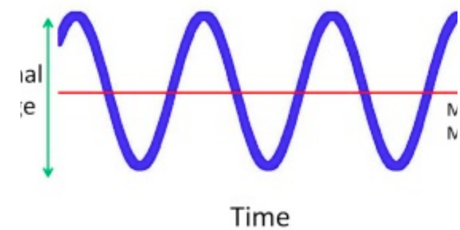
Soil, Carbon, Water, Climate: Lessons from the Marin Carbon Project

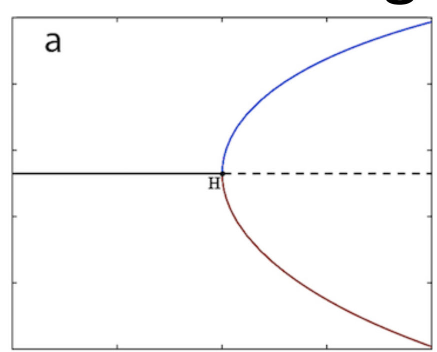
Jeff Creque jcreque@carboncycle.org
Carbon Cycle Institute www.carboncycle.org
Marin Carbon Project www.marincarbonproject.org

General System Theory

- GST suggests systems are either:
  - changing or;
  - remaining the same
- System (***homeo)stasis*** is maintained by *deviation dampening* **negative feedbacks** (not true stasis, but dynamic equilibrium; or flux around a mean)



- System ***change*** is driven by *deviation amplifying* **positive feedbacks** driving directional change ***(homeorhesis; or steady flow)***

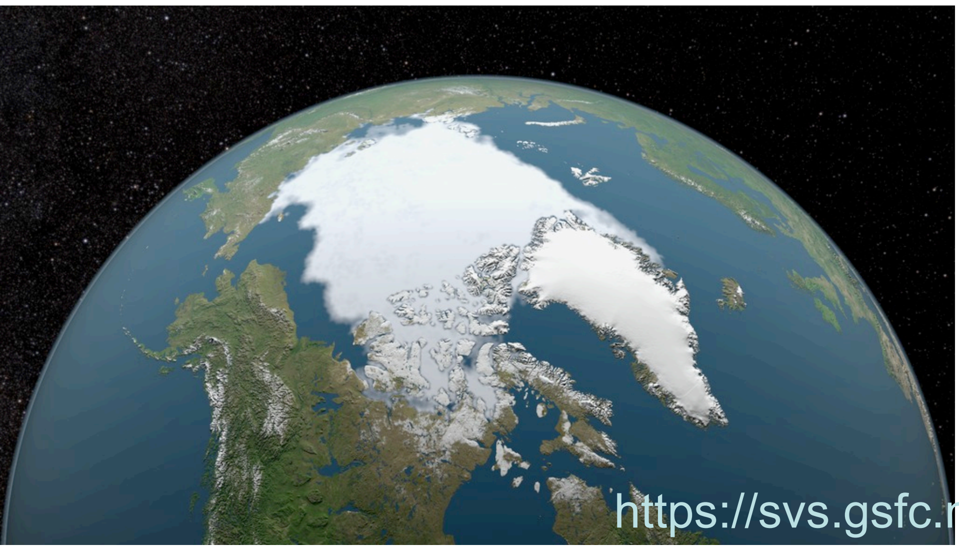


Negative Feedbacks: *deviation-dampening* system processes

Positive Feedbacks:
Deviation Amplifying System Processes

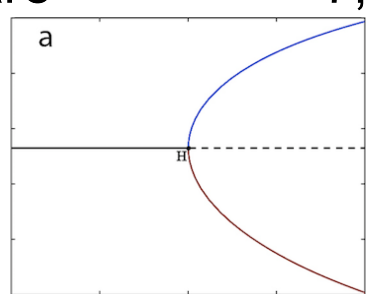
(Arctic September Ice, 1979 and 2015)

(Process Driving Pattern Driving Process…)



Arctic minimum sea ice, September 21, 1979; 6.455 million square kilometers.

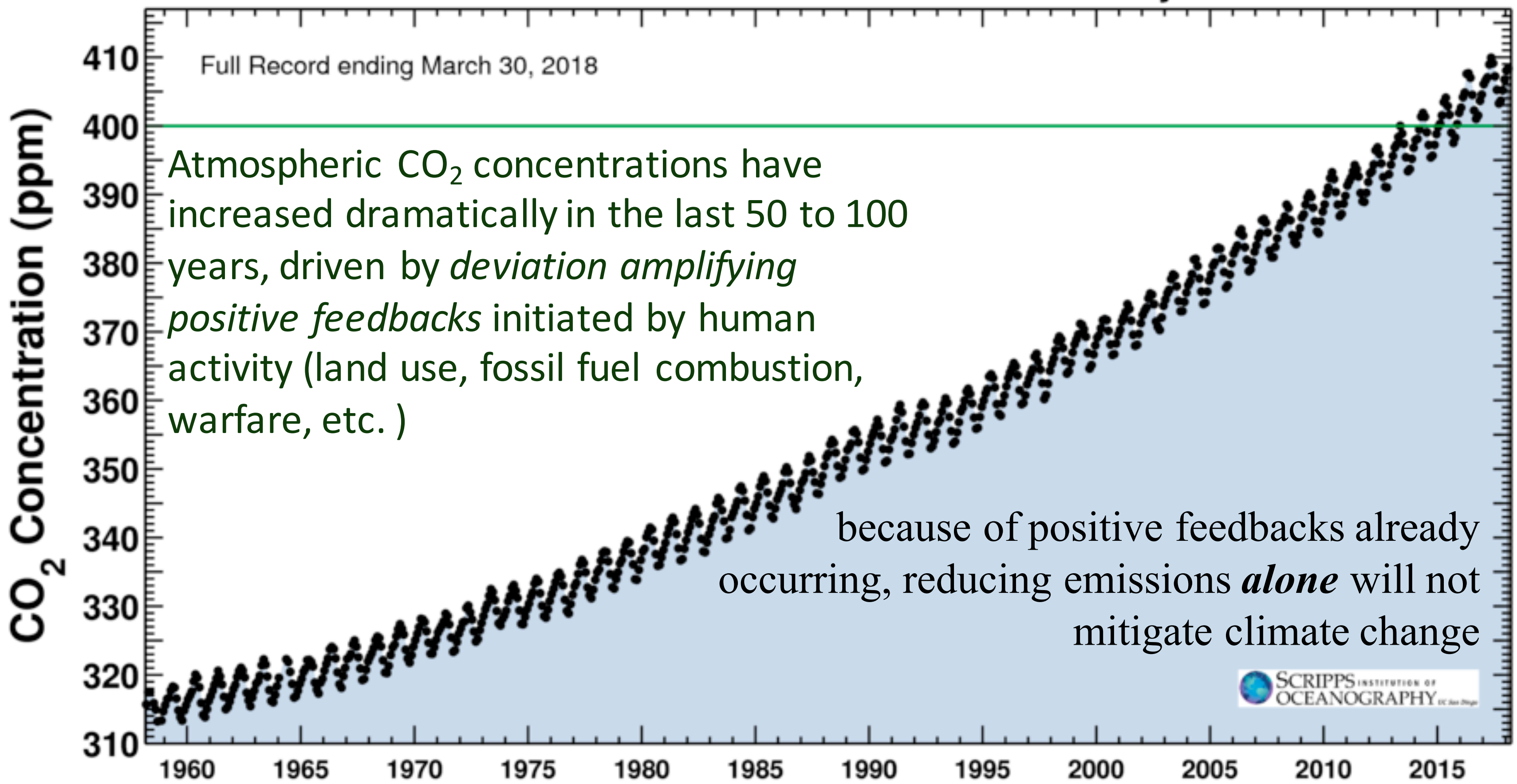
Arctic minimum sea ice, September 7, 2015; 3.884 million square kilometers.



Latest CO_2 reading
March 30, 2018

409.89 ppm

Carbon dioxide concentration at Mauna Loa Observatory



Atmospheric CO_2 concentrations have increased dramatically in the last 50 to 100 years, driven by *deviation amplifying positive feedbacks* initiated by human activity (land use, fossil fuel combustion, warfare, etc.)

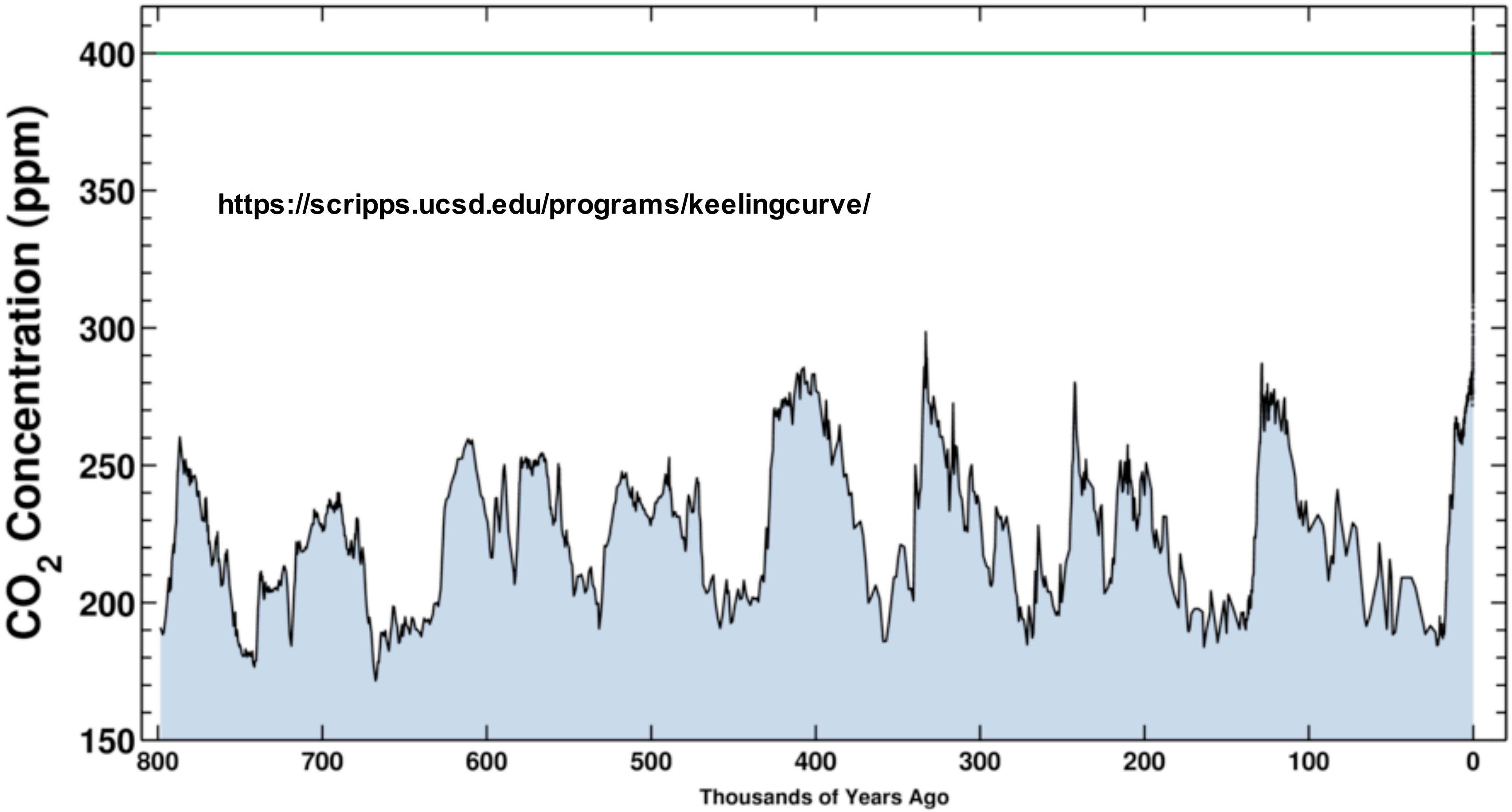
because of positive feedbacks already occurring, reducing emissions ***alone*** will not mitigate climate change

