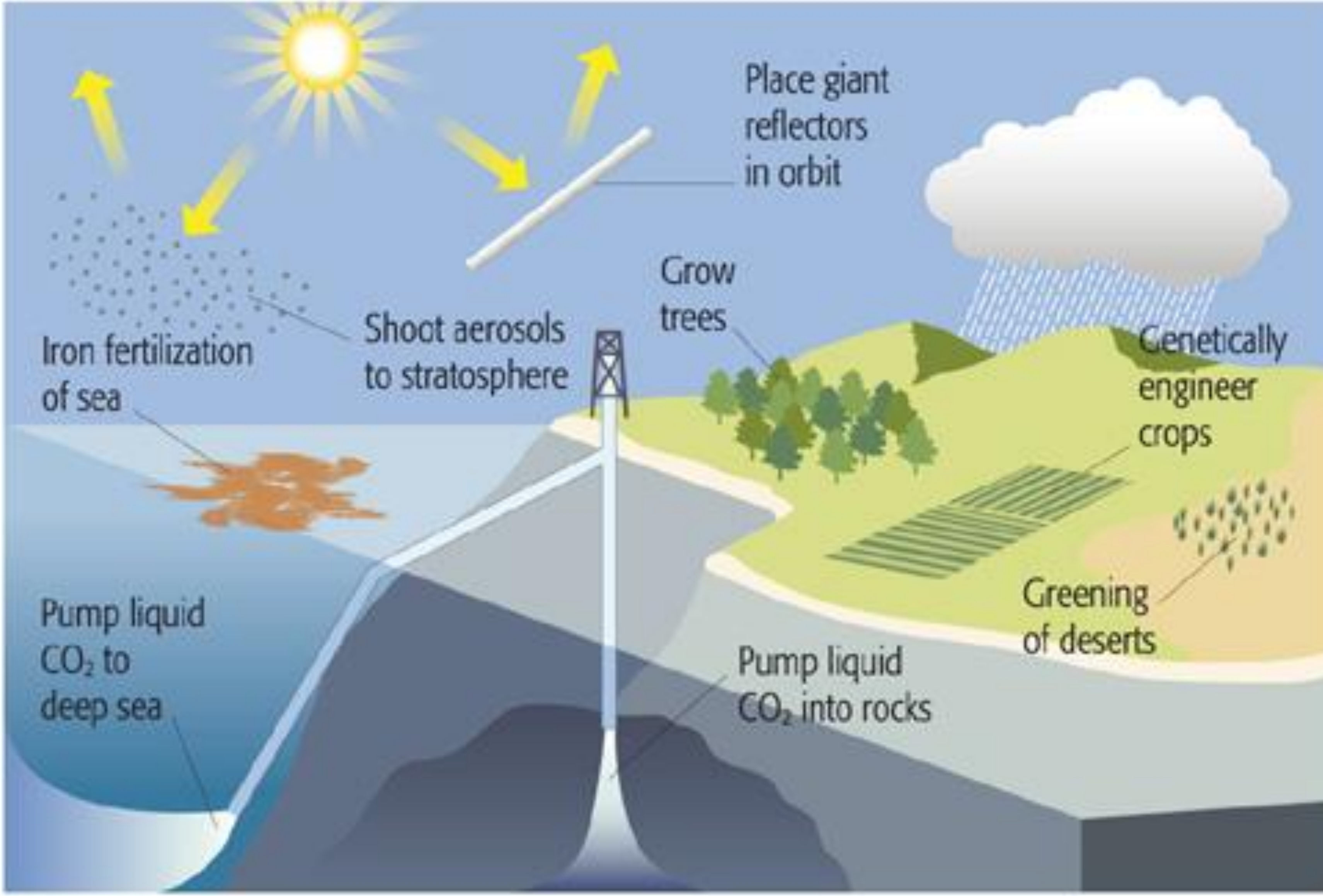


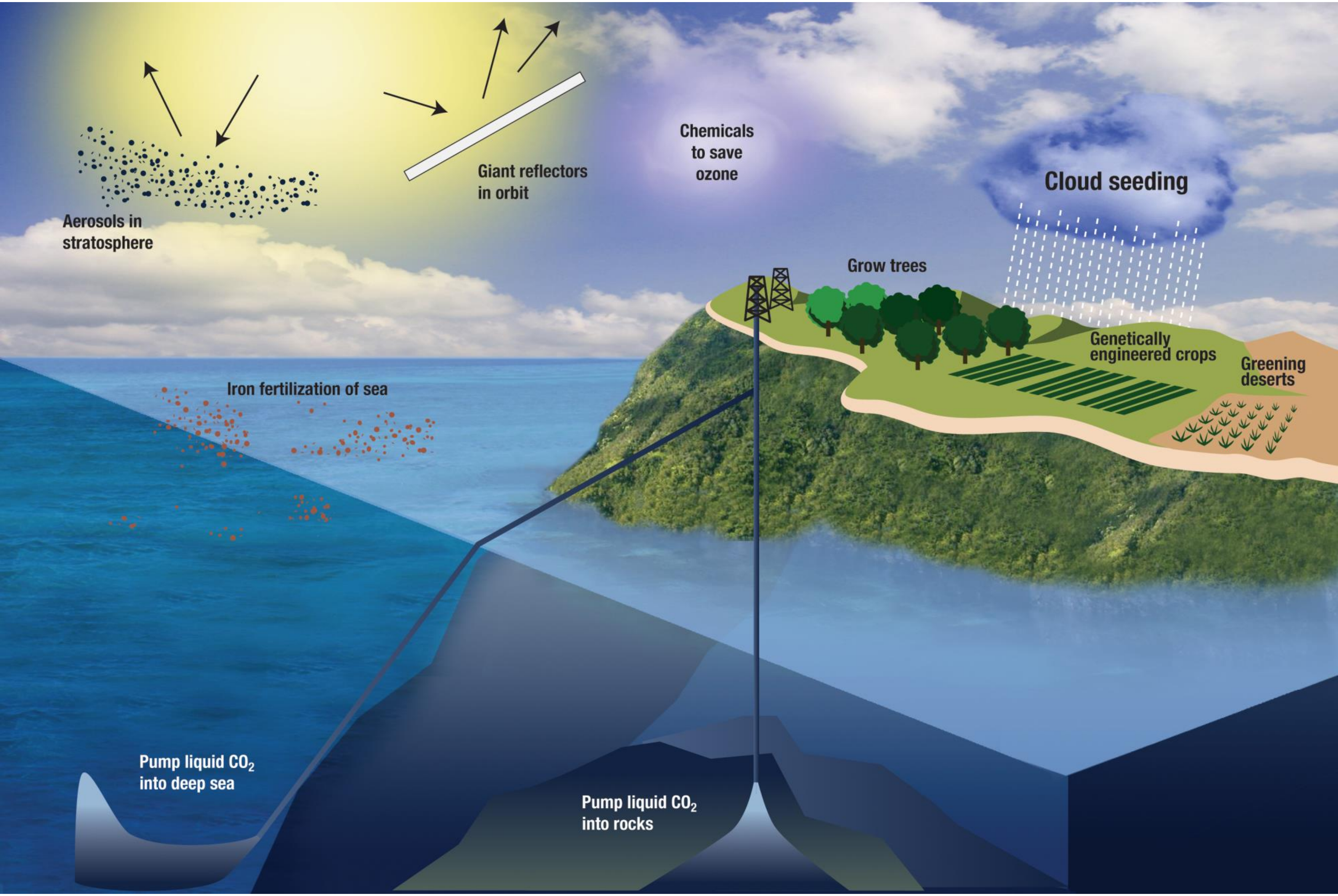
Source: World resources institute

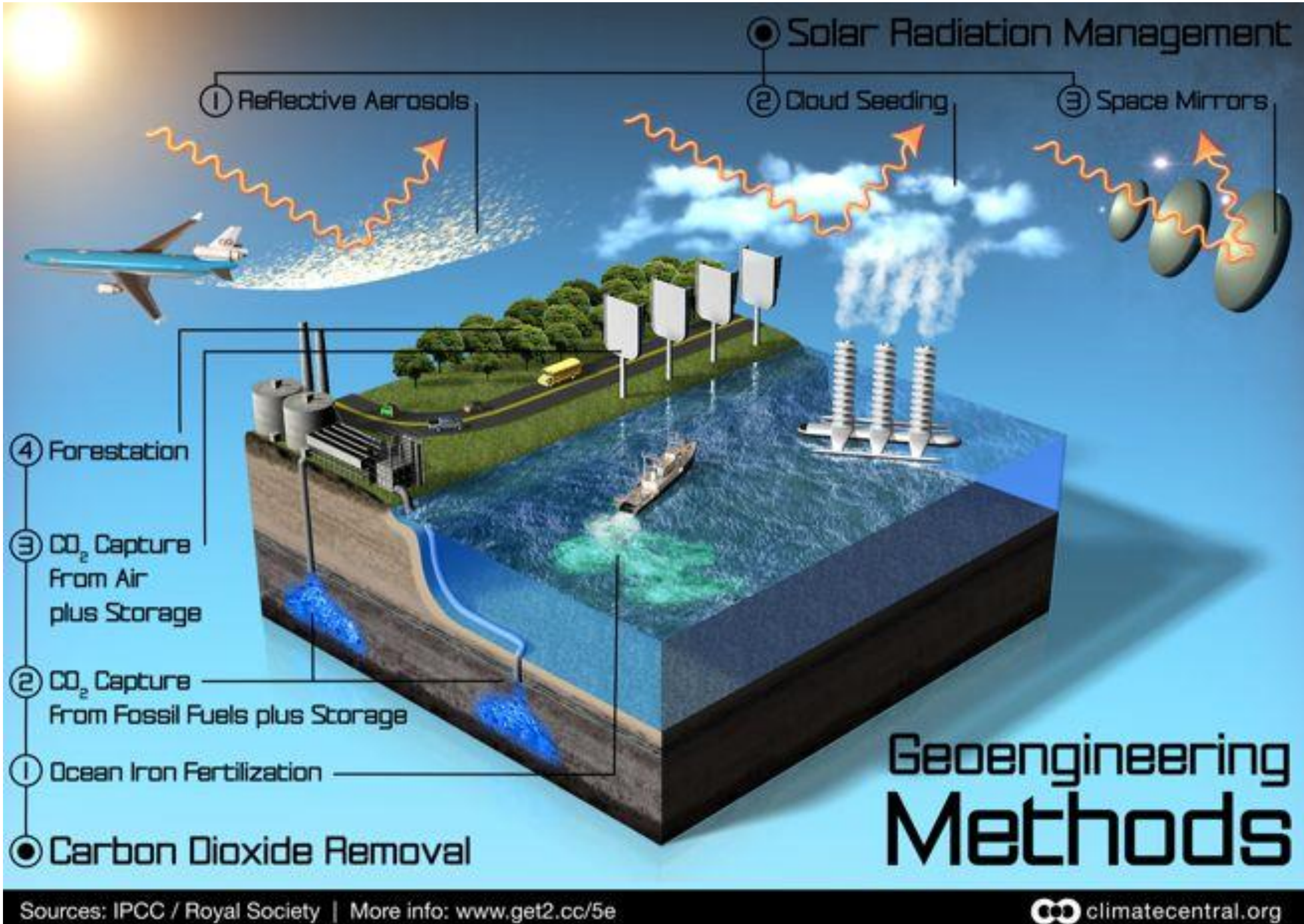

CHEMICALS TO SAVE OZONE
GIANT REFLECTORS IN ORBIT
AEROSOLS IN STRATOSPHERE
CLOUD SEEDING
GROW TREES
GENETICALLY ENGINEERED CROPS
GREENING DESERTS
IRON FERTILISATION OF SEA
PUMP LIQUID C02 INTO ROCKS
PUMP LIQUID C02 INTO DEEP SEA

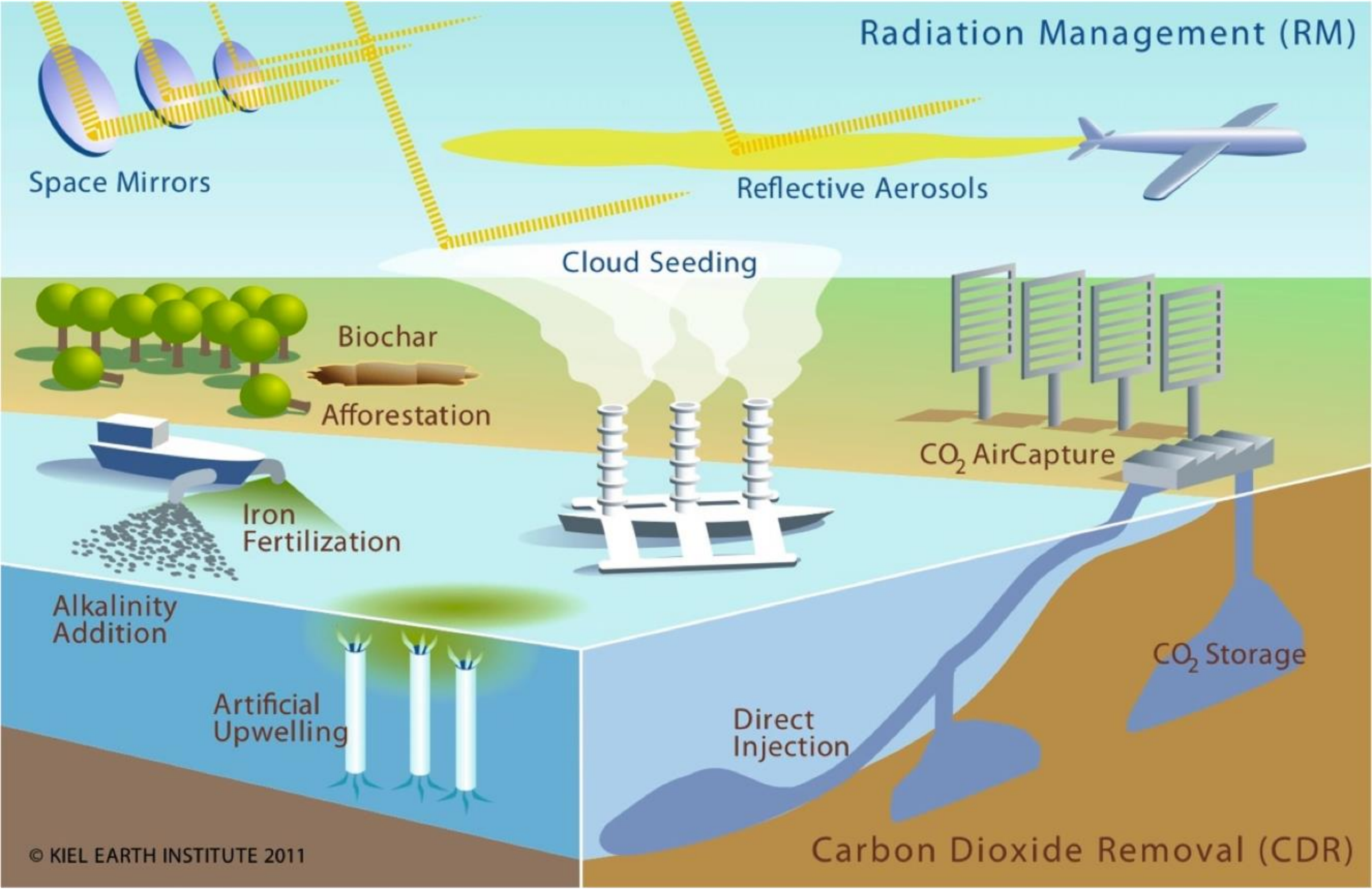

Marine cloud seeding
Reflectors in orbit
Aerosols in stratosphere
Reflecting white roof
Planting new trees
Iron fertilization
Reflecting materials on oceans
Direct injection of CO_2
Geologic sequestration of CO_2

GEOENGINEERING SOLUTIONS TO CLIMATE CHANGE




Aerosols in stratosphere
Giant reflectors in orbit
Chemicals to save ozone
Cloud seeding
Grow trees
Genetically engineered crops
Greening deserts
Iron fertilization of sea
Pump liquid CO_2 into deep sea
Pump liquid CO_2 into rocks


Solar Radiation Management
1 Reflective Aerosols
2 Cloud Seeding
3 Space Mirrors
4 Forestation
3 CO_2 Capture From Air plus Storage
2 CO_2 Capture From Fossil Fuels plus Storage
1 Ocean Iron Fertilization
Carbon Dioxide Removal
Geoengineering Methods
Sources: IPCC / Royal Society | More info: www.get2.cc/5e
climatecentral.org



Radiation Management (RM)
Space Mirrors
Reflective Aerosols
Cloud Seeding
Biochar
Afforestation
CO_2 AirCapture
Iron Fertilization
Alkalinity Addition
Artificial Upwelling
Direct Injection
CO_2 Storage
© KIEL EARTH INSTITUTE 2011
Carbon Dioxide Removal (CDR)


HEVI
0
10
20
VPA
GS

Analyze problem!

