World Agroforestry Centre

Basic concepts of carbon sequestration & Challenges in enhancing soil carbon storage

Mehmood Hassan, December 2018

Key Findings from Climate Science

- It is warming
- It is because of us and about us
- We are sure
- It is bad
- We can fix it

We have 11 years to limit climate change catastrophe, warns UN

www.theguardian.com

…BUT….

https://350.org/science/

Huffington Post

Climate Change Already Affects People

Digital Journal Sierra Leone

Carbon Brief

Annenberg Learner

Pierre Joris

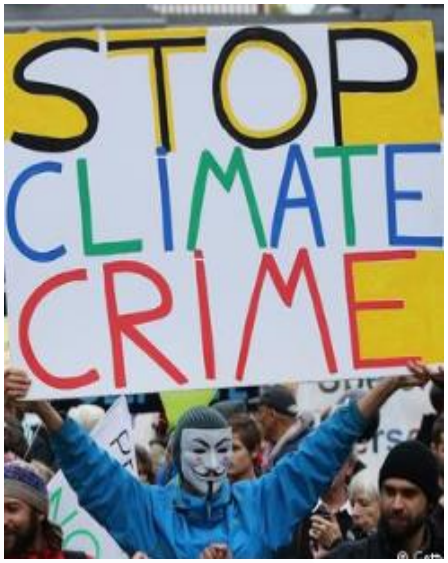
The Independent

CCAFS - CGIAR

Protests Against Lack of Action

400 People Bury Their Heads in the Sand to Protest Australian Prime Minister's Stance on Climate Change

The Conversation



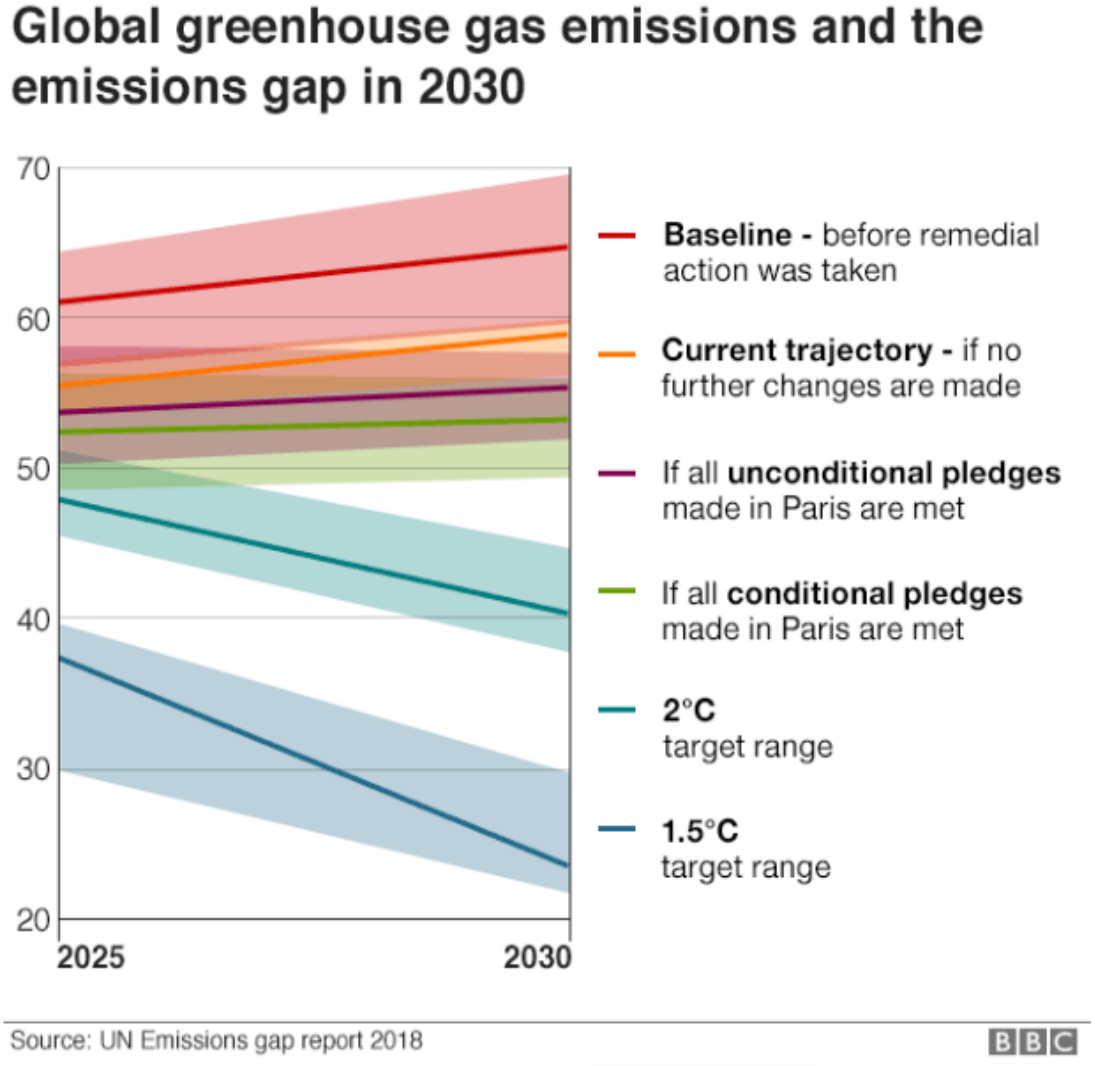
DW

People's Global Climate March 2015

Common Dreams

According to the UN, to keep the world below the target of 1.5C, global greenhouse gas emissions in 2030 would have to be 55% lower than today.

Right now, the world is heading for a temperature rise of 3.2C by the end of this century



Matt McGrath , BBC November 2018

Climate Emergency

" If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO_2 will need to be reduced to at most **350 ppm**, but likely less than that."