https://scripps.ucsd.edu/programs/keelingcurve/

Latest CO_2 reading
March 30, 2018

409.89 ppm

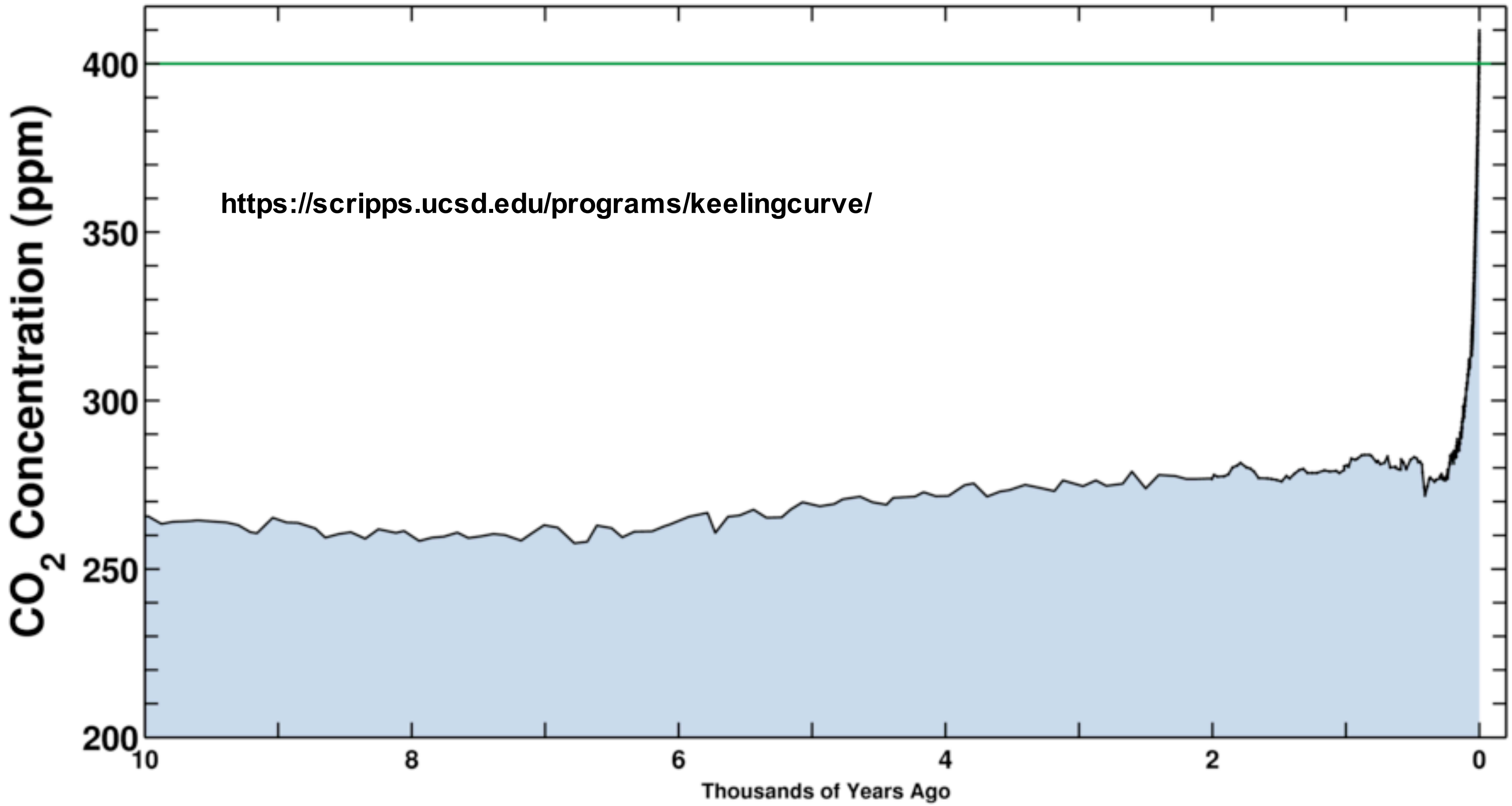
Ice–core data before 1958. Mauna Loa data after 1958.



Latest CO_2 reading
March 30, 2018

409.89 ppm

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



Long-term intensive cultivation and inorganic fertilization of agricultural fields has reduced soil organic C content by more than 1000 Tg in the United States. This soil C was largely released to the atmosphere as CO_2. (1 Tg = 1MMT)

-Kern and Johnson 1993

Intensification of agricultural production is an important factor influencing greenhouse gas emissions, particularly the relationship between intensive tillage and soil C loss.

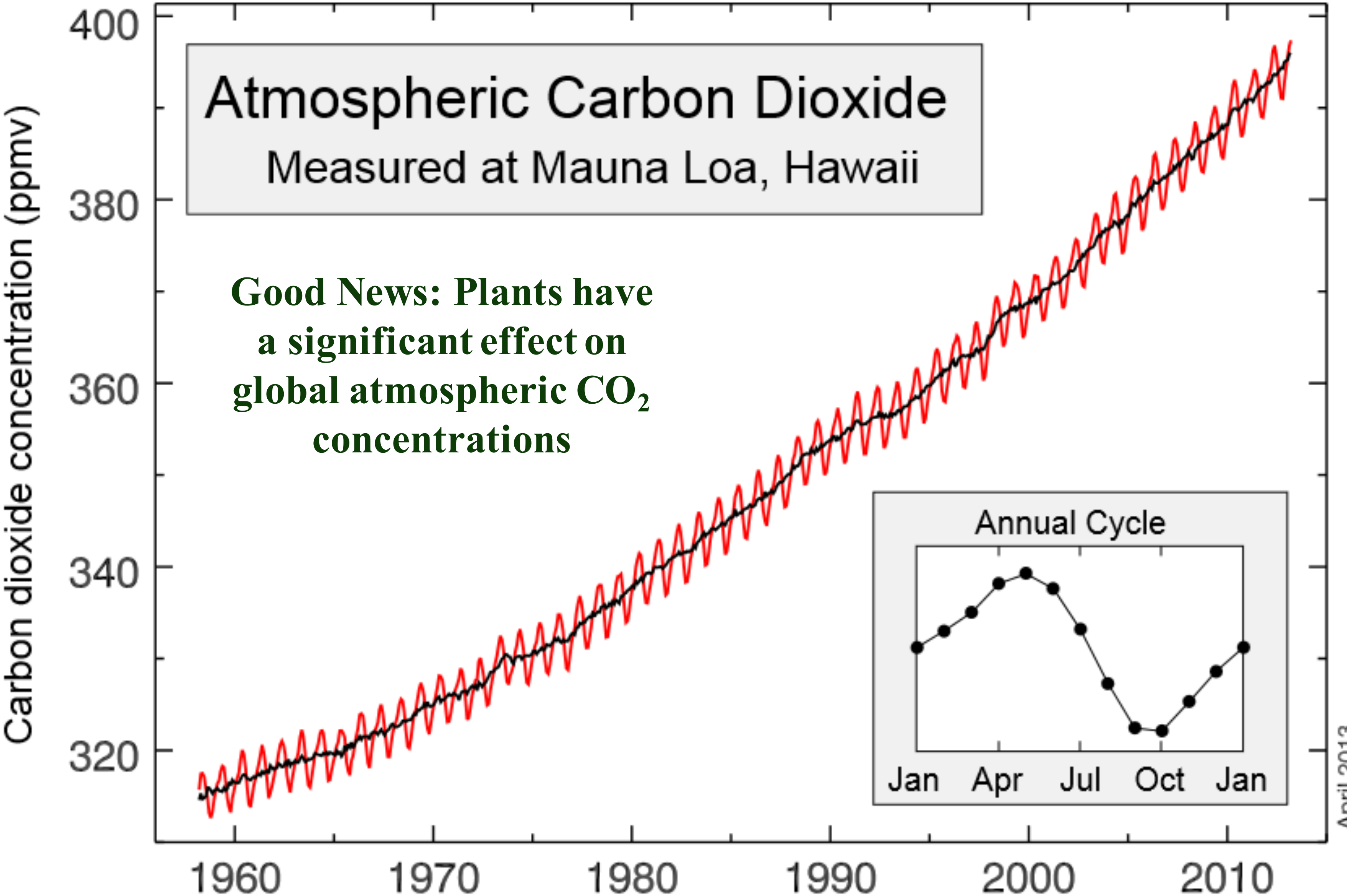
-Reicosky and Archer, 2007

…agriculture is more exposed to climate change impacts than any other sector.

-COP 23, Bonn, Germany, 12 November 2017
http://enb.iisd.org/climate/cop23/agriculture-action-day/

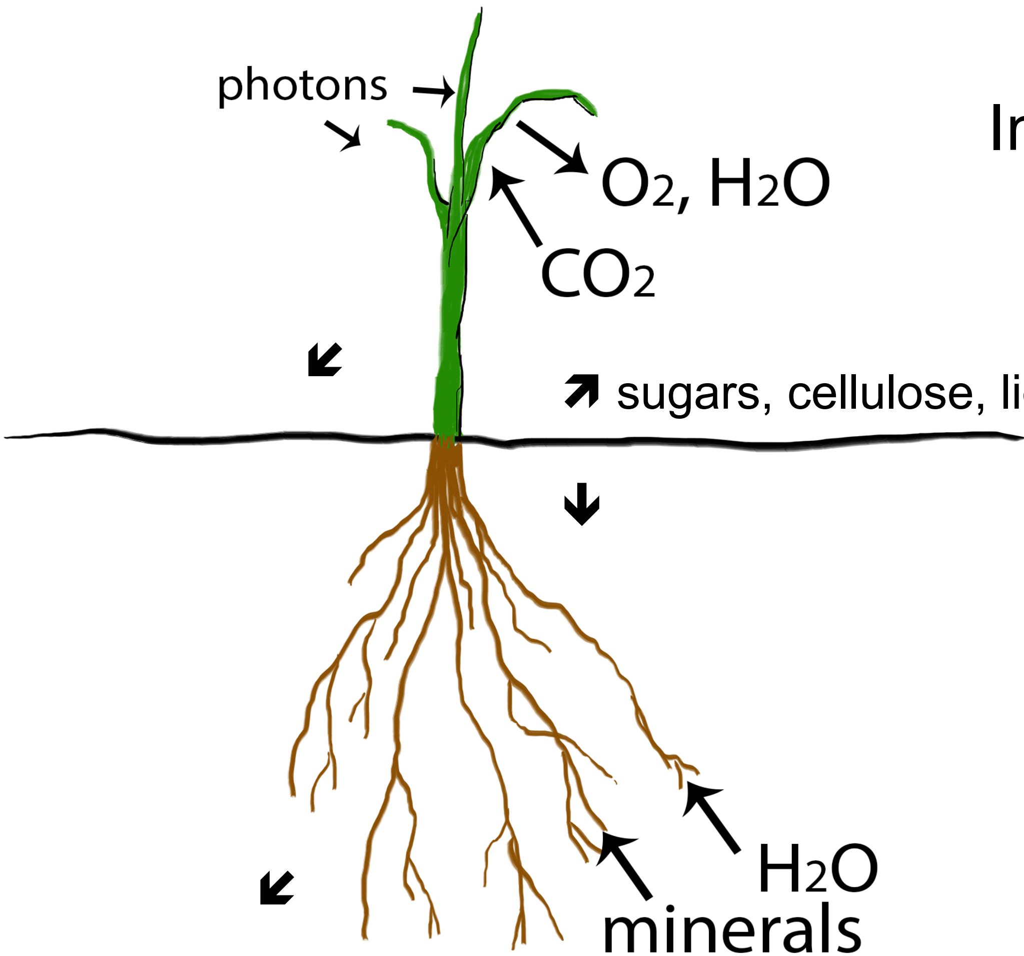
…enhancing soil carbon is the only viable option to achieve negative emissions….

-Celine Charveriat, Executive Director, Institute
for European Environmental Policy. COP 22, 2016.


Atmospheric Carbon Dioxide
Measured at Mauna Loa, Hawaii
Good News: Plants have a significant effect on global atmospheric CO_2 concentrations
Carbon dioxide concentration (ppmv)
400
380
360
340
320
1960
1970
1980
1990
2000
2010
Annual Cycle
Jan
Apr
Jul
Oct
Jan
April 2013

Photosynthesis:

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



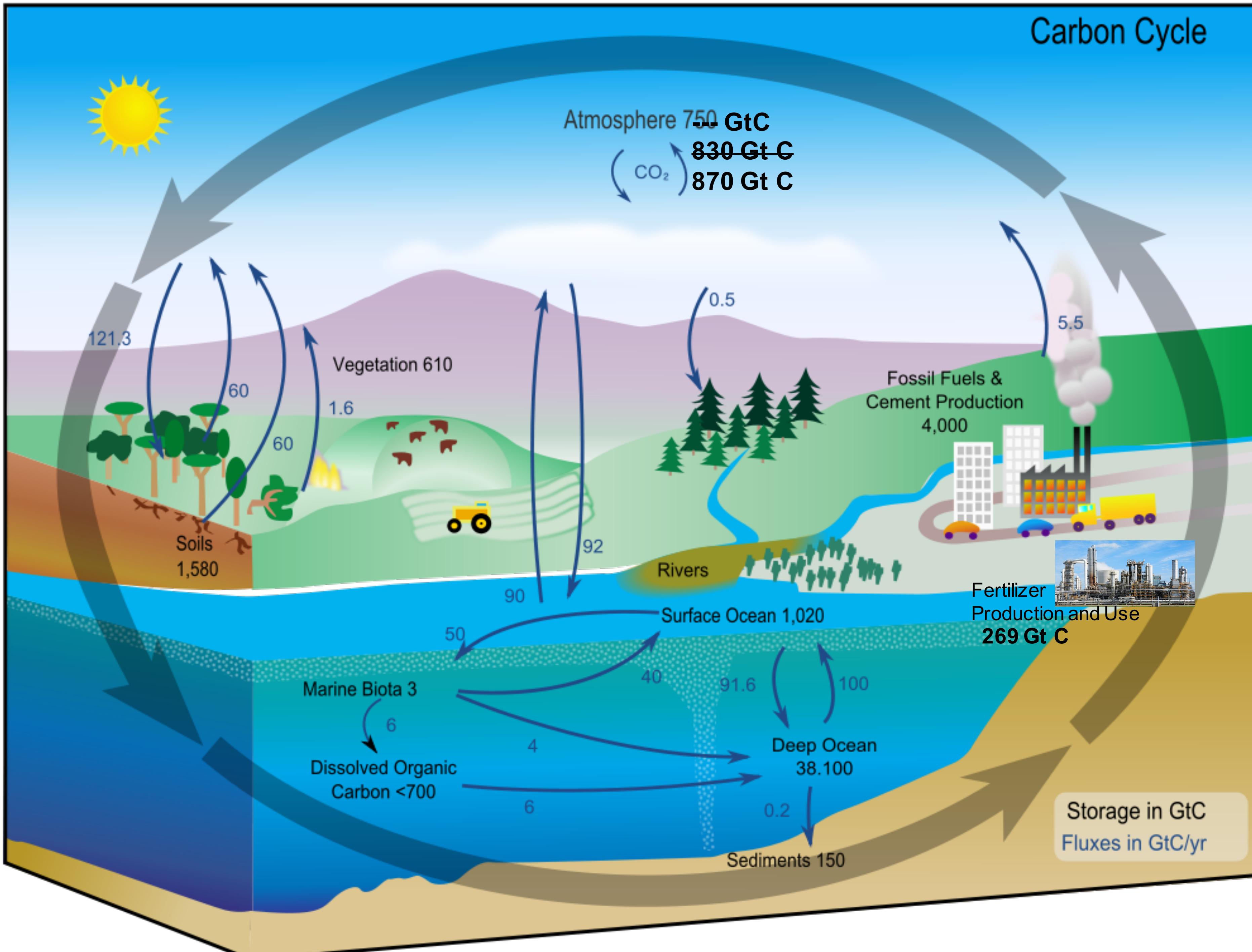
ALL the **C**ARBON
In **CARBO**HYDRATES
comes from the
AIR