What is the source of the problem?

農業為造成氣候變遷的主因

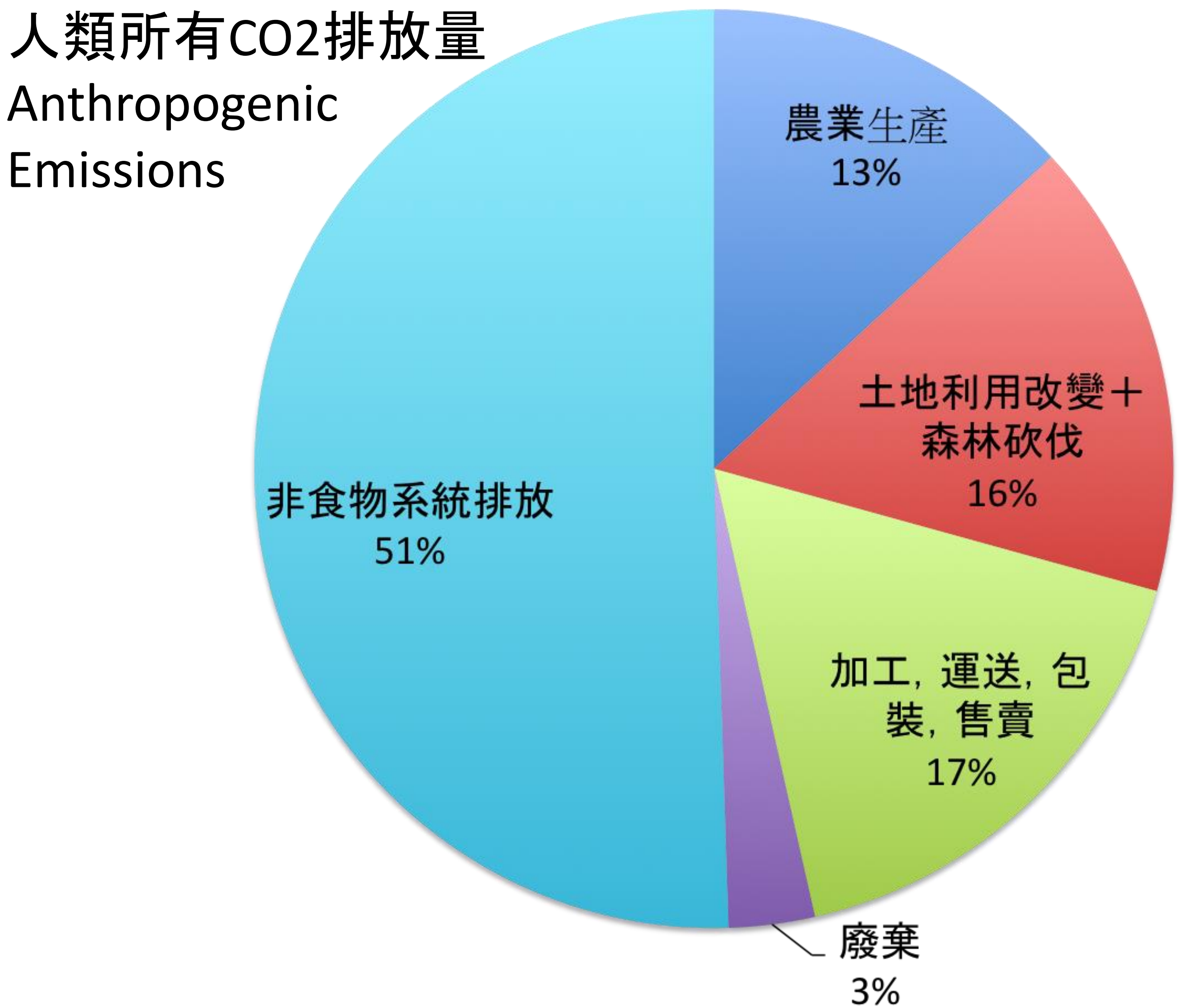
Agriculture is leading cause of climate change

- 食物的**生產**, **製造過程** 及**分配**
  (需要整合在地策略)

- 國際糧農組織（FAO）: 76%的農業溫室氣體 CH_4 **及** N_2O （甲烷及一氧化二氮）排放來自**稻田**、**反芻家畜**與管理不當的**動物糞肥**

- 農業用土已流失25%至75%的碳

Fig 1.2 Emissions from agriculture, land clearing for agriculture, the food system, and food waste amount to roughly half of all anthropogenic emissions



目標

- **現況：**
  空氣中有過多二氧化碳（2000億噸 ）（2009）

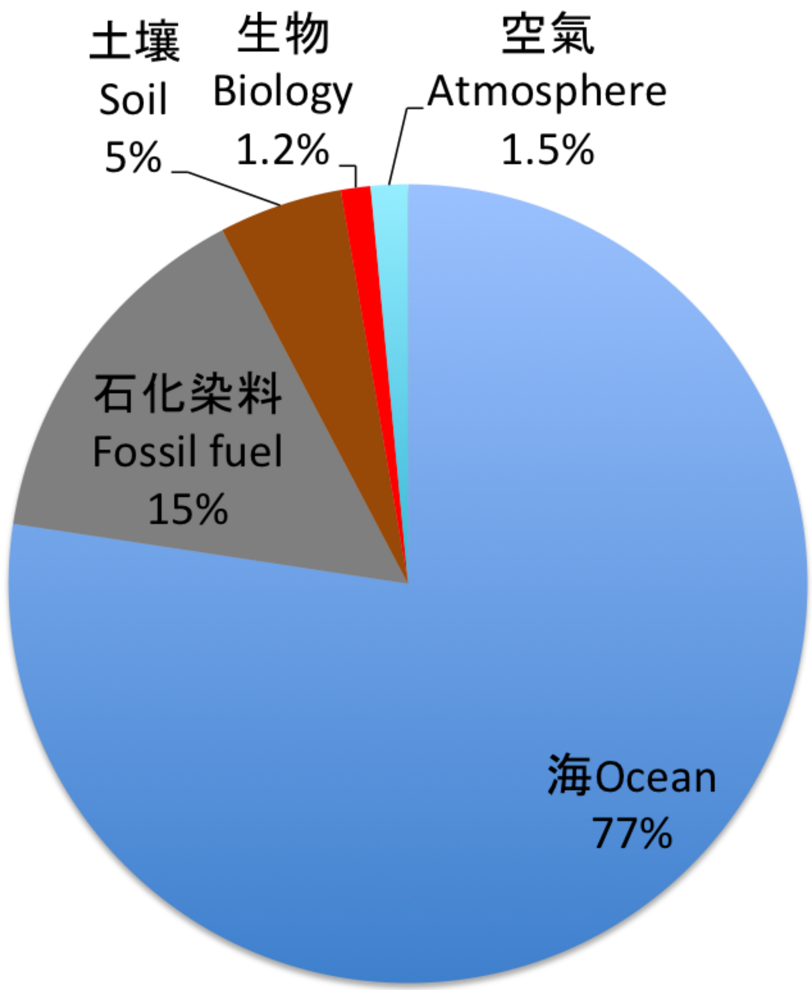
  Problem: Excess CO_2 in atmosphere: 200 billion tonnes (2009)
  Current annual carbon emissions: 10 billion tonnes

- **目標:**
  從空氣中取得超過2000億噸的二氧化碳
  - 農業為解決方法之一
  - 重新取回流失的土壤碳

  - Goals: stop emitting greenhouse gases; extract over 200 billion tonnes from atmosphere
    - Farming can be part of solution
    - Lost soil carbon can be recaptured

Planetary Carbon Cycle

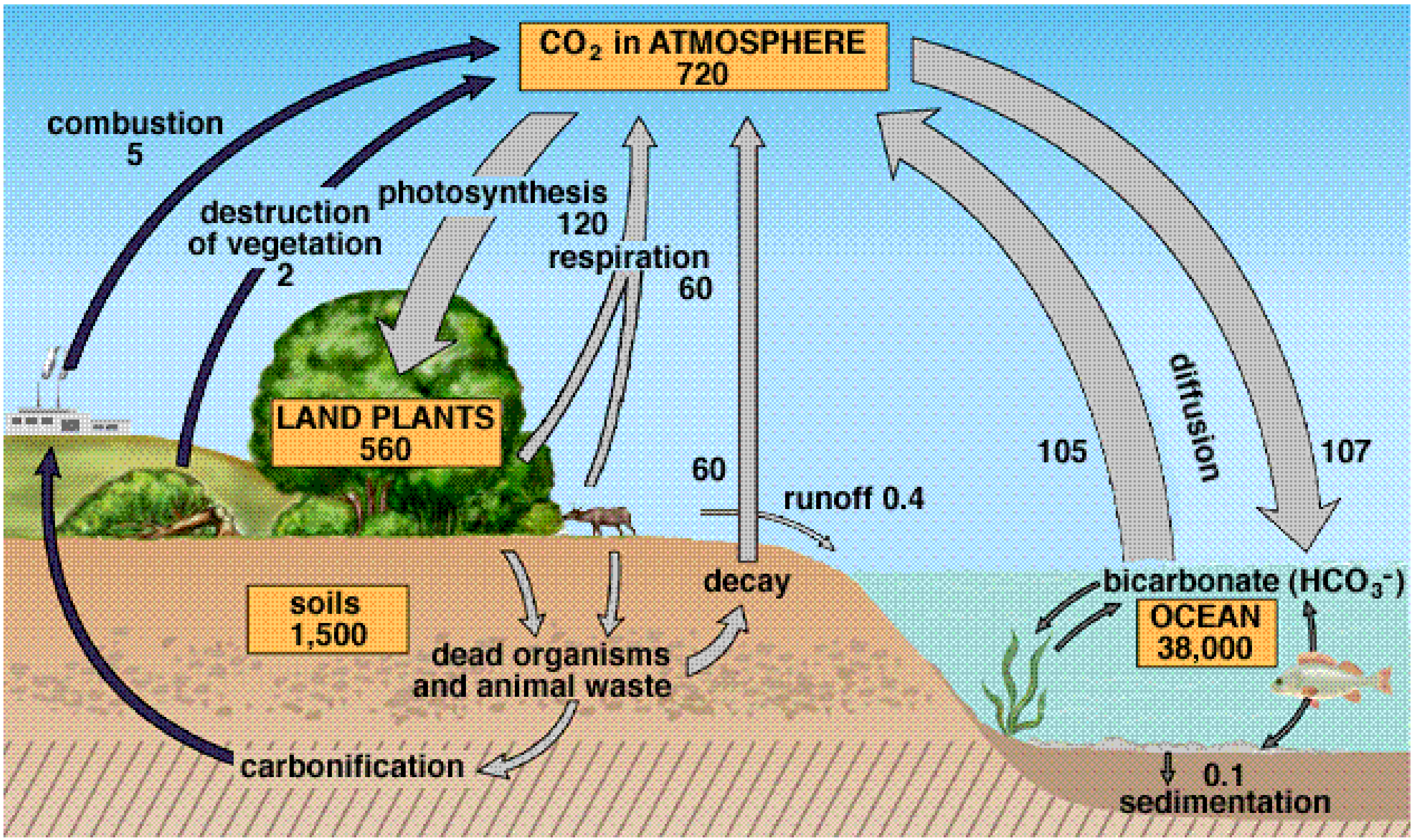
地球五大碳庫 Earth's 5 great carbon pools



- The terrestrial biosphere currently sequesters 2 billion tonnes of carbon annually. (USDA)
- We need to reach 200 billion!
- If we stopped all fossil fuel burning it would take 100 years to reach goal

碳循環Carbon Cycle High potential to put carbon back into the soil

Soil is the largest carbon sink over which we have control



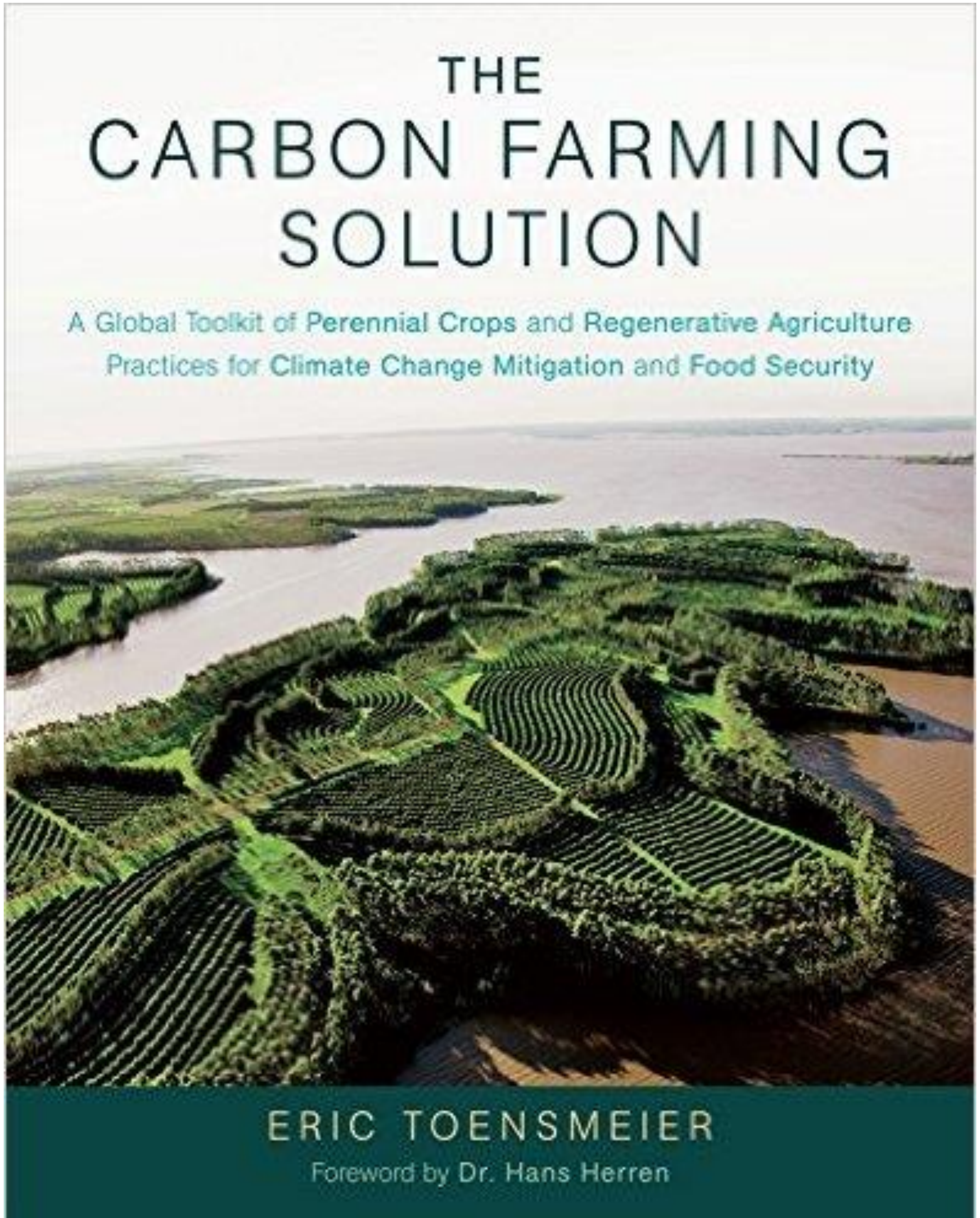
Unit:

GtC

gigaton

10^9

An increase of 1.6% soil organic matter on crop lands globally would sequester excess atmospheric CO_2 - Alan Yeomans



Contents:

1.氣候現況 – 多功能的解決方案 Climate Realities – a multifunctional solution

2. 實踐和物種的全球性工具包 Global Toolkit of Practices and Species

3.主要的多年生作物 Perennial Food Crops

4.工業用多年生作物 Perennial Industrial Crops

5.實行的路線圖 Road Map to Implementation

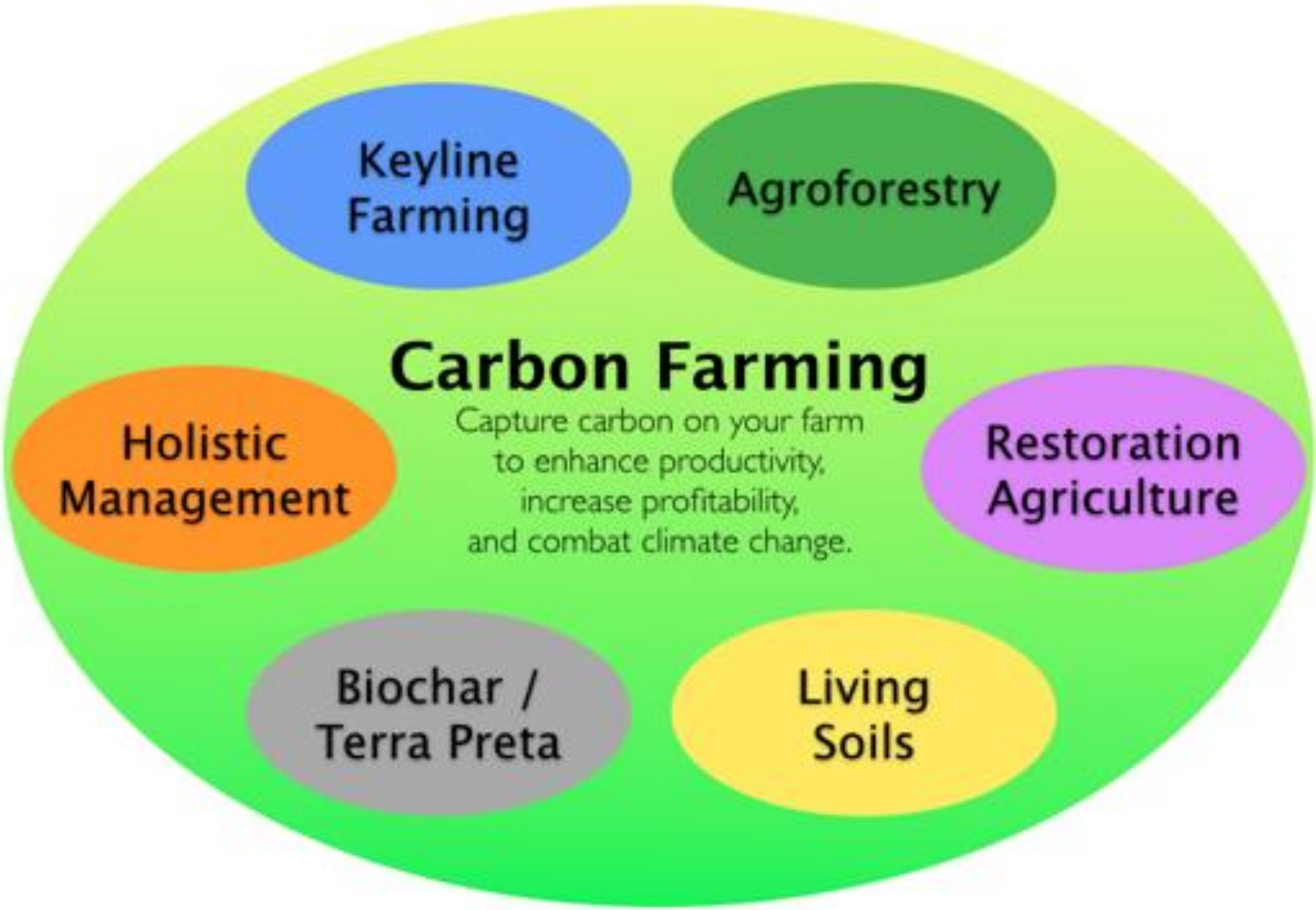
www.perennialsolutions.org

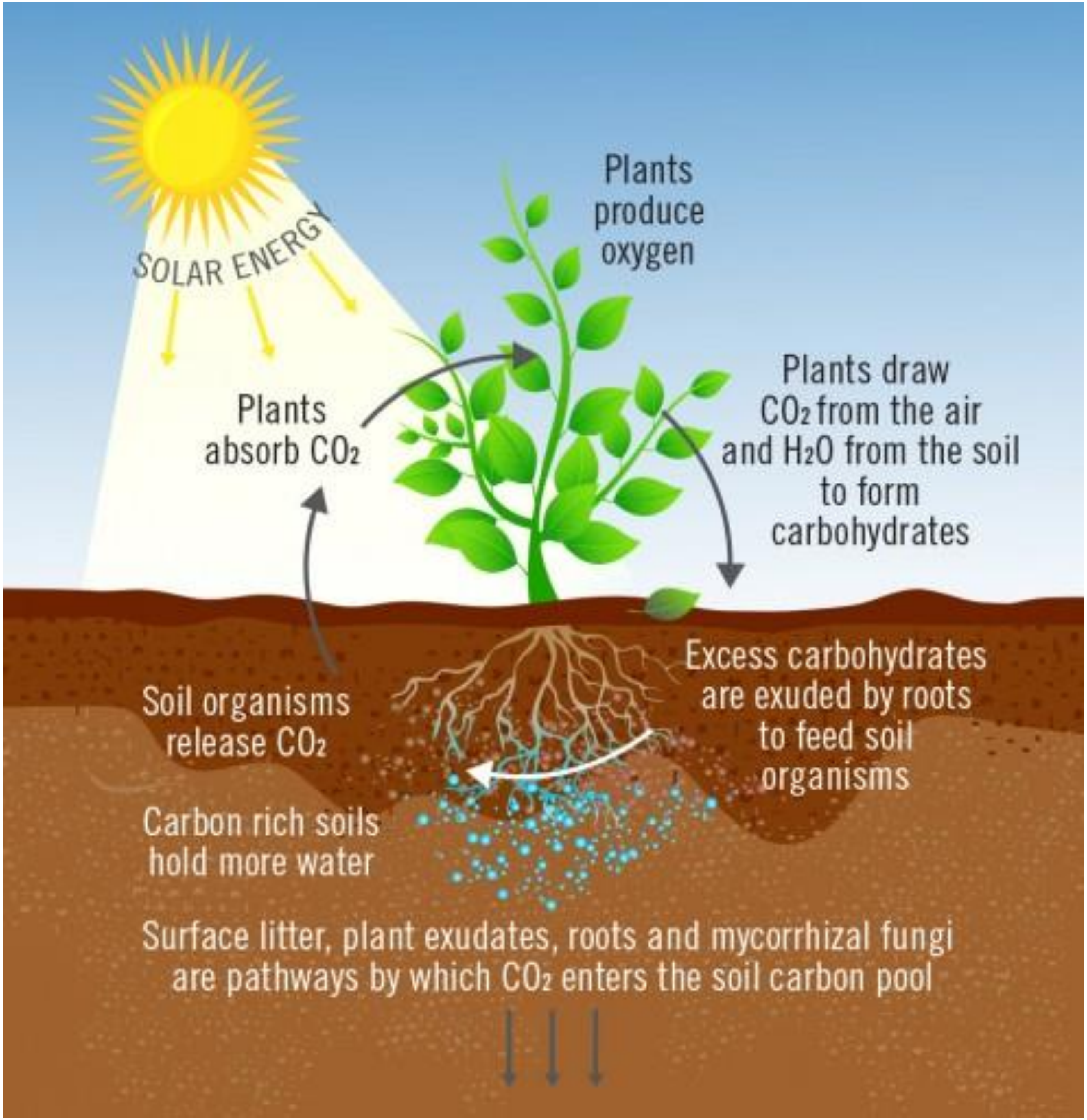
雙贏解決策略

- 提供食物、飼料、原料並同時建造土壤及穩固氣候的方法Solutions that provide food, fodder, feedstocks while building soil and preserving stable climate

- 與成本昂貴但減緩氣候變遷緩慢的地球工程（geoengineering）不同, 再生型多年生農業（regenerative perennial agriculture ）透過封存碳，引導人類面對許多挑戰（如土石流、食物主權及水資源等）Unlike expensive geoengineering approaches to slowing climate change, regenerative perennial agriculture **addresses many of the challenges facing humanity today** *while sequestering carbon*. (erosion, food sovereignty, water, etc.)

Carbon Farming combines cutting-edge agricultural practices with the tools of ecological design to build healthy soil and profitable farms.




SOLAR ENERGY
Plants produce oxygen
Plants absorb CO_2
Plants draw CO_2 from the air and H_2O from the soil to form carbohydrates
Soil organisms release CO_2
Excess carbohydrates are exuded by roots to feed soil organisms
Carbon rich soils hold more water
Surface litter, plant exudates, roots and mycorrhizal fungi are pathways by which CO_2 enters the soil carbon pool

植物！

- 50% 植物體由碳組成50% of plant mass is carbon
- 1/3 的碳儲存於地表的生物質，另 2/3則存於地底
1/3 of carbon is in aboveground biomass; 2/3 of carbon is in underground biomass
- 光合作用10%-40% 的碳在一小時內便可直接從根部送入土壤，與腐殖質結合（液態碳高速公路） 10%-40% of carbon captured through photosynthesis passes out of the roots within 1 hour! (“liquid carbon highway”) Carbon passed through roots becomes bound into humus

光子

$$6\ CO_{2(氣體)} + 6\ H_2O_{(液體)}$$

$$\rightarrow C_6H_{12}O_{6(液體)} + 6\ O_{2(氣體)}$$

蕈類將植物根系的網絡延伸，可增加根系吸收養分的能力，同時與植物交換糖分。

Fungi extends root network and increases nutrient availability in exchange for plant sugars.

沒有蕈類，死去物質的回收率會很低Without fungi, there would be little recycling of dead matter

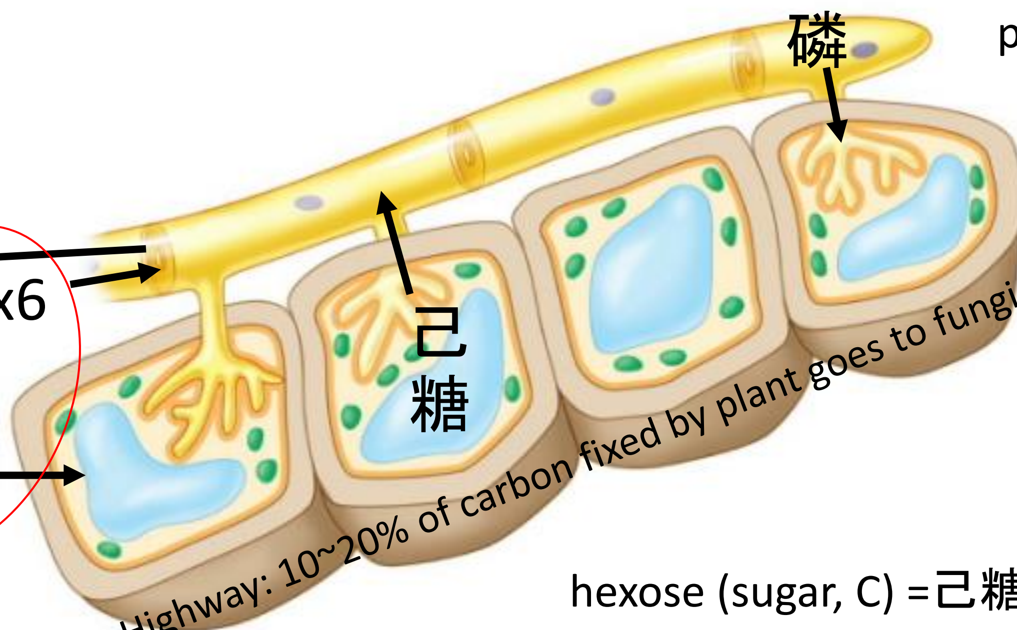
一公里的菌絲可能與一棵中在盆子裡的植物是相連結的One kilometer of hypae may be associated with a plant growing in a one-liter pot

叢枝菌根穿過植物的根，以糖分（c）交換營養*Arbuscular mycorrhizae* (“AM fungi”) penetrates plant roots to exchange sugar (C) for nutrients

這是碳捕集過程中很重要的部份

This is an important part of carbon sequestration

This kind of mycorrhizae can uptake P up to 6x faster than plants can – some plants rely entirely on this source and don’t even bother taking it up themselves



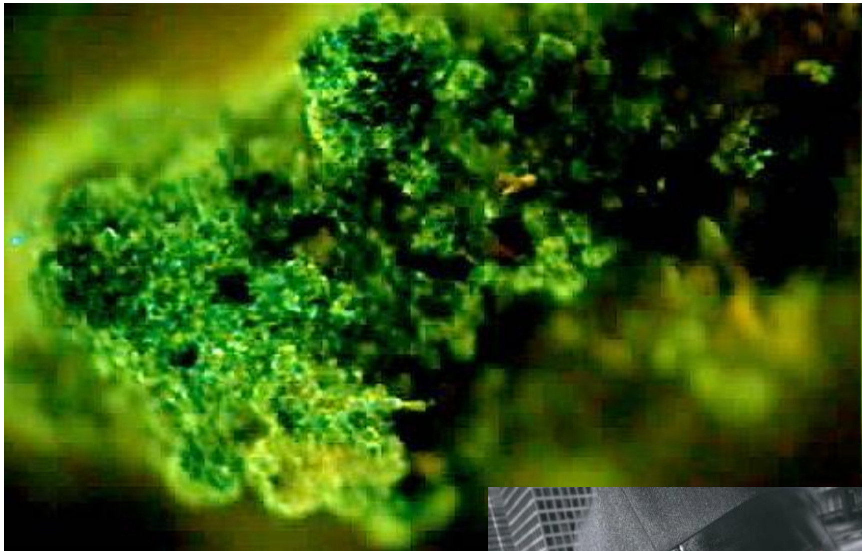
phosphorus (P)=磷

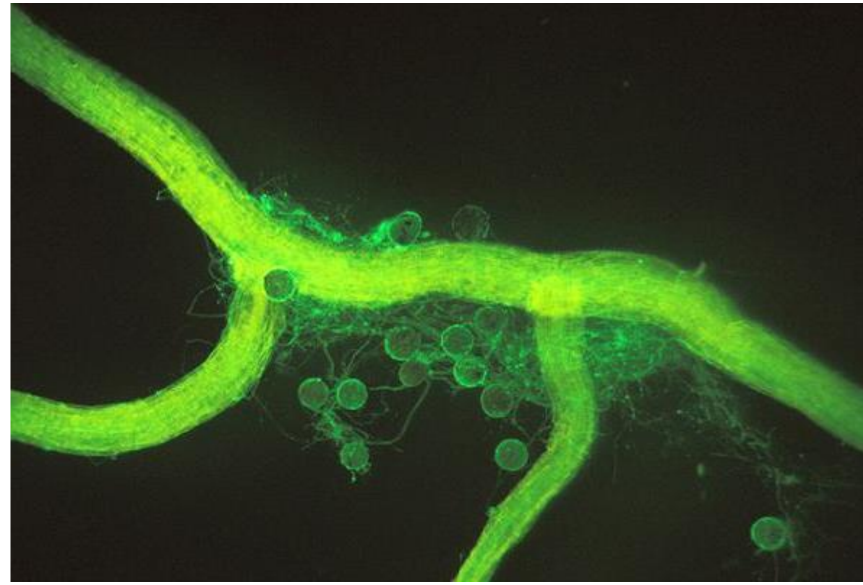
CO_2

hexose (sugar, C) =己糖

http://apbiosemonefinalreview.pbworks.com/f/1262581837/31_04bHaustoria-U4.JPG

球囊霉素(*Glomalin*) Is Key To Locking Up Soil Carbon

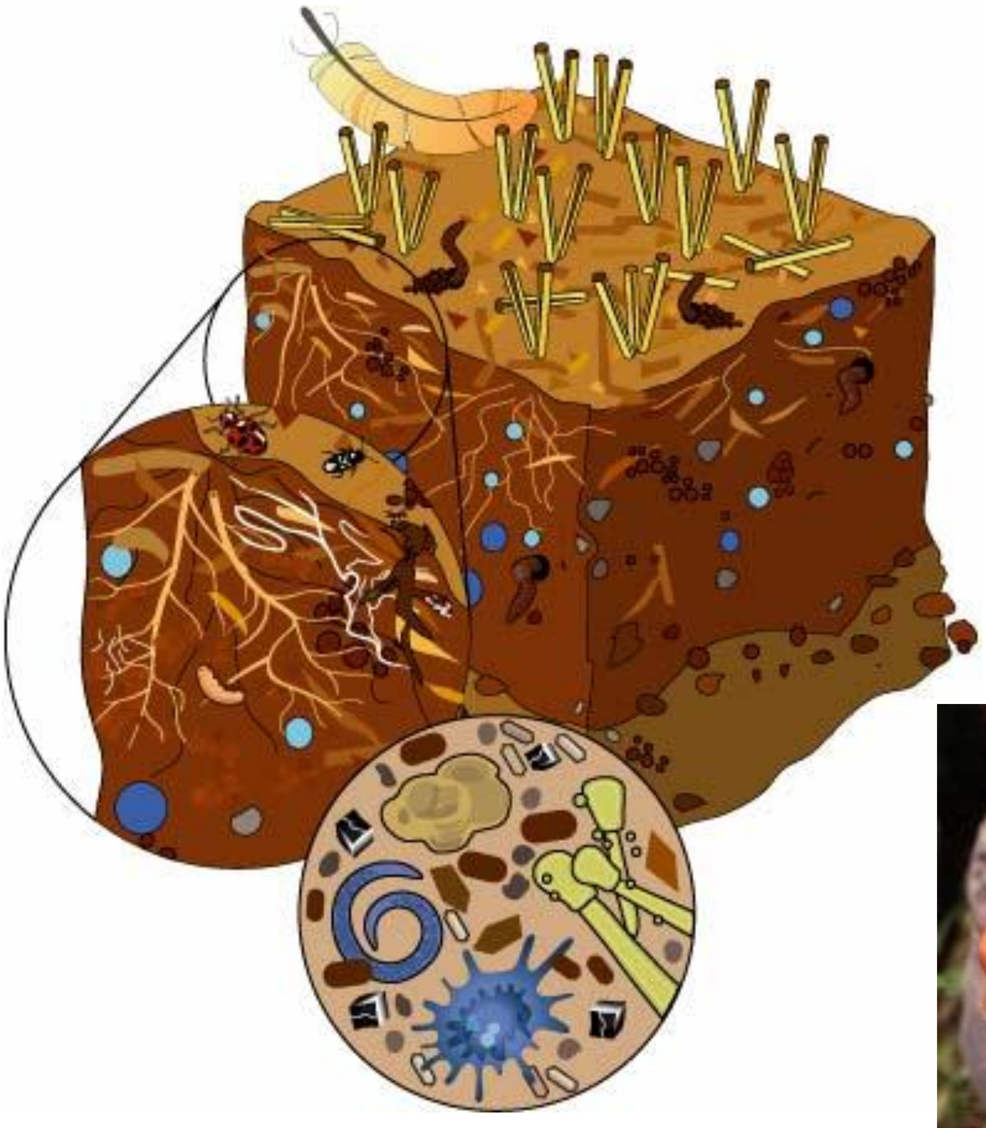




Glomalin, the substance coating this microscopic fungus growing on a corn root, can keep carbon in the soil from decomposing for up to 100 years. (Credit: Photo by Sara Wright)