- James Hansen (2008)

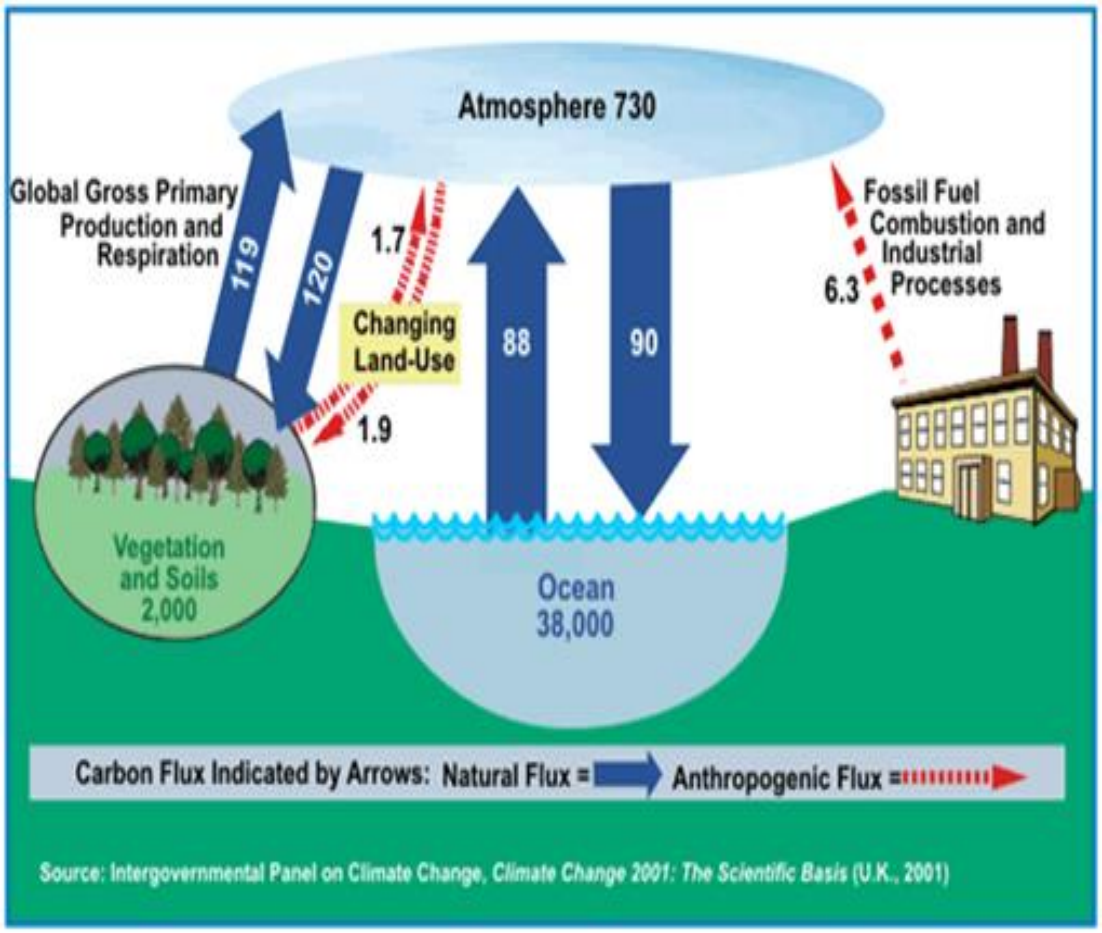
- In 2017: CO_2 concentration = 400 ppm
- Paris Agreement's goal: temperature < + 2°C by 2100
- This means CO_2 concentration < 480 ppm by 2100

⇒Negative Emissions (Carbon sequestration in soils and Biomass) is absolutely needed