John Wick
Marin Carbon Project

AGRICULTURE:

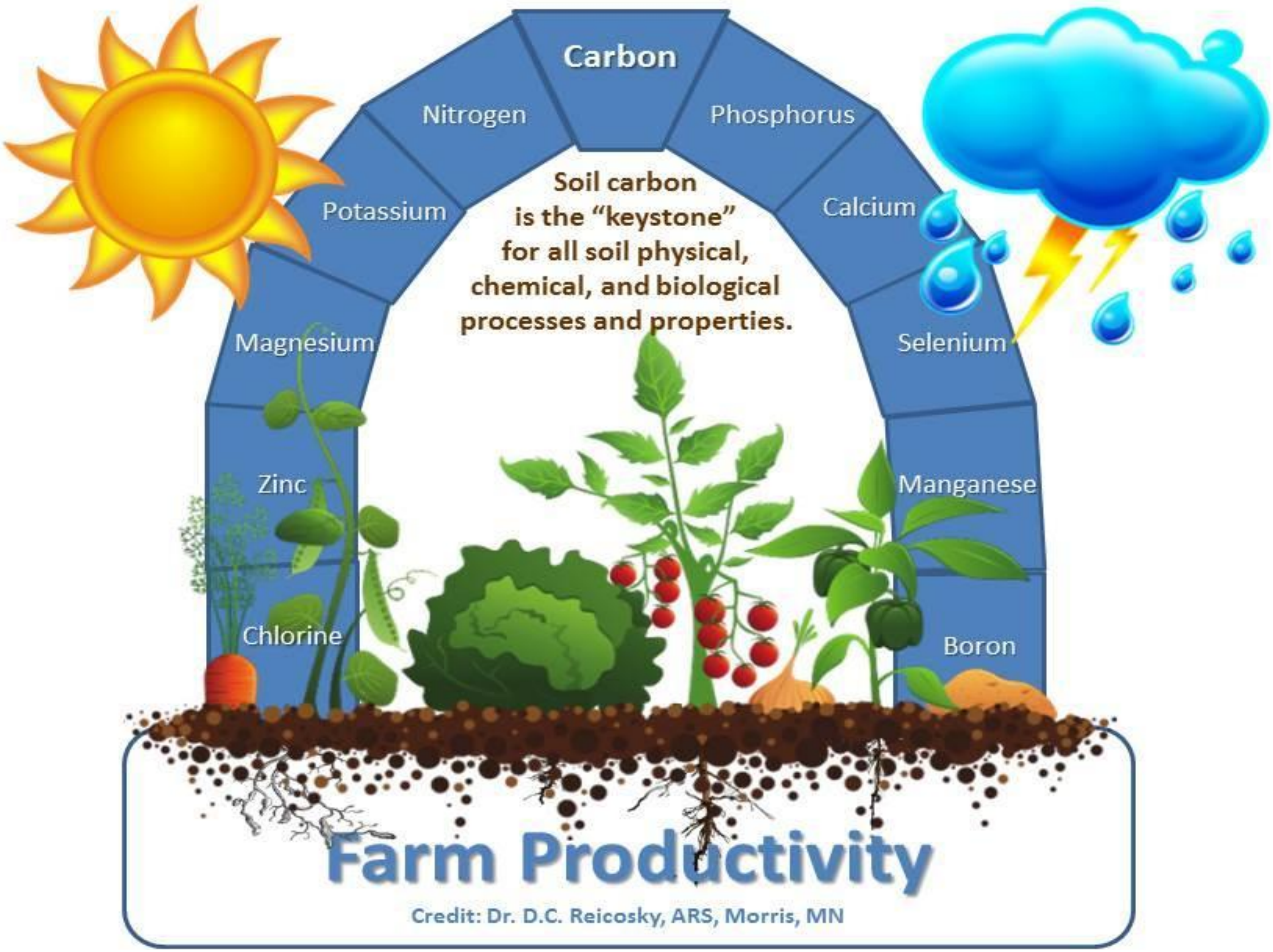
“THE ART
OF MOVING CARBON
BETWEEN CARBON POOLS
TO PRODUCE
FOOD, FUEL, FIBER, AND FLORA”

-John Wick
Co-founder, Marin Carbon Project

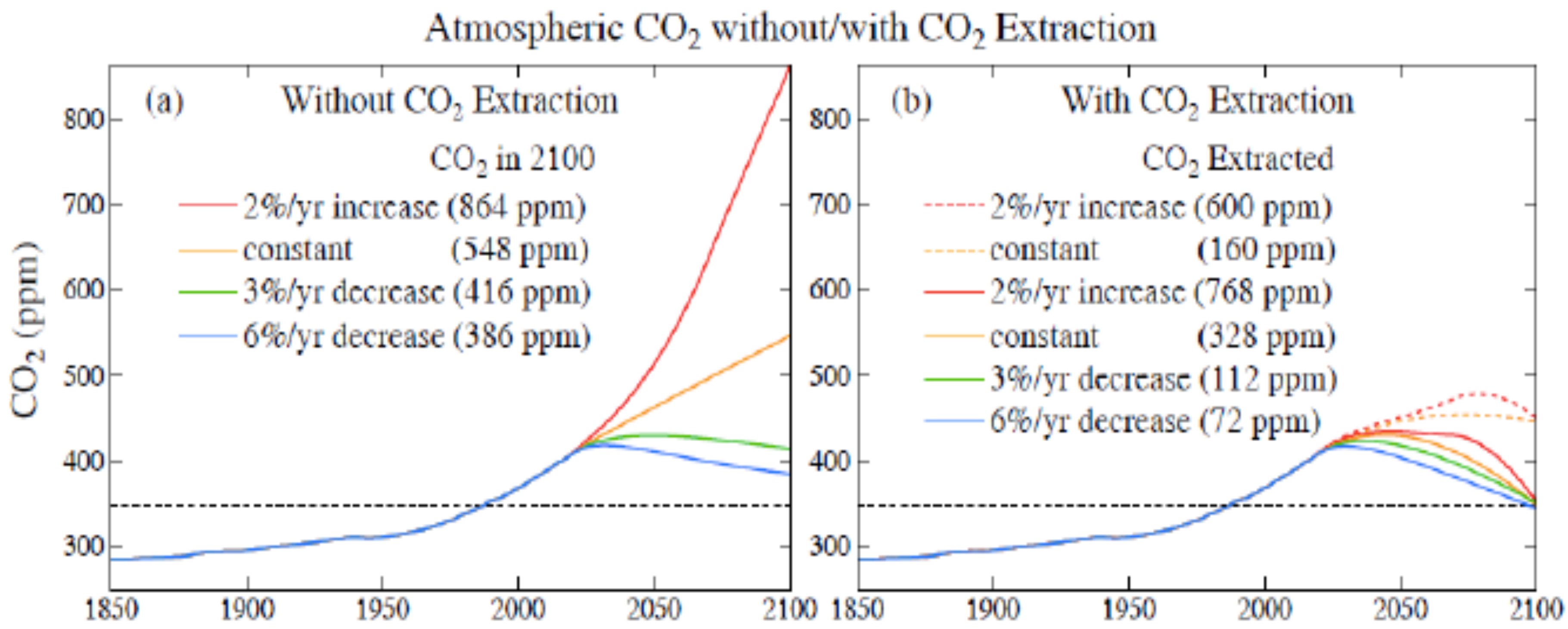

Carbon Cycle
Atmosphere 750 GtC
830 Gt C
870 Gt C
CO_2
121.3
60
60
1.6
Vegetation 610
90
92
0.5
5.5
Fossil Fuels & Cement Production 4,000
Soils 1,580
Rivers
Fertilizer Production and Use
269 Gt C
Surface Ocean 1,020
50
40
91.6
100
Marine Biota 3
6
4
Dissolved Organic Carbon <700
6
Deep Ocean 38.100
0.2
Sediments 150
Storage in GtC
Fluxes in GtC/yr

Carbon:

The Key to Agricultural Productivity and Resilience



We cannot stop –or survive- global warming without significant sequestration of soil carbon in our working landscapes



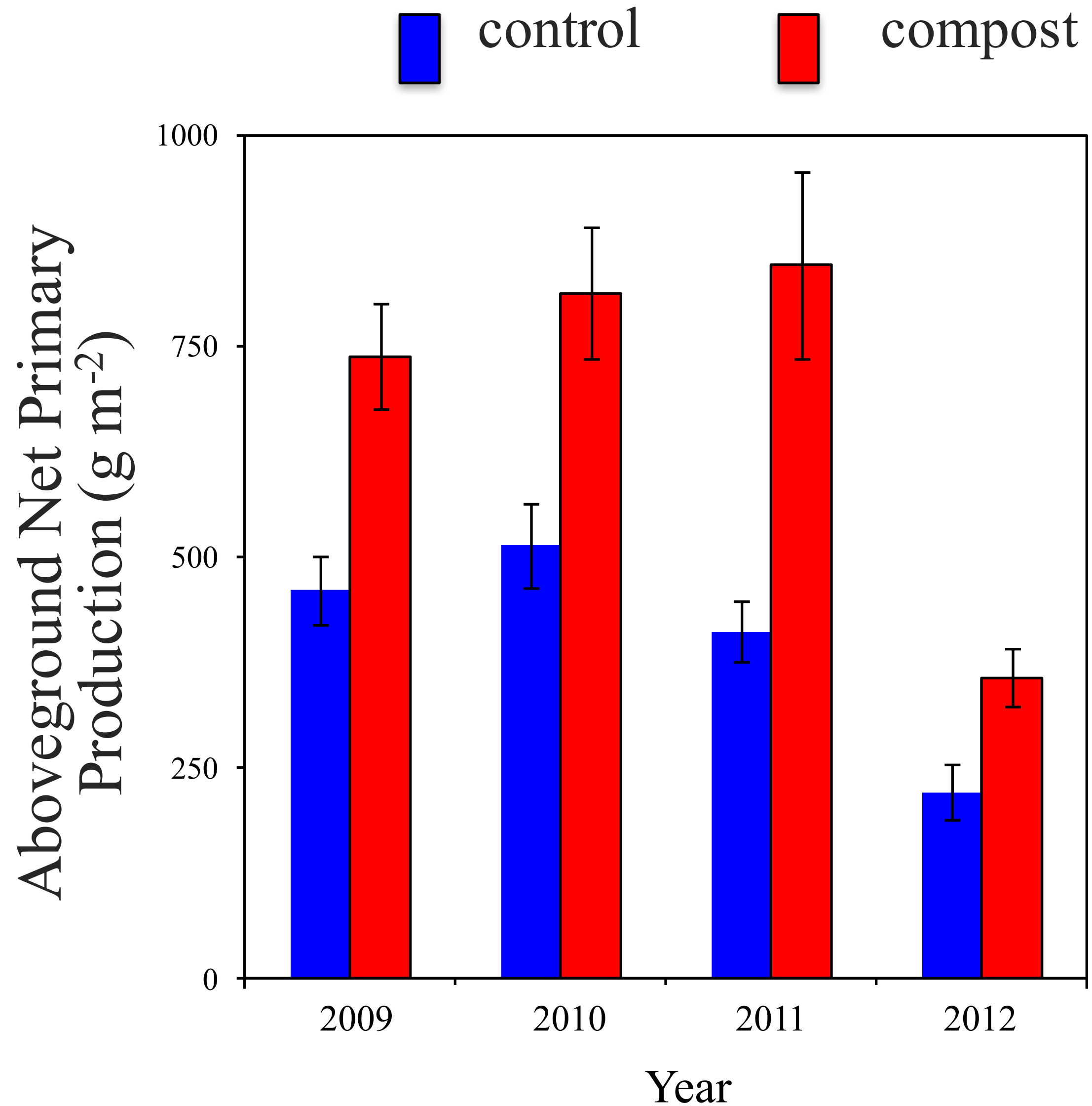
(a) Atmospheric CO2 emission reduction scenarios

(b) Atmospheric CO2 including effect of CO2 extraction that increases linearly after 2020 **(after 2015 in +2%/year case)- *we have missed this window***.
(1 ppm is ~2.12 GtC).