Glomalin is a sticky substance secreted by threadlike fungal structures called hyphae that funnel nutrients and water to plant roots. Glomalin acts like little globs of chewing gum on strings or strands of plant roots and the fungal hyphae. Into this sticky “string bag” fall the sand, silt and clay particles that make up soil, along with plant debris and other carbon-containing organic matter. The sand, silt and clay stick to the glomalin, starting aggregate formation, a major step in soil creation.
On the surface of soil aggregates, glomalin forms a lattice-like waxy coating to keep water from flowing rapidly into the aggregate and washing away everything, including the carbon. As the builder of the formation “bag” for soil, glomalin is vital globally to soil building, productivity and sustainability, as well as to carbon storage.

http://www.sciencedaily.com/images/2008/06/080629075404.jpg



http://www.directseed.org/soil_quality.htm

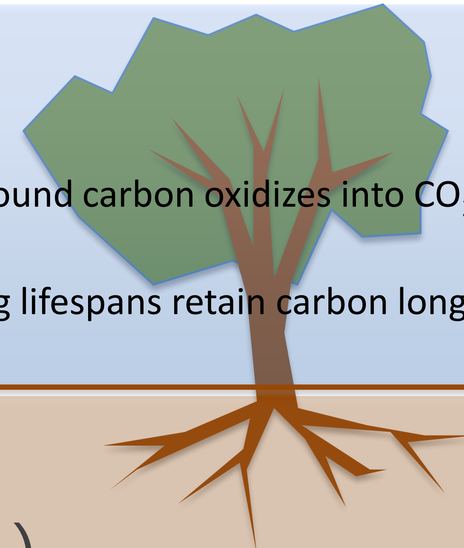
Poor Good

http://www.nrsl.umd.edu/research/NRSLResearchAreaInfo.cfm?ID=14

土壤！

- 在不擾動的狀態下，腐殖質可存於土壤100至5000年Humus stays in soil 100 to 5000 years *if undisturbed*
- 每增加1%的土壤有機質，即在一甲地封存21噸的碳Every 1% increase in soil organic matter means 21 tons of carbon sequestered per hectare (甲)
- 土壤中的生物碳可保存100至1000年 Biochar in soils is likely to persist for 100 to 1000 years.
- 當土壤碳庫封存的碳達到飽和，封存速度將漸緩至不再封存Soil carbon sinks can reach saturation points and sequestration slows down to zero.

平均滯（ㄓˋ)留時間 影響因素
（MRT：mean residence time）



地表： aboveground

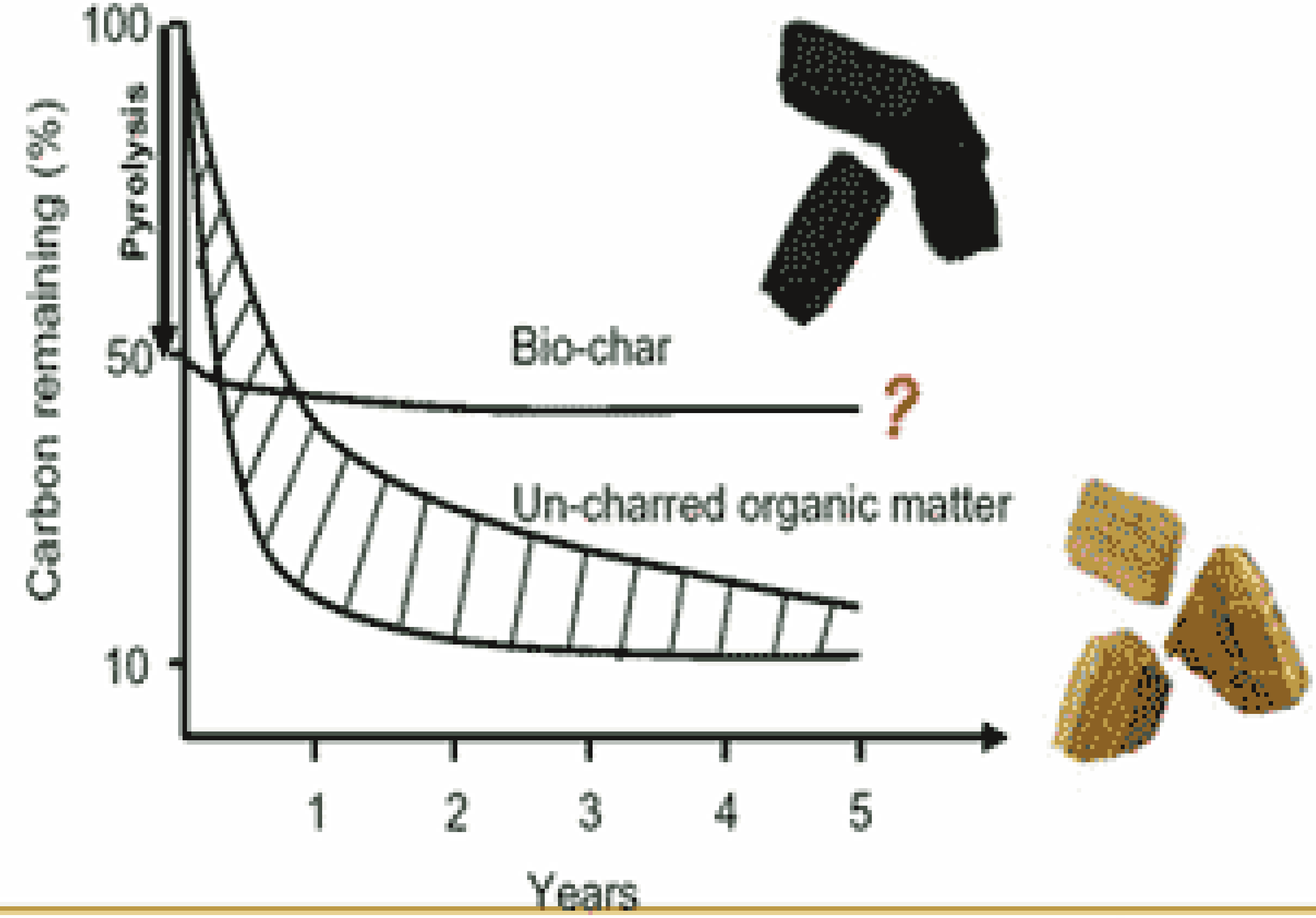
- 2/3 的碳氧化成為二氧化碳2/3 of aboveground carbon oxidizes into CO_2
- 壽命越長的樹可儲存碳越久Trees with long lifespans retain carbon longer

地底： underground

- 土壤質地（黏土較易與腐殖質結合） Soil type (clay binds humus better)
- 氣候（冷乾 v.s. 濕熱） Climate (cold dry –vs– hot wet)
- 農耕實踐： Farming practices:

Long MRT	Short MRT
多年生作物, 覆蓋, 稻田減少泡水狀態, 減少翻土,放牧管理 , 整合農作物及家畜, 持續有植被perennial crops, mulching, non-flooded rice, reduced tillage, managed grazing, crop-livestock integration, continuous cover	一年生作物, 翻土, 貧瘠土壤 Annual crops, tillage, bare soils

The essential stability of bio-char



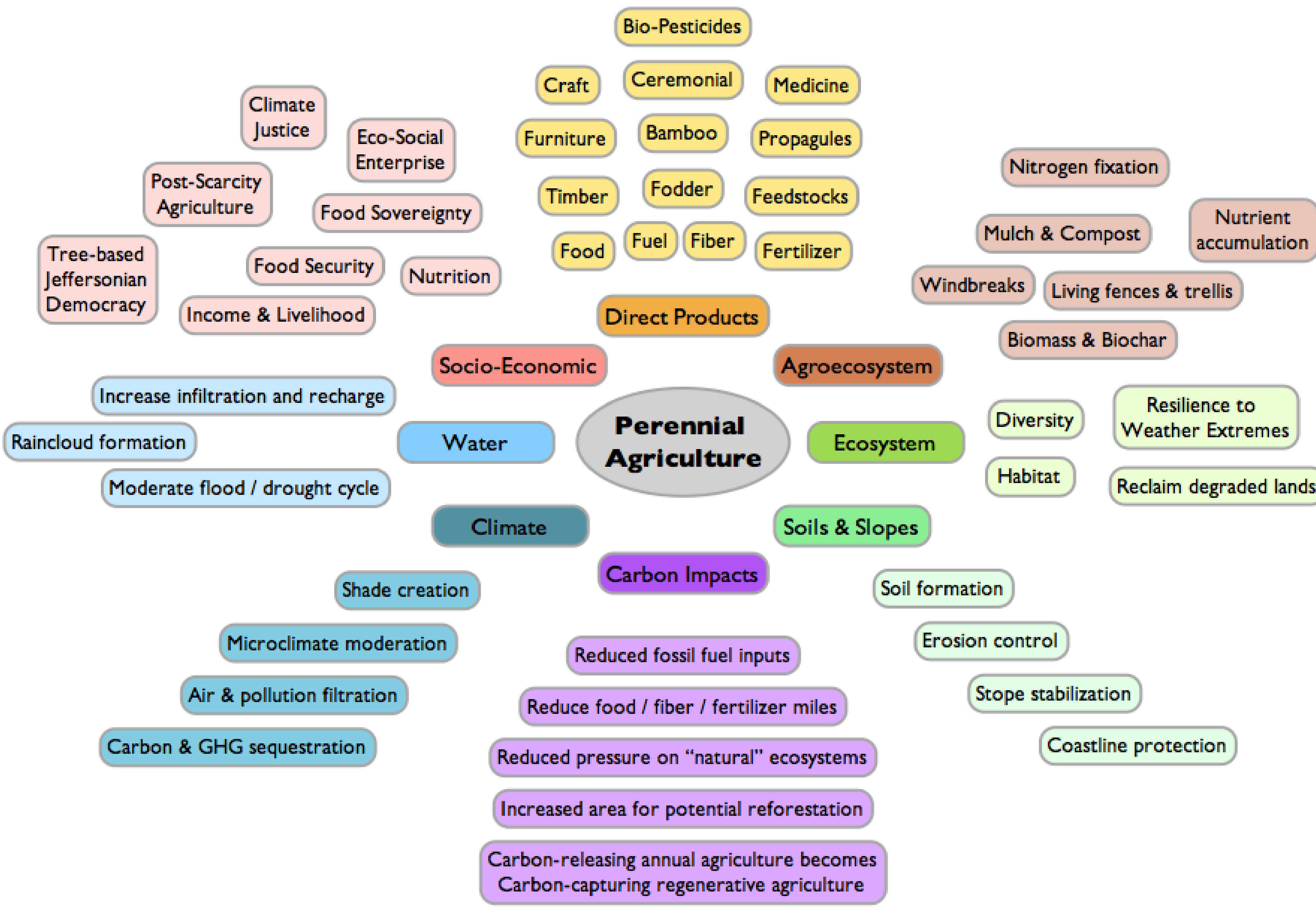
Lehmann et al., 2006, *Mitigation and Adaptation Strategies for Global Change* 11, 403-427

Five Tenets of Carbon Sequestration

- **NO-TILL** Tilling mixes soil with air, allowing carbon to oxidize back into the atmosphere. Instead, focus on perennial crops that don't require tillage, or use a no-till seed drill for large-scale annual plantings.
- **ORGANIC MULCH** Cover the soil around small-scale plantings with a wood chip or straw mulch to prevent carbon losses. On large plantings, leave crop residue in place as mulch. As it decomposes, the residue fuels the carbon cycle in the soil.
- **COMPOST** Compost is rich in a stable (not easily oxidized) form of carbon. Carbon farmers recommend dusting it over the surface of the soil—you can spread it directly over the grass in your pasture—rather than tilling it in.
- **LIVESTOCK ROTATION** Moving concentrated herds and flocks of animals through a series of small paddocks on a regular basis is preferable to letting the animals forage continuously over a single large area. Many carbon farmers move their animals every day and try to let each paddock "rest" as long as possible between grazings.
- **COVER CROPS** Fast-growing species such as clover and vetch keep the soil covered and enriched with carbon through the winter and may also be planted together with cash crops during the growing season to compensate for carbon lost when those crops are harvested.

Multiple Functions of Perennial Agriculture

Version 1.5, Developed by Eric Toensmeier, mind-mapped by Ethan Roland



可達成固碳和適應氣候變遷的策略

2.2 strategies that both sequester carbon and adapt to climate change

議題 Issue	挑戰 Adaptive challenge	固碳與適應氣候變遷的策略 Sequestration and adaptation strategies
水 water	無法預期，極乾或極濕Unpredictable and extreme wet or dry	雨水搜集, 滴灌系統, 旱作, 水稻強化栽培系統（SRI）Rainwater harvesting, drip irrigation, arid-land crops, SRI
土壤 soil	需要有機質來改善土壤Need to build organic matter to improve resilience	免耕農業, SRI, 覆蓋, 輪作及活覆蓋物, 多年生作物, 混農林業, 動物林業, 飼料銀行No-till, SRI, mulching, rotation and cover crops, perennial crops, agroforestry, silvopasture, fodder banks
生產作物 Crop production	利用有效且可恢復產力的方法Utilize efficient and resilient production techniques	固氮, SRI, 多樣化, 生態農業, 混農林業Nitrogen fixation, SRI, diversification, agroecology, agroforestry
家畜 Livestock	利用有效且可再生的方法Utilize efficient and resilient techniques	放牧管制, 混農林業, 動物林業, 飼料銀行Managed grazing, agroforestry, silvopasture, fodder banks

3.1 IPCC summary of mitigation, implementation, and time-scale potential for selected carbon farming techniques

IPCC對於特定固碳農業技術所做之緩解、執行和時間規劃的大綱

Category	Practices	Potential Global Impact	Ease of Adoption	Readiness of Practice
Afforestation of farmland	Monocultures or mixed species, including tree crops and multipurpose trees	Medium	Easy	Ready
Crop management	Rotations, cover crops, perennial crops, improved varieties	Medium	Easy	5-10 years
Tillage+residue management	Reduced tillage, crop residue retention	High	Easy	Ready
Water management	Rainwater harvesting and other strategies	Medium	Moderate	5-10 years
Rice paddy management	Straw retention, reduced flooding, nutrient management	Medium to high	Moderate to easy	Ready
Biochar application	Application of biochar for fertility and carbon sequestration	High	Moderate	Still developing
Pasture management	Improved species, fodder banks, etc.	Low	Easy	Ready
Managed grazing	Stocking densities, improved grazing management, fodder production and diversification	Low	Moderate to easy	Ready
Manure application	Application of manure to cropland for fertility; livestock-crop integration	High	Easy	Ready
Livestock feeding	Methane-reducing feed and forage	Medium	Moderate	5-10 years
Manure management	Modified bedding, changed feeds, biodigestion, etc.	High	Moderate to easy	Ready
Agroforestry	**Integration of trees with crops and/or livestock**	**Medium**	**Moderate**	**Ready**
Mixed biomass	Productive shelterbelts and riparian buffers,	Medium	Easy	Ready

3.2 lifetime soil carbon stocks of carbon farming systems compared

比較固碳農業系統的土壤碳儲量

Category	Practice	Location	Lifetime soil organic carbon gains per 甲
Annual cropping	Conservation agriculture	India, USA	-4 to +20
	Improved annual cropping	Global	30-50
Silvoarable agroforestry	Tree intercropping	Tropic humid	0-150
	Tree intercropping	Temperate	Up to 200
	Protective systems (windbreak, etc.)	Arid	Up to 100
Grazing systems	Improved grazing + pasture management	Global	30-50
	Improved grazing + pasture management	Global	Up to 16
Livestock with trees	Silvopasture	Global	Up to 250
	Fodder banks	Tropical	Up to 140
Woody biomass	Coppiced firewood lots	Tropical	Up to 140
Woody polyculture	Multistrata agroforestry	Humid tropics	Up to 300

3.3 carbon sequestration by multistrata agroforestry systems and natural forest in the Philippines

菲律賓藉由多層次農林業複合系統和天然森林來固碳

System	Average age of 3 sampling sites	Annual sequestration rates (噸C/甲/年)	Aboveground carbon stocks
Old growth forest	100+ 年	2.3	234.5
Natural forest	100+ 年	1.5	147.5
Multistrata agroforest	38 年	4.1	155.8
Homegarden	21 年	9.4	159.7

Homegardens and multistrata agroforestry (timber, fruit, nut, coffee, banana, native trees) outcompete natural forest in annual carbon sequestration and aboveground carbon stocks, and outcompete preserved old-growth forest in annual carbon sequestration.