Harris et al 2017

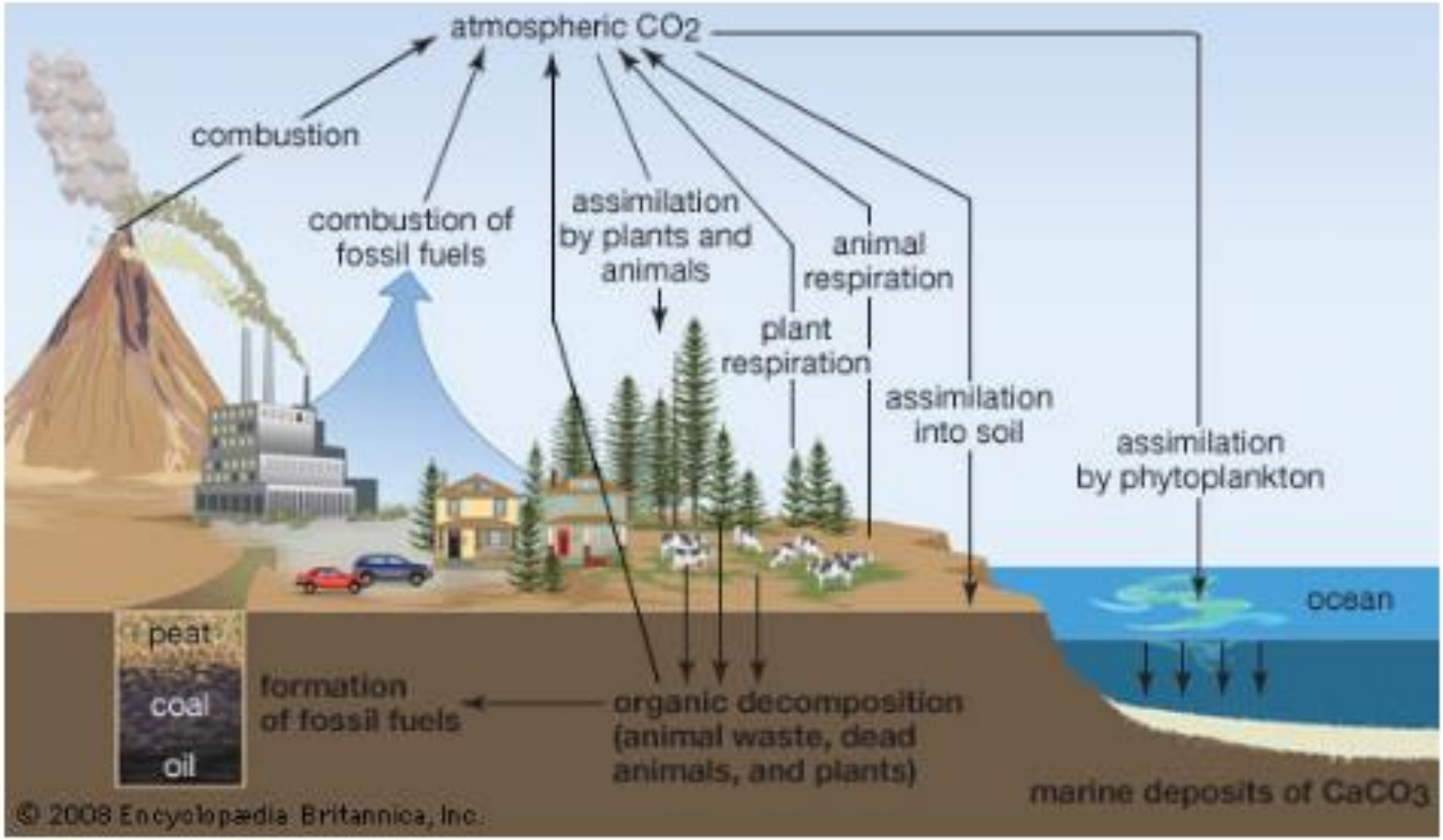
Earth's Carbon Cycle

- The earth contains huge storehouses of carbon. Carbon is sequestered in our oceans, soils and vegetation
- Carbon is continuously flowing back and forth between these carbon storehouses and the atmosphere.
- When plants grow they take in atmospheric carbon dioxide. When the plant dies, the carbon in the plant is released into the atmosphere
- If our plant life is not able to take that carbon dioxide in quickly enough, it stays in the atmosphere or it sinks down into the world's oceans.



https://www.agmrc.org/renewable-energy/biofuelsbiorefining-general/biochar-a-multitude-of-benefits

Carbon Sources And Carbon Sinks



Britannica 2018

Carbon Sequestration (CS) As a Way to Mitigate Climate Change

What Is Carbon Sequestration?

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. It is one method of reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change.

Source: https://en.wikipedia.org/wiki/Carbon_capture_and_storage

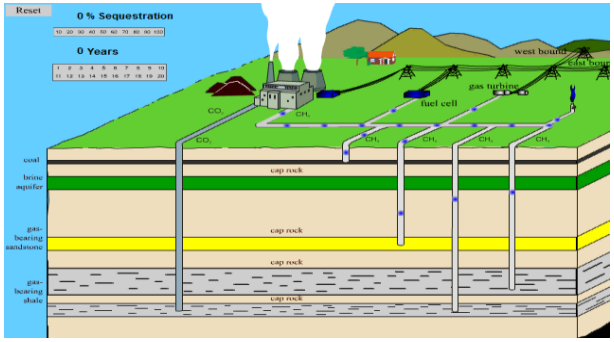
Types of Carbon Sequestration

- Carbon sequestration can be **geologic or biologic** (USGS 2018).

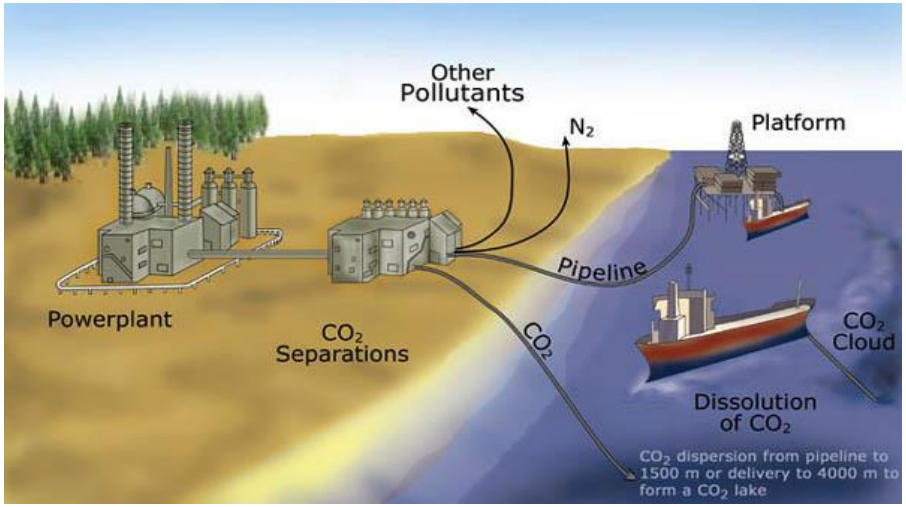
Terrestrial carbon sequestration by Balansay

Biologic CS refers to storage of atmospheric carbon in vegetation, soils, woody products, and aquatic environments.

- ✓ **In plants and soil** "terrestrial sequestration" ("carbon sinks")
- ✓ Deep in ocean "ocean sequestration"



Geologic CS is the process of storing carbon dioxide (CO2) in **underground** geologic formations or **as a solid material** (still in development).



Ocean Sequestration, Balansay

Terrestrial Carbon Sequestration

- The process through which CO2 from the atmosphere is absorbed naturally through **photosynthesis & stored as carbon in biomass & soils.**
- **Tropical deforestation** is responsible for 20% of world's annual CO2 emissions, though offset by uptake of atmospheric CO2 by forests and agriculture
- **Ways to reduce greenhouse gases:**
  - avoiding emissions by maintaining existing carbon storage in trees and soils
  - increasing carbon storage by tree planting or conversion from conventional to conservation tillage practices on agricultural lands

Terrestrial Carbon Sequestration (continued)

