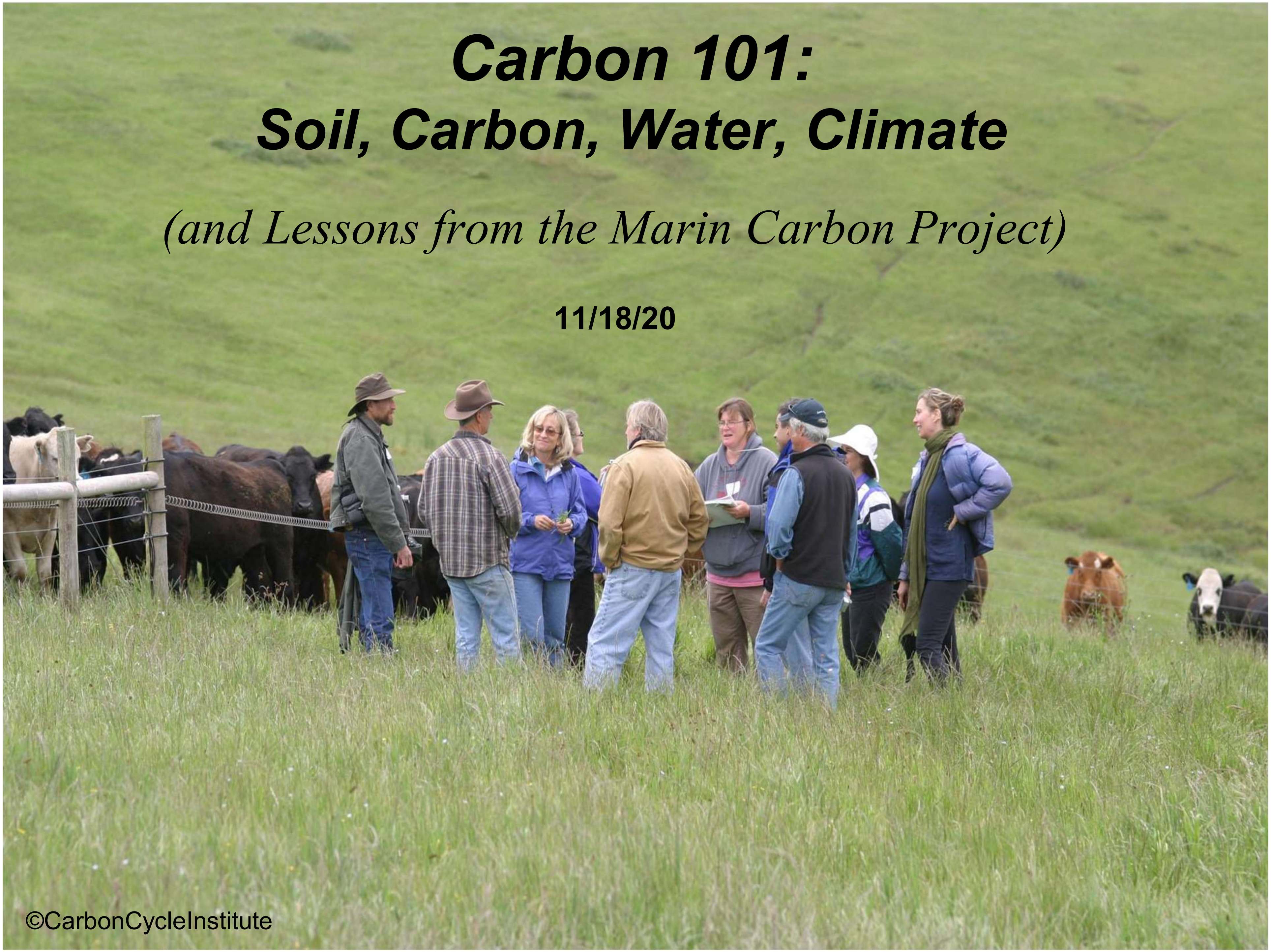
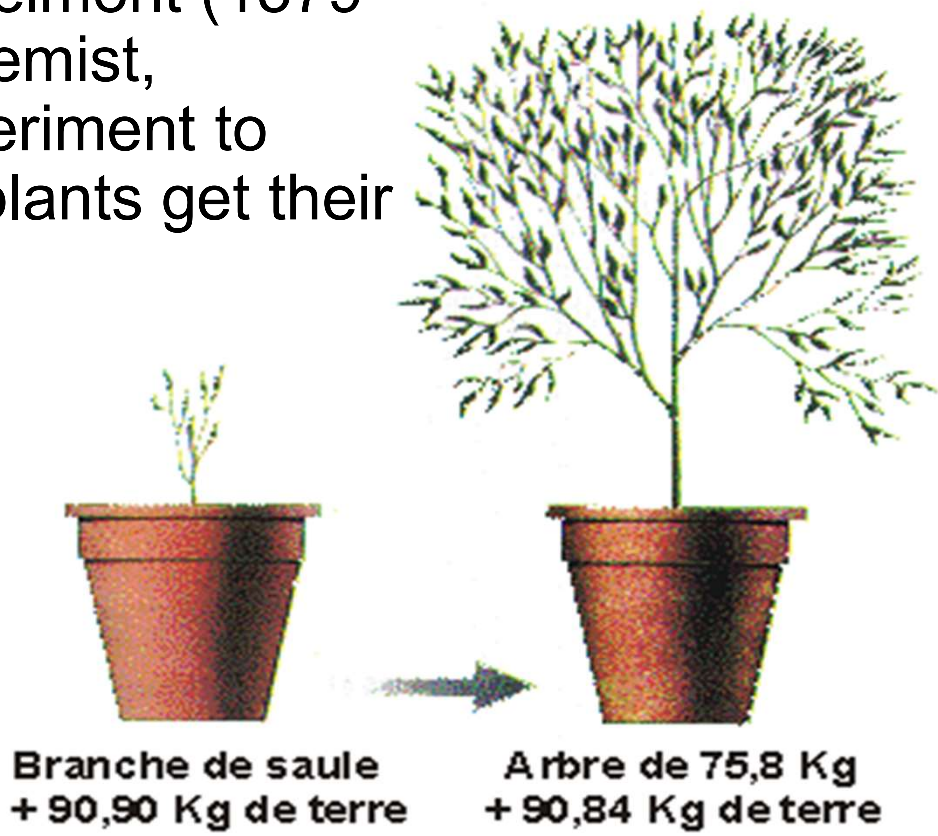
Carbon 101:
Soil, Carbon, Water, Climate

(and Lessons from the Marin Carbon Project)

11/18/20



Jan Baptist Van Helmont (1579-1644), Flemish chemist, conducted an experiment to determine where plants get their mass.

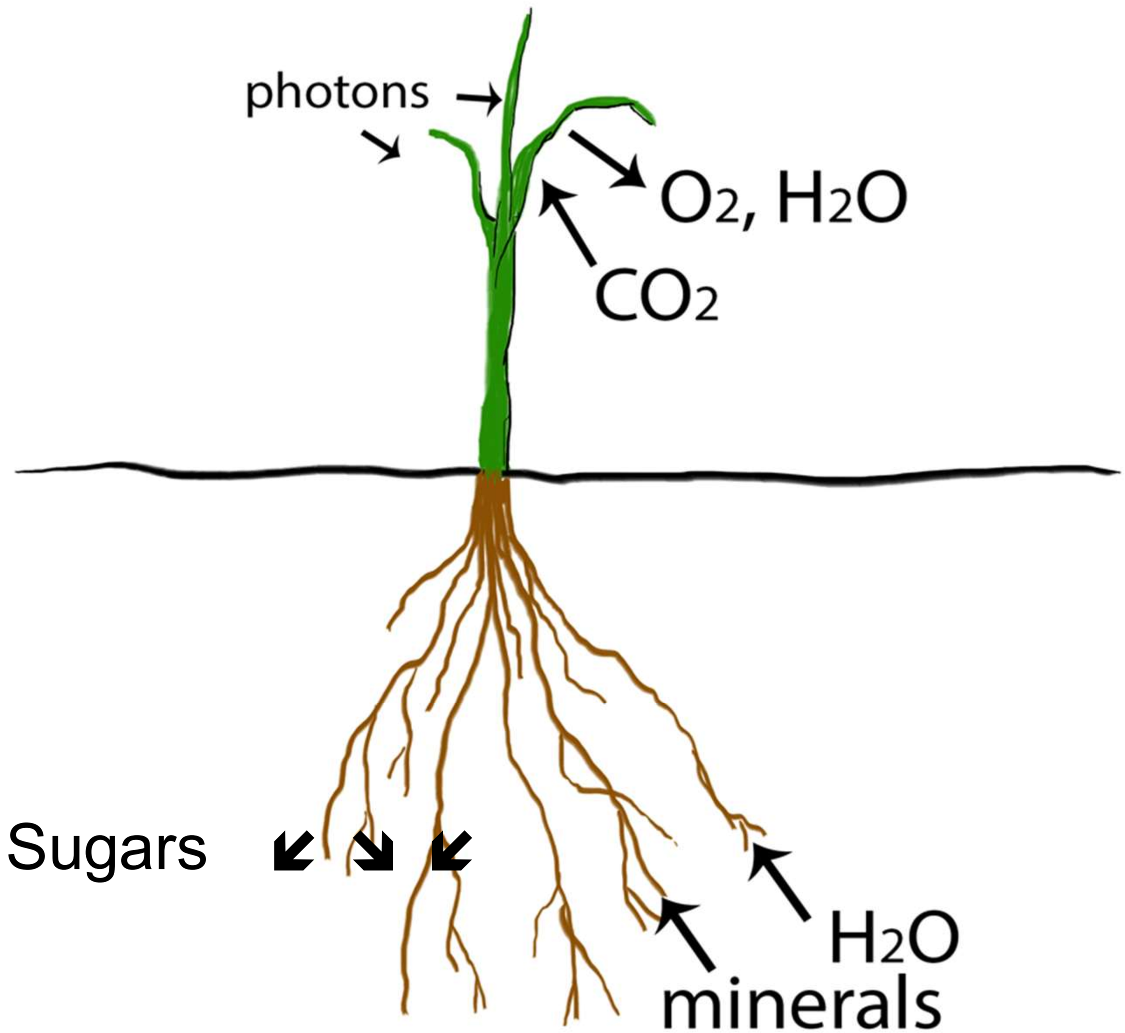


He planted a willow cutting in a pot, after first weighing the soil it contained, and provided nothing but water.

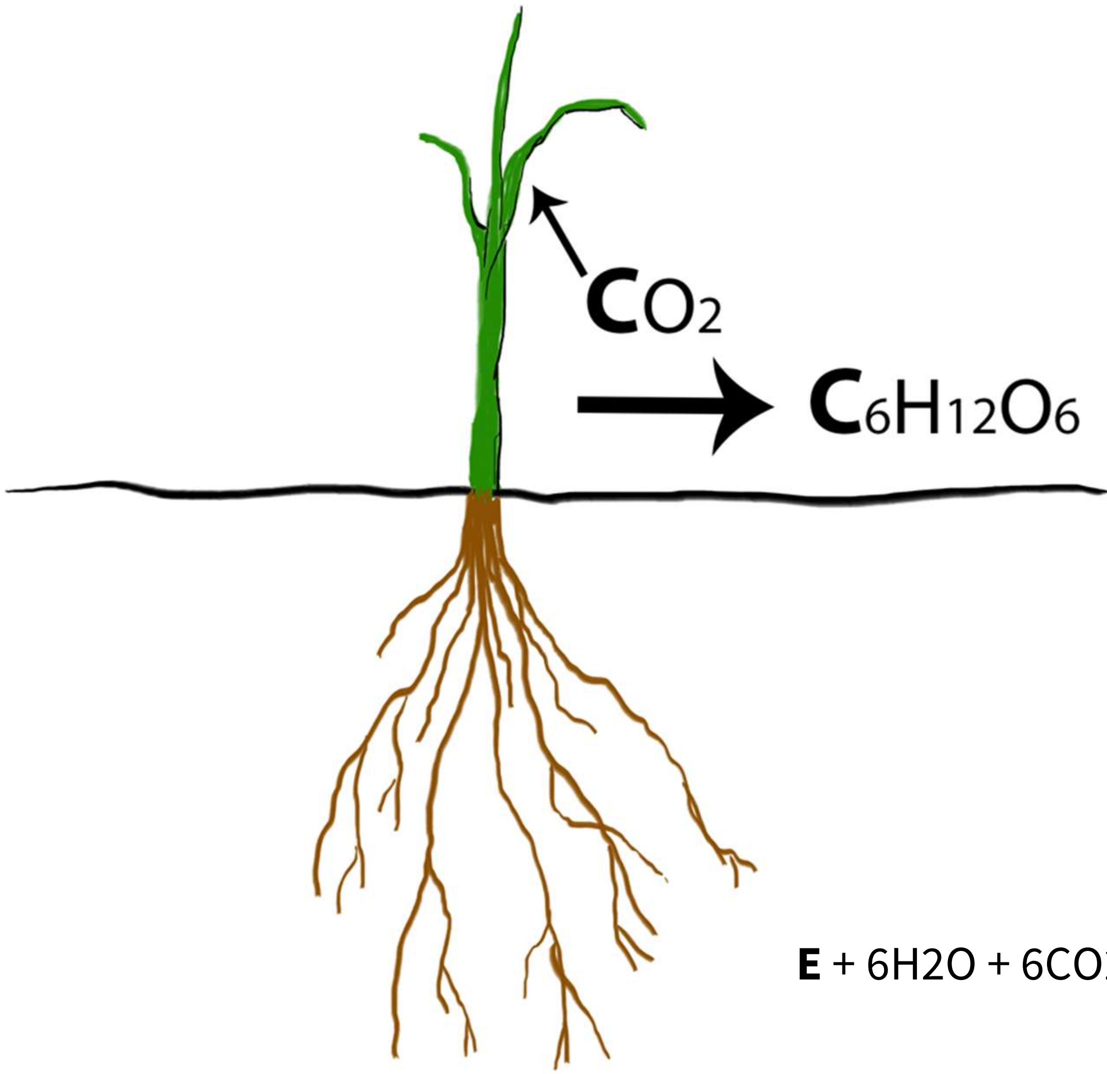
After 5 years, the cutting had grown to a tree weighing more than 75 kg, while the soil in the pot had lost less than 60 g.