In the Philippines, a country of 99 million people, 70% of all households have homegardens.

Annual sequestration rates (噸C/甲/年)

Plant or system	噸C/甲/年	page
"Average staple tree crop"	5	37
olive	27	31
mango	18	
peach	17	
Cacao agroforest	41	
Oil palm monoculture	6	
Shade coffee	7	
Coconut monoculture	5	
homegardens	8-16	
Food forest (multistrata agroforest)	1-17	
Banana with mixed fruits	13	
Banana monoculture	6	
Moso bamboo	21-34	
Intensive bamboo	13	
leucaena	12	
Maize with fruit and timber	8	
Intensive silvopasture plus timber	34	
silvopasture	3-10	
Regenerative organic (multiple practices)	2-6	
Manure application	2	
Cover cropping	0.2	

3.4 estimates of global sequestration impact of carbon farming.

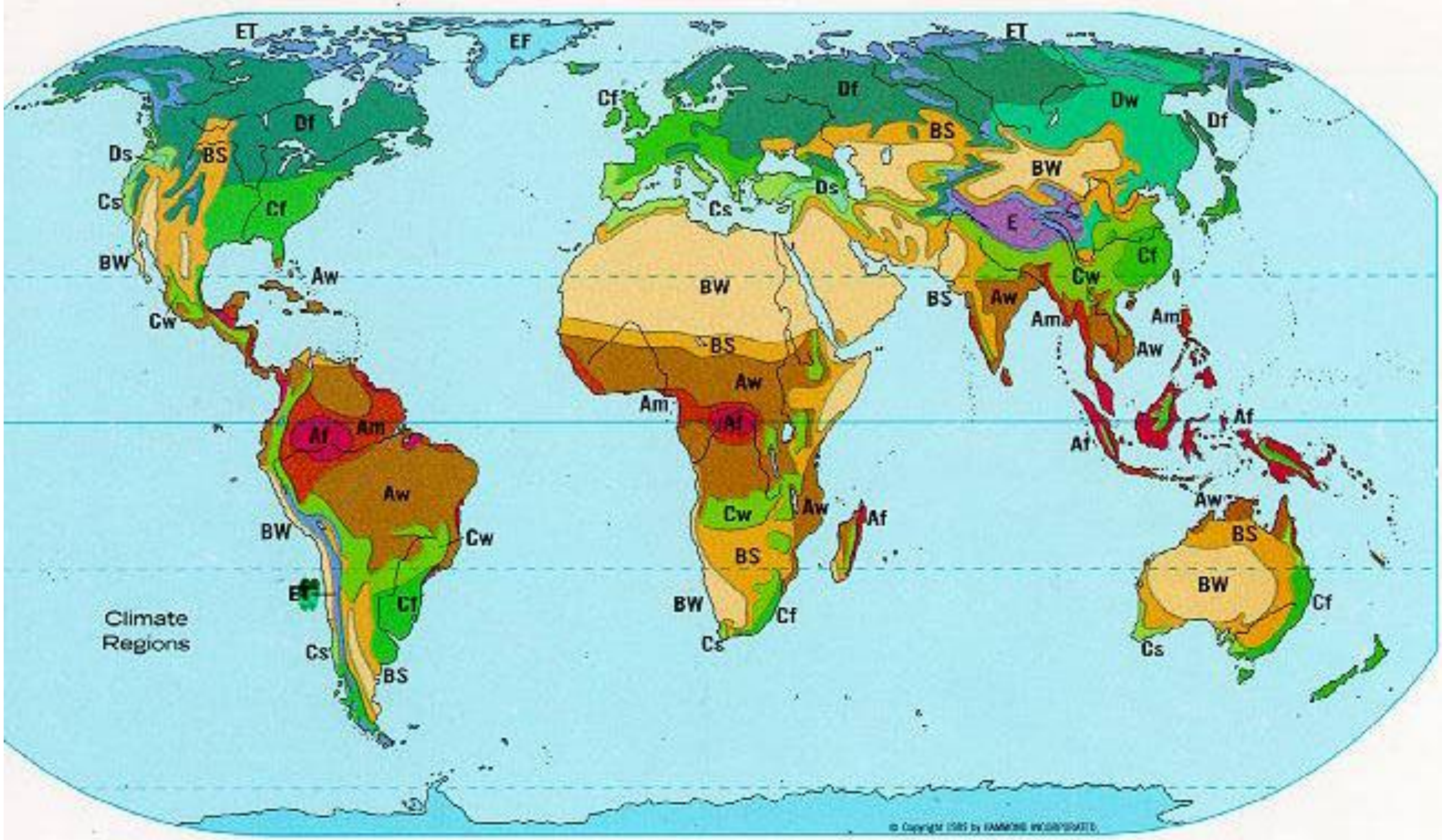
估計全球農業碳存封的影響

(Goal: 200,000,000,000 tonnes!)

Scenario	Global Annual Rate in Tonnes	Lifetime Impact	Details
Global agricultural impact (IPCC)	81,000,000 to **1**,200,000,000		By 2030 (no agroforestry)
Conservation agriculture and forestry (Lal)	400,000,000 to **1**,200,000,000	**20**,000,000,000 to **120**,000,000,000 (or 50ppm)	Over 50-100 years
Pasture and grazing management (FAO)	54,000,000 to 216,000,000		By 2030 (no agroforestry)
Global agricultural impact (Smith)	**1**,500,000,000 to **1**,600,000,000		By 2030
Agroforestry (Leakey)		**1**,800,000,000 to **135**,000,000,000	
Woody staple crop conversion (Toensmeier)	394,000,000	**10**,200,000,000	Only 10% of tropical annual staple cropland

WORLD-CLIMATE

CWA 14-15



A HUMID TROPICAL CLIMATE
- Af — No Dry Season
- Am — Short Dry Season
- Aw — Dry Winter

B DRY CLIMATE
- BS — Semiarid
- BW — Arid

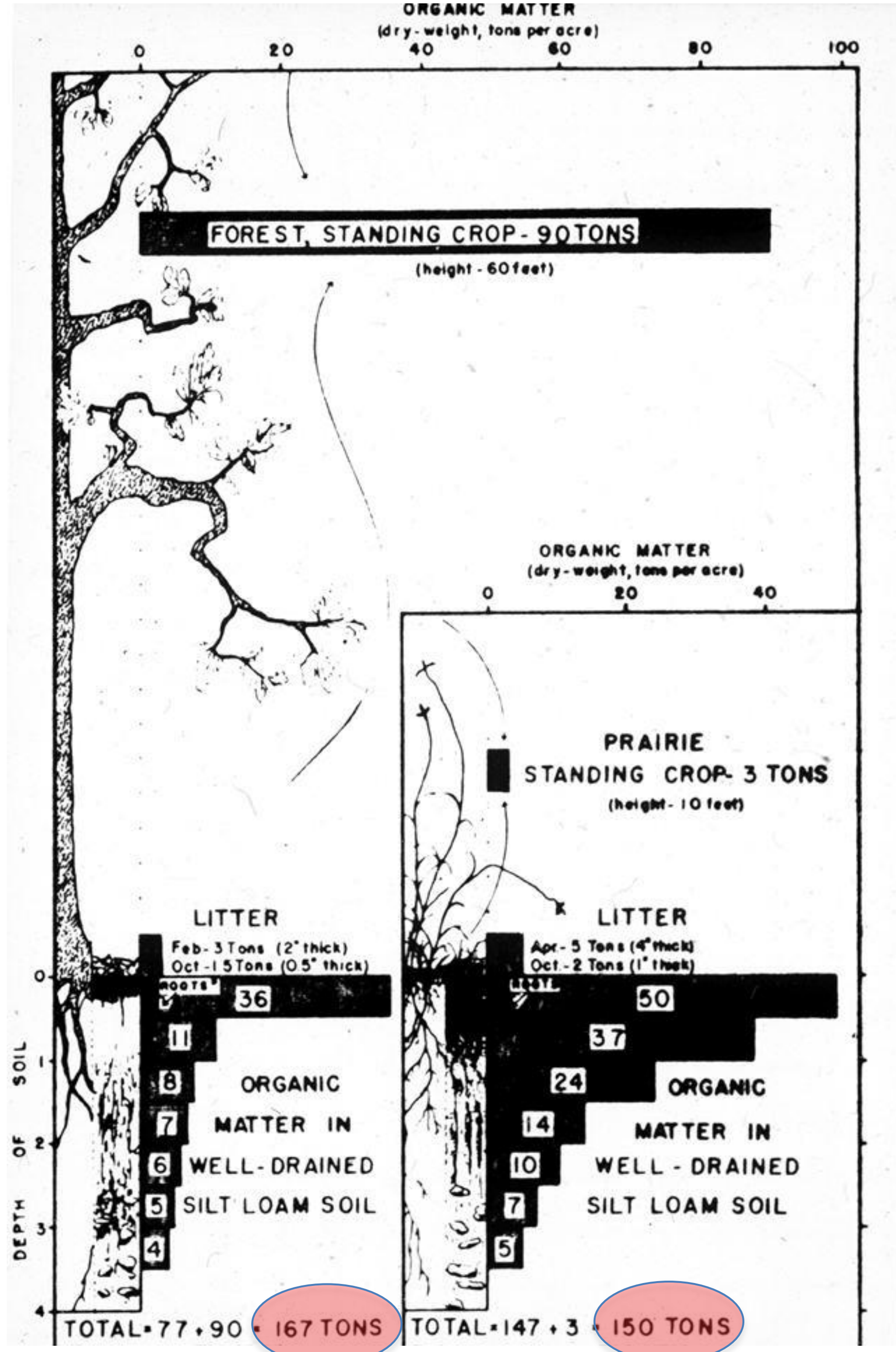
C HUMID WARM CLIMATE
- Cf — No Dry Season
- Cw — Dry Winter
- Cs — Dry Summer

D HUMID COLD CLIMATE
- Df — No Dry Season
- Dw — Dry Winter
- Ds — Dry Summer

E COLD POLAR CLIMATE
- ET — Short Cool Summer, Long Cold Winter
- EF — Perpetual Frost
- E — Cold and Unclassified Highlands

森林

草原



Some say soil carbon in pasture situations is more permanent carbon storage than aboveground carbon in forest situations. In reality both are prone to rapid depletion due to consumption of aboveground biomass as well as tillage of carbon-rich soils.

Interestingly, at least in tropical regions, the most powerful climate impact of agroforestry is not in the carbon sequestered on-farm (which is significant), but in the reduction of pressure on wild trees and forests. Because agroforestry provides fuelwood and reduces or eliminates the need for shifting cultivation, **every hectare of agroforestry prevents the deforestation of 2.5-10 hectares of wild forest.** (Nair & Montagnini 2004).

In 1980s, Ecuador govt said anyone could own a piece of forest if they could put it into production. This took away lots of indigenous lands. Permaculturist helped indigenous identify productive species and put up more obvious plots around borders of their land to convince govt. that they are using this land. Needed to grow in rows in order to get govt inspectors to recognize as a 'crop'. Only needed to plant the edge cause govt inspectors are afraid of the jungle. Point: entire rainforests in Amazon are actually well-managed productive systems.

Swidden

- "slash and burn"
- Forest fallows are guided to productive state
- Common indigenous practice in tropics globally

PEKARANGAN
Food Forest
Yields 1,310 cal/m^2/yr

Yield calories m2/yr	Vertical Strata
450	Over 10m
500	5-10m
300	2-5m
45	1-2m
15	0-1m

E: (over 10m) Coconut, albizia

D: (5-10m) fruit trees: soursop, jakfruit, pisitam, guava, mountain apple, cloves, breadfruit, avocado, mango, mangosteen, rambutan

C: (2-5m) banana, papaya, small fruit trees (belimbil, starfruit) salek, coffee, cacao, ipil ipil

B: (1-2m) cassava, Xanthosoma, arrowroot, gembili yam (D.esculenta) cardamom, galangal

A: (0-1m) starch foods, vegetables & spices e.g. sweet potato, taro, chilli, eggplant tumeric

Retain perennial systems on marginal land (slopes, valleys)

If a targeted international project began just focusing on these most vulnerable agricultural areas, 9% of total world farmland (which has slopes greater than 30%!), we could (at 25 t/ha, towards the low end of agroforestry's potential) still sequester 3.3 billion tons of carbon – equal to a third of all human-caused carbon emissions released annually.