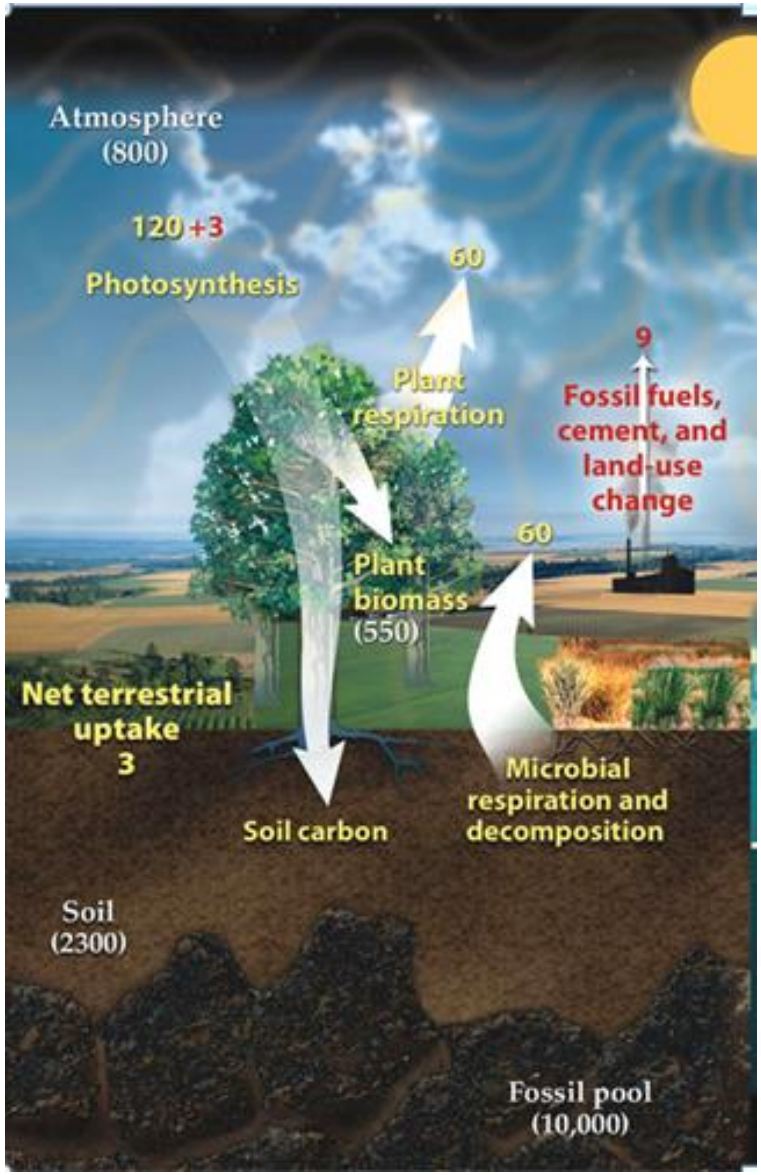
- Carbon seq. rates differ based on **the species of tree, type of soil, regional climate, topography & management practice**
  - Pine plantations in SE United States can accumulate almost 100 metric tons of carbon per acre after 90 years (~ 1 metric ton : 1 year)
- Carbon accumulation eventually reaches **saturation point** where additional sequestration is no longer possible (when trees reach maturity, or when the organic matter in soils builds back up to original levels before losses occurred)
- After saturation, the trees or agricultural practices still need to be sustained **to maintain the accumulated carbon** and prevent subsequent losses of carbon back to the atmosphere

Soils: the Largest Carbon Sink

Carbon in Atmosphere: 860 Gigatons

Carbon in Plant biomass: 550 Gigatons

Carbon in Soils: 2300 Gigatons



Carbon in topsoil (40cm = 16 inches): 860 Gigatons

Regenerating Soils: a Win-Win Solution For Mitigating Climate Change And For Food Security

- Restore soils to sequester carbon back where it belongs, in the soils and in the plants: this is the most efficient and safest climate mitigation strategy (no need for geoengineering!)

- Restore soils to enhance Food security: + 1 ton of soil carbon per hectare per year increases crop yield by
  * 20 to70 kg per hectare of wheat,
  * 10 to 50 kg per hectare of rice,
  * 30 to 300 kg per hectare of maize

which would lead to an increase of 24 to 40 million metric tons in grain production at the global level

Technical Potential for Soils Carbon Sequestration

- – Agricultural soils: 1.4 GtC/year (ca. 0.48% of top soil organic C stock)
- – Forests soils and agroforestry soils: 1.3 GtC/year
- – Salt affected and degraded soils: 0.5-1.4 GtC/yr

Total estimated to 3.4 Gt per year

Sources: Rattan Lal (2010), Ohio State Univerty

Why SOM Is Important To Sequester Carbon?

Nearly 90% of the technical mitigation potential of agriculture comes from soil carbon sequestration. Many agricultural mitigation options, particularly those that involve soil carbon sequestration, also benefit adaptation, food security, and development. These options involve **increasing the levels of soil organic matter**

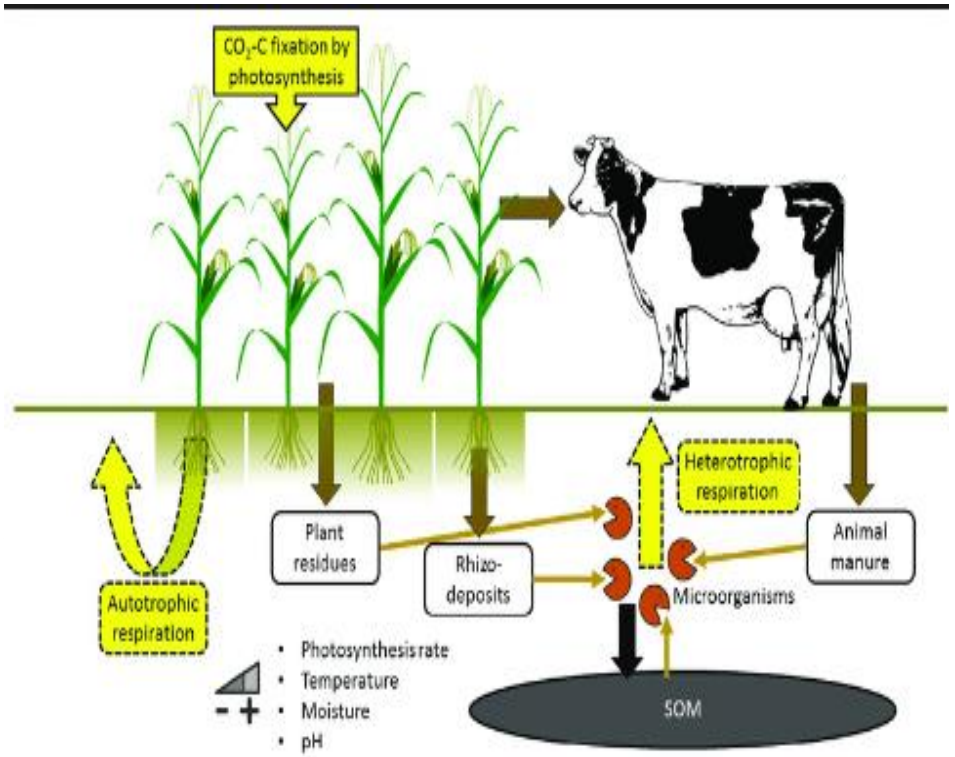
FAO 2009, cited in Cantab 2009

https://www.ecowatch.com

Soil Organic Matter (SOM)

Soil organic matter is the source of **food for soil fauna** and contributes to soil biodiversity by acting as reservoir of soil nutrients such as **nitrogen, phosphorus and sulphur.** Soil organic matter is the main contributor to soil fertility.