Conclusion?

Photosynthesis:
the *synthesis* of carbohydrates from *sunlight,* **carbon dioxide** and water



John Wick
Marin Carbon Project



ALL OF THE
CARBON
IN
CARBOHYDRATES
COMES FROM
THE **AIR.**

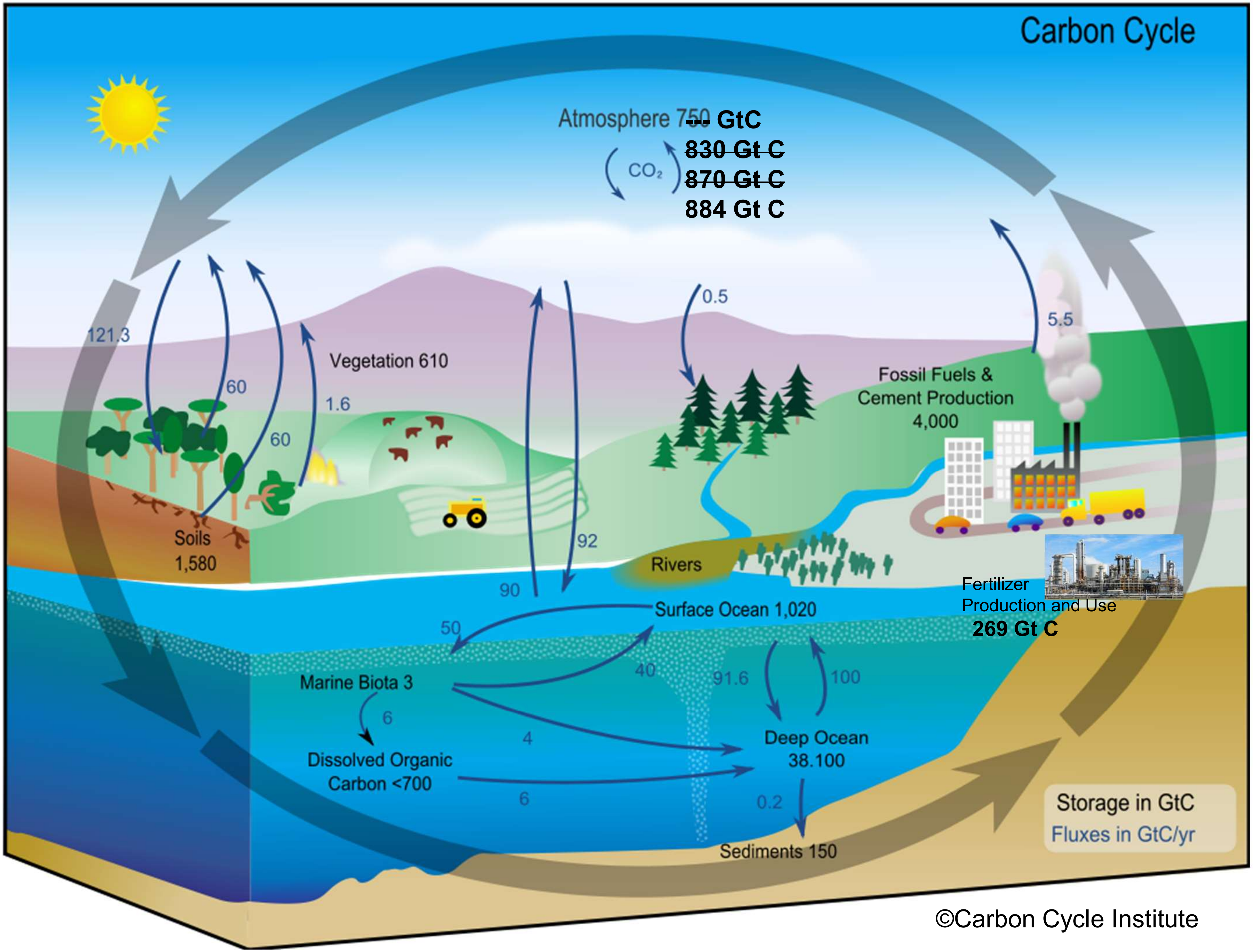
E + 6H2O + 6CO2 ------> C6H12O6+ 6O2

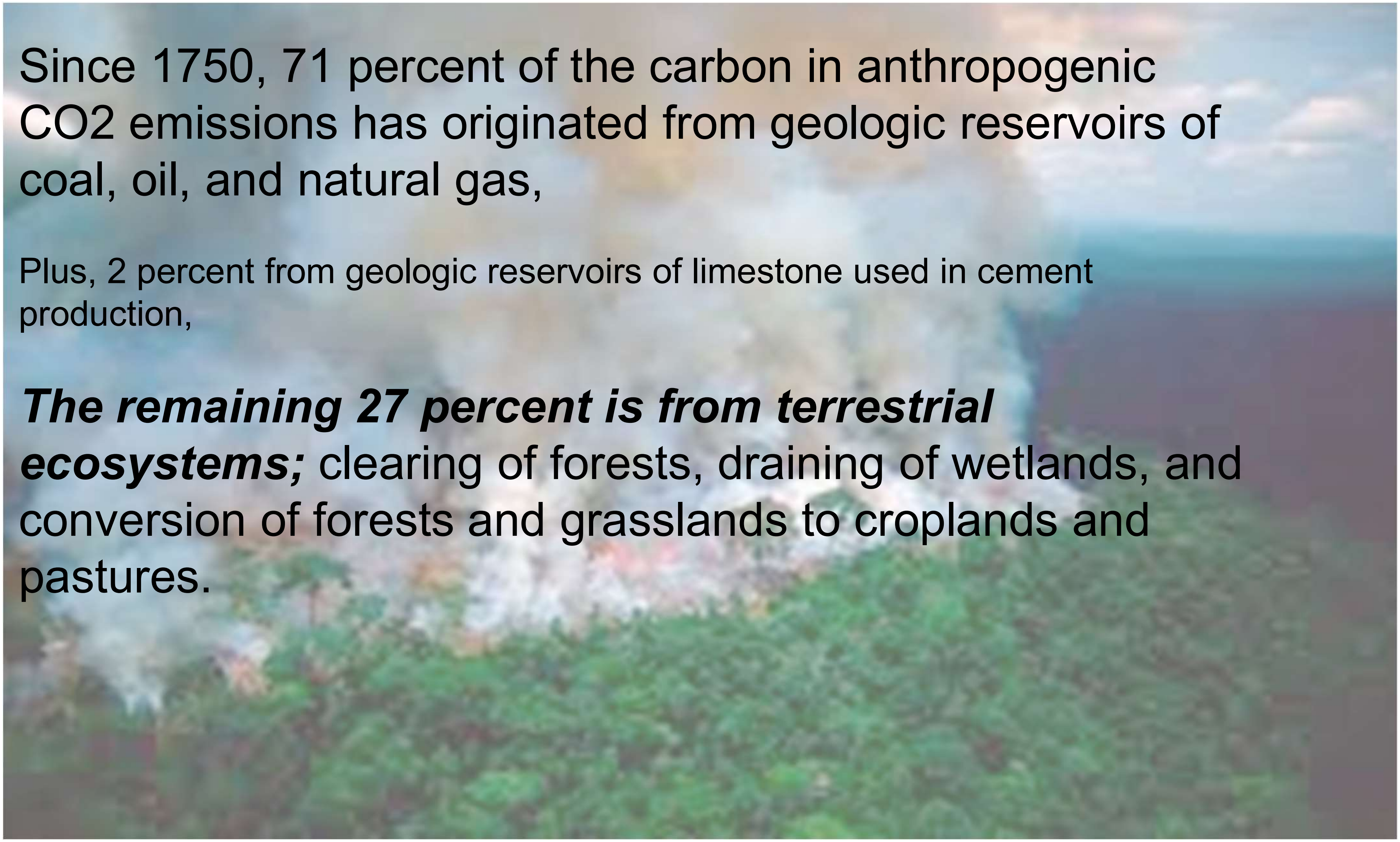
John Wick
Marin Carbon Project

AGRICULTURE:

"THE ART
OF MOVING CARBON
BETWEEN CARBON POOLS
TO PRODUCE
FOOD, FUEL, FIBER, AND FLORA"

-John Wick
Marin Carbon Project


Carbon Cycle
Atmosphere ~~750~~ GtC
~~830 Gt C~~
~~870 Gt C~~
884 Gt C
CO₂
121.3
60
60
1.6
Vegetation 610
90
92
0.5
5.5
Fossil Fuels &
Cement Production
4,000
Soils
1,580
Rivers
Fertilizer
Production and Use
269 Gt C
Surface Ocean 1,020
50
40
91.6
100
Marine Biota 3
6
Dissolved Organic
Carbon <700
4
6
Deep Ocean
38.100
0.2
Sediments 150
Storage in GtC
Fluxes in GtC/yr



Since 1750, 71 percent of the carbon in anthropogenic CO_2 emissions has originated from geologic reservoirs of coal, oil, and natural gas,

Plus, 2 percent from geologic reservoirs of limestone used in cement production,

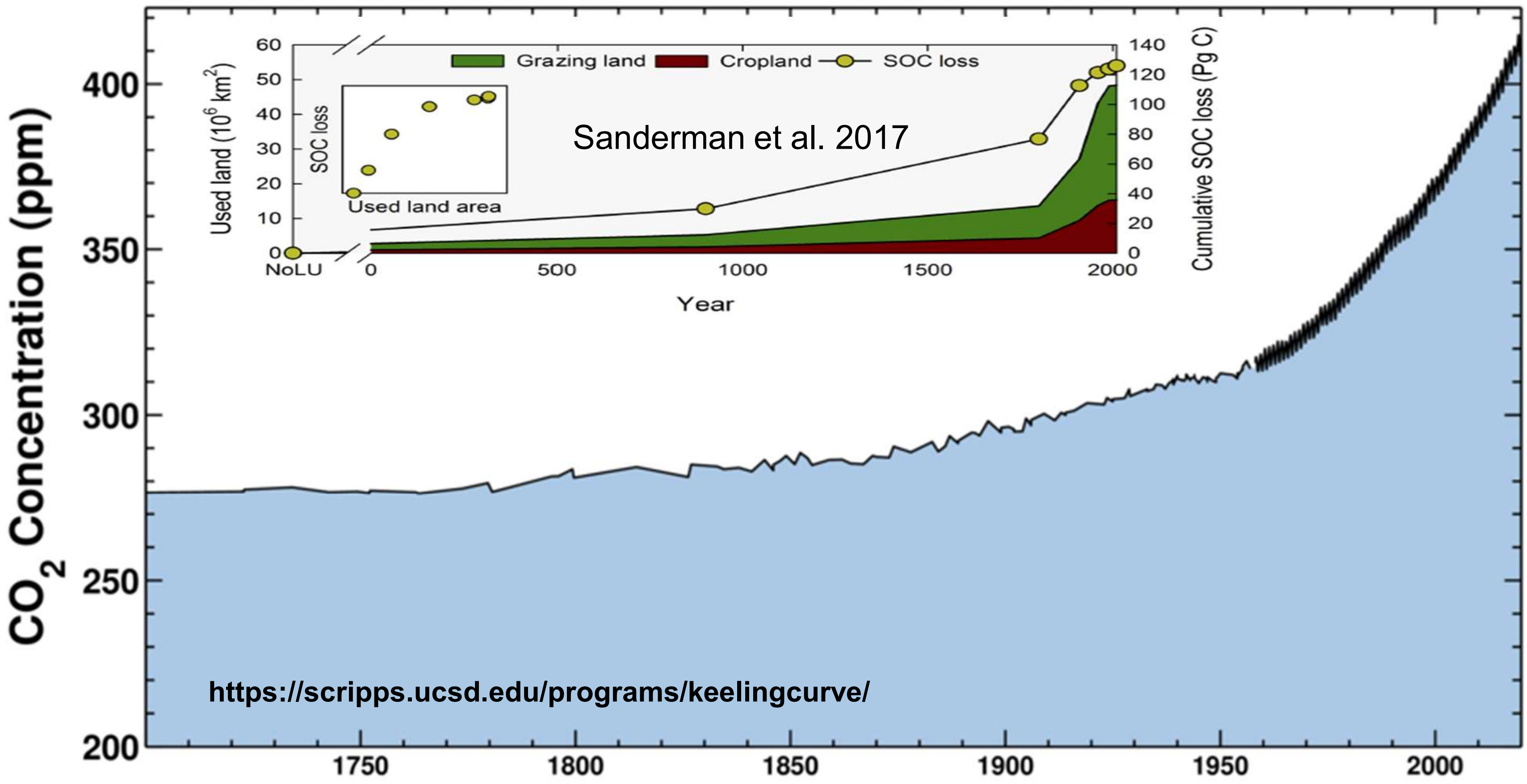
The remaining 27 percent is from terrestrial ecosystems; clearing of forests, draining of wetlands, and conversion of forests and grasslands to croplands and pastures.