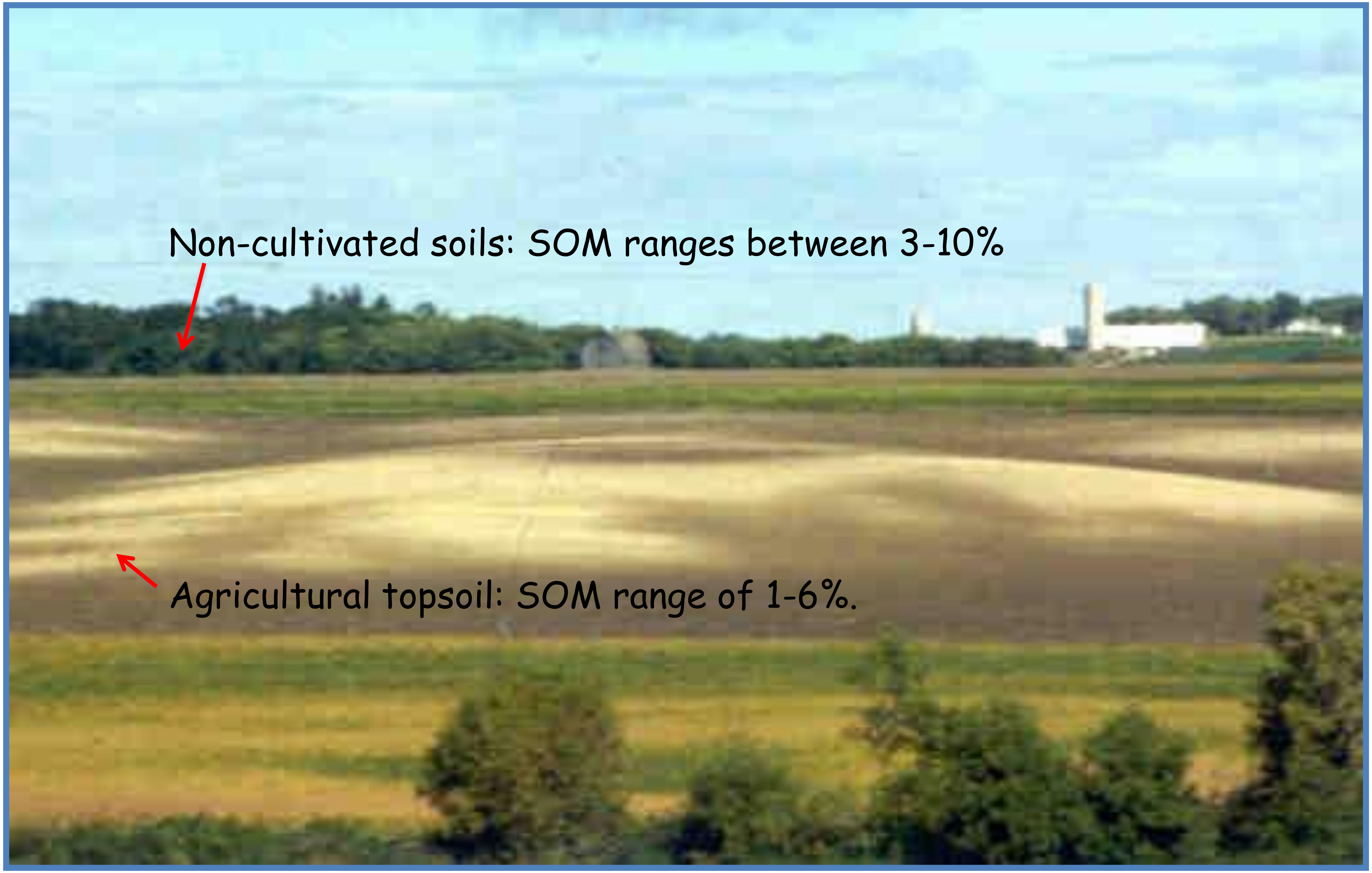
systems

Yeomans plow for keyline farming


THE KEYLINE PLOW
YEOMANS
YEOMANS
YEOMANS

Lehmann Plow vs Chisel Plow

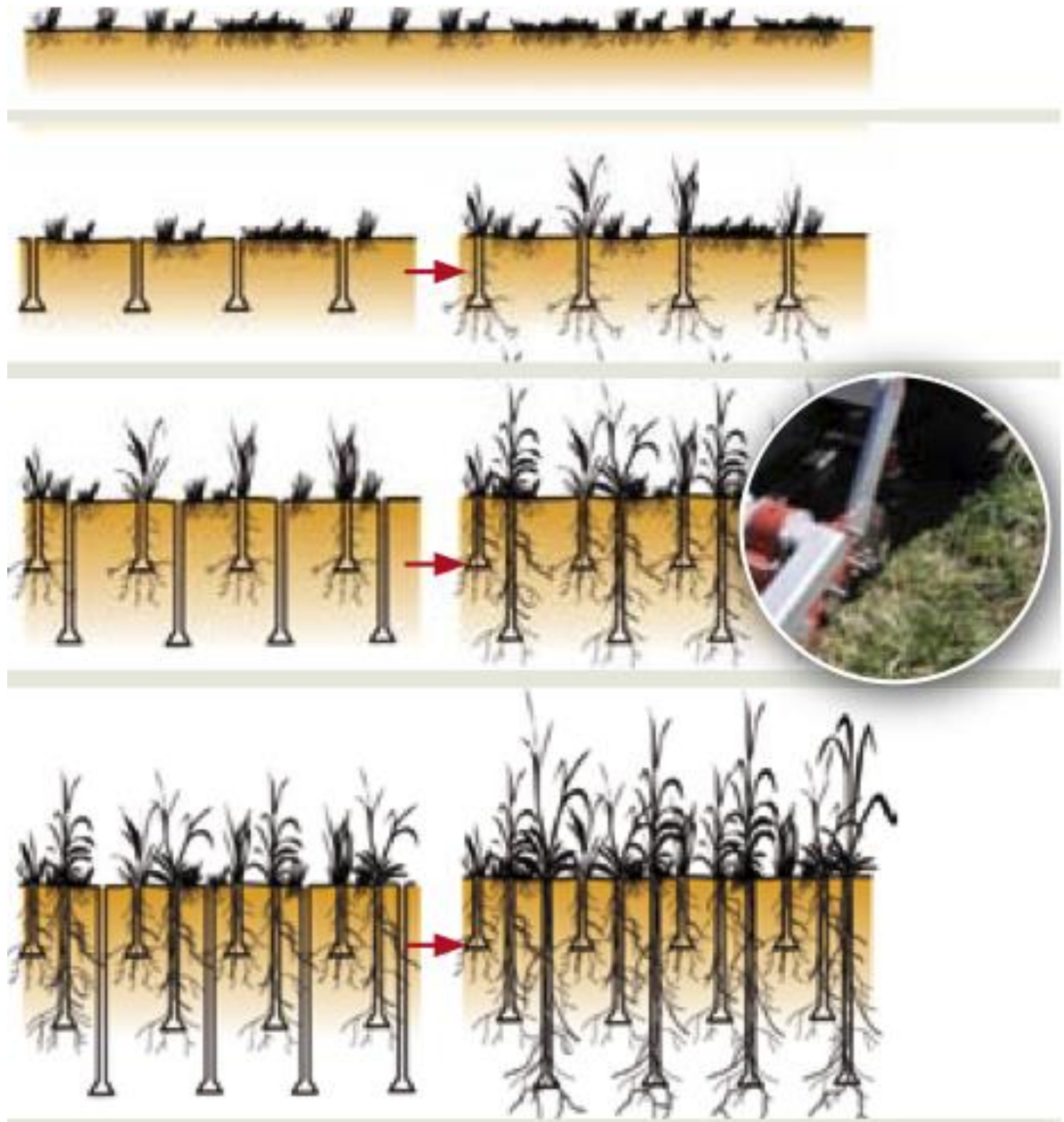
Keyline design can reverse loss of soil organic matter



Yeomans Keyline Plow – Plowing for Rapid & Cheap Soil Development (Pasture)

Existing Condition:

Shallow, Compacted, Drought-Prone Topsoil



1. Soil Test – Mineral/Soil Food Web

2. Plow to 2” below hard pan

3. Remove stock for 4-6 weeks

4. Just at onset of flowering:

Planned graze to 3 leaf stage

1. Plow to 2” below new root depth

2. Remove stock for 4-6 weeks

3. Just at onset of flowering:

Planned graze to 3 leaf stage

1. Plow to 2” below new root depth:

Max out at 12-15”

2. Remove stock for 4-6 weeks

3. Just at onset of flowering:

Planned graze to 3 leaf stage

And Another Thing:

1% increase in Organic Matter =

57 tonne/ha capture in Atmospheric CO_2 !

(That’s twice your total annual emissions)

No till

No-till soybeans

“All soil biology eats carbon, and that’s how nutrients cycle…. Farmers need to think of carbon as their fertilizer, because it’s what drives a healthy system.”

25 countries pledged to pursue carbon farming during the December climate talks in Paris—but ranchers like Gabe Brown, who raises livestock and an array of crops on 5,000 acres outside Bismarck, North Dakota, have preached its virtues for decades. Brown, a former conventional commodity-crop farmer, still grows **corn, but with a groundcover of clover** or vetch beneath the stalks. **He follows each cash crop with a mix of pearl millet, Sudan grass, cowpeas, sunflowers, and other soil-enriching cover crops, combining up to 70 different species in a single planting.** Each occupies a slightly different niche in terms of height, root depth, leaf shape, and growth rate, forming a dense blanket of vegetation that pumps carbon from the sky to the soil and provides a rich “cocktail” on which his livestock graze.


9983
XZ 30

Yeomans Keyline Plow – Shank Pot Seeders

Drilling Oats/Vetch as Weed Suppression/Carbon Crop

Mark Shepard: New Forest Farm, Wisconsin

- Same area
- Same rainfall
- Same soils
- Same plant species
- Same season (pictures taken on the same day)

- The area above actually has more livestock
- It also has far more wildlife, including buffalo, elephant, and lion
- The only difference is management

During and after restoration, landscapes need periodic grazing and trampling to stay healthy -- because **nature depends on grazers to maintain dryland ecosystems.**

德國研究指出

- 豬覓食過的地方植物多樣性會增加一倍

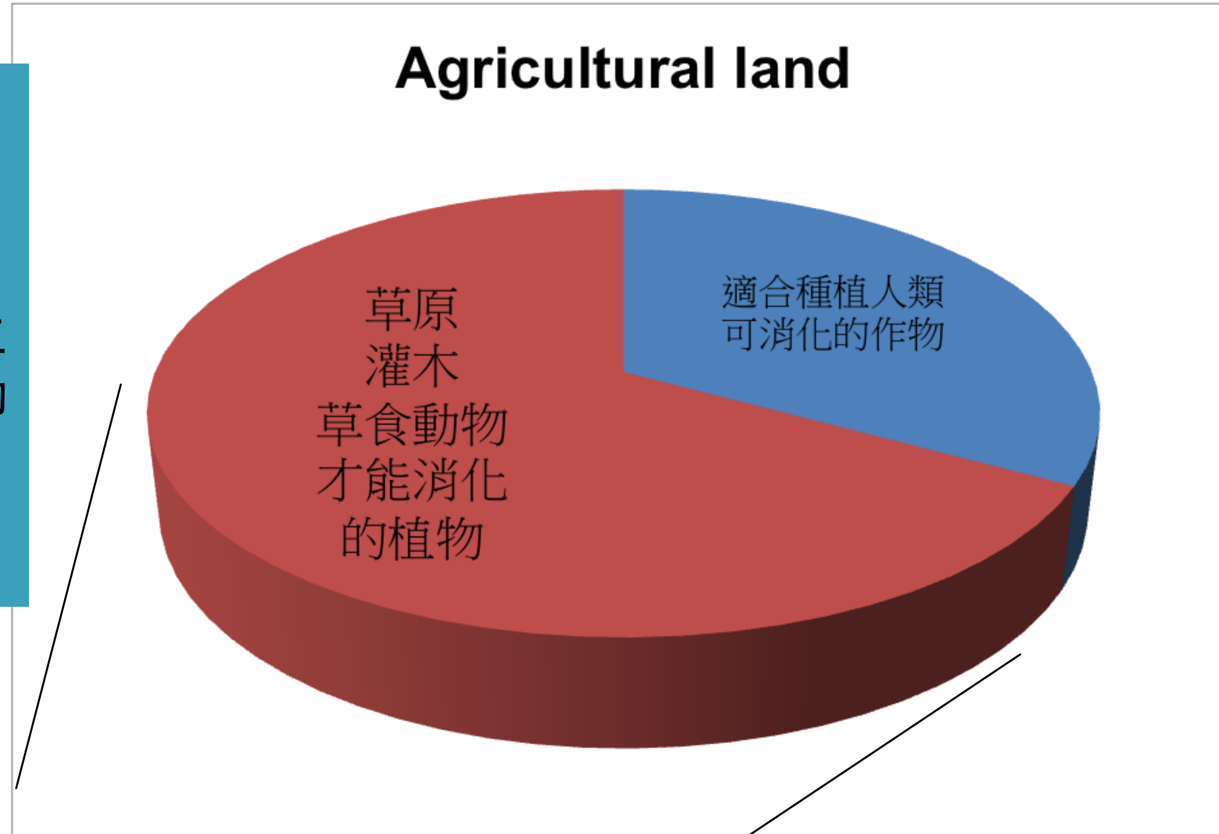
- 被豬干擾過的表土與植被更有利於其他植物的生長

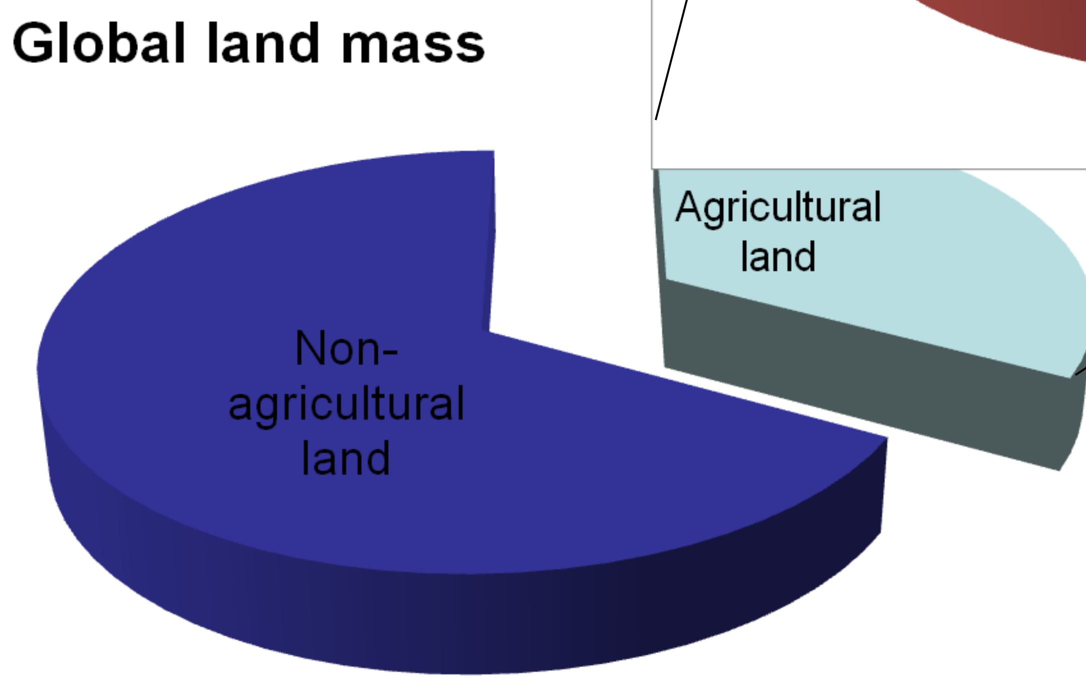
Yet a common “cure” for desertifying land is to remove grazing animals, as happened here:

Results of 100 years of rest on the Santa Rita Experimental Range near Tucson, Arizona (western U.S.)

全球土地中只有30%是農業可耕地

而可耕地中僅有三分之一適合種植人類可消化的作物，其他三分之二多為草原，灌木等草食動物才能消化的植物(草食動物可將其轉換成為人類可消化的蛋白質)





永續的放牧系統

- 將人類無法消化的植物轉換成人類的食物
- 提供重要的生態服務
- 高能源效益

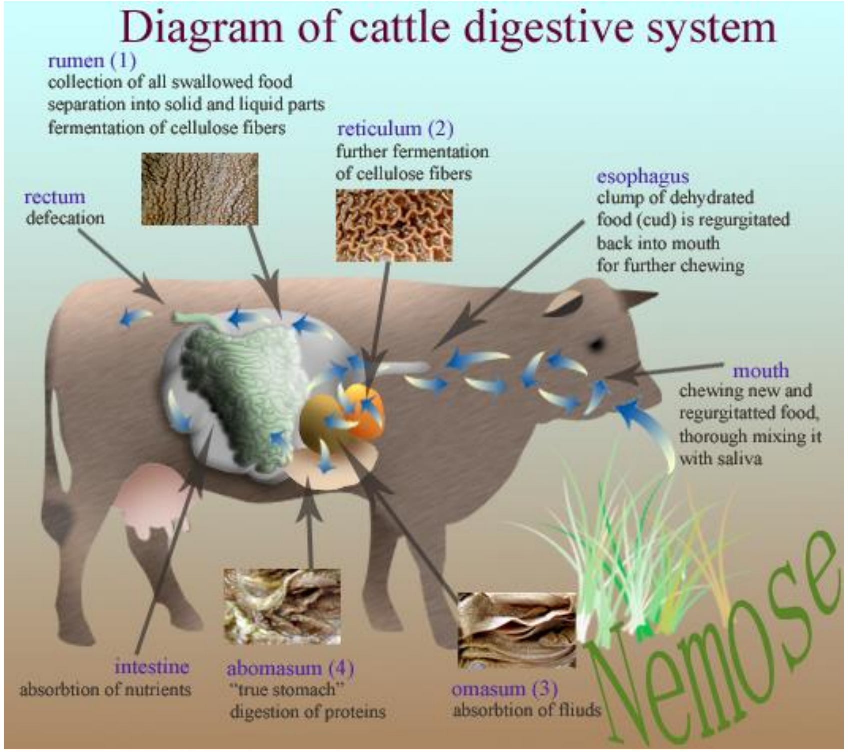
生態服務包括:

- 營養循環
- 種子傳播
- 生物質量的控制
- 共生系統

Source: Robyn Francis

自然情況下，牛可以創造健康的土壤

- 固碳最快的地方是草原
- 讓牛吃草（而非玉米）能快速將碳吸收，降低甲烷排放
- 健康土壤中的**甲**烷**氧化菌 (Methanotrophs)能消化牛所排放的甲**烷



一隻牛平均每天(8 小時)可消化約70 kg草

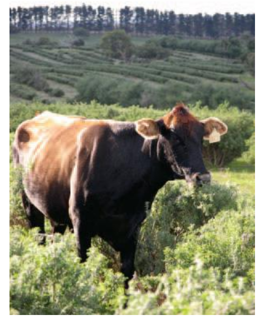
Sources for further research: Allan Yeomans, Dr. Christine Jones, Dr. Rattan Lal

This 2 hectare (5 acre) study plot was briefly grazed by 149 cattle the first year, increasing to over 1,000 by the eighth year.


The result: More and healthier grass inside the fence than outside it.

Holistic Management international

healthy land. sustainable future.