When soil organic matter decays, it releases carbon dioxide (CO2) into the atmosphere; on the other hand when it is formed, CO2 is removed from the atmosphere



https://www.agric.wa.gov.au/

…forming SOM is thus important…

Change in SOM (Soil Organic Matter) is Determined By

i) the crop rotation pattern,

ii) the input rates of organic matter,

iii) the chemical composition of organic matter inputs,

iv) the soil type and texture (hence by the degree of protection or bonding of the stable carbon fraction within the soil),

v) the previous land use,

vi) the climatic conditions

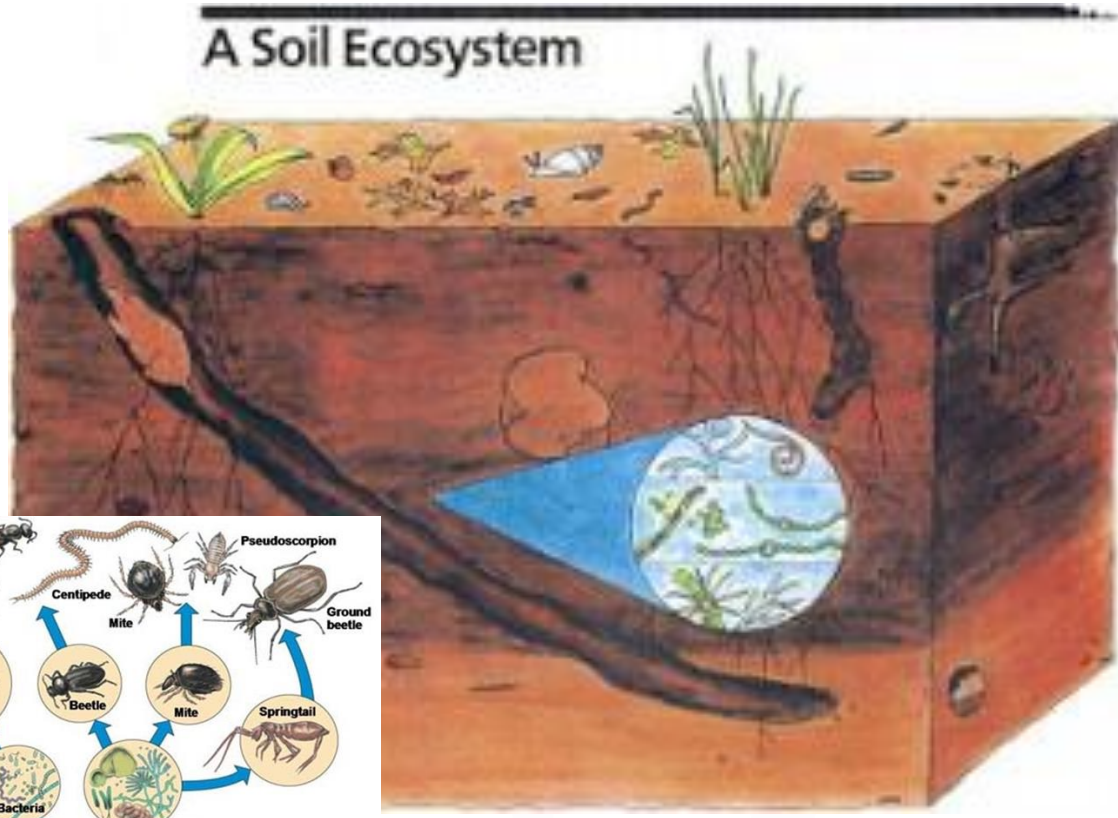
Healthy Soils Are Full Of Carbon

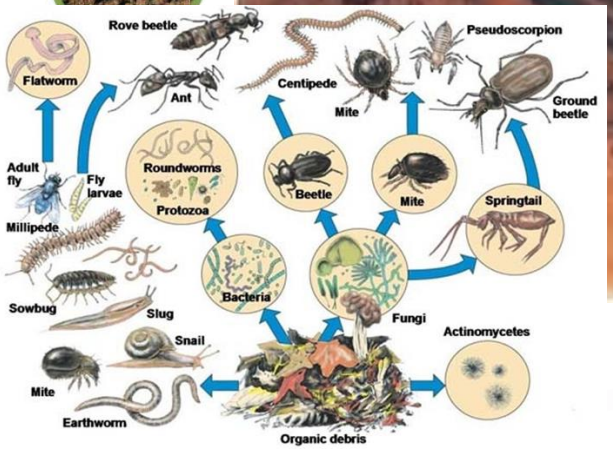
The world's cultivated soils have lost between 50 and 70 percent of their original carbon stock, much of which has oxidized upon exposure to air to become CO2

Soil in a long-term experiment appears red when depleted of carbon (left) and dark brown when carbon content is high (right).

Source: Rattan Lal, quoted in http://e360.yale.edu/feature/soil_as_carbon_storehouse_new_weapon_in_climate_fight/2744/

Healthy soils are thriving ecosystems: Soils are alive





A handful of soil has more living organisms than there are people on planet Earth. Soils are the stomach of the earth, consuming, digesting, and cycling nutrients and organisms.

How Can We Manage SOM?

- Slowing down decomposition rates. This can be done by reducing tillage intensity.
- Increasing the amount of organic matter in the soil. This can be done through adding organic materials in the soil by using cover crops or compost amendments.

Daily Management Review

https://esdac.jrc.ec.europa.eu/projects/SOCO/FactSheets/ENFactSheet-03.pdf

Biological CS

Different technologies to improve carbon sequestration can be applied.

Low Carbon Concrete - Cembureau

Which Areas are Most Suitable for Carbon Sequestration?

Biological Carbon Sequestration can be practiced on any lands used or suitable for agriculture.

But organic matter decays more rapidly at higher temperatures, so soils in **warmer climates tend to contain less organic matter** than those in cooler climates.

The **wetter a soil** is, the less oxygen is available for organic matter to decay, so that it accumulates Carbon

https://esdac.jrc.ec.europa.eu/projects/SOCO/FactSheets/ENFactSheet-03.pdf

How Is CS Implemented?

There are **agriculture-related technologies** and **technologies outside agriculture**. In some cases, both types of technologies might be practiced in the same area.

Technologies to Sequester Soil Carbon

…within agriculture (This event)

- 1. Afforestation, Reforestation, Agroforestry
- 2. Other Vegetation
- 3. Biochar
- …….