https://www.google.com/search?q=photos+of+amazon+agriculture&client=firefox-b-1-d&tbm=isch&source=iu&ictx=1&fir=ZJJTtLxkKD-ifM%253A%252CYcppXkbSCVBGFM%252C_&vet=1&usg=AI4_-kRU0j7DlPK2CydEENMnH9sjWtMp8g&sa=X&ved=2ahUKEwjyw9T_iv_kAhVMs54KHUdTCigQ9QEwAXoECAUQCQ#imgrc=ZJJTtLxkKD-ifM:

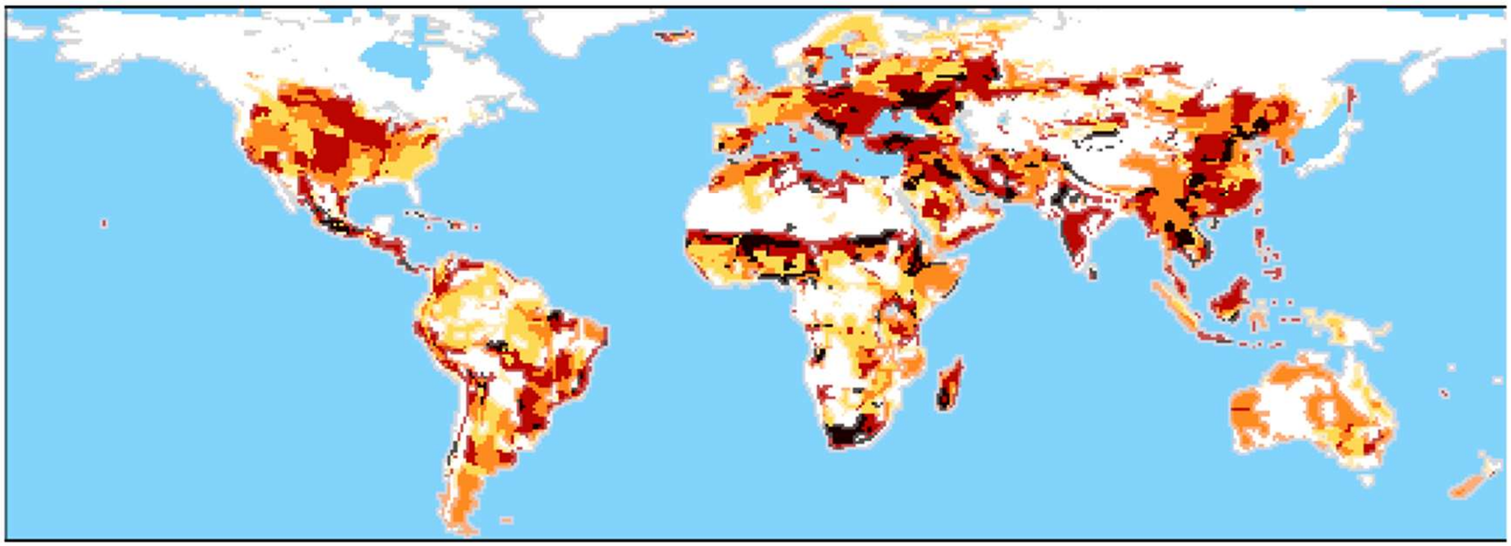
Latest CO_2 reading: 412.34 ppm

November 16, 2020

Ice-core data before 1958. Mauna Loa data after 1958.



Soil Degradation Severity



Low   Medium   High   Very High   Non-degraded

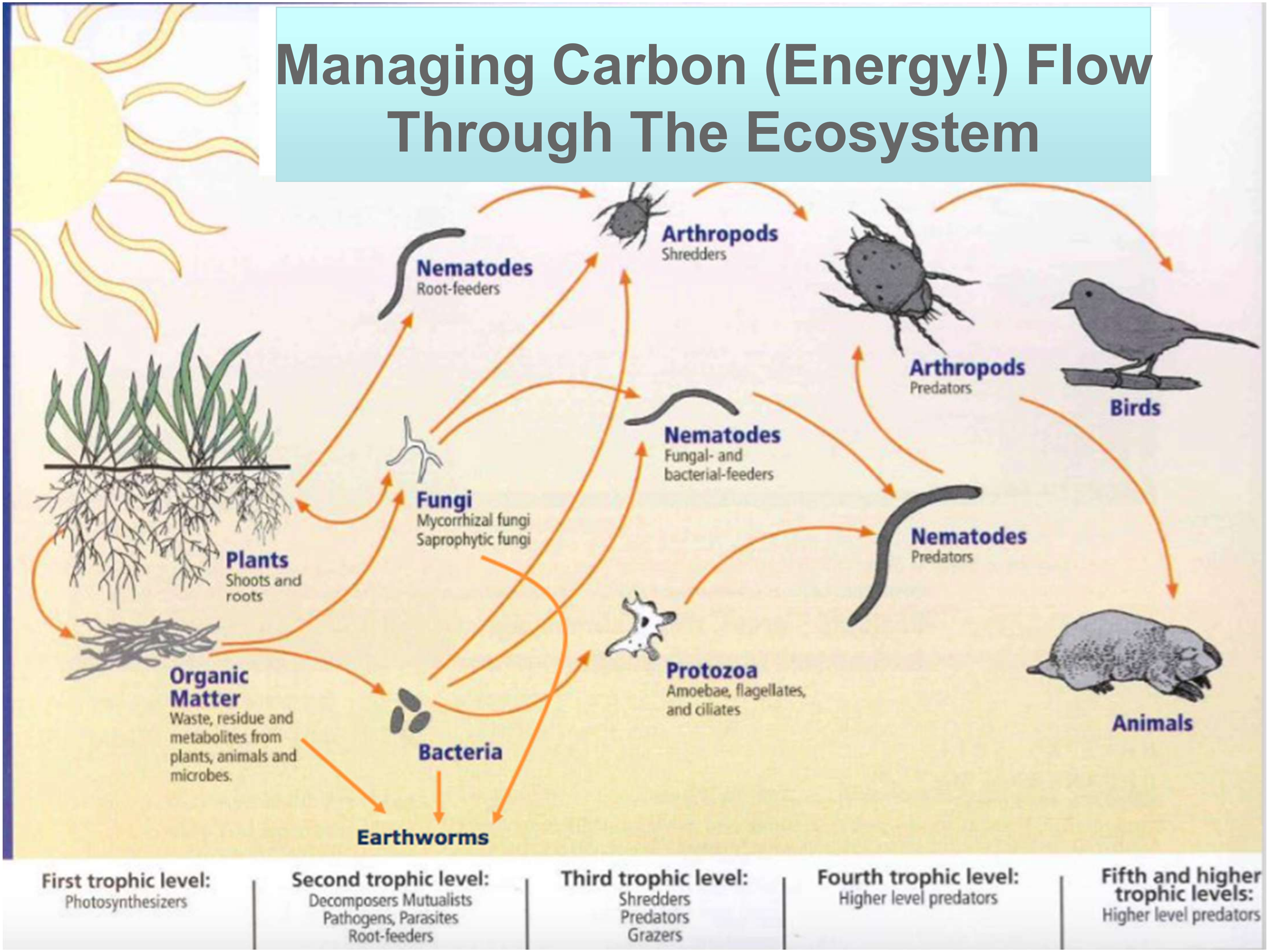
PROJECTION: Geographic
SOURCES: UNEP/ISRIC

FAO 2015:
60 Harvests?

UNEP
EAD/GRID-Geneva

Oklahoma, 1935
or
California, 2035?

Managing Carbon (Energy!) Flow Through The Ecosystem

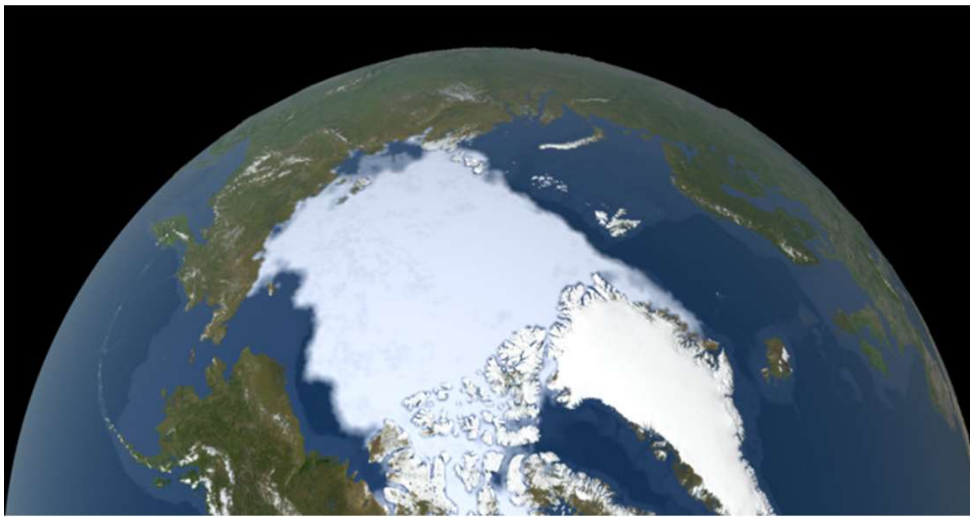


Positive Feedbacks: *deviation amplifying* processes *driving directional system change*

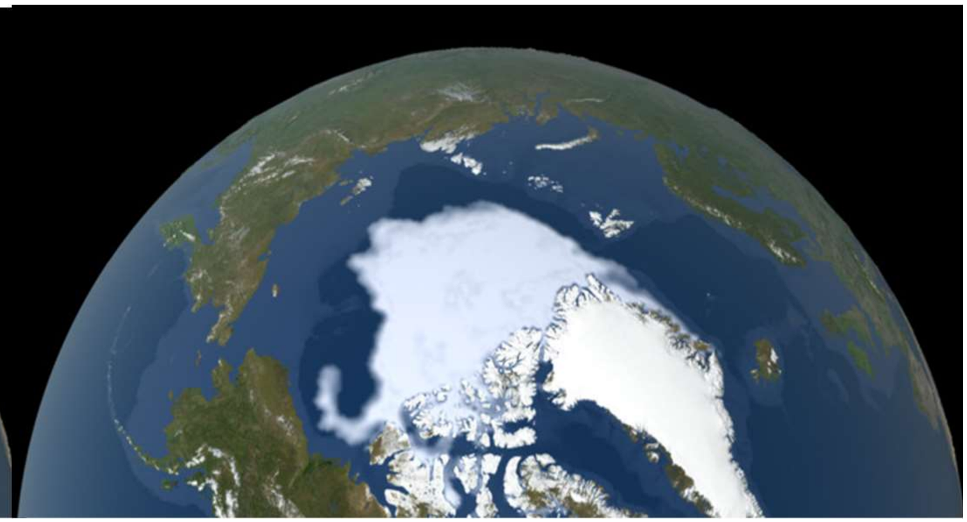
(Arctic September Ice, 1979 and 2020)

Steady Flow Dynamics

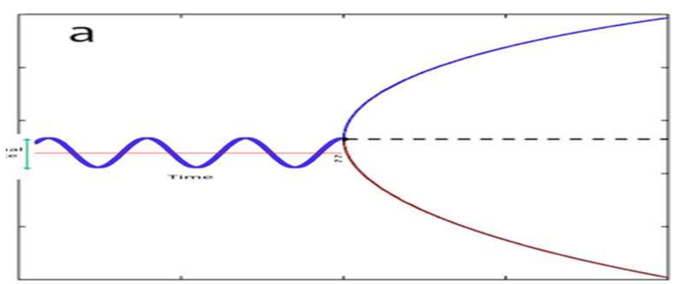
https://climate.nasa.gov/vital-signs/arctic-sea-ice/