Hansen et al 2016, Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-42, 2016

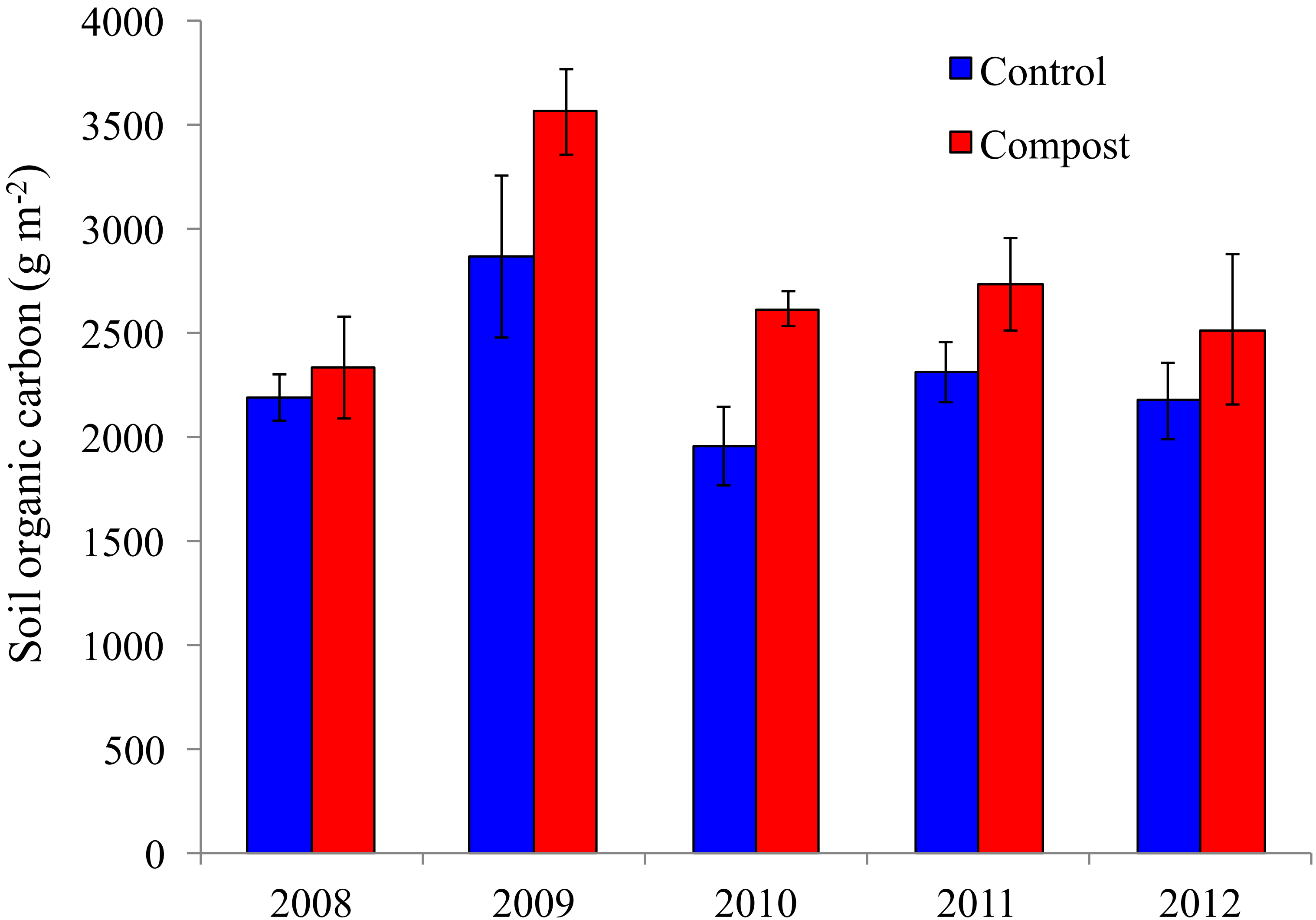
Marin Carbon Project 2008
H1: Management can increase soil carbon
and: we can measure it

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, Ryals et al. 2014.

Compost increased soil C pools



Ryals et al. 2014 Soil Biology & Biochemistry

(Process Driving Pattern Driving Process…)

“A Virtuous Cycle”:

deviation-amplifying positive feedbacks.
Steady-flow dynamics toward a new System State;
“ homeorhesis”

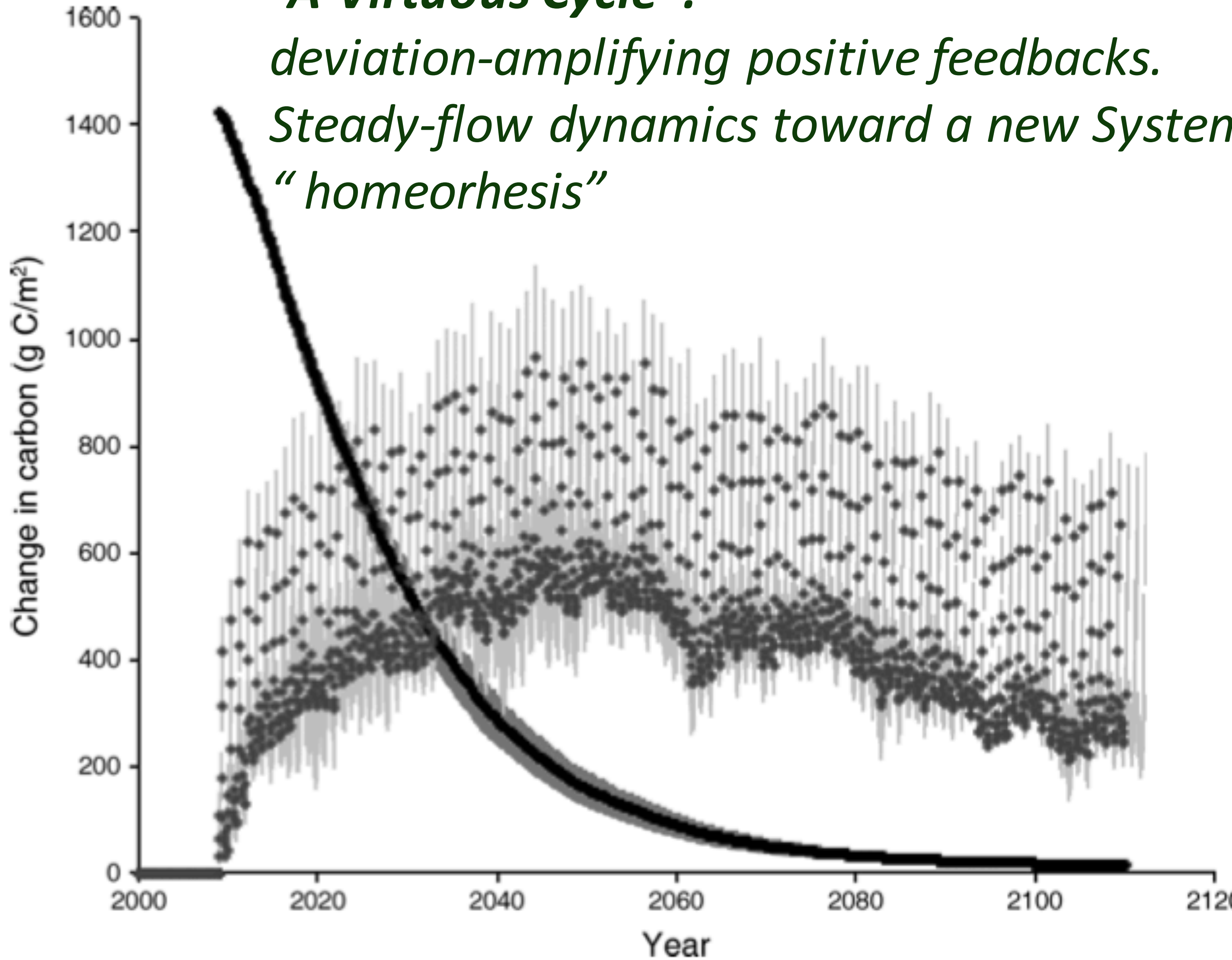
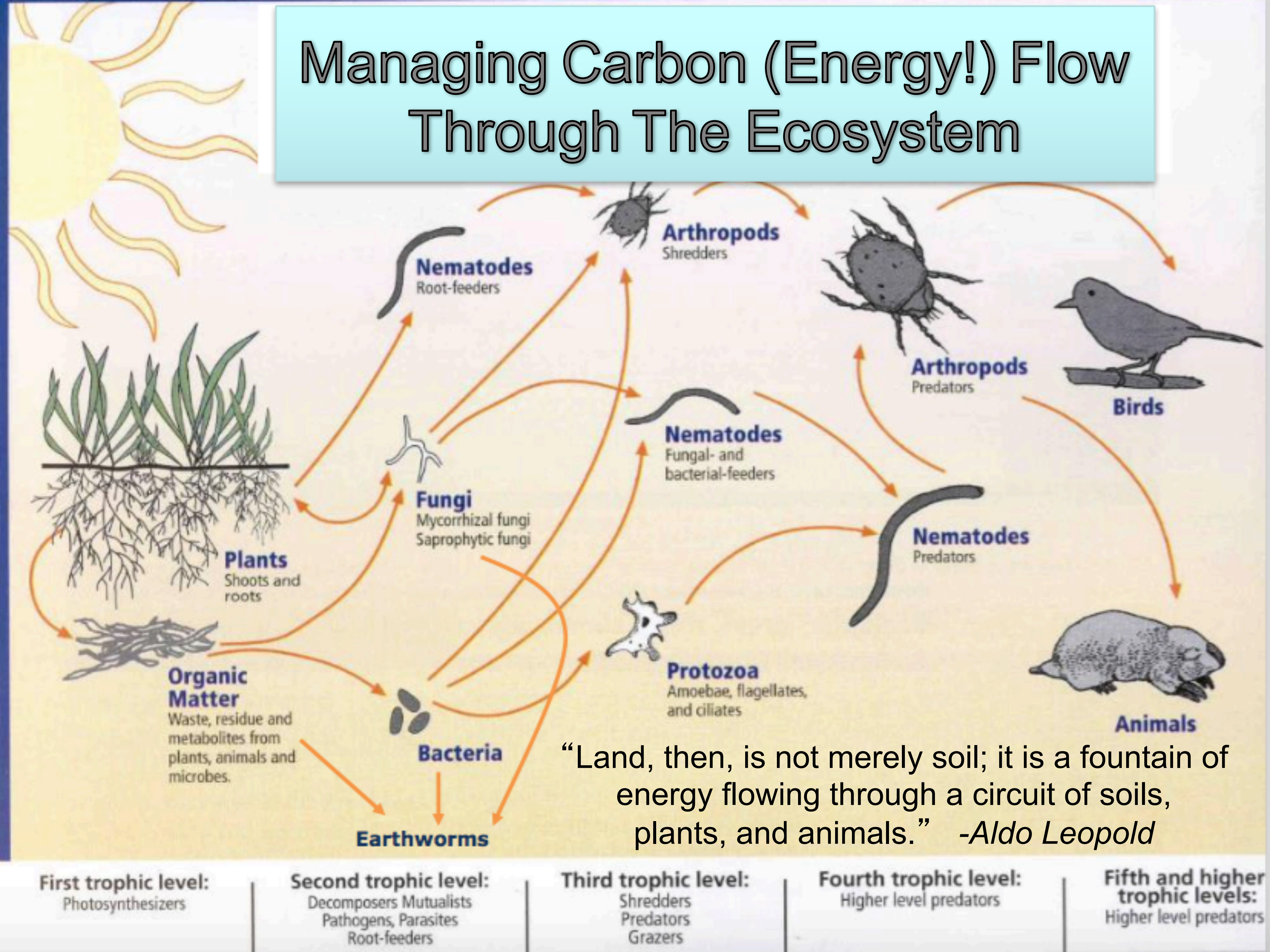


FIG. 3. The black line shows simulated decomposition of the compost following application to grassland soils. Gray circles show the monthly change in total ecosystem carbon, not including compost carbon. Values are averages across site characterizations, with standard error bars in light gray. Ryals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

Managing Carbon (Energy!) Flow Through The Ecosystem

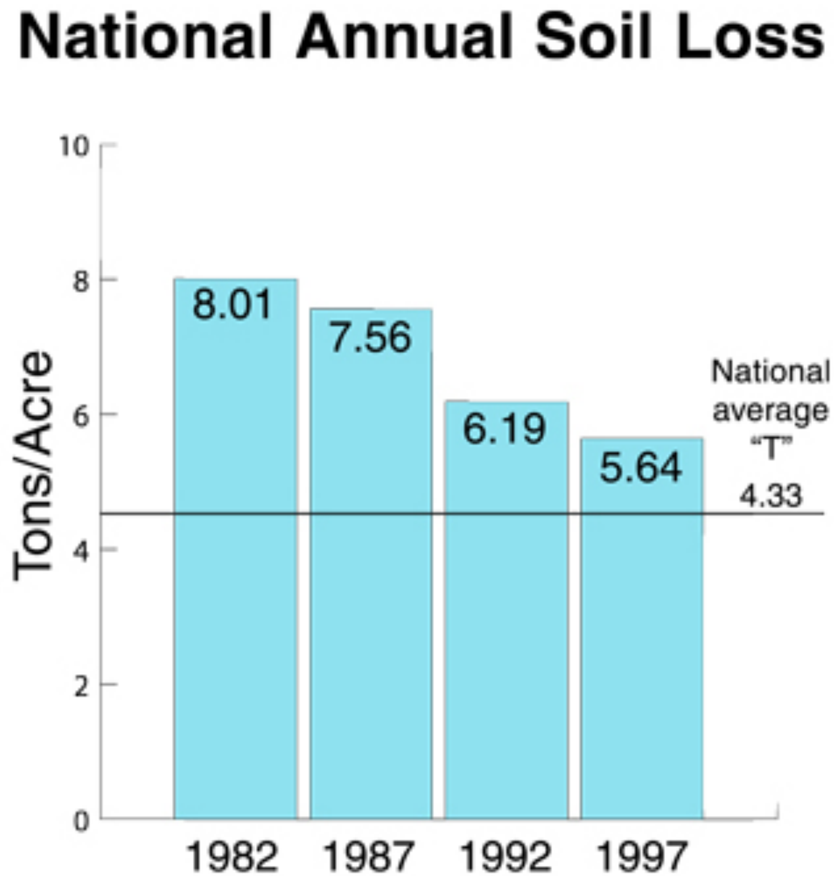


"Land, then, is not merely soil; it is a fountain of energy flowing through a circuit of soils, plants, and animals." *-Aldo Leopold*