Carbon-rich topsoil from beneath perennial grass (left hand) compared to adjacent carbon-poor soil (right hand). By holding more air, sustaining moisture and having higher bioavailabilities of soil nutrients, carbon-rich soils benefit plants and soil biota.

植物的根提供土壤中生物的棲息地，並會釋出碳。兩者對形成腐植質及土壤中碳的穩定皆很重要。持續性的放牧會抑制根系（左），但在輪休放牧的方式下，根系會較為強健（右）。Plant roots provide habitat for soil biota and exude carbon, both of which are important for humification and soil-carbon stabilisation. Continuous grazing stunts grass root systems (left), which are more robust under rest-rotation grazing (right).

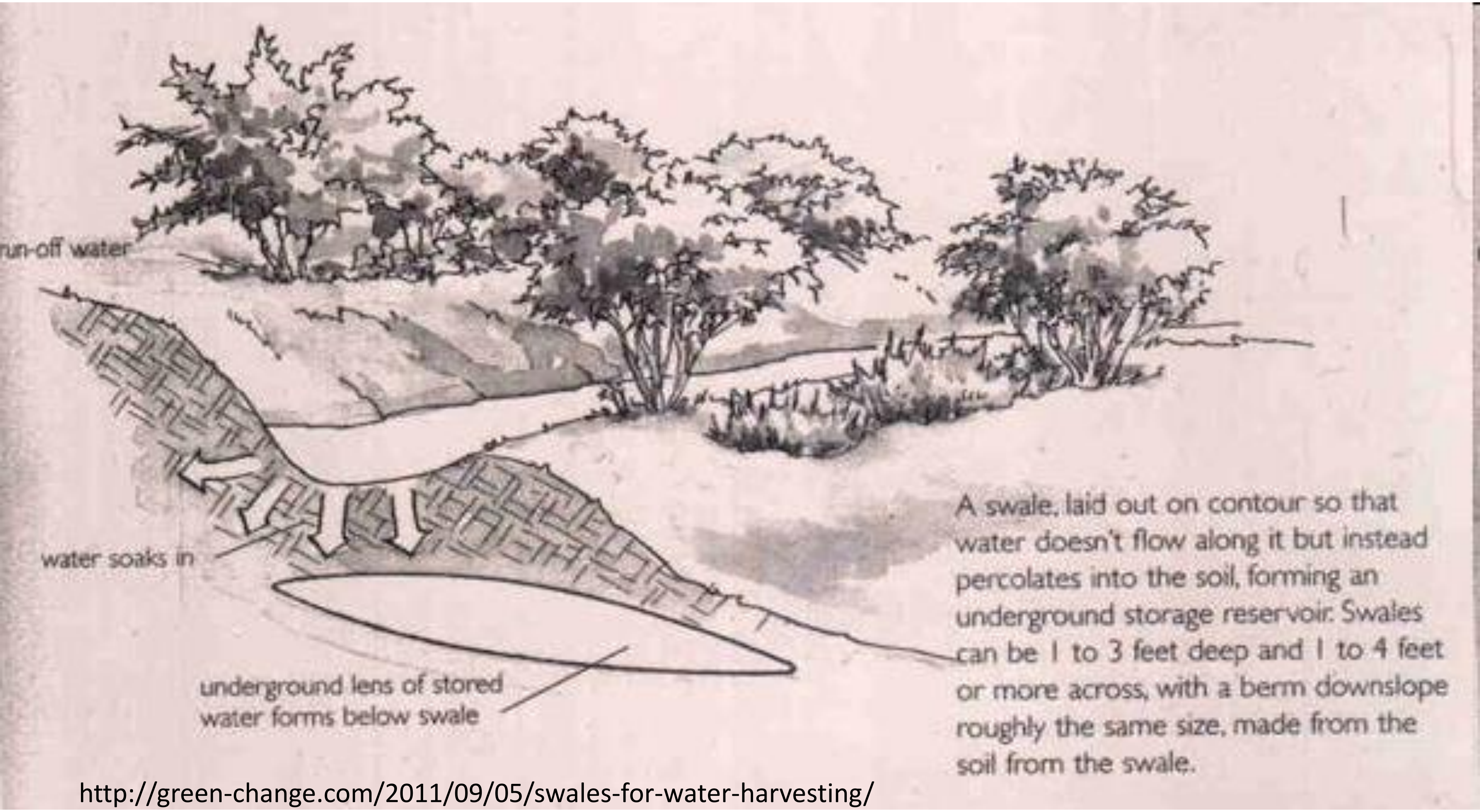
但需要是有管理的放牧，且要適地操作。圖中這個區域比較適合多年生森林

But it has to be controlled grazing and only in suitable areas. This area is more suited to permanent forest.

Annuals –vs- perennials

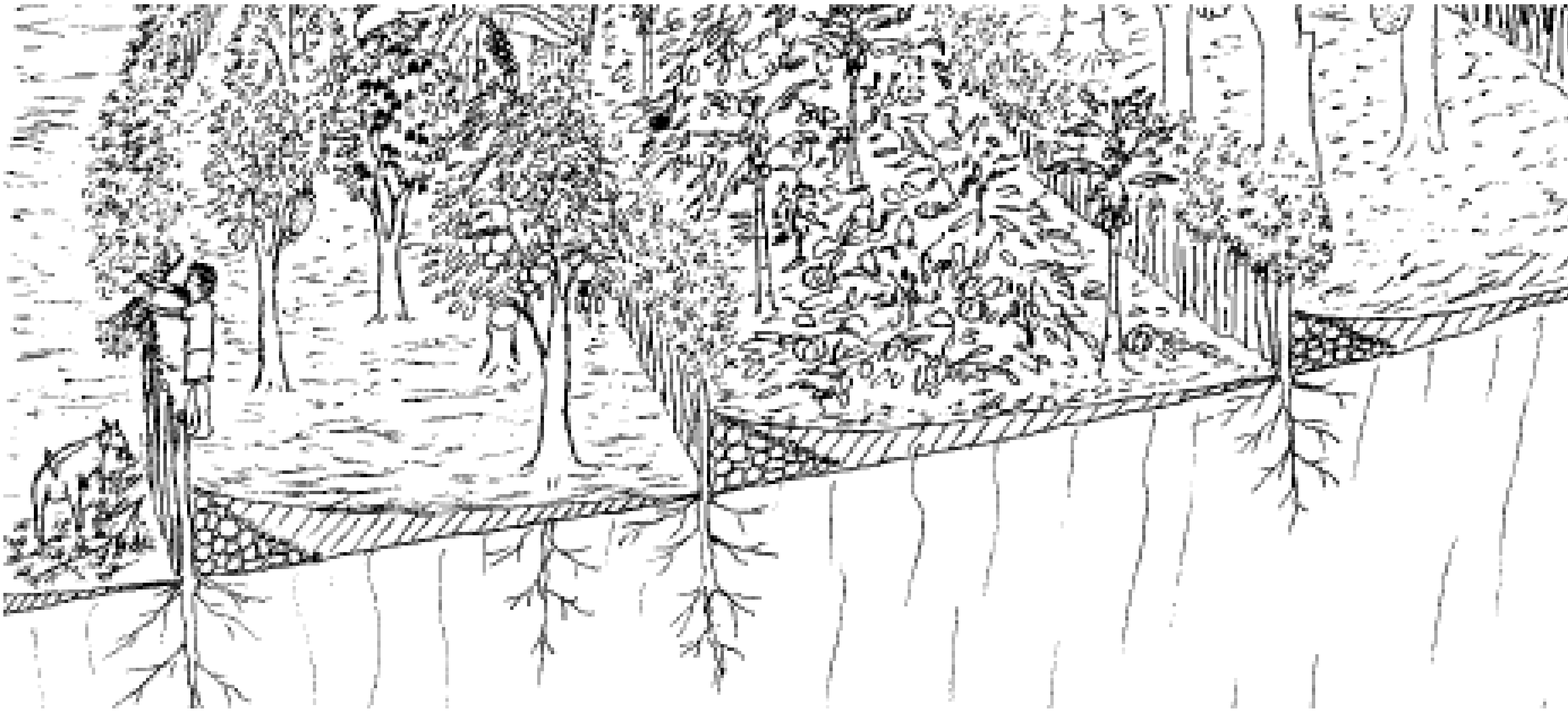

silvopasture

等高線集水溝 Swale



http://green-change.com/2011/09/05/swales-for-water-harvesting/

In flatlands, a 30cm-high swale can back up water up to 6km!



植樹於等高線上

在巷道式作物系統中，將果樹種植于等高線上。

Darren Doherty
http://picasaweb.google.com/permaculture.biz/Permacu

巷道式作物

混合種植水果、飼料（豆科植物）與一年生作物。

當樹木長大後，接著種植耐陰的多年生作物。

Alley cropping

巷道式作物

混合種植水果＆飼料（豆科植物）與一年生植物（小麥）

當樹木長大後，接著種植耐陰的多年生作物。

Broad-scale alley cropping

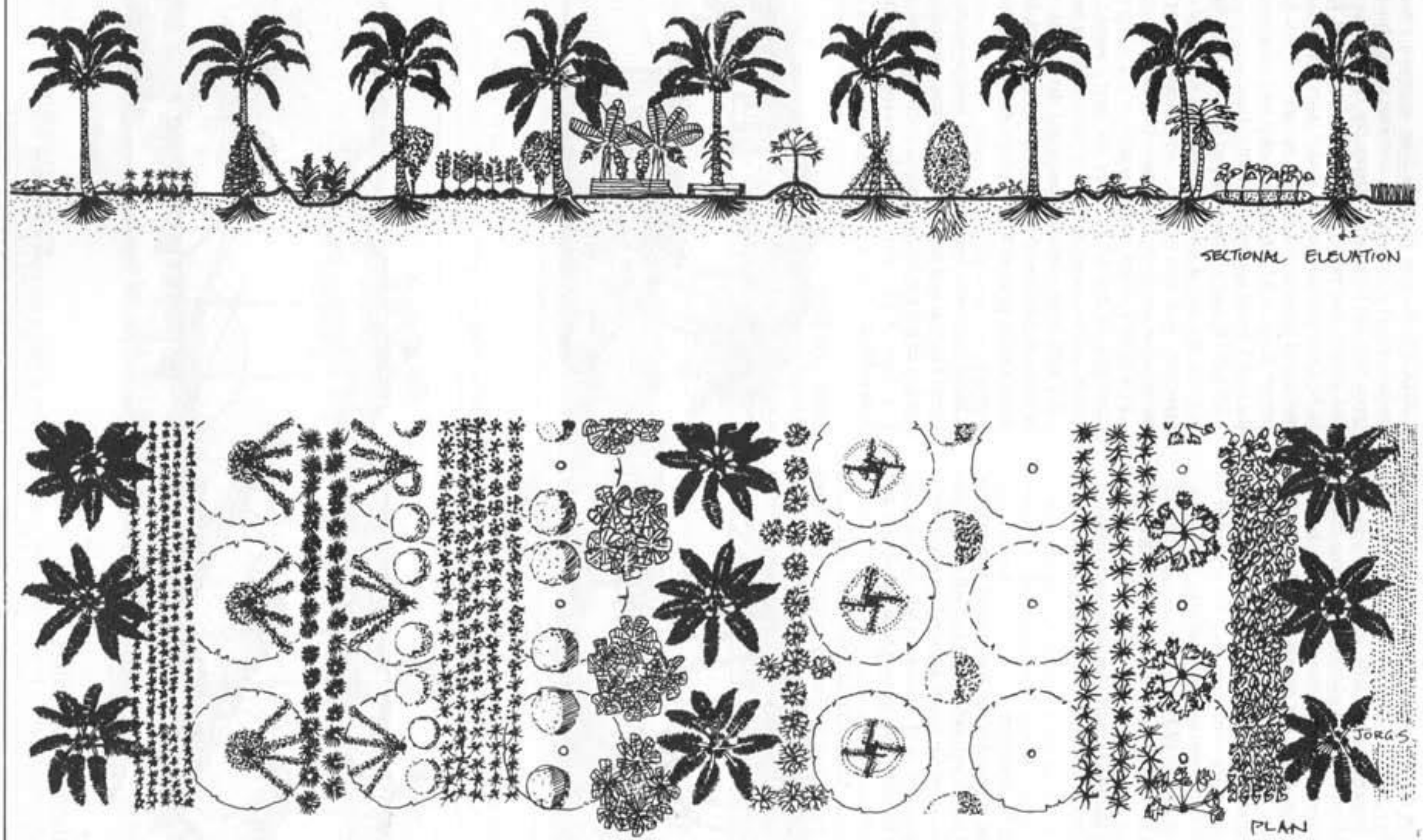
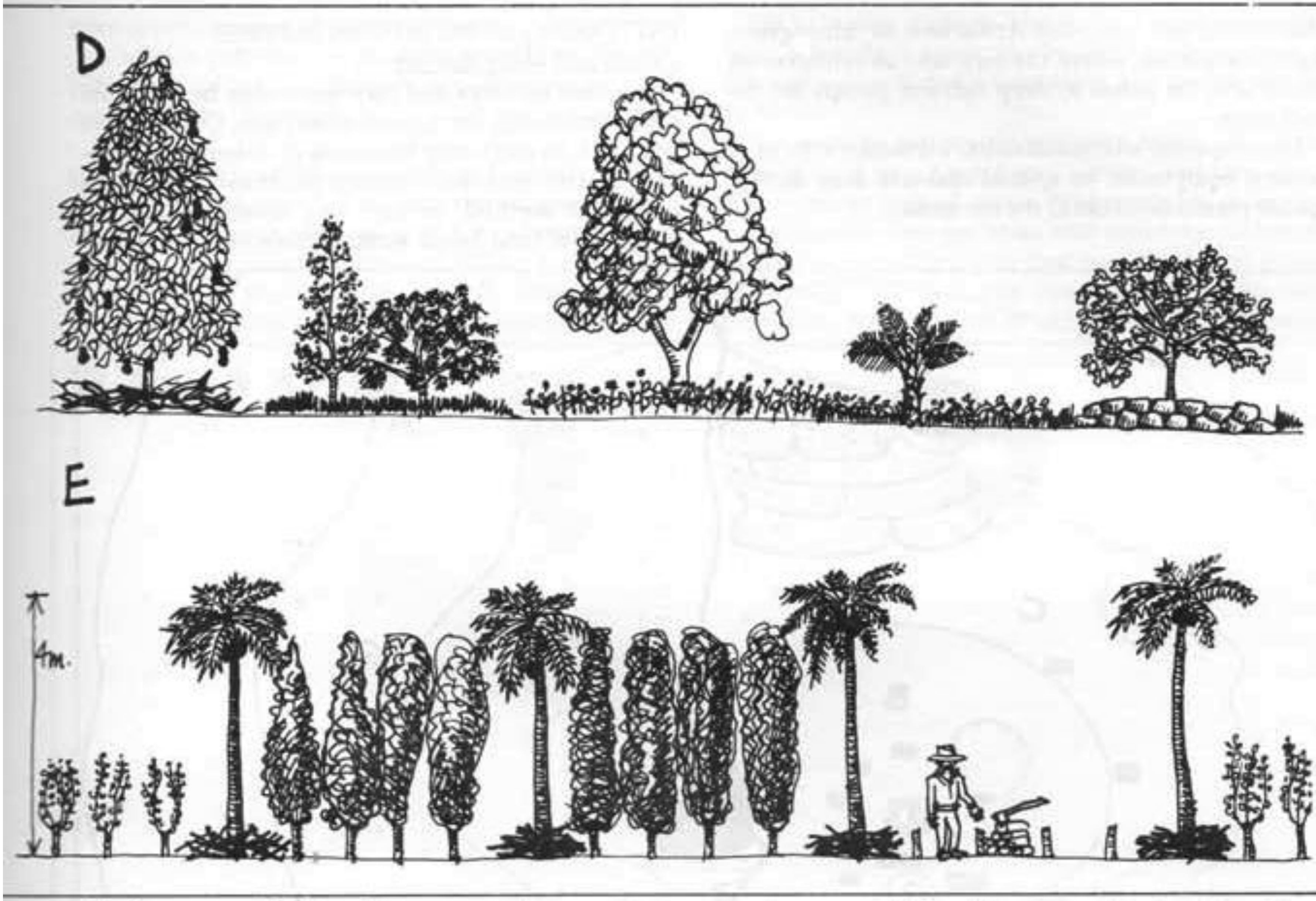


FIGURE 10.38
PALM INTERCROP.
A wide variety of crop, and accessory earth, or trellis, structures can be integrated with palms after years 4–7. [Jörg Schultz].


D
E
4m.

Kiruhily
Coffee Estate
Sth India


LOCALLY PRODUCED

Carbon-sequestering permanent agriculture: experimental rows at Badgersett with (from left) neohybrid chestnut, hazel, hickory (with pawpaw seedlings in tree tubes below), and more neohybrid hazel.