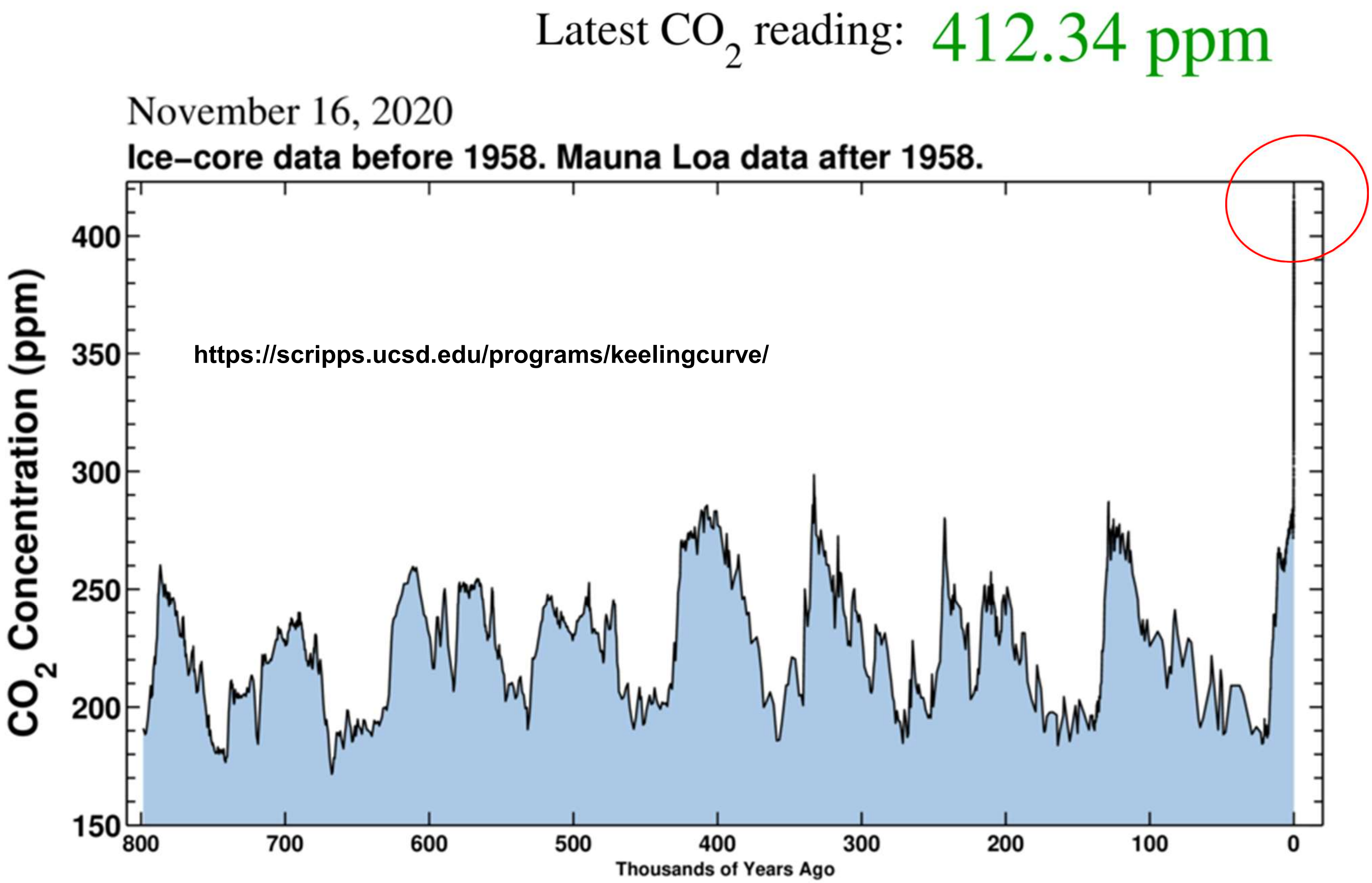


Arctic sea ice, 1979 minimum



Arctic sea ice, 2020 minimum




Latest CO_2 reading: 412.34 ppm
November 16, 2020
Ice-core data before 1958. Mauna Loa data after 1958.
https://scripps.ucsd.edu/programs/keelingcurve/
CO_2 Concentration (ppm)
150
200
250
300
350
400
800
700
600
500
400
300
200
100
0
Thousands of Years Ago

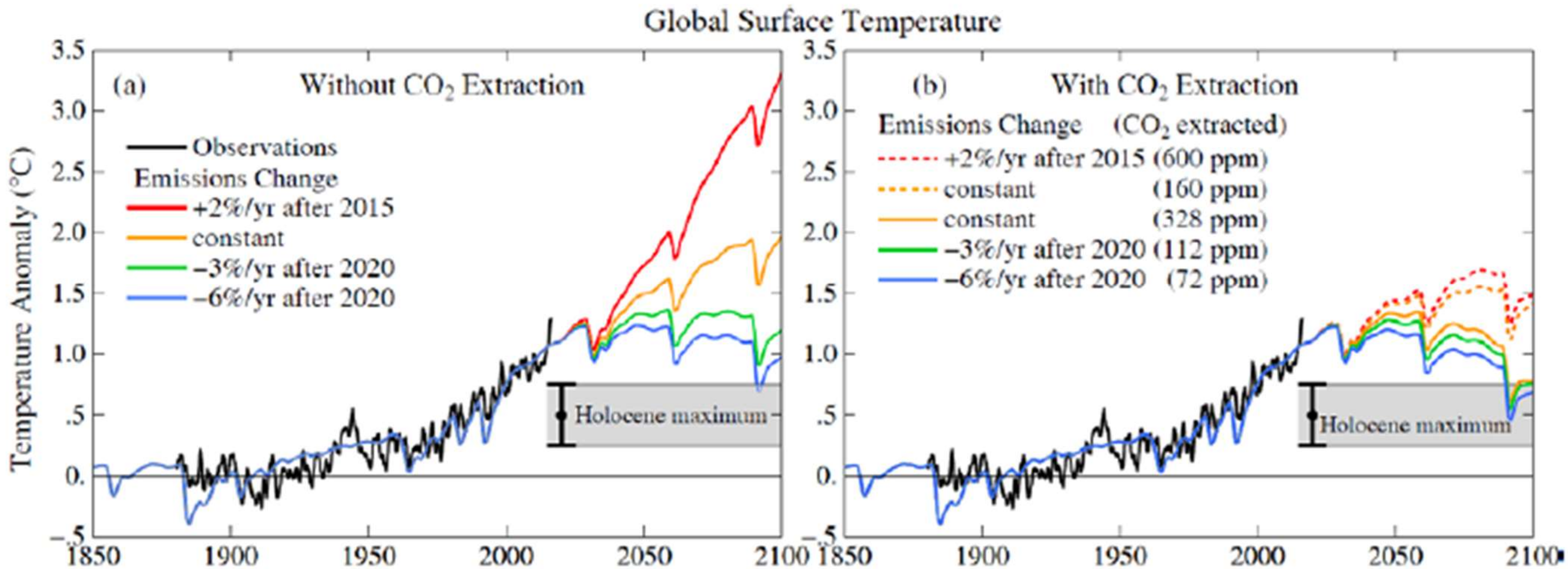
"A large fraction of the anthropogenic climate change resulting from CO2 emissions is irreversible on a multi-century to millennial time scale, ***except in the case of a large net removal of CO2 from the atmosphere over a sustained period****."*

IPCC SPM 2.4 (2014)

*"…**enhancing soil carbon** is the only viable option to achieve negative emissions."*

Celine Charveriat, Executive Director,
Institute for European Environmental Policy, 2017

Global temperatures under varying emissions and sequestration scenarios.

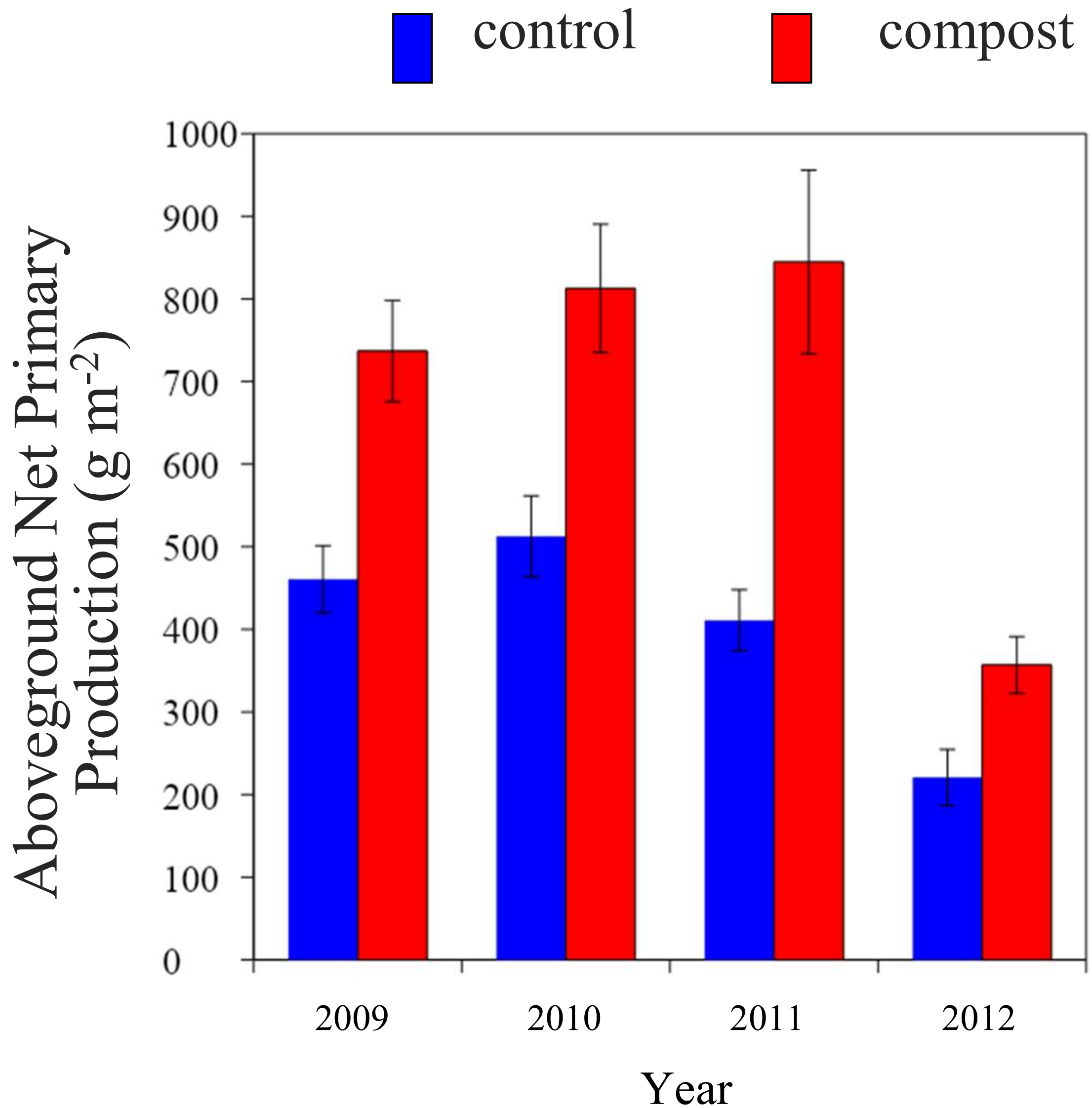


Gray area is 95% confidence interval for centennially-smoothed Holocene maximum.

Hansen et al 2017.

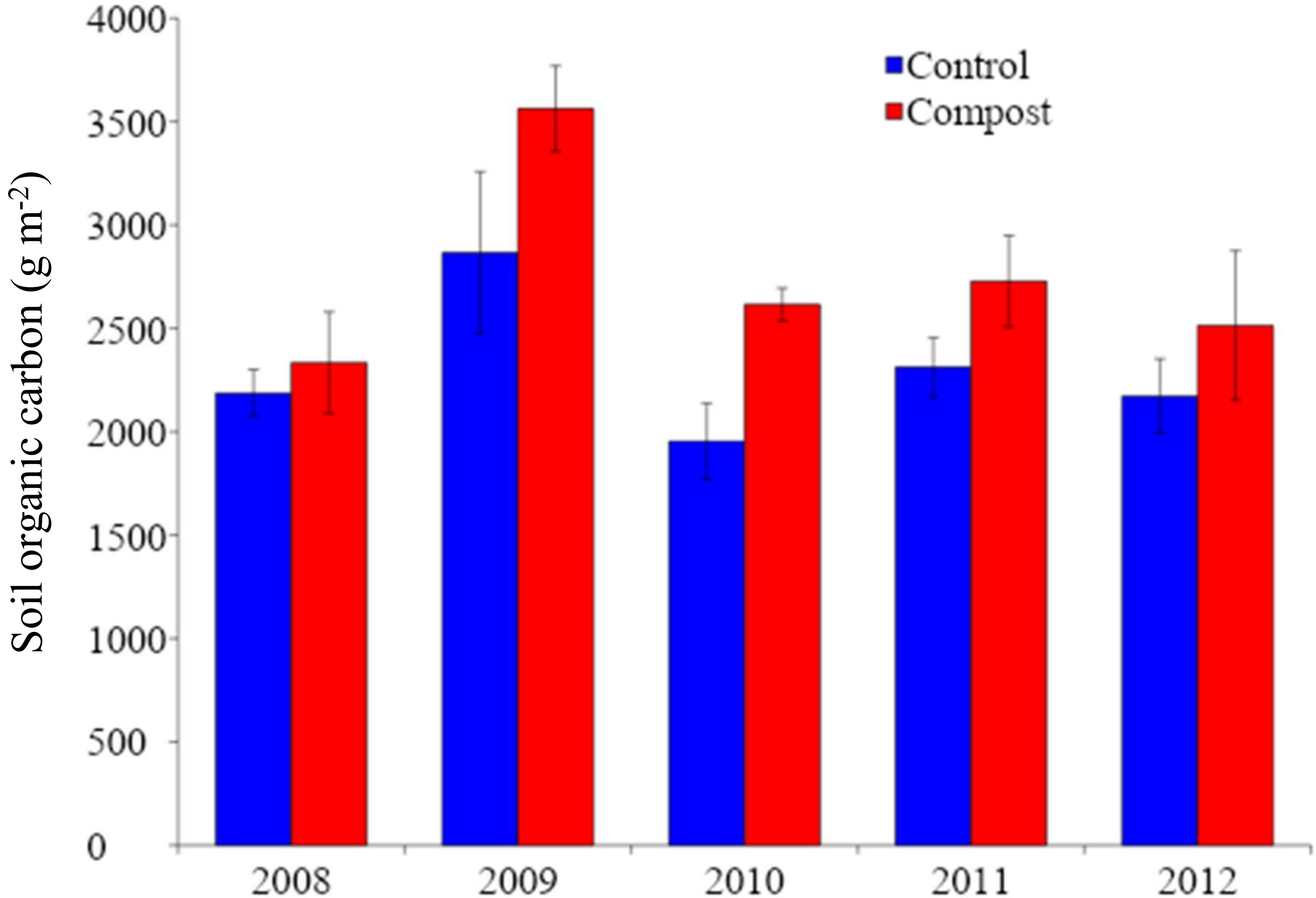
Marin Carbon Project 2008
H1: Management can increase soil carbon
and we can measure the change