…outside agriculture

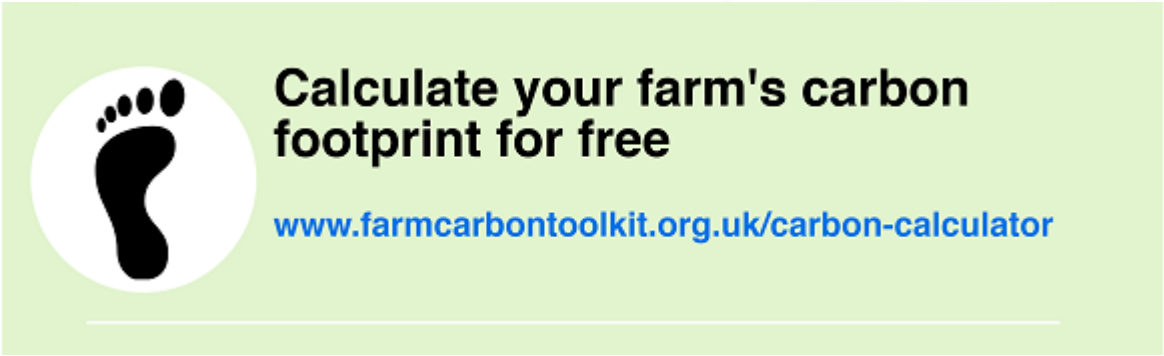
1. Carbon Farming
2. Bioenergy & Bury
3. Fertilizing the Ocean
4. Rock Solutions
5. Direct Air Capture and Storage

https://www.ecowatch.com/carbon-sequestration-2461971411.html

Support Tools and initiatives

Free Farm Carbon Calculator

A Farm Carbon Calculator is a free tool for farmers and growers to work out the greenhouse gas emissions and carbon sequestration associated with their businesses. It is created **by farmers for farmers.**



https://farmcarbontoolkit.org.uk/carbon-calculator

Carbon labeling for agricultural products is gaining importance

Purchasing will be affected by carbon labels:

"Our study indicates that when consumers receive appropriate guidance about embodied carbon emissions, they may adjust purchasing preferences and favour green-labelled goods, collectively representing about 5% of total purchases." Vanclay et al (2010)

http://www.wamis.org/agm/meetings/teco14/S5-Desjardins.pdf

“Carbon farming” by the 3 billion rural poor

Sequestering an additional ton of carbon costs

- $70 to $140 per year, for croplands soils
- $180 to $280 per year, for grasslands and forests

Mostly labor costs => more jobs in rural areas (reduce the exodus of rural poor to urban slums)

⇒ Total cost of sequestering 3.5Gt C per year = **$500billions**

3 billion rural poor => $160 per person per year

How to finance it? **Redirect current agricultural subsidies** (which benefit large corporate agro-business) **towards “Carbon farming” subsidies which benefit small scale subsistence farmers**

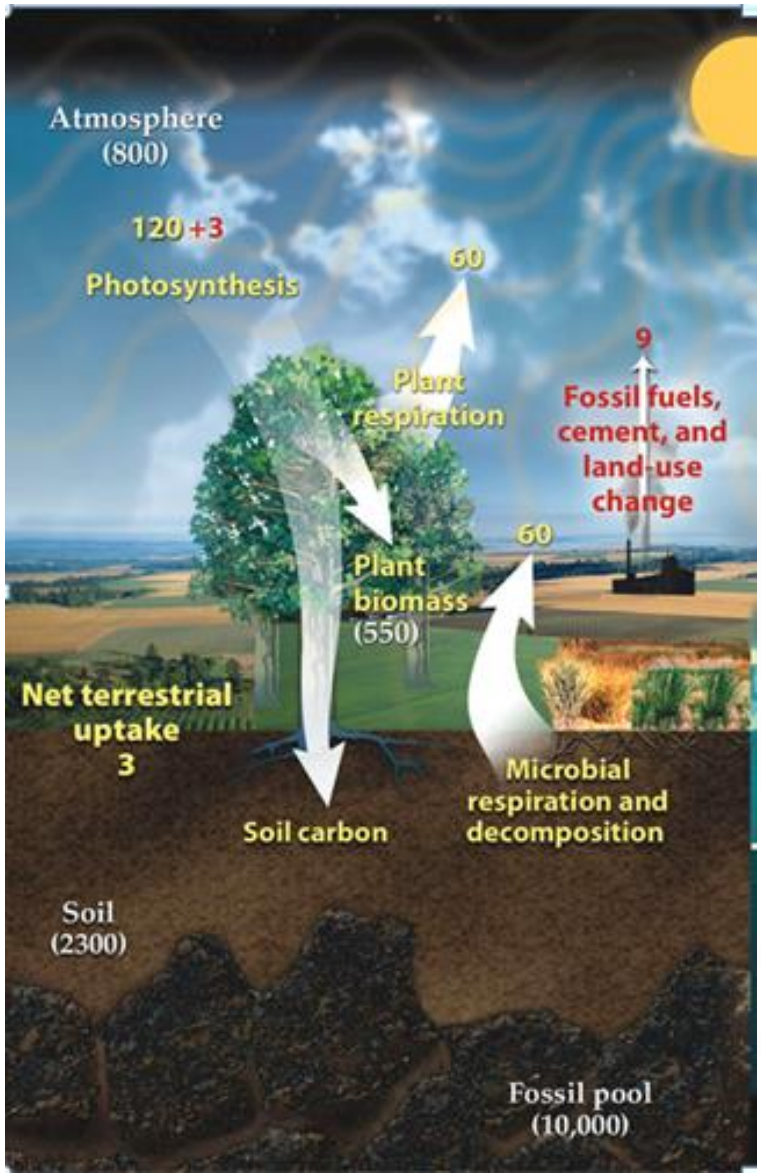
International Soil Carbon Initiatives

Policy Title	Focus	Agency(ies)
4 per 1000: Soils for Food Security and Climate[28]	Efforts and commitments to increase soil organic carbon by four parts per thousand (0.4%) per year	French Ministry of Agriculture and other international partners
Regenerative Development to Reverse Climate Change[29]	Funding to support regenerative agriculture programs in 52 member nations in The Commonwealth of Nations (the former British Empire)	The Commonwealth of Nations
Land Degradation Neutrality Fund (LDNF)[30]	Innovative financial market for investing in profit-generating sustainable land management and restoration projects globally in support of the UN Sustainable Development Goal 15.3 for assuring land degradation neutrality.	UNCCD, UNEP, Mirova
Climate Smart Agriculture (CSA)[31]	Goal of food security and development, by enhancing agricultural productivity, and climate adaptation, and mitigation	FAO, World Bank, Dutch Government

4per1000:
A growing international coalition of nation-states, international organizations, NGOs, research centers, universities, farmers organizations, and businesses