Badgersett's work in the last three decades has focused on developing "neohybrid" hazel and chestnut strains, for production in coppiced systems on 5-10 year rotations. Rutter envisions hazel and chestnut replacing corn and soybeans, transforming Iowa into a vast food forest.

Agroforestry CO_2 sequestration potential ranges widely, depending on several variables:

- **Rainfall**: humid climates sequester more than dry ones
- **Climate**: temperate climates sequester more than tropical ones
- **Species**: sequestration varies by species, with some standouts like mesquite
- **Management**: layout and management practices have a huge impact
- **Design**: polycultures sequester more carbon than monocultures in some studies

社區堆肥

堆肥

Farm scale composting

Urban strategies

- Water harvesting to plantings
- Tree adoptions
- Useful park trees

www.ia.nrcs.usda.gov/features/images/Gallery

www.ia.nrcs.usda.gov/features/images/Gallery

HarvestingRainwater.com (mesquite has roots 48 meters deep!)

Institutional Solutions

- Carbon Cycle Institute has plan to enhance carbon literacy of farmers, associations, government agencies and consumers
- Marin Carbon Project

Online Calculators

Dairy Greenhouse Data Input:

Initially we take a simplified view of the likely diet quality of these type of stock.

State: VIC

	Cows	Heifers	Yearlings	Y/bulls	Bulls
Number	200	60	60	1	1
LWt(kg)	550	400	300	300	770
MY	15.5 L				

Pasture	100 ha.	Diesel	10000 Litre
Crops	20 ha.	Power	20000
N Fert	4000 kg	Source	Brown Coal-Victorian
Tree Area	20 ha		
Type	Eucalyptus globulus - Blue gum		
R/fall	Hi (>700mm)		Calculate Emissions

Global Toolkit of Practices and Species

- Reducing agricultural emissions
  - Conventional nitrogen fertilizers can use renewable energy sources
  - Industry

Perennial food crops

Air
potato

Enset
Edible starch

Piquia
Edible oil crop

Perennial Industrial Crops

Perennial Industrial Crops (Homescale + regional industry!)

- Materials
- Chemicals
- Energy

- Emphasize bioregionally appropriate technology

材料

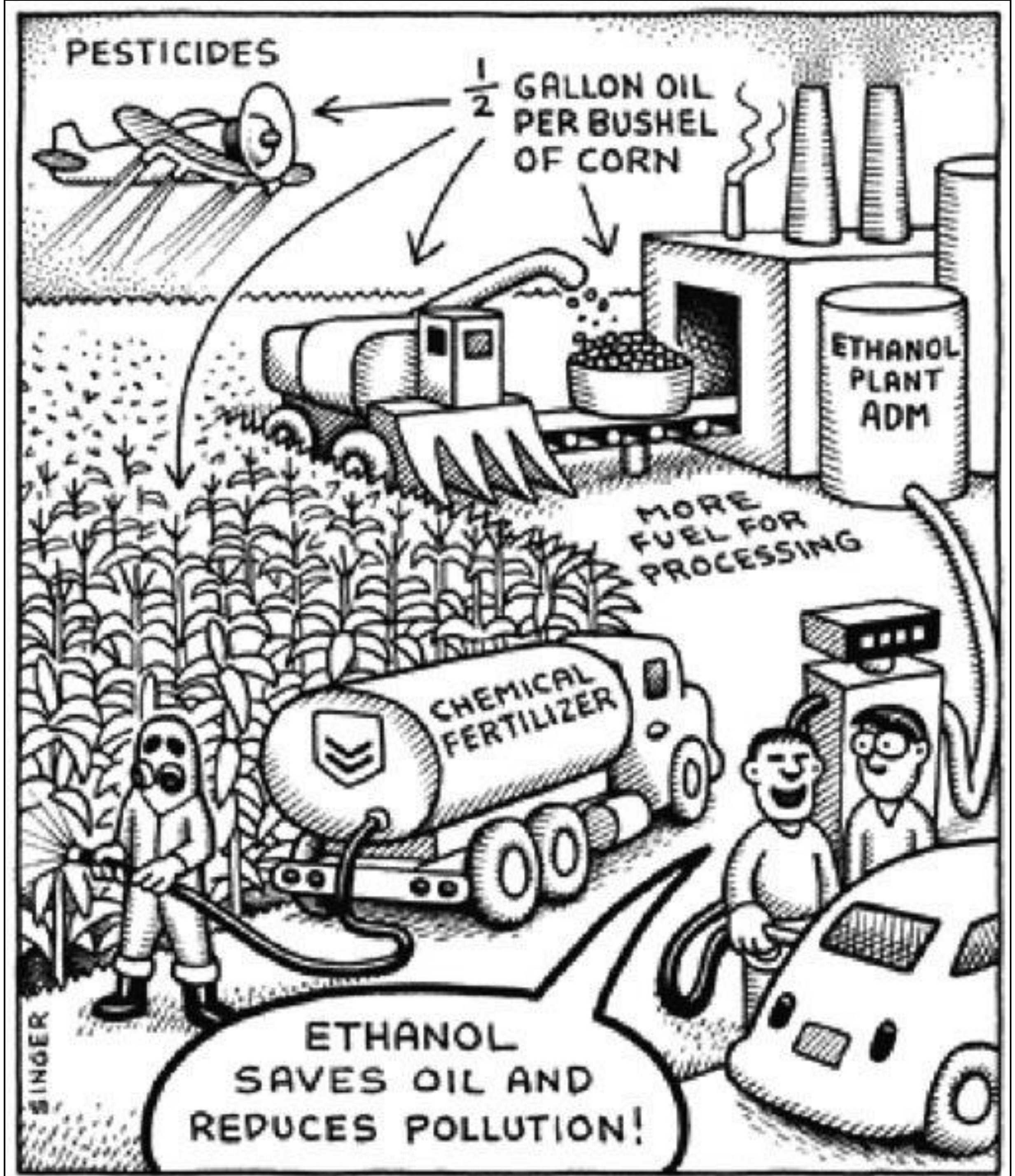
（1950以前，歐洲1/3的農田種植工業作物）

- 柴火
- 木材
- 茅草屋頂
- 紙
- 紙板
- 織品/纖維
- 炭
- 塑膠
- 橡膠
- 合成木料（合板）
- 塗料
- 肥皂
- 膠水
- 油漆
- 潤滑油
- 染料
- 藥
- 溶劑
- “platform chemicals” 穩定劑, 分散劑, 凝膠...

Switching the entire world’s current plastic production to biobased feedstocks would take 4%-5% of agricultural land

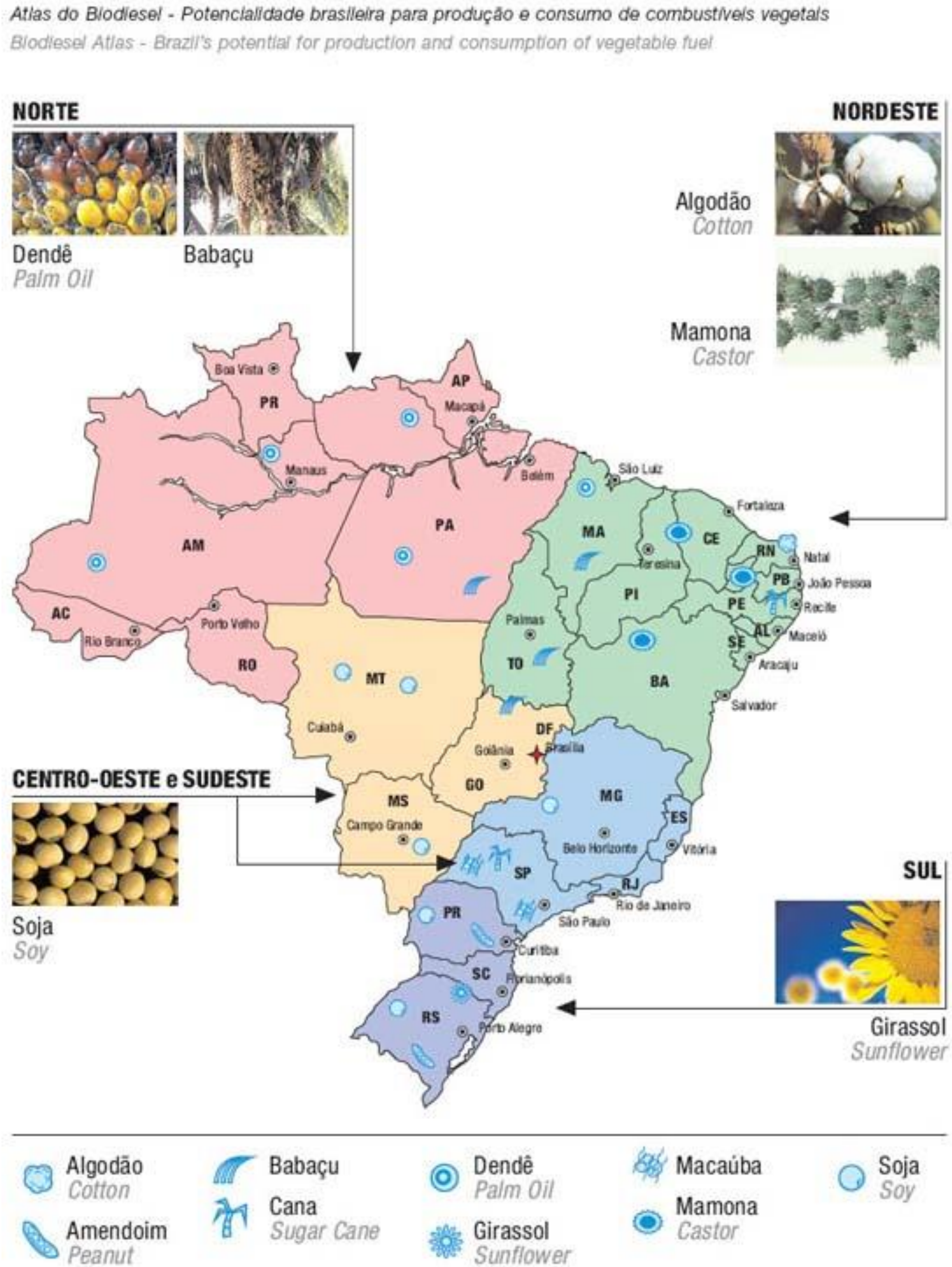
Biofuel is currently made from food plants.

The amount of maize it takes to fill an SUV tank could feed a person for a year.



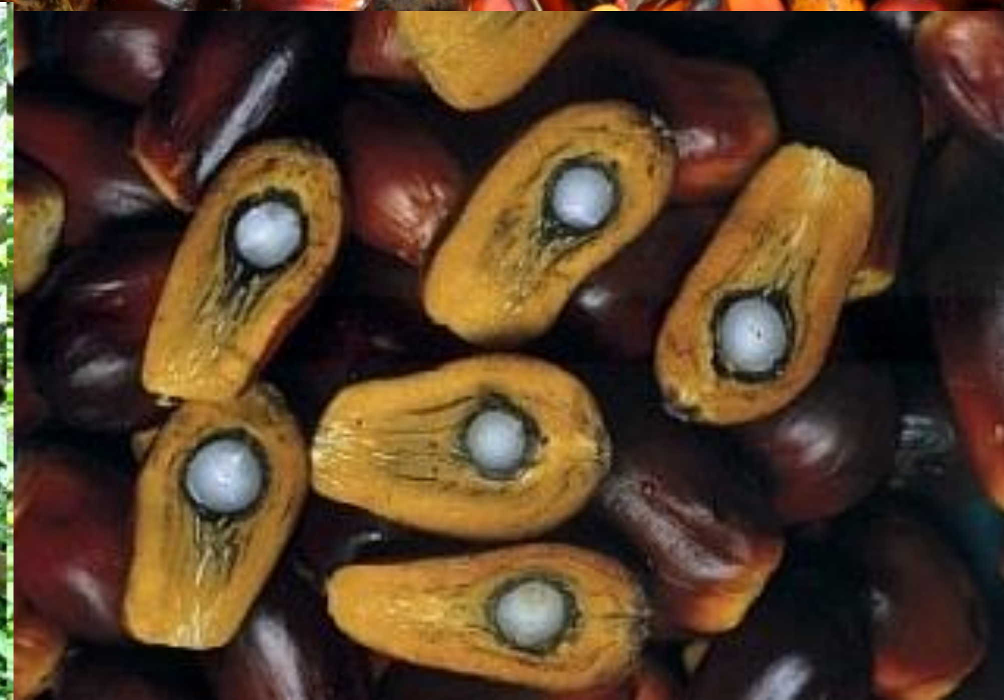
http://www.nczoo.org/biofuels/images/BiodieselGraphi

http://www.inhabitat.com/images/biodiesel_bus.jpg



http://www.biodieselbr.com/i/biodiesel/biodiesel-brasil-potencial.jpg



Willie Smits 分享了 1 條連結。
7月31日

15–30% of the wood you buy originates from illegal logging. Please take care.

能源

Darren Doherty

Agroforestry for Wood Energy in Cambodia

能源

Short-rotation coppice
wood is sun-dried

Wood fed from top;
Here the gasifier is being fired up

Dendro-thermal energy in Sri Lanka; a 35kW down-draft solid biomass gasifier

Gas is combusted in internal combustion or diesel engine
which generates electricity

Producer gas generated runs
through as series of filters

Source: www.re-focus.net Dec 2002

能源

- 在不犧牲食物產量的前提下，西元2050時，生質能源僅可達到目前能源使用的10%至20%Biofuels could only reach 10%-20% of current energy use by 2050 without sacrificing food production
  - 此種土地利用方式將與生物碳、工業化原料、棲息地恢復及其他土地利用相抗衡This land use would compete with biochar, industrial feedstocks, habitat restoration and other land uses
  - 需要水及養份Require water and fertilizer
  - 將人們轉移至邊際土地Displace people on marginal lands

生物質

- 竹子Bamboo
  - 目前全球有7億2700萬噸的碳儲存於竹子裡 (單竹子即可輕易達到我們目標2000億噸的0.5%) Today 727 million tons of carbon stored in bamboo around the world (bamboo alone could reach 0.5% of our 200 billion ton goal)
  - 相較天然竹林，經管理的竹林可存取較多碳Managed bamboo forests capture more carbon than natural bamboo forests
- 健壯的大型草本植物Vigorous giant grasses
  - 自然建築, 編籃, 製紙, 飼料, 甘蔗, 紙莎草Natural building, basketry, papermaking, fodder, sugarcane, papyrus,
- 多年生木本植物Resprouting woody plants
  - 銀合歡, 桉樹, 楓樹, 藤, 桑樹, 冰淇淋豆, 印度苦楝, 牧豆樹, 柳樹Leucaena, Eucalyptus, Maples, Rattan, Mulberry, Ice cream bean, Neem, Mesquite, willow
- 外來種

工業化澱粉作物Industrial starch crops

- 歐洲每年有17%的穀物拿去製紙（用食物做紙板！）Currently 17% of European grain annuals go to papermaking (using food to make cardboard!)
- 西元1800起便有人以自然素材做塑料（福特在二戰前1941做了大部分以大豆為基礎的塑料車）Plastics have been made from natural materials since 1800s (Ford made a car of mostly soy-based plastics in 1941 - then WWII)
- 現今90%的塑料可由生物為基礎的原料製成90% of current plastics could be made with biobased feedstocks
- 重點: 可以使用多年生（perennial, non-destructively harvested feedstocks, non-food crops）
- *Open Source Ecology* has a bioplastic extruder in their toolkit of 50 most important machines for civilization that can be built from scratch (如灌溉水管等.)
- 一甲地可在當地生產2至4噸的生物塑料原料1甲 land can produce feedstock for 2-4 tons bioplastic locally

Industrial oil crops

邁向實踐的道路

1. 支持農人及農業組織轉型
2. 有效地補助固碳農業
3. 破除國際間的屏障

Road Map to Implementation

1. Support farmers and farming organizations to make the transition
2. Effectively finance carbon farming efforts
3. Remove national and international policy barriers

Carbon offsets

Studies have shown that the more incentives are available for farmers, the more carbon they can draw down. One way is carbon offsets.

Australia started a system but conservative govt is scrapping it!

KEY STEPS OF THE CARBON FARMING INITIATIVE

1. Identify a methodology - all projects to generate carbon credits must use a methodology that has been approved by the Domestic Offset Integrity Committee. While a few methodologies have been developed to date, more are being developed as the market matures.

2. Become a recognised offsets entity or aggregator - a fomal

3. Develop and submit a project outlining the methodology you will use

4. Set up a reporting schedule to account for the amount of carbon

5. Apply for credits that have been generated by your project. Credits will not be issued until there is proof that you project has actually reduced emissions or stored carbon.

6. Sell you credits!





ALBERT GEA/REUTERS