Results: Above-ground production (forage) has exceeded controls by 40-70% ***every year*** following the single ½" compost application in 2008

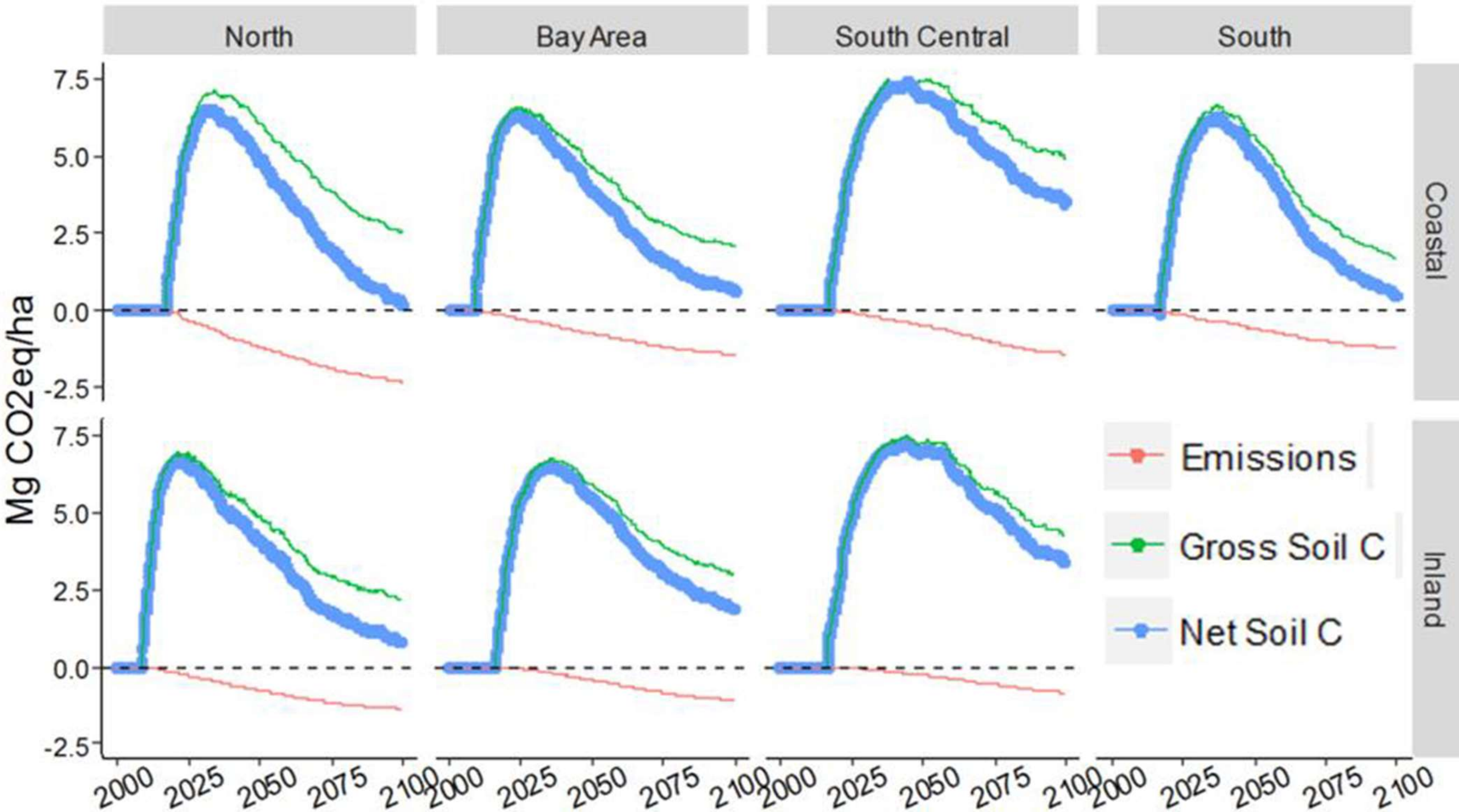


Ryals and Silver 2013

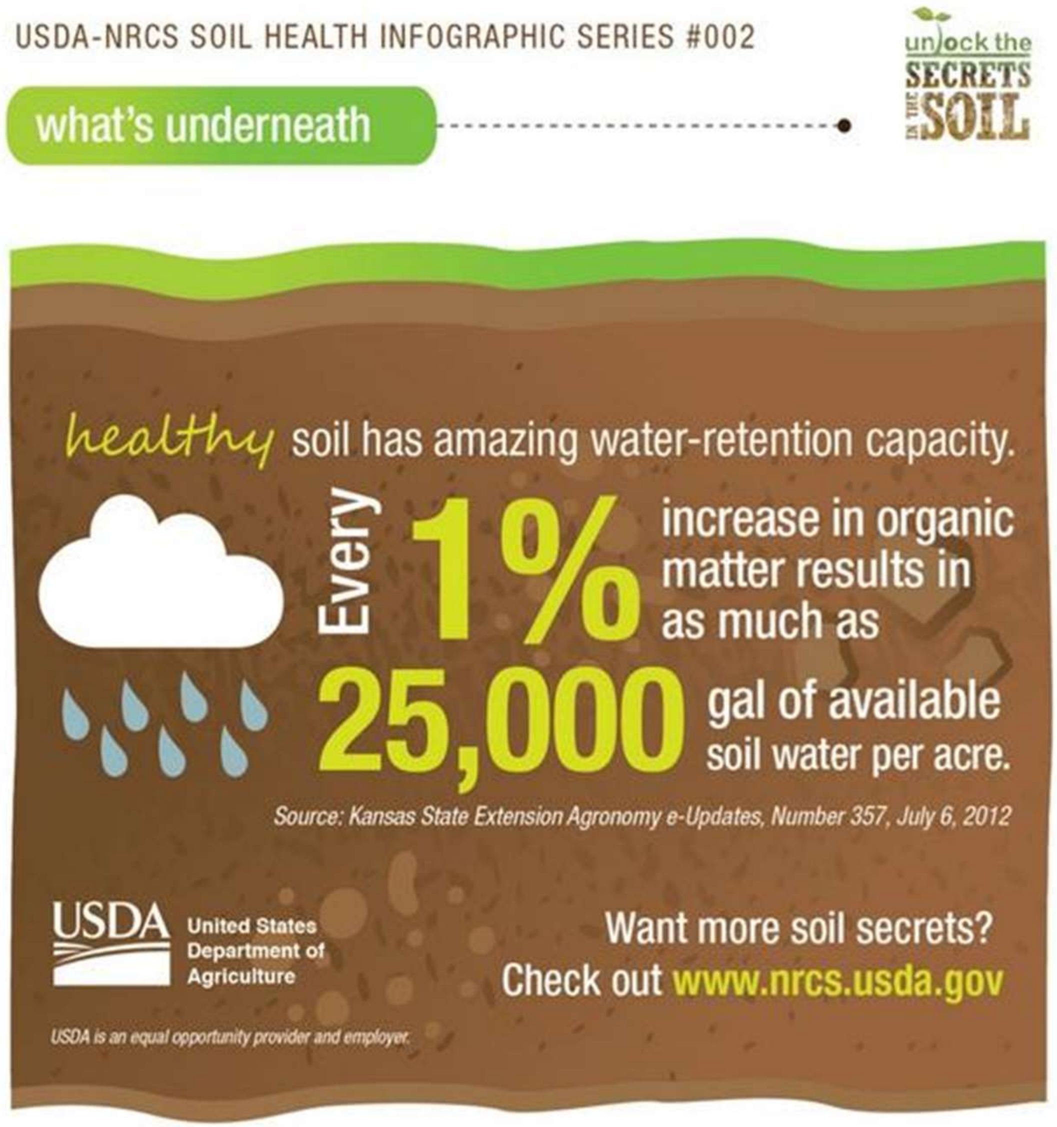
Compost increased soil C pools



Ryals et al. 2014

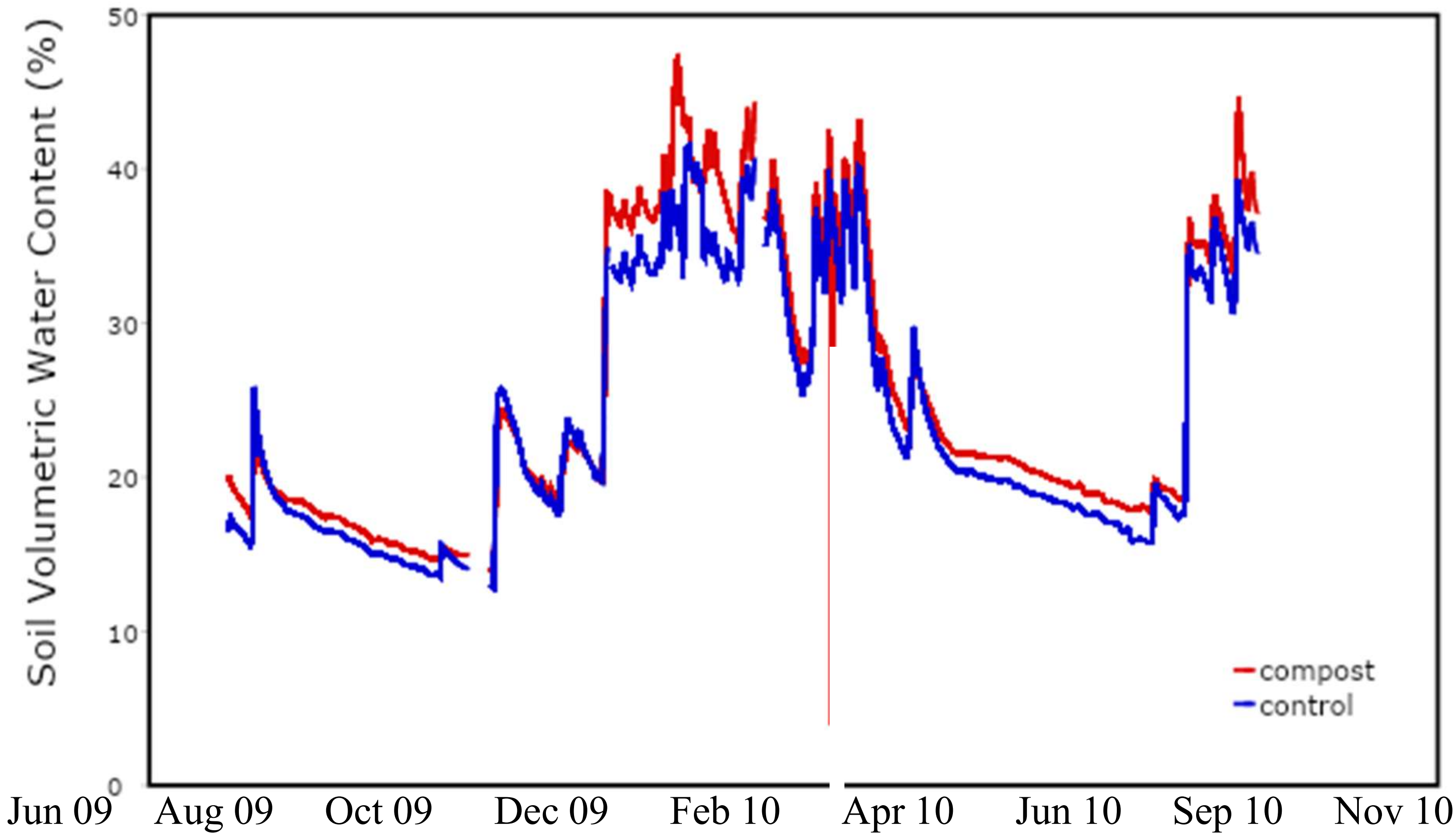


Total enhanced soil C storage due to compost (Gross Soil C: green line) is greater than GHG emissions stimulated by compost application to soil (red line), resulting in a net climate benefit (Net soil C sequestration: blue line) for all sites through the end of the century (RCP4.5) (Mayer and Silver 2018).



https://www.agronomy.k-state.edu/documents/eupdates/eupdate070612.pdf;
Emerson, W.W. 1995. Water retention, organic carbon and soil texture.

Increasing Soil Organic Carbon increases Soil Water Holding Capacity



UCSFREC, Browns Valley, Ryals and Silver 2013

Farmland after rain (right): waterlogging due to poor structure resulting from cultivation, compaction and lack of soil cover (and roots!). Different management, including denser groundcover, on the adjacent paddock (left) results in higher soil carbon, leading to better structure and improved water absorbing and holding capacity.

Patrick Francis, Australian Farm Journal

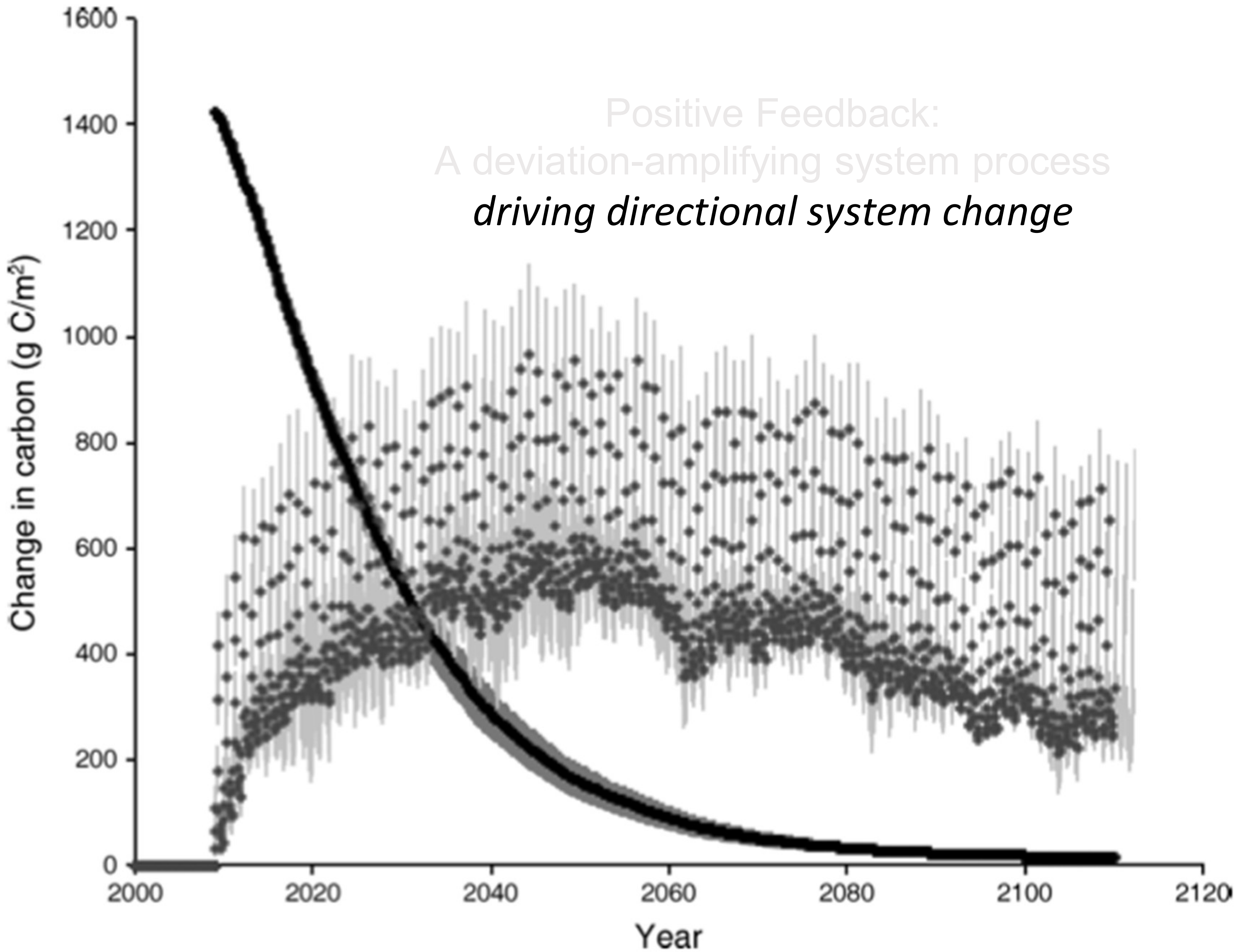
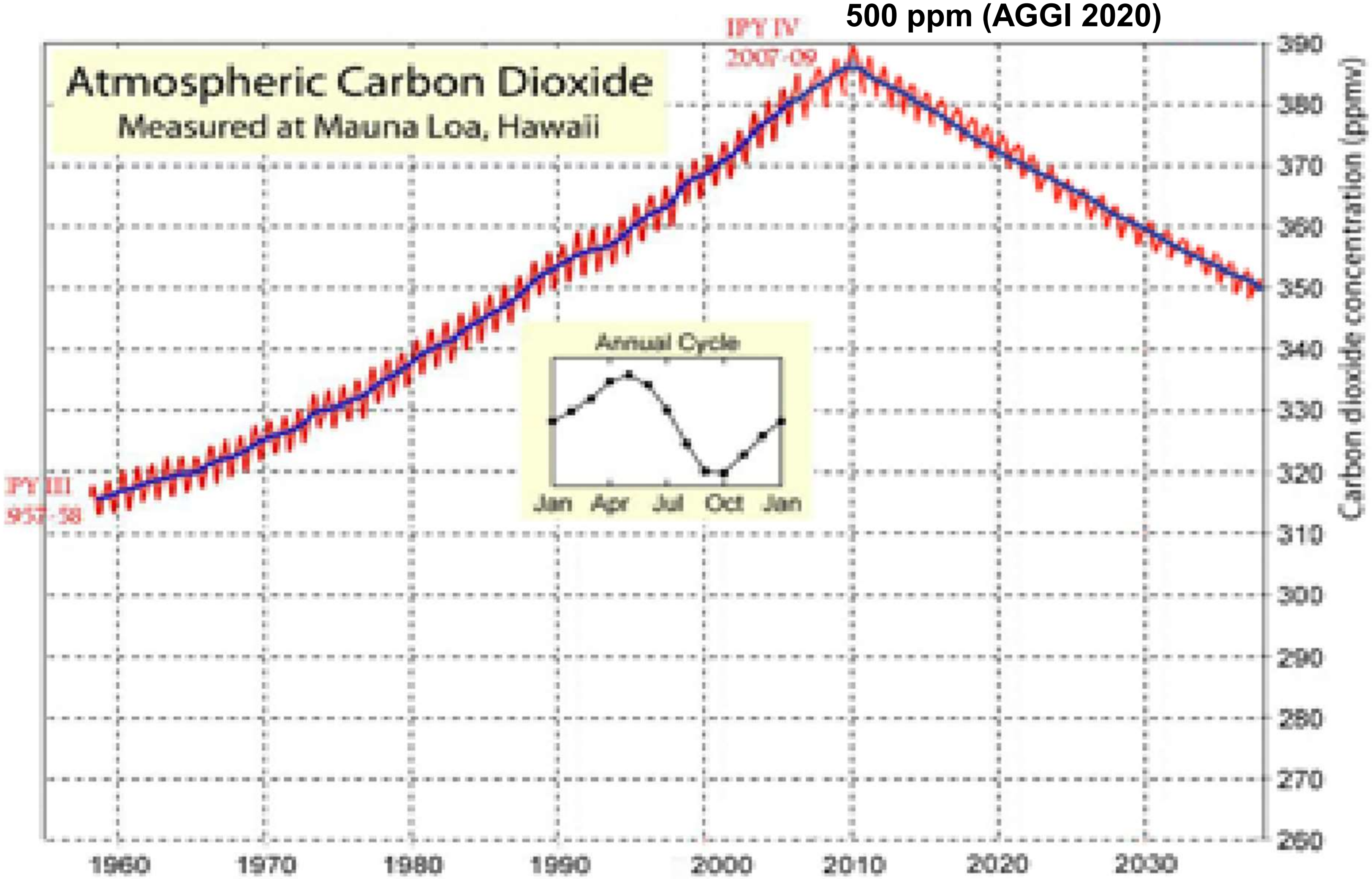


FIG. 3. The black line shows simulated decomposition of the compost following application to grassland soils. Gray circles show the monthly change in total ecosystem carbon, not including compost carbon. Values are averages across site characterizations, with standard error bars in light gray. Ryals et al, 2015. Ecological Applications, 25(2): 531–545.

Driving Directional System Change

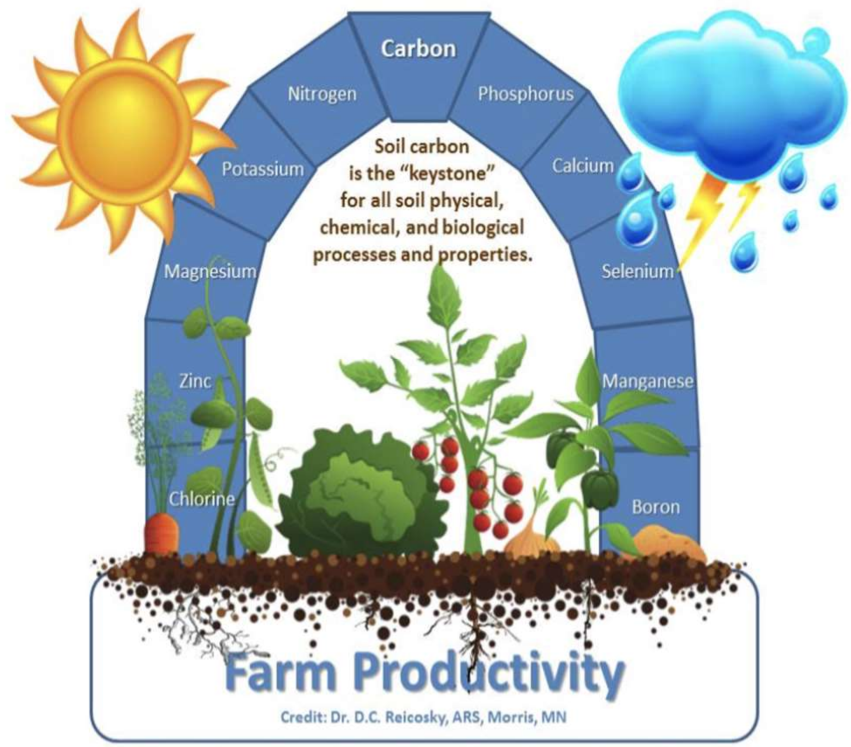
Measured effect of ***unintentional*** anthropogenic forcing of atmospheric C, with hypothetical effect of ***intentional*** anthropogenic forcing of soil organic C at global scale

500 ppm (AGGI 2020)



Questions

Carbon Farm Planning is based upon the USDA NRCS Conservation Planning process, ***but uses the carbon cycle and carbon capture as the organizing principle around which the Farm or Ranch Plan is constructed.*** This ***simplifies the planning process*** and connects on-farm practices directly with ecosystem processes, including energy flow, on-farm water holding capacity, soil health, agricultural productivity, climate change mitigation and on-farm climate resilience.



Carbon as the keystone for agricultural productivity and resilience

All Farming is Carbon Farming

Carbon entering the farm from the atmosphere ends up in one of three pools:

- in the harvested portion of the crop;
- in the soil as soil organic matter, or
- in standing carbon stocks on the farm, such as perennials, other permanent vegetation such as windbreaks or riparian vegetation.