- 30 countries (18 European countries; 10 countries in the Global South)
- 8 International Organizations (including the World Bank, the Global Environmental Facility, and the FAO)
- 26 Universities and research institutes
- 30 farmers organizations
- 25 businesses
- 50+ NGOs

4 per 1000 per year:



Carbon in topsoil (40cm = 16 inches): 860 Gigatons

Adding an extra 3.4Gt of Carbon in topsoils per year:

3.4/860 = 0.004
= 4 per 1000

REDD+
Biomass sink enhancement

- REDD+ Reducing Emissions from Deforestation and Forest Degradation
- Halt deforestation 1.1 GtC/y
- Remove CO_2 by restoring forest capacity over next 50 years at average rates of
  - Allow current second growth forests to reach maturity 2 GtC/y
  - Restore degraded forests 1 GtC/y
  - Reforest recently deforested lands 1 GtC/y

(From: William Moomaw,
"Meeting the Paris Goals: Clean Energy, Forests, and Soils", presentation at ISEE, June 2016)

Challenges of Carbon Sequestration

1. Incentivizing deployment at various levels;
2. Needs flexible and adaptable regulatory frameworks; and
3. Funding large-scale testing and demonstration projects to resolve technical and integration uncertainties as well as reduce high costs.
4. Addressing these three challenges will help solve a fourth: **public acceptability.**

https://www.wri.org

Further Learning Resources

Anne-Marie, C., Itzkan, S., Moomaw, W., Thidemann, K. and Harris, J. (2017) Hope below our feet. Soil as a climate solution. Global Development and Environment Institute Tufts University. Climate Policy Brief. Available online: http://www.ase.tufts.edu/gdae/Pubs/climate/ClimatePolicyBrief4.pdf

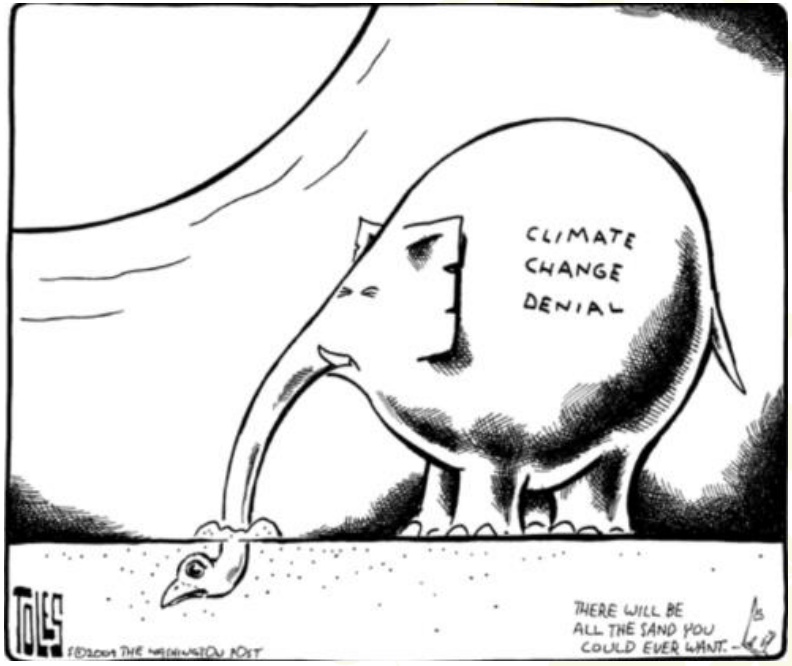
Cantabm G, (2009) Soil Carbon and Organic Farming, A review of the evidence on the relationship betweeb agriculture and soil carbon sequestration, and how organic farming can contribute to climate change mitigation and adaptation, Soil Association. Available online: https://www.soilassociation.org/media/4954/policy_soil_carbon_full_review.pdf [accessed Nov 15 2018].

Encyclopedia Britannica (2018) Carbon Sequestration. Available online: https://www.britannica.com/technology/carbon-sequestration/media/1219977/118423 [accessed Nov 15 2018].

Hoff, M. (2017) 8 Ways to Sequester Carbon to Avoid Climate Catastrophe. Available online: https://www.ecowatch.com/carbon-sequestration-2461971411.html [accessed Nov 14 2018].

USGS (2018) How does carbon get into atmosphere? https://www.usgs.gov/faqs/how-does-carbon-get-atmosphere?qt-news_science_products=0#qt-news_science_products [accessed Nov 14 2018].

Questions?