"The most practical way to enhance soil health today is to promote better management of soil organic carbon. In short, we should go beyond T (tolerable soil loss) and manage for C (carbon)…" –NRCS

http://soils.usda.gov/sqi/concepts/soil_organic_matter/som.html

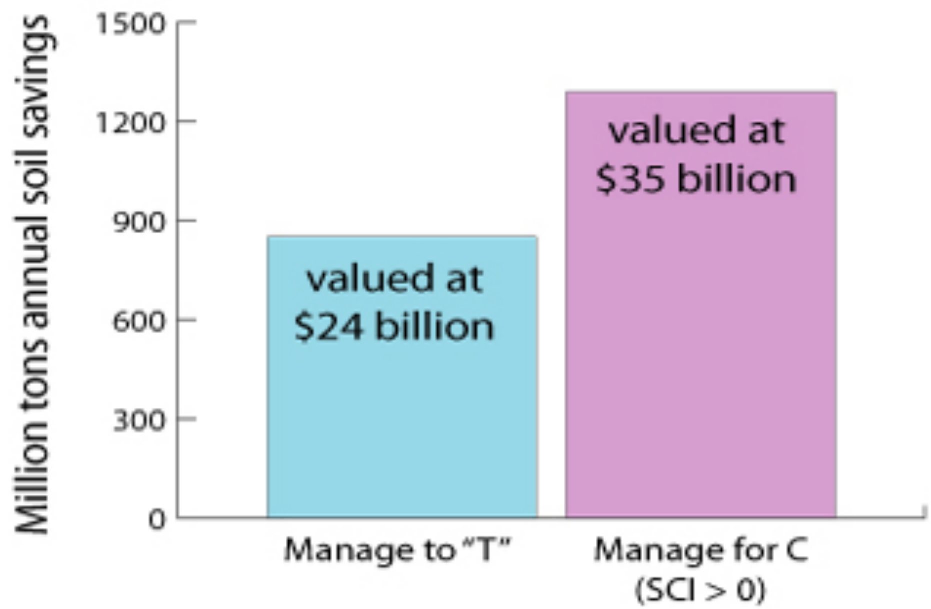
"T" factor: managing for equilibrium

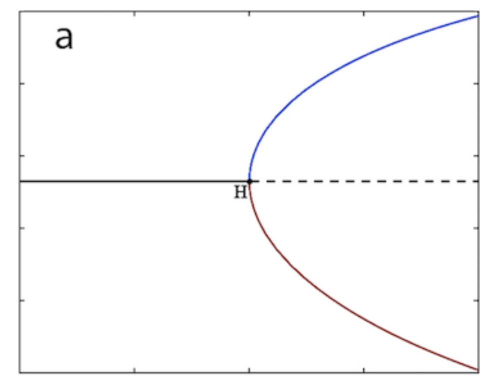


Annually, 1.8 billion tons of soil are lost from cropland. 120 million acres of cropland are eroding at a rate greater than T. (NRCS 2011).

C factor: managing for change

Managing for soil organic matter can save more soil.





If all cropland were managed for C (SCI>0), US soil loss would decline by *at least* 1.29 billion tons, NRCS, 2011.

(at 1% SOC, that is 12.9 MMT tons of C, or 47 MMT CO_2e/yr).

As shown by the Marin Carbon Project results, managing for a SCI > 0 means managing a deviation amplifying process.

(SCI = Soil Conditioning Index)

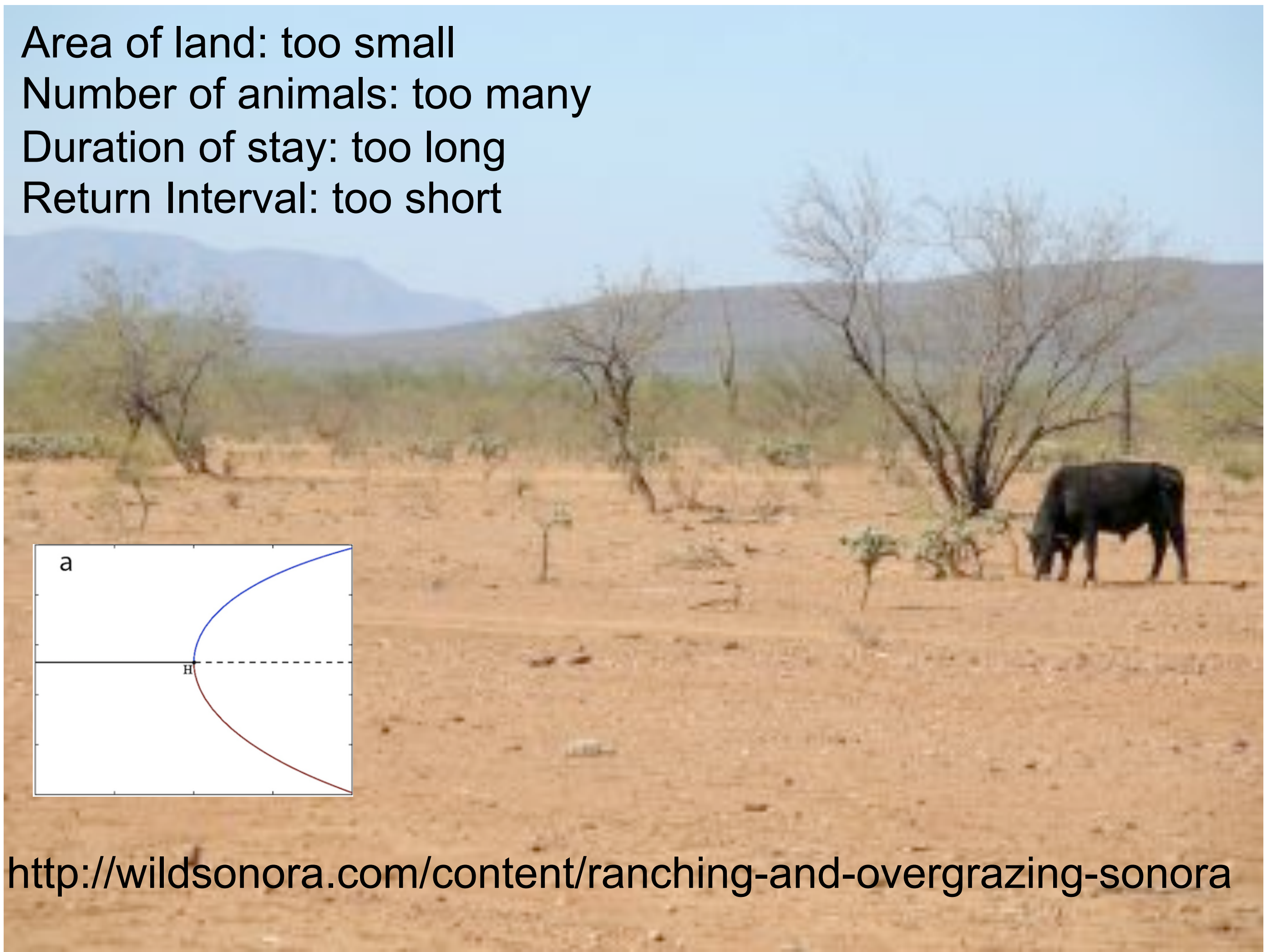
Can livestock impacts be managed to initiate deviation-amplifying positive feedbacks to drive system change?

We Manage the *Direction* of System Change by Managing Energy (Carbon) Flow Through the System

(Process Driving Pattern Driving Process…)

Positive Feedback Leading to Land Degradation Through Loss of Carbon (Energy!) from the System – the Downward Spiral of Desertification

(Process Driving Pattern Driving Process…)



We Manage Energy (C) Flow Through the System by Managing the Scale of Disturbance

Space, Time, Frequency and Magnitude:

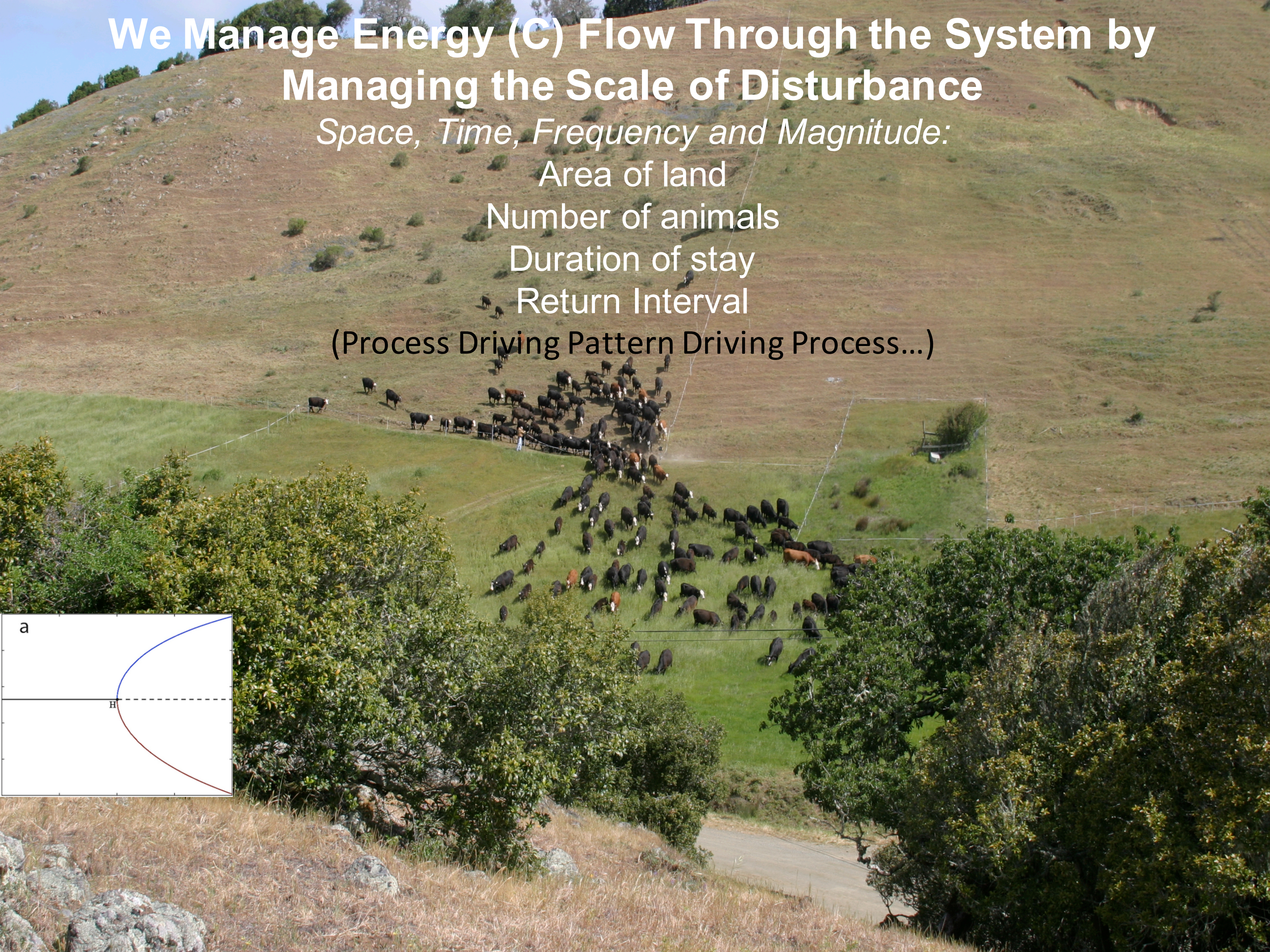
Area of land

Number of animals

Duration of stay

Return Interval

(Process Driving Pattern Driving Process…)



Scaling Livestock Impacts to Increase Carbon Capture:
Managing Disturbance: Space, Time, Frequency and Magnitude:

Area of land
Number of animals
Duration of stay
Return Interval

(Process Driving Pattern Driving Process…)

John Wick Photo

Lessons of the Marin Carbon Project:

to initiate a “virtuous” deviation-amplifying positive feedback process in the Agro-ecosystem, capture more solar energy (as C) and allocate more of that C to the Soil

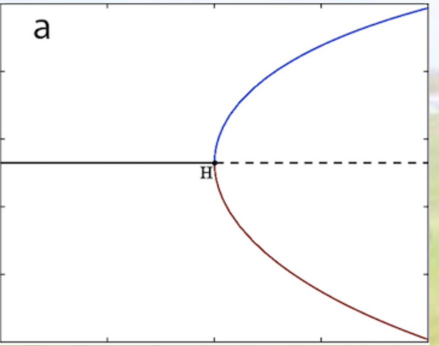
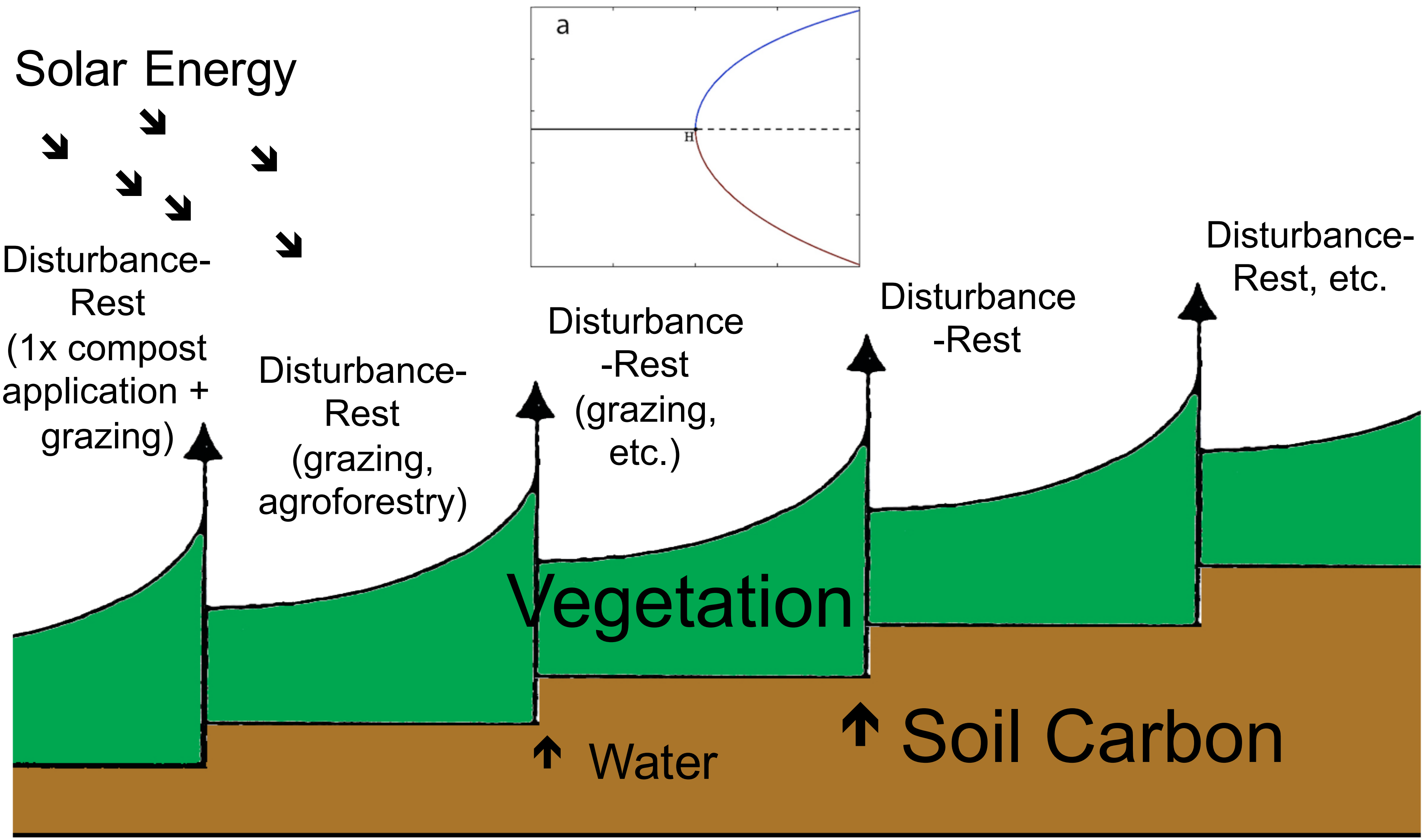


Photo: StempleCreekRanch

"Positive" Positive Feedbacks Driving an Upward Spiral of Increased Soil C, Productivity and Resilience



"These are changes to our creek in…. the last 28 years…we can make a huge difference in ecological health, habitat, carbon sequestration and biodiversity. We have over 30 types of migratory birds that nest in this habitat…. We are still learning, but we are paying attention and building soil, which can never be a bad thing."

-Loren Poncia, Stemple Creek Ranch

Windbreak/Shelterbelt

Hedgerow

Silvopasture

Riparian Forest Buffer

Nutrient Management – Replacing Synthetic Nitrogen Fertilizer with Organic Matter Amendments

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, better structure and improved water absorbing and holding capacity.

Patrick Francis, Australian Farm Journal

Same Mendocino soil: different input and management histories

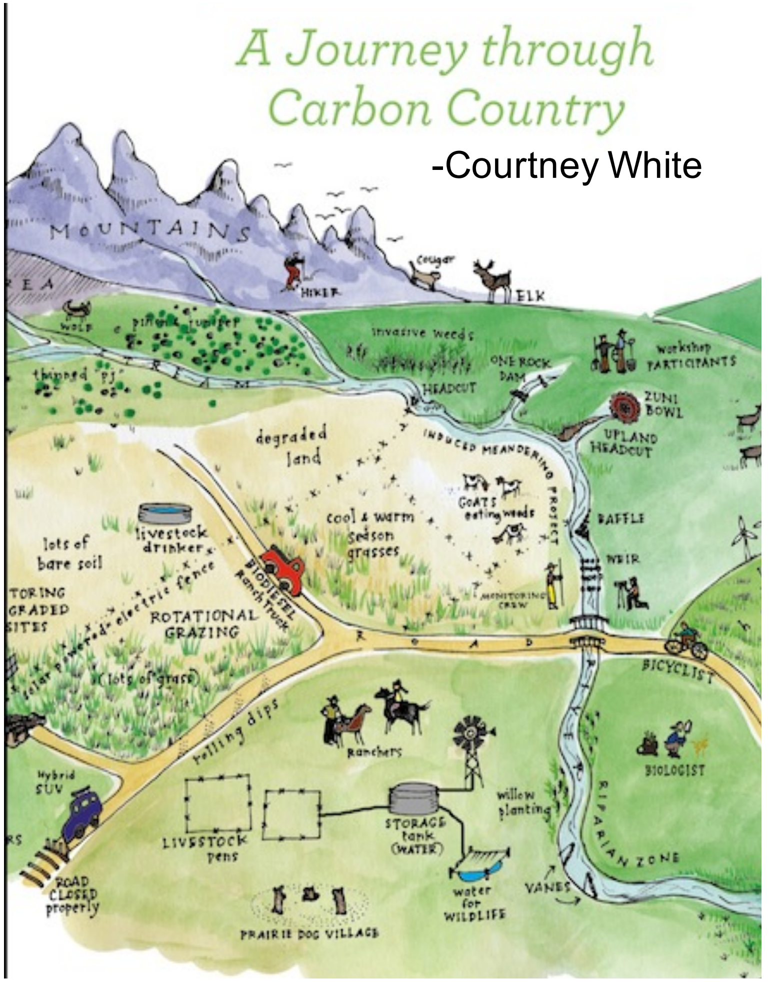
Photo: G. Batist, 2017

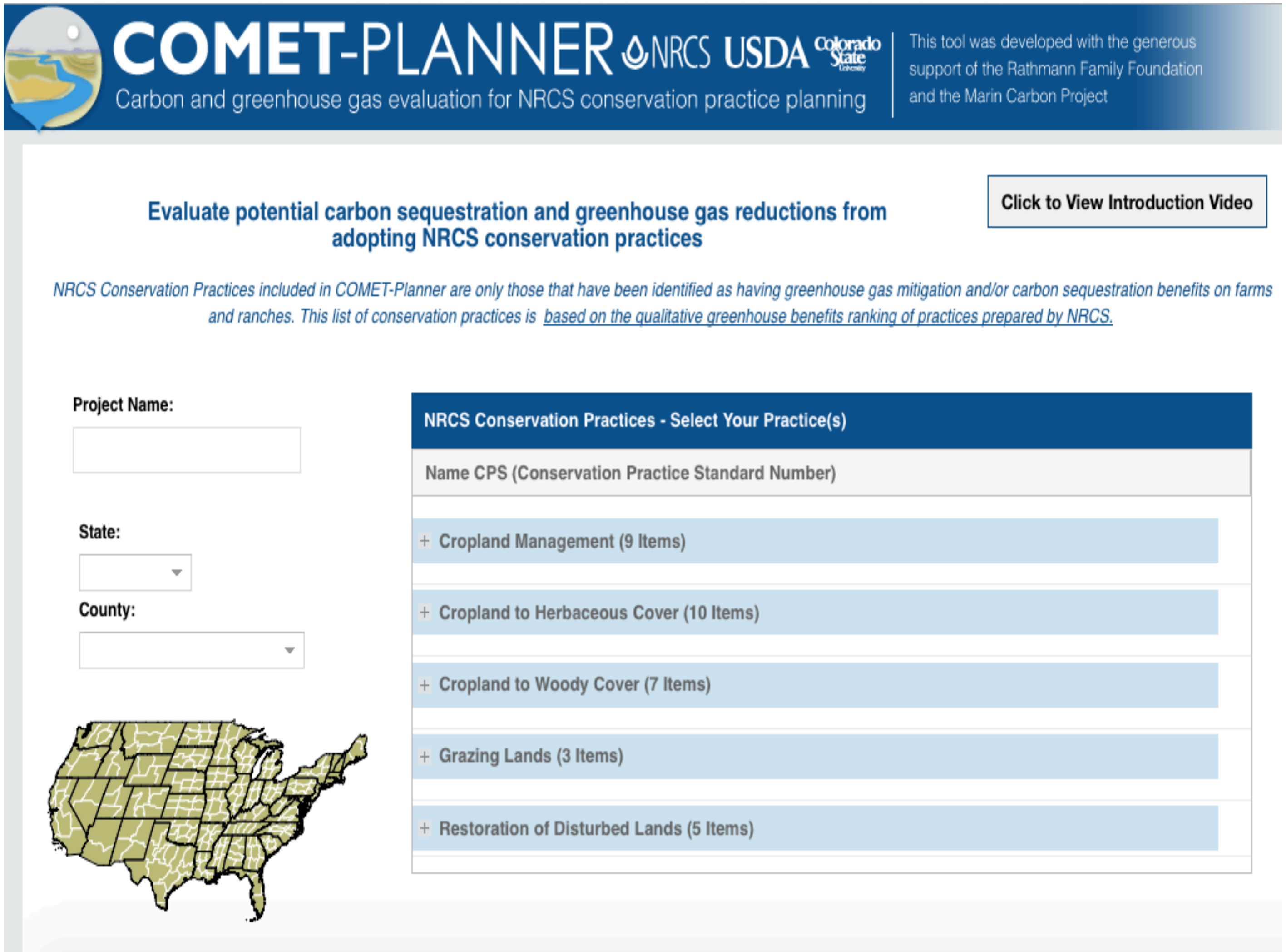
Carbon Farm Planning

CONSERVATION PLANNING through a carbon lens:

- *Increase terrestrial carbon*
- *Reduce GHG emissions*
- *Quantify carbon benefits of conservation practices*

- *Recognize the co-benefits of increasing on-farm carbon:*
  - ↑ *Production*
  - ↑ *Soil Health*
  - ↑ *Water Quantity*
  - ↑ *Water Quality*





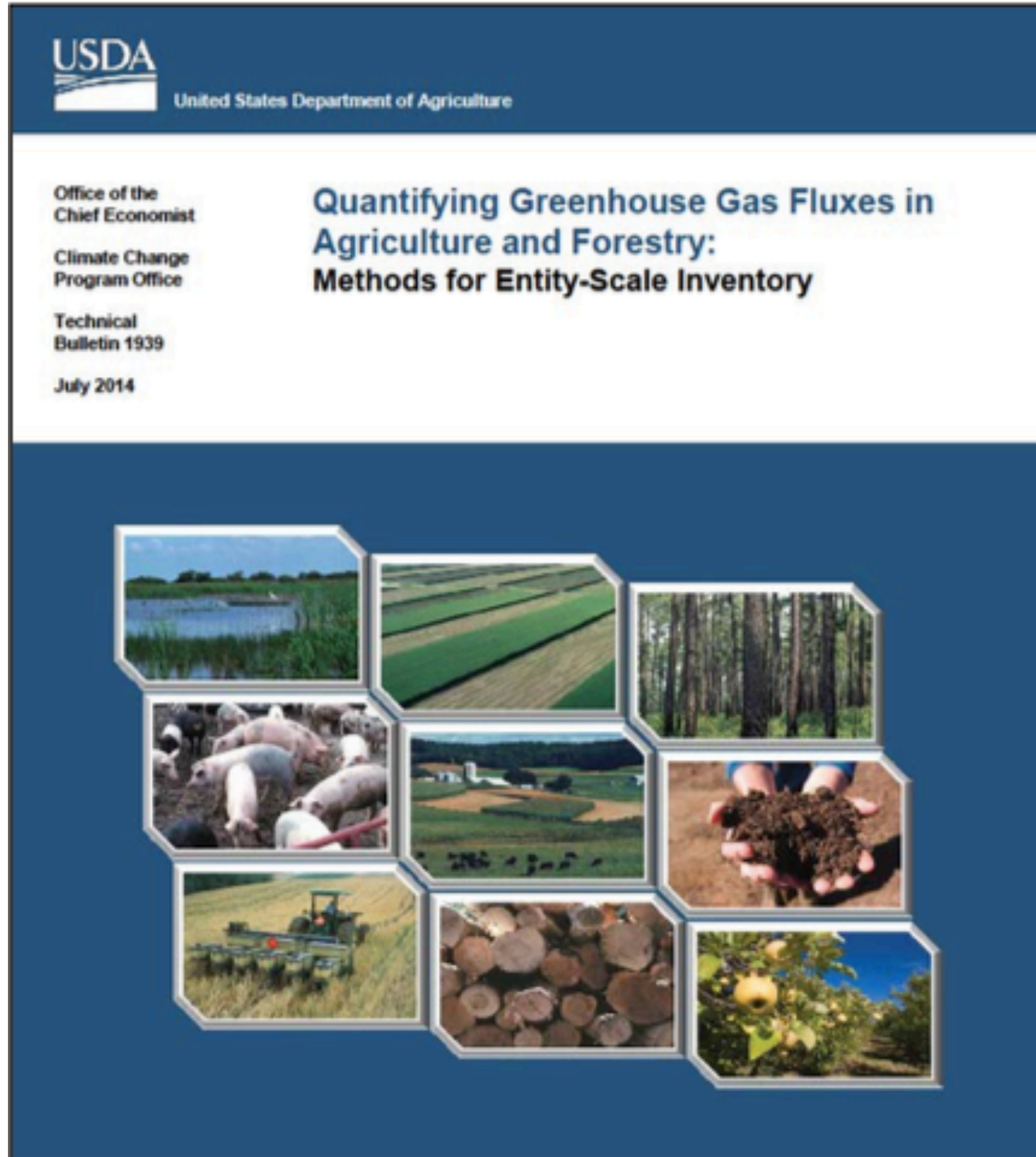
Quantifying the Carbon capture potential of over 35 NRCS Conservation Practices

LOCAL DATA where available

COMPOST: R.Ryals et al 2013; M.DeLonge et al 2013

CREEK CARBON: D.Lewis et al 2015

The USDA Entity-Scale GHG Methods Report is a transparent, scientifically rigorous set of standardized methods that can be used to quantify changes in GHG emissions and carbon storage following a change in management or adoption of a new practice or technology.



Eve, M., D. Pape, M. Flugge, R. Steele, D. Man, M. Riley-Gilbert, and S. Biggar, (Eds), 2014. *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory*. Technical Bulletin Number 1939. Office of the Chief Economist, U.S. Department of Agriculture, Washington, DC. 606 pages.

Marin Carbon Project - Carbon Farm Plan
BLAKES LANDING DAIRY

Legend

Property Boundary, 493 acres

Carbon Farm Practices

Anaerobic Digester, 2004

Compost Application 2013, 28 acres

Compost Facility

Compost Application, 100 acres
Nutrient Managment, 200 acres
Pasture Planting, 200 acres
Range/Prescribed Grazing, 300 acres

Agroforestry Systems

Windbreak Planting: 12,000 linear feet

Low

Low and Medium

Riparian Forest Buffer, 15 acre

Riparian Restoration: 9 acres
Critical Area Planting
Riparian Herbacious Cover

Carbon Farm Practices (NRCS Practice#)

1. Anaerobic Digester (366)
2. Compost Managment Facility (370)
3. Compost Application (484)
4. Critical Area Planting (342)
5. Fencing or Access Control (382/472)
6. Hedgerow Planting/Windbreak (422/380/601)
7. Nutrient Management (590)
8. Pasture Planting/ Forage and Biomass Planting (512)
9.Riparian Herbaceous Cover (390)*
10. Riparian Forest Buffer (391)*
11. Range Management/ Prescribed Grazing (528)
12. Water Development (516/614)
13. Residue and Tillage Management No–Till system (329)

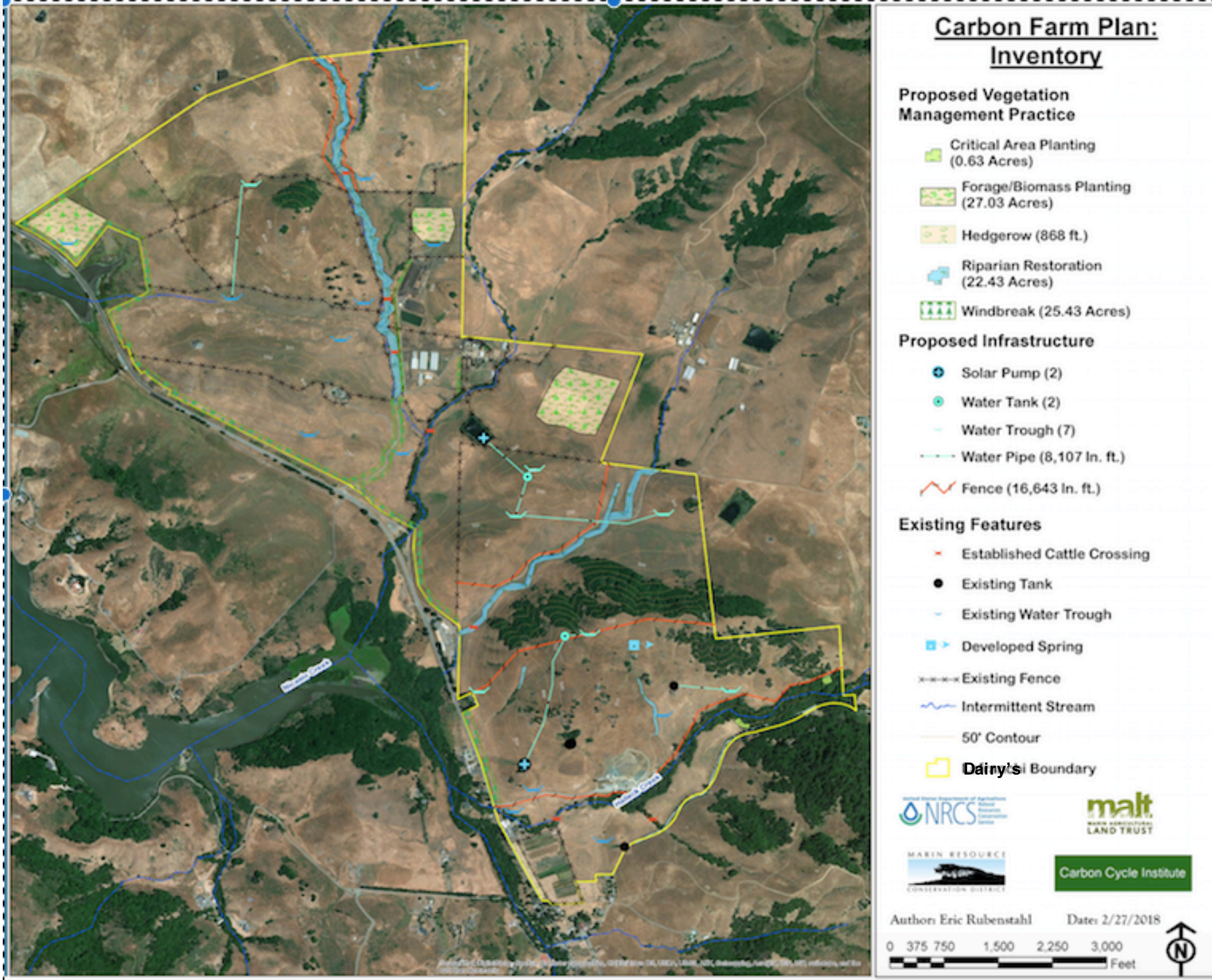
MARIN RESOURCE CONSERVATION DISTRICT

malt MARIN AGRICULTURAL LAND TRUST

Author:Lynette K Niebrugge

(Process Driving Pattern Driving Process…)

Date Saved: 4/1/2015 4:38:23 PM



Carbon Farm Plan: Inventory
Proposed Vegetation Management Practice
Critical Area Planting (0.63 Acres)
Forage/Biomass Planting (27.03 Acres)
Hedgerow (868 ft.)
Riparian Restoration (22.43 Acres)
Windbreak (25.43 Acres)
Proposed Infrastructure
Solar Pump (2)
Water Tank (2)
Water Trough (7)
Water Pipe (8,107 ln. ft.)
Fence (16,643 ln. ft.)
Existing Features
Established Cattle Crossing
Existing Tank
Existing Water Trough
Developed Spring
Existing Fence
Intermittent Stream
50' Contour
Dairy's Boundary
NRCS
malt
MARIN AGRICULTURAL LAND TRUST
MARIN RESOURCE CONSERVATION DISTRICT
Carbon Cycle Institute
Author: Eric Rubenstahl
Date: 2/27/2018
0 375 750 1,500 2,250 3,000
Feet
N

Greenhouse Gas Reduction Benefits, CDFA-AMMP Flush to Dry Scrape Conversion Project, 2018

The **CDFA AMMP calculator** suggest the project will reduce manure methane (CH_4) emissions by **1,155 MT CO_2e/yr, or by 76% from 1,519 MT CO_2e/yr.**

But:

The net annual GHG emission reduction from the project is estimated to be at least 2,608 MT CO_2e, when avoided CH_4, N_2O and CO_2 emissions are all considered.

CDFA calculator avoided CH_4 value (**1,155 MT CO_2e/yr**);
avoided manure N_2O **(120 MT CO_2e/yr)**, and
CO_2e reduction resulting from composting mixed organic wastes diverted from anaerobic storage or disposal **(1,333 MTCO_2e).**

Does *not* include increased CO_2e reductions resulting from enhanced pasture productivity associated with compost applications, estimated to be at least 1.49 metric tons CO_2e per acre per year (Ryals and Silver, 2013).

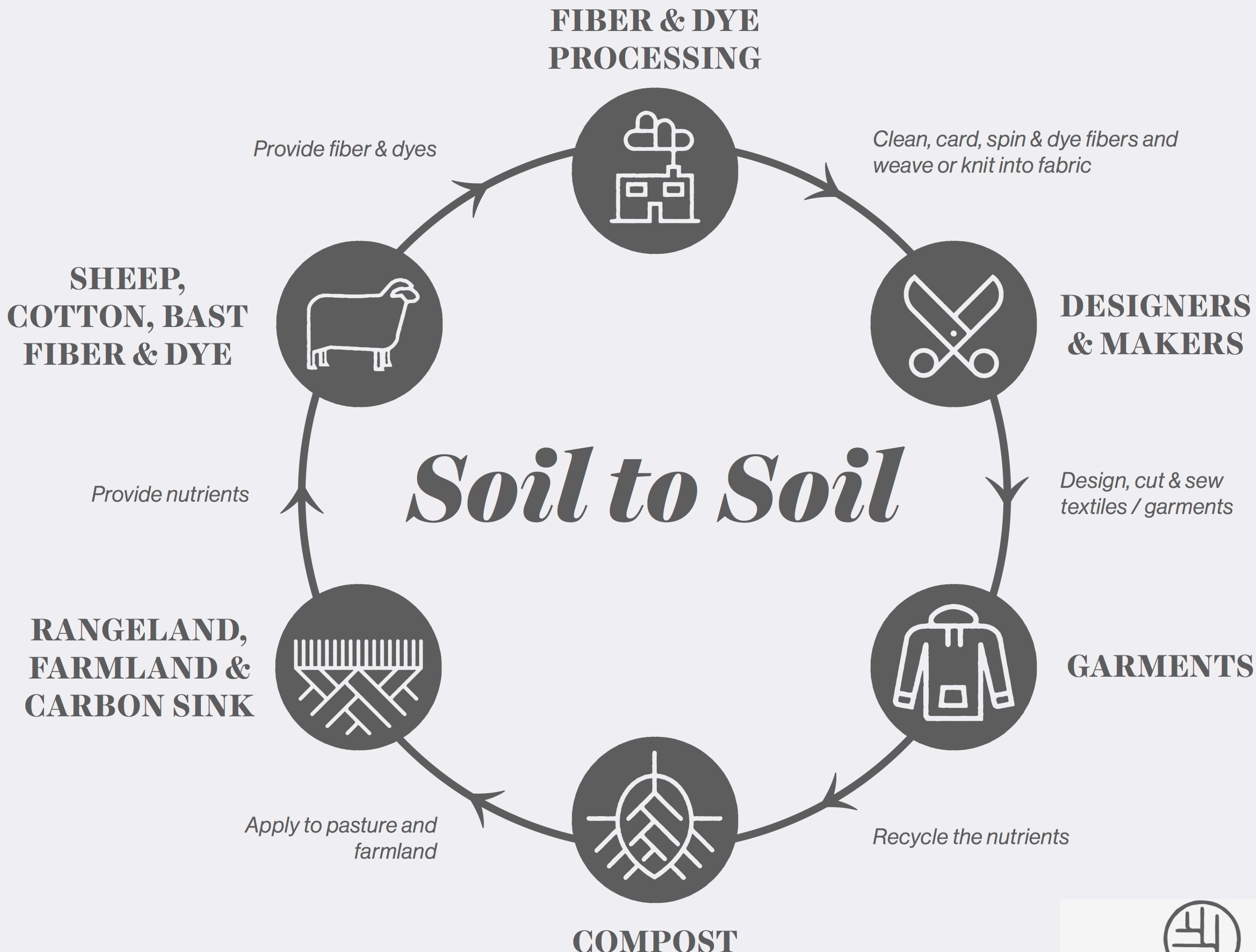
"It's somewhere around 200 to 250 gallons of diesel a month that we're not using."

Communicating Carbon Farming Value

Carbon Farm Planning:

Toward a Climate Beneficial Agriculture

Paige Green Photo


FIBER & DYE PROCESSING
Provide fiber & dyes
Clean, card, spin & dye fibers and weave or knit into fabric
SHEEP, COTTON, BAST FIBER & DYE
DESIGNERS & MAKERS
Soil to Soil
Provide nutrients
Design, cut & sew textiles / garments
RANGELAND, FARMLAND & CARBON SINK
GARMENTS
Apply to pasture and farmland
Recycle the nutrients
COMPOST
FIBERSHED

Carbon Farm Planning: Estimated CO2e Reduction/Sequestration Potential, Bare Ranch

Practice	Average Annual CO2e Sequestration (Mg)	20 yr CO2e Sequestration
Rangeland Compost	167	31,826
Cropland Compost (590)	1,097	21,938
Shelterbelts (380)	20	404
Riparian Restoration*	368*	7353*
Prescribed Grazing (528)	790	15,800
Range Planting (550)	720	14,400
Minimum-Tillage (345)	104	2,080
Silvopasture (381)	94	1,880
Irrigation System (443)	780	15,600
Totals	**4,140**	**111,581**

Carbon Farming

Climate-Beneficial Agriculture

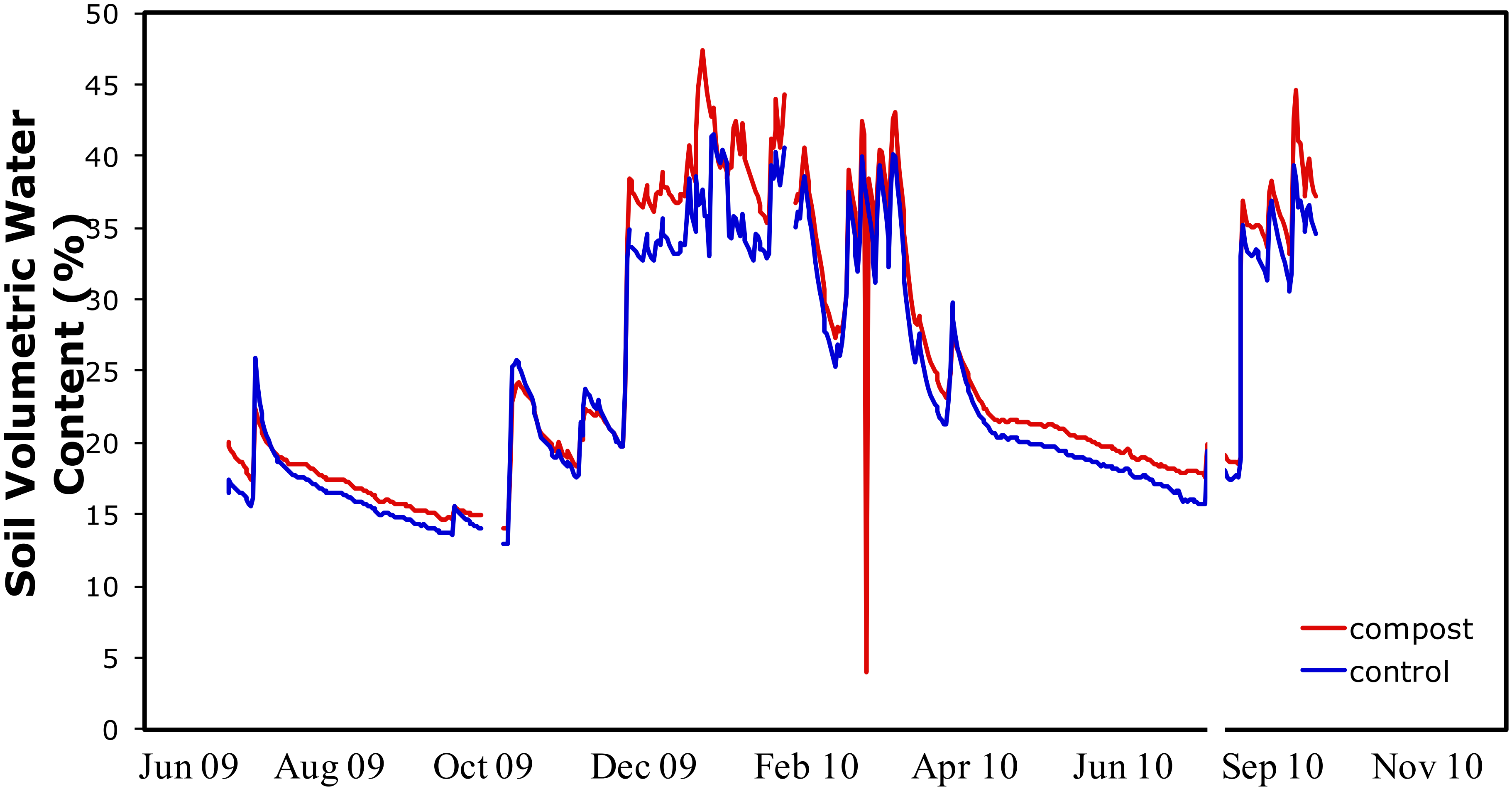
Using published (Wiedemann et al 2015) on-farm GHG emission values for wool production, implementation of this Ranch's Carbon Plan would offset 6 to 9.5 times the GHG emissions associated with its wool production each year.

Carbon Farming provides a robust framework for a 'Climate-Beneficial' agriculture.

"I like to think of the carbon farming and the climate beneficial work that we're doing now as a change of thought; so instead of doing things normally –obviously, we're raising sheep the same way that it's been done for hundreds of years– we also think about the soil and the land when we're making decisions."

- Lani Estill, Bare Ranch, CA

Increasing Soil Organic Matter increases Soil Water Holding Capacity



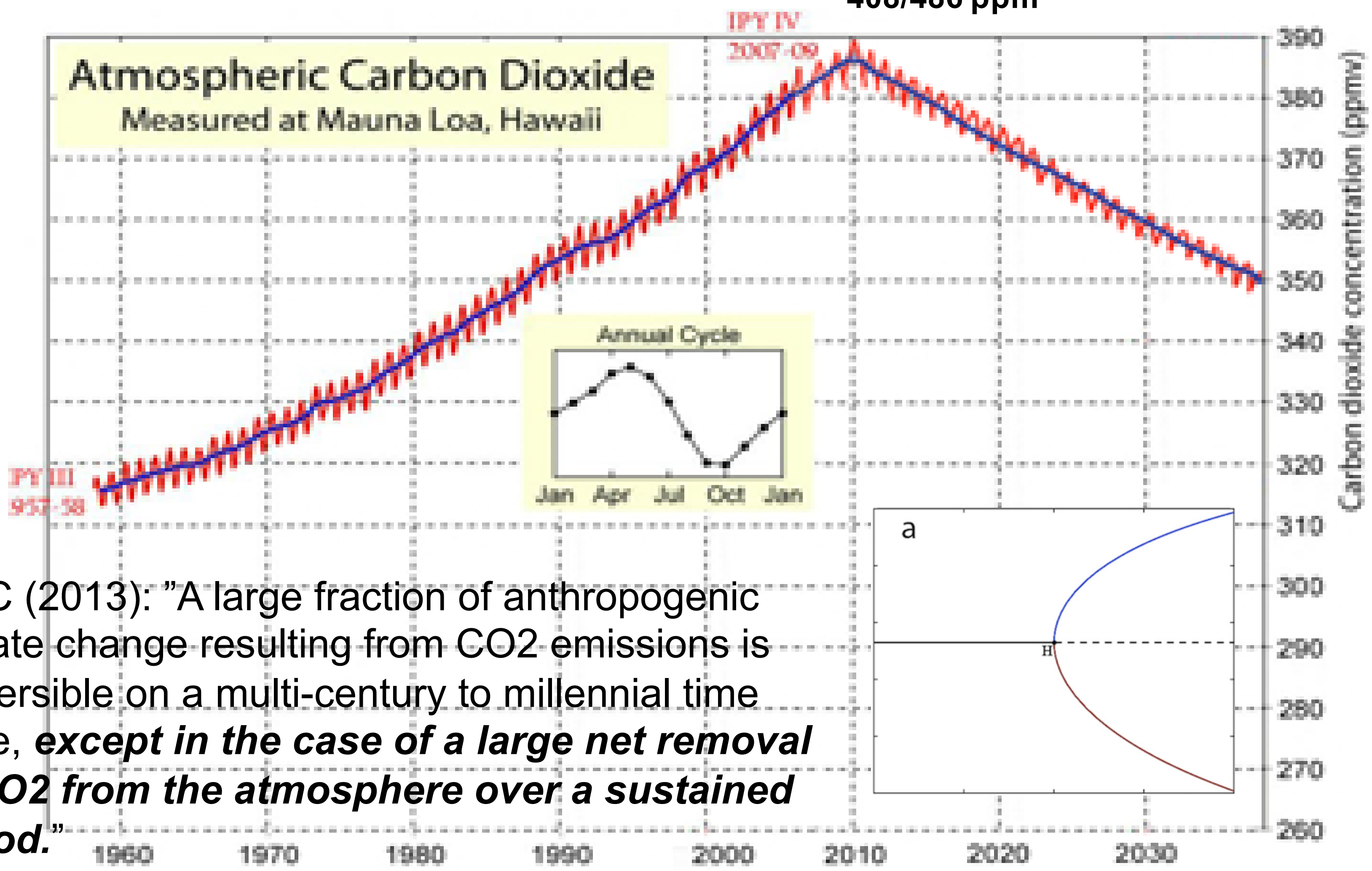
UCSFREC, Browns Valley, Ryals and Silver 2013

Estimated Additional Annual Soil Water Holding Capacity, Bare Ranch, With Carbon Farm Plan Implementation, Year 20

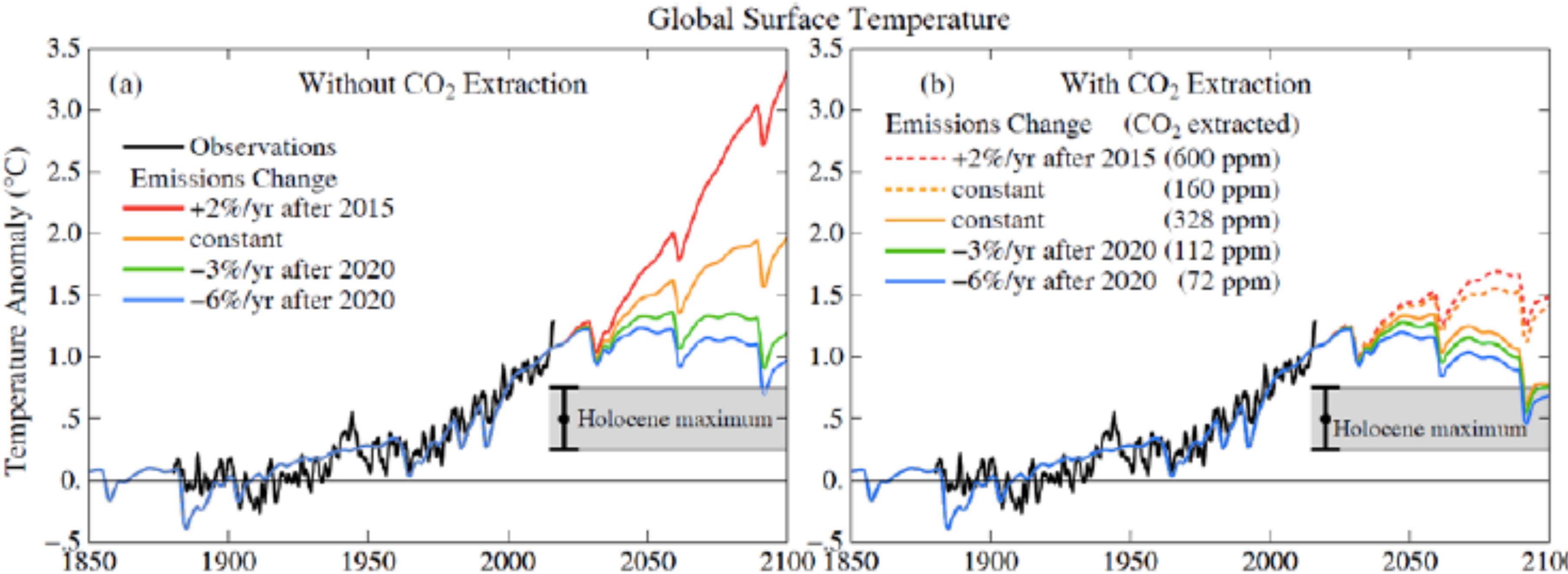
PRACTICE	DESCRIPTION	20 YEAR SOM INCREASE (Mg)	ANNUAL WHC INCREASE BY YEAR 20 (AF)
Compost application on Rangeland (NRCS practice standard in development)	Application of 1/4" of compost to 1600 acres of permanent pasture.	17344.09	158.99
Compost application on Cropland (590)	Application of compost to 537 acres of cropland to 5% SOM	11,955.00	109.59
Shelterbelts (380)	6.78 miles (16.44 acres) of 20' wide shelterbelts	98.35*	0.90*
Prescribed Grazing (528)	Grazing management to favor perennials and improve production on 4411 acres	8,610	78.93
Riparian Restoration	32.36 acres of riparian system along 4.45 miles	1,048.00*	9.60
Minimum-Tillage (345)	Conversion of tilled crop fields to minimum tillage on	1,134	10.39
Silvopasture (381)	Establish trees on approximately 134 acres of pasture	270**	2.35
Conversion of flood irrigation to pipe irrigation (443)	Conversion of flood to pipe irrigation on 1,000 acres permanent pasture	8,501.00	77.93
Range Planting (550)	No-till interseeding of forage species in irrigated pasture within the Saline Bottom ecological site (2,107 acres)	7,847.00	71.93
TOTAL		64,274.44	521.63

Reversing the ***unintentional*** industrial forcing of ***atmospheric C*** with ***intentional*** agricultural forcing of ***soil organic C***

408/486 ppm



IPCC (2013): "A large fraction of 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.***"

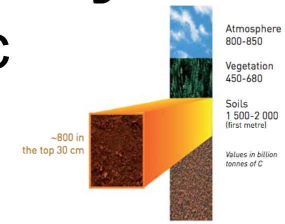


Hansen et al 2016

Simulated global temperature forcings under varying emissions and sequestration scenarios. Gray area is 95% confidence interval for centennially-smoothed Holocene maximum.

Increasing Soil C Storage in Working Lands is Critical for Climate Change Mitigation, Food Security and Agricultural Sustainability

- there is 2–3 times more carbon in soil organic
  - matter than in atmospheric CO_2;



▲ Terrestrial carbon stocks (Gt).

- 1.4 billion metric tons (Gt C) can be stored annually in agricultural soils, equivalent to an annual storage rate of 0.4% in topsoil;

- 80% of this potential could be reached for **\$100 per ton of CO_2**, *a price compatible with the 2° C global warming target*. (We know that even 1.5° C is too high)

Jean-Francois Soussana, French National Institute for Agricultural Research (INRA), *in:*
Land Management Practices for Carbon Dioxide Removal and Reliable Sequestration:
NAS Proceedings
ISBN null | DOI 10.17226/25037 March, 2018.

LAO LEGISLATIVE ANALYST'S OFFICE

Estimated Average GHG Reduction Cost Is High With Wide Variation Across Programs

Estimated Average Cost Per Ton of Reduction Varies Greatly

Program	Cost Per Ton[a]
Organics and recycling loans	$4
Forest health	4
Dairy digester research and development program	8
Organics composting/digestion grants	9
Forest legacy	10
Recycling manufacturing	15
Delta and coastal wetlands restoration	30
State water and efficiency and enhancement program	33
Clean vehicle rebates	46
Sustainable agricultural lands conservation	59
Mountain meadow ecosystems restoration	113
Urban and community forestry	116
Water-energy grant program	141
Affordable housing and sustainable communities	191
Single-family solar photovoltaics[b]	209
Transit and intercity rail capital	259
Single-family energy efficiency and solar water heating[b]	282
Large multifamily energy efficiency and renewables[b]	343
Enhanced fleet modernization program "plus-up"	414
Truck and bus voucher incentives	452
Incentives for public fleets pilot project for DACs	725
Overall Average	**$57**

[a] Calculated as the amount of cap-and-trade funds awarded to a program divided by the total estimated greenhouse gas (GHG) emission reductions from the projects that receive cap-and-trade funds.

[b] Assumes GHG reductions at the midpoint of the administration's estimated range.

DACs = disadvantaged communities.

Policy and Economic Supports for Carbon Farming

Regional

- BAAQMD: Approval of Rangeland Compost Protocol for CEQA; AMMP
- Bay Area Regional Climate Plans
- Bay Area IRWMP: 2015+ Priorities (