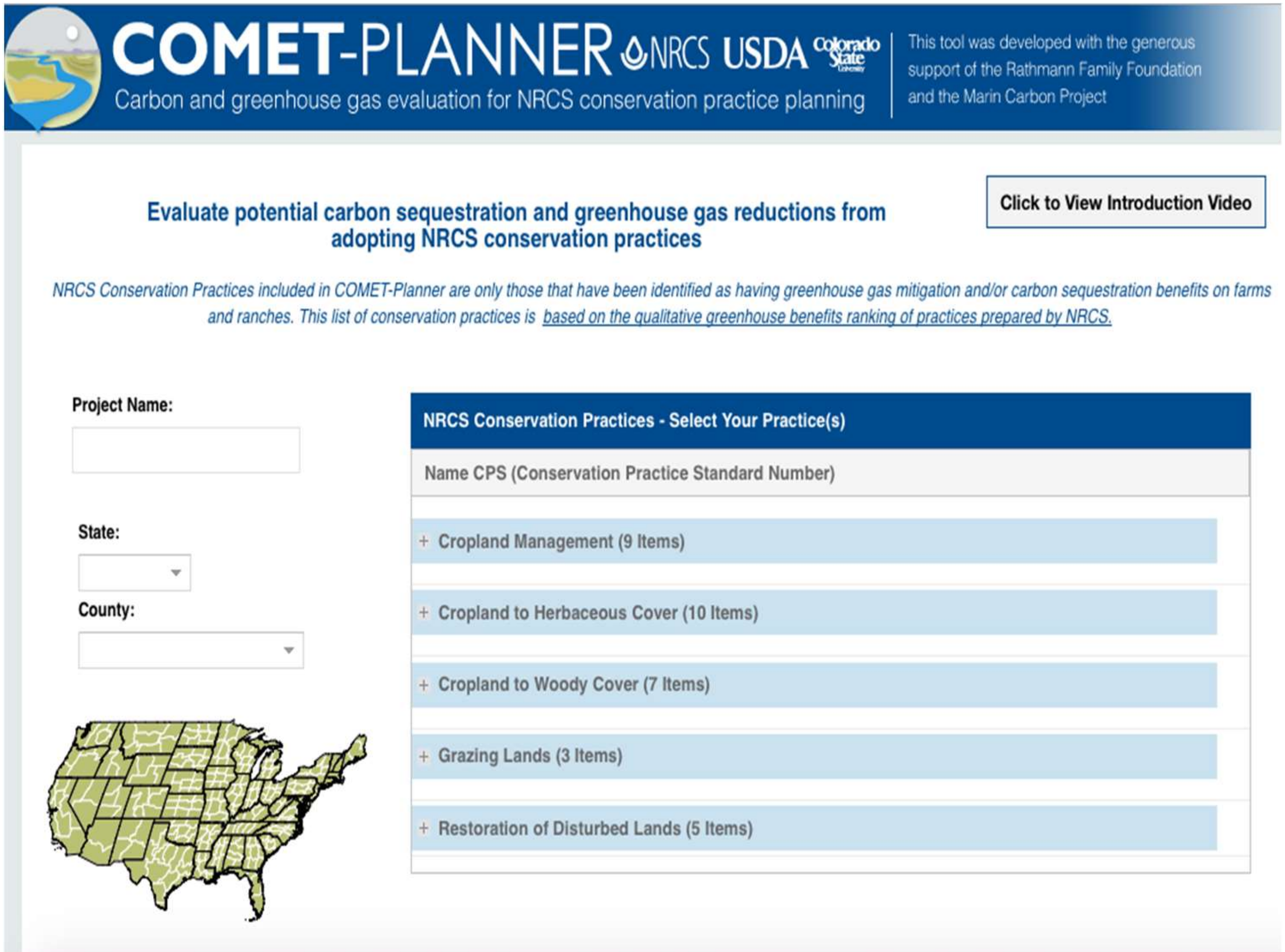
All farming is completely dependent upon atmospheric carbon dioxide in order to produce its products, but different farming practices, and different farm designs, can lead to very different amounts of carbon capture on the farm.

The lesson of van Helmont's willow:

(almost) everything in that wheelbarrow

came from the air

Carbon Farming:
Quantifying On-farm Carbon Capture Potential



LOCAL DATA, where available…
COMPOST: Ryals et al 2013; DeLonge et al 2013
CREEK CARBON: Lewis et al 2015

Cover Crops

https://www.google.com/search?q=multi+species+cover+crop+images&client=firefox-b-1-d&tbm=isch&source=iu&ictx=1&fir=7EKGiz7v-WisTM%252C5wCIZyOUnoj-eM%252C_&vet=1&usg=AI4_-kSwKillMnjZNqZNYAp4Nd6RmZBbrA&sa=X&ved=2ahUKEwj0xLH49L7qAhVBsp4KHTtjDpcQ9QEwA3oECAcQGQ&biw=1455&bih=651#imgrc=7EKGiz7v-WisTM

Windbreaks/Shelterbelts

https://www.emergingvines.co.uk/blog/2019/7/19/hidden-spring

Silvopasture

https://www.agforward.eu/index.php/en/agroforestry-for-poultry-systems-in-the-netherlands.html

Prescribed Grazing

Same Mendocino, CA soil: different input and management histories

©CarbonCycleInstitute

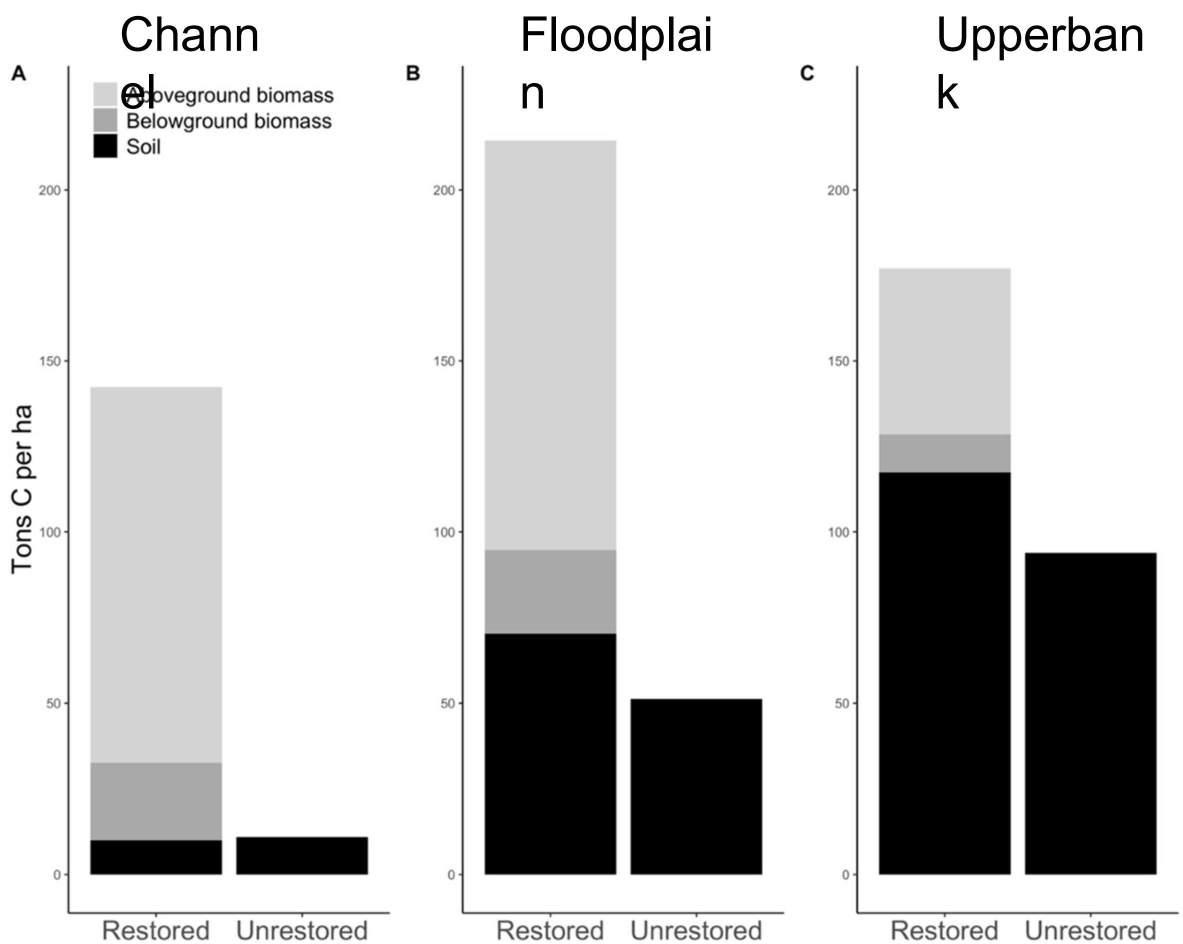
G. Batist photo, 2017

"These are changes to our creek in my short lifetime.
We can make a huge difference in ecological health, habitat, carbon sequestration and biodiversity.
We have over 35 species of migratory birds that nest in this habitat that was created in the last 28 years."

-Loren Poncia, Stemple Creek Ranch

Upscaling Findings: 20 years after restoration efforts in Marin

Maztek et al 2020



The modeled additional carbon in soil and biomass at 20 years is 284,836 Mg C or 1,044,399 Mg CO_2e. Enough to offset emissions from electricity usage of 6,026 homes for 20 years.

Carbon Farm Planning:
Toward a
Climate Beneficial Agriculture

Climate Beneficial Materials:
Stemple Creek Ranch & Jensen Ranch + *Coyuchi*

Climate Beneficial Wool Dryer Balls

$24.00

Climate Beneficial Wool Mattress Topper

$348.00 - $498.00

Climate Beneficial Wool Duvet Insert

$348.00 - $498.00

shop.coyuchi.com

Carbon Farming

Organic Valley

Powering the Good™

ORGANIC VALLEY SUSTAINABILITY

Organic Valley's top 10 farming practices that remove excess carbon dioxide from the air, where it causes harm, and sinks it into plants and soil where it is a benefit.

COVER CROP

Grasses, legumes, forbs and other herbaceous plants established for seasonal cover and conservation (prevent erosion, increase organic matter etc).

REDUCED TILLAGE

Limiting soil disturbance to manage the amount and distribution of crop/plant residue on the soil surface.

RIPARIAN BUFFER

Streamside plantings of trees, shrubs and grasses that prevent erosion, protect water quality and enhance wildlife habitat.

SILVOPASTURE

Combining trees and pasture together. The trees are managed for wood, fruit, or nuts, while providing shade and shelter for livestock.

HEDGEROWS

Establishment of shrubs and tall grasses to reduce wind speed and provide wildlife/pollinator habitat. Hedgerows are at lower plant heights than windbreaks (3-12 ft. tall).

ROTATIONAL GRAZING

Frequent moving livestock between sub-divided pastures (called paddocks) on a planned basis to prevent over-grazing and optimize pasture growth.

WINDBREAKS

One or more rows of trees and/or shrubs planted in a linear configuration that reduce wind speed, thereby protecting crops, livestock and soil.

COMPOST APPLICATION

Compost application to cropland or grazed land.

RANGE PLANTINGS

Establishment of deep-rooted perennials such as grasses, forbs and legumes to improve grazing for livestock..

CROP ROTATION

A planned sequence of crops grown on the same field over a period of time (usually 3-5 years).

A SUCCESSFUL CARBON FARM PLAN CULTIVATES CARBON FARMERS!

GOLD RIDGE
RESOURCE CONSERVATION DISTRICT

malt
MARIN AGRICULTURAL LAND TRUST

MARIN RESOURCE CONSERVATION DISTRICT

STEMPLE CREEK RANCH

SONOMA
RESOURCE CONSERVATION DISTRICT

McCLELLAND'S DAIRY
Natural Goodness From She to Thee
EST 1938

Mendocino County
Resource Conservation District

Stornetta Ranch
WS

Fortunate Farm
Caspar, Ca

Questions

Carbon Farming Network

To date: 39 RCDs & Partner Organizations

Developed over 100 Carbon Farm Plans

- 58,000 acres
- Sequester 1.5 MMT CO2e over 20 years.

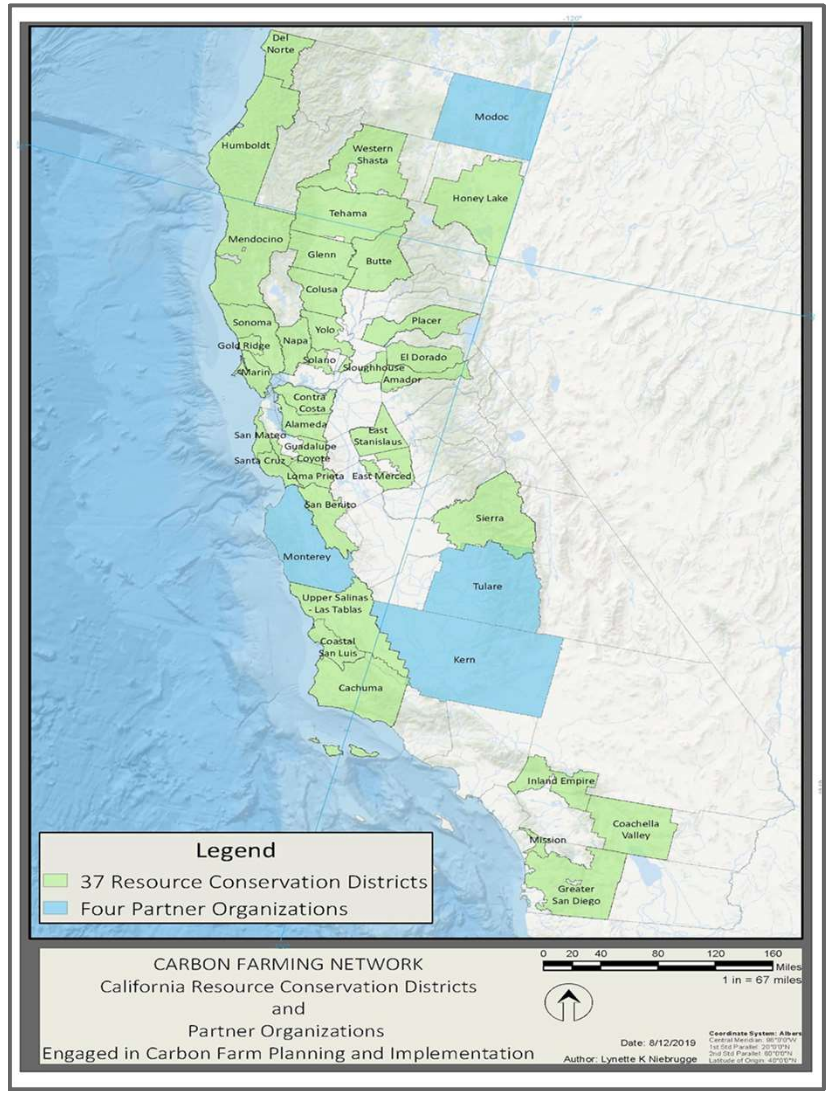
In progress: 58 CFPs

Demand:

- 6-8 applications per CFP

Non-RCD Carbon Farming partners (blue polygons)

20 Plans in Marin; 20 producers waiting for plans



Carbon Farming Network Regional Hubs

7 Regional Hubs
(39/96 RCDs)

North Coast (6 RCDs)

Bay Area (7 RCDs)

Southern Central Coast (4 RCDs)

Southern California (4 RCDs)

North Sacramento Valley (8 RCDs)

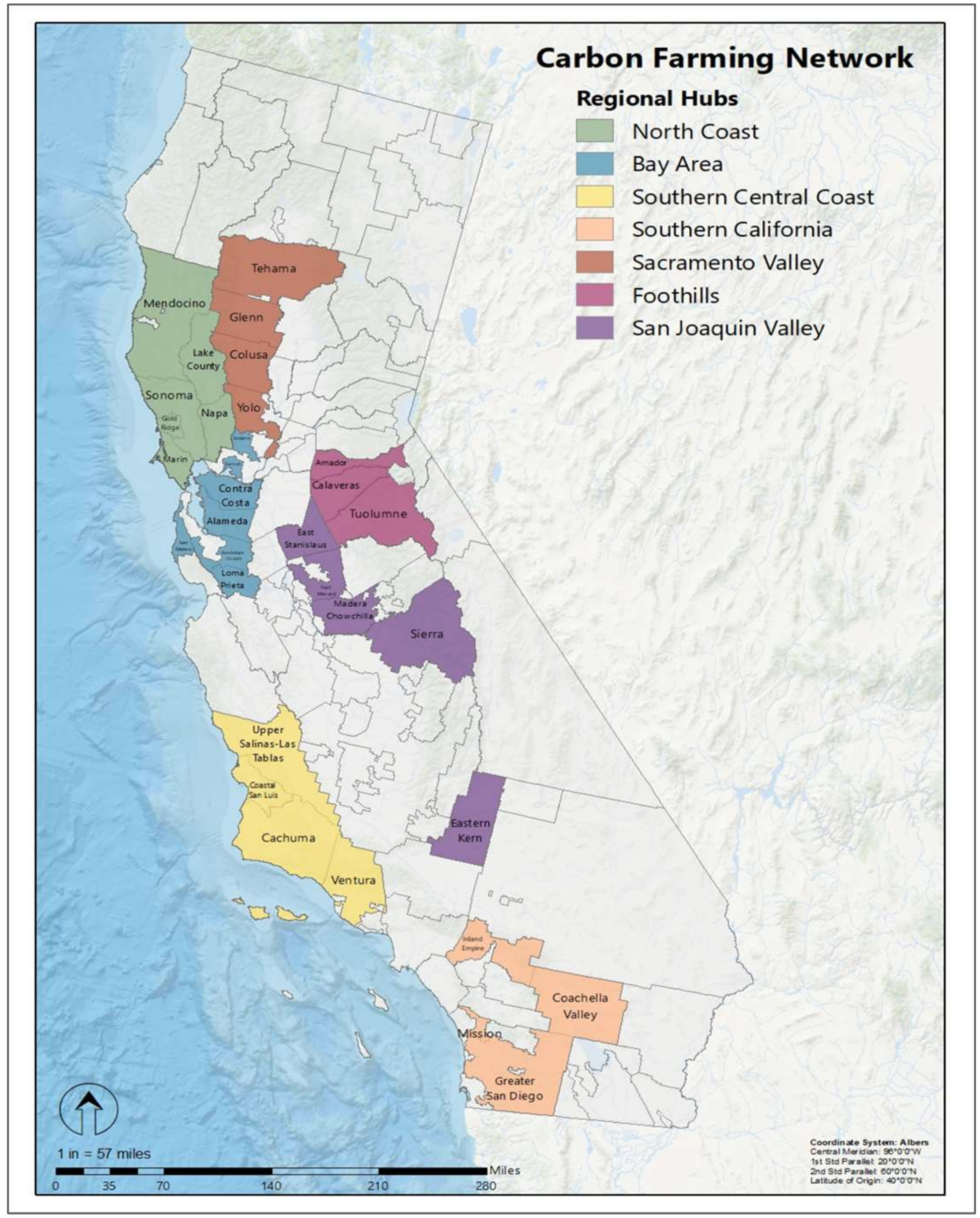
Foothills (3 RCDs)

San Joaquin Valley (7 RCDs)

Increasing on-the-ground technical capacity through collaboration at the regional level (sharing resources, staff, etc.)

Neutrality for CA Agriculture = 36MMT/year

A 1% increase in SOM in the state's 20M arable acres = **334 MMT CO2e** removed from the atmosphere;
33 M acres of forest land
57 M acres of rangeland




CALIFORNIA CLIMATE STRATEGY
An Integrated Plan for Addressing Climate Change
VISION
Now, carbon neutrality
Reducing Greenhouse Gas Emissions to 40% Below 1990 Levels by 2030
GOALS
50% renewable electricity
50% reduction in petroleum use in vehicles
Double energy efficiency savings at existing buildings
Carbon sequestration in the land base
Reduce short-lived climate pollutants
Safeguard California

JANUARY 2019 DRAFT California 2030 Natural and Working Lands Climate Change Implementation Plan

CalEPA California Environmental Protection Agency

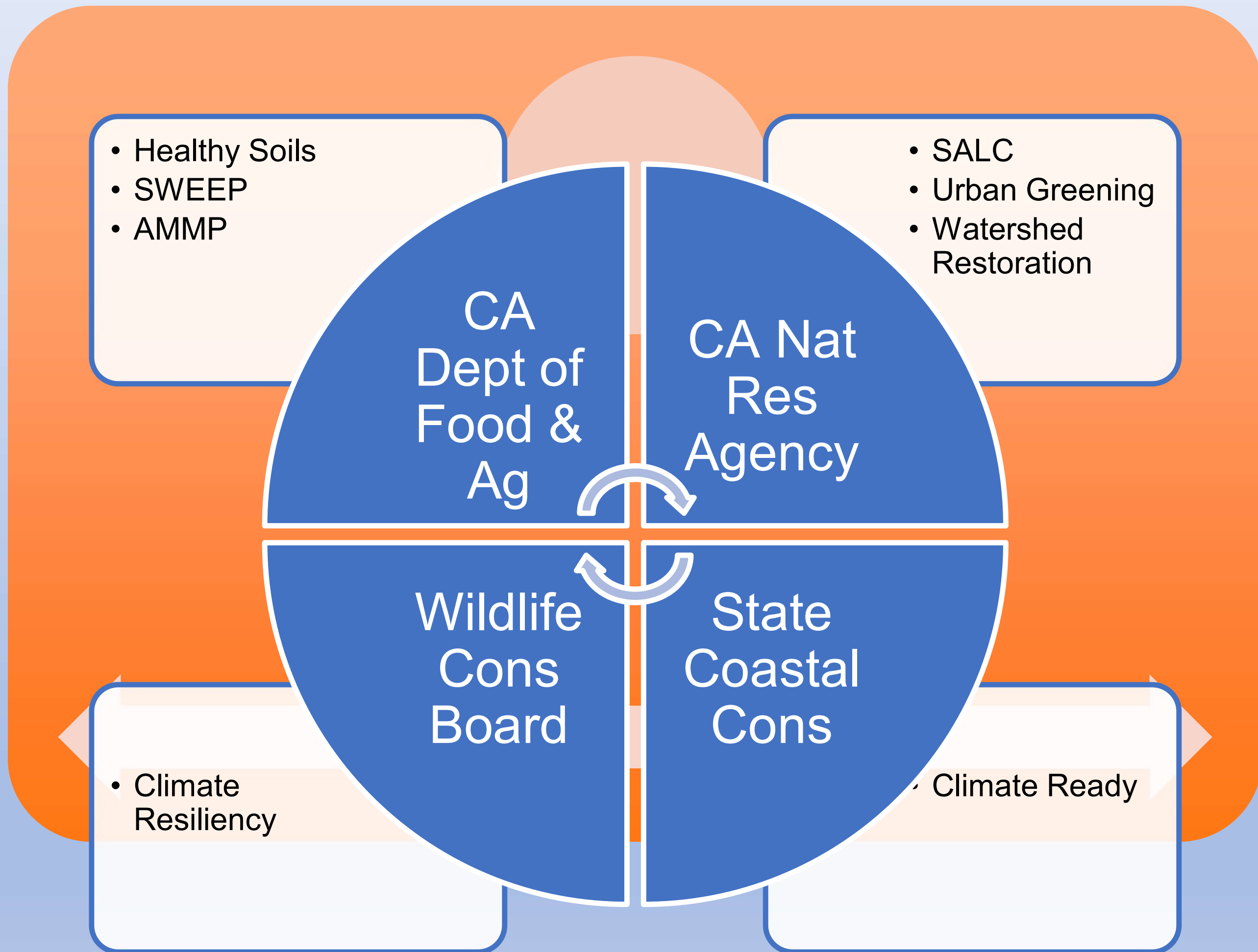
California Natural Resources Agency

cdfa California Department of Food & Agriculture

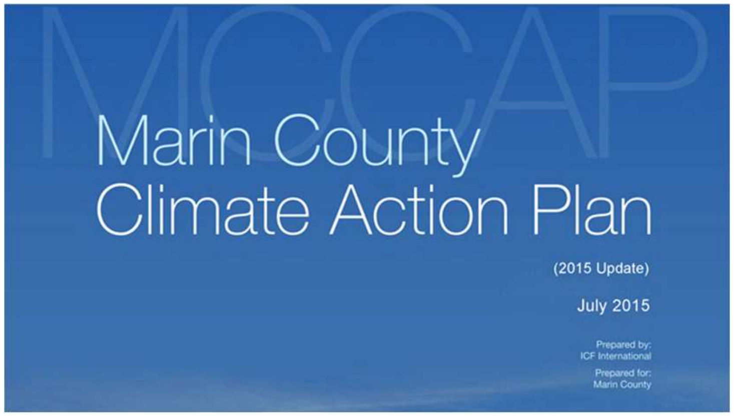
California Air Resources Board

California Strategic Growth Council

Current State Funding Programs



Natural Resource Conservation Service - EQIP/RCPP



Agricultural emissions are calculated using **ICELI's Community Protocol**, which provides a framework for local governments to assess GHG emissions from activities within their boundaries. Agricultural emissions in Marin are assessed in three main categories:

- **Enteric Fermentation**
- **Manure Management**
- **Fertilizer Application**

2015 CAP :

Carbon farming mentioned as a possible future measure

2020 Marin CAP Update:
Agricultural carbon sequestration as a primary mitigation strategy

TABLE 15: AGRICULTURE AND WORKING LANDS STRATEGIES

ID	Strategy	GHG Reduction by 2030 ($MTCO_2e$)
AG-C1	Carbon Farming ***(Drawdown: Marin Endorsed Solution)***	55,752
AG-C2	Manure Management	26,191
AG-C3	Urban Forest and Natural Lands Management	106
AG-C4	Agricultural Land Preservation	-
AG-C5	Blue Carbon	-
AG-C6	Energy Efficiency	-
AG-C7	Low Carbon Off-Road Vehicles and Equipment	-
AG-C8	Agricultural Institute of Marin's Center for Food and Agriculture ***(Drawdown: Marin Endorsed Solution)***	-
TOTAL		82,049

Marin County Agricultural Lands
Estimated Carbon Sequestration Potential at Full Implementation

Agricultural Practice	Total Potential Acres	Sequestration Factor (MTCO2e/acre/year)	Sequestration Potential (MTCO2e/year)	Sequestration Lifespan
Riparian restoration	5,700	9.16	52,212	20
Compost on rangelands	60,217	1.49	89,723	20
Compost on croplands	407	1.18	482	6
Compost on vineyards	195	4.4	860	1
Hedgerow planting	267	1.49	399	34
Prescribed grazing	101,496	0.005	507	10
Range planting	28,271	0.502	14,192	10
Silvopasture	17,254	1.48	25,486	80
Windbreak/shelterbelt	852	1.48	1,263	80
Critical area planting	353	1.9	671	10
Total:			**185,795**	

Good News: Excess Carbon Dioxide in the Atmosphere Can Be Transformed to Food, Fuel, Flora, Fiber, ***and Soil Organic Matter***,

Yielding Production, Soil Health, Biodiversity and other Ecosystem Benefits ***and*** New Opportunities for Agriculture

NB: models suggest we must act NOW, at scale, to avoid a 3^{o}C rise in global temperature by 2100.

Photo: Abe Collins, CarbonFarmersofAmerica.org

Thank you

www.carboncycle.org