World Agroforestry Centre

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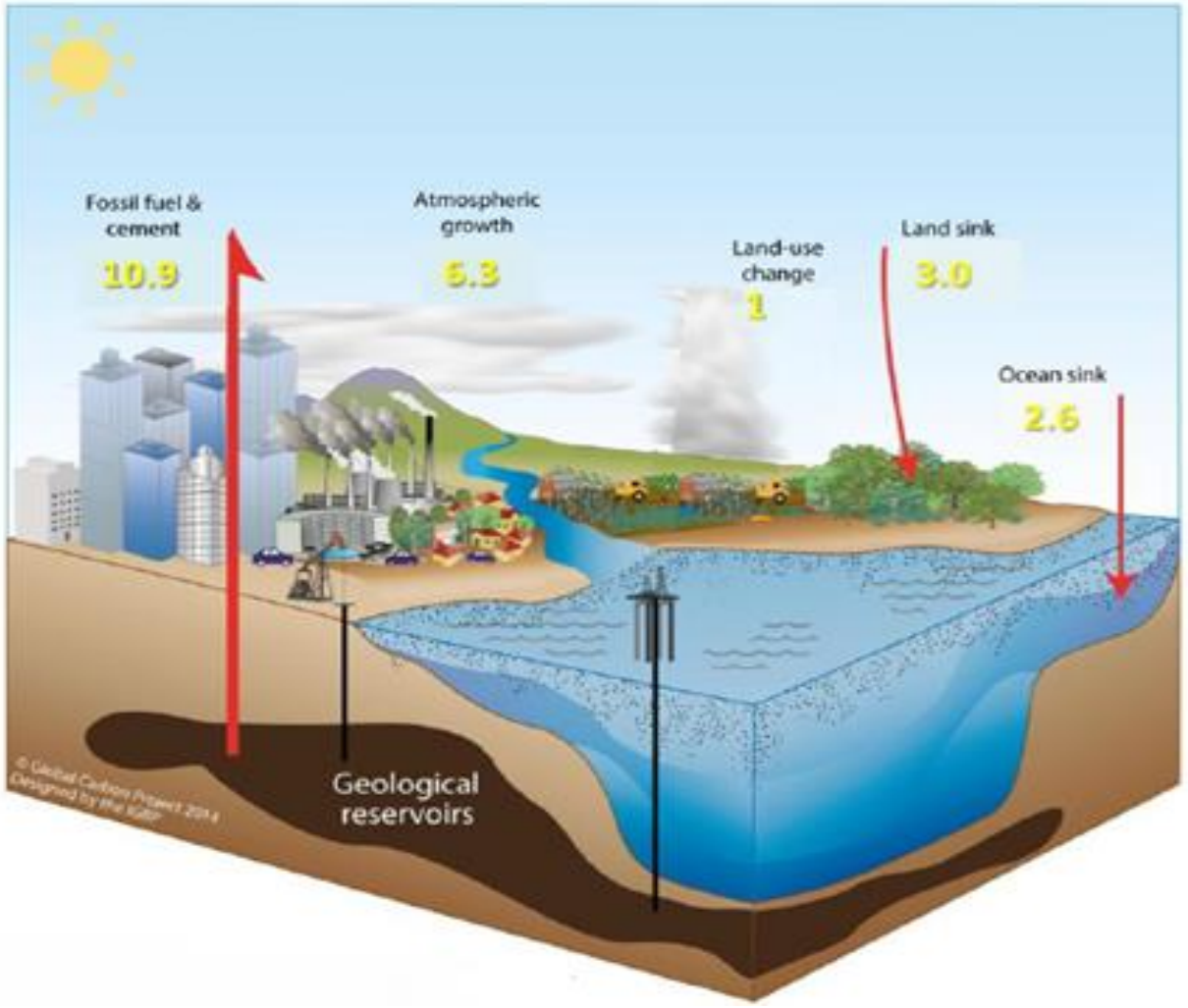
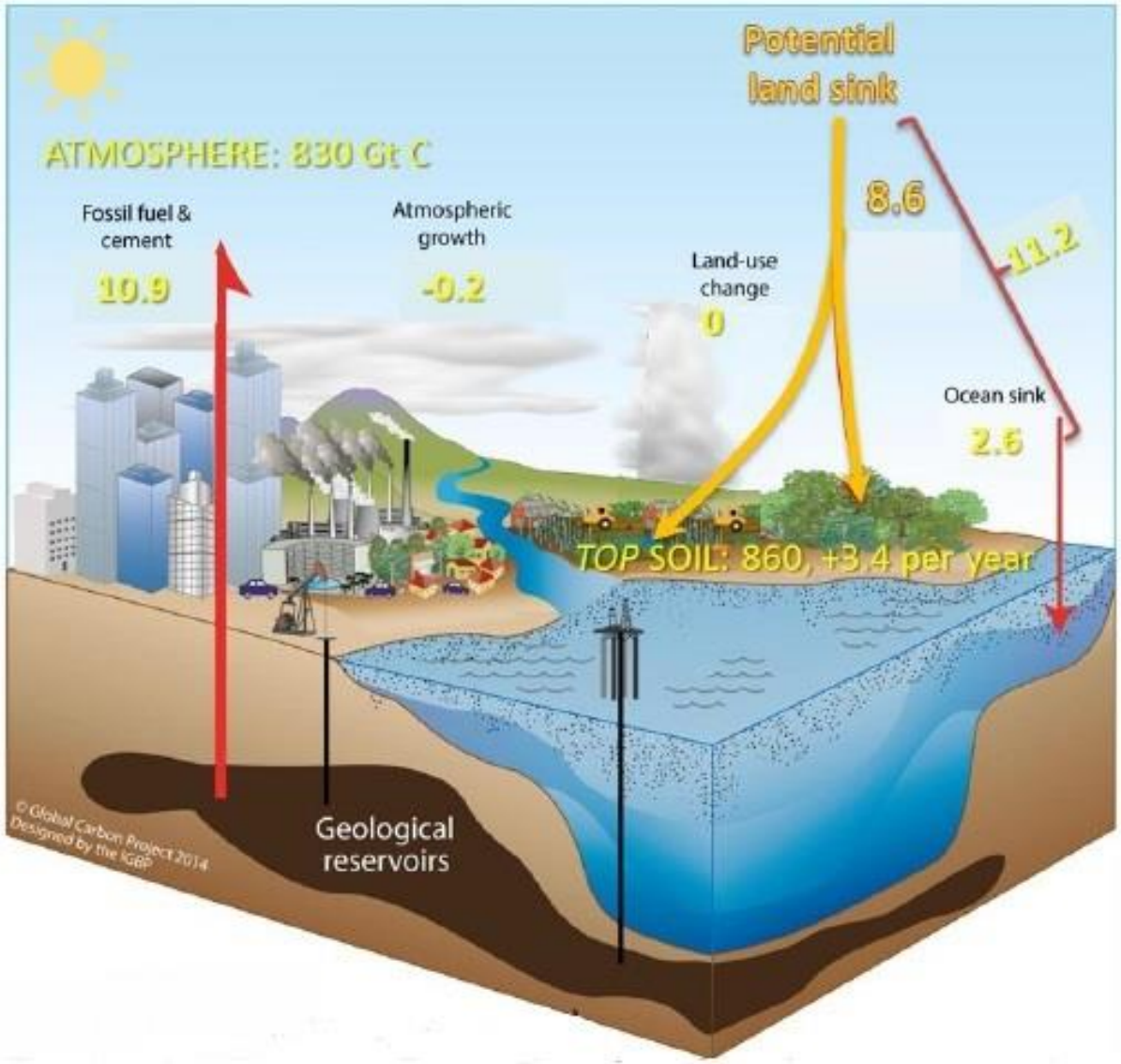
CGIAR
Science for a food-secure future

Paris agreement without soil regeneration and biomass sink improvements – horizon 2030



http://ase.tufts.edu/gdae

With implementation of soil regeneration and biomass sink enhancement (4per1000 and REDD+)



Potential land sink:
3Gt
+ additional 3.4Gt in soils
+ additional 2.1Gt in biomass
(conservative figure)
= 8.6Gt

Offset Greenhouse Gas Emissions?

- At the global level, the IPCC Third Assessment Report estimates that ~100 billion metric tons of carbon over the next 50 years could be sequestered **through forest preservation, tree planting and improved agricultural management.**
  - Offset 10-20% of estimated fossil fuel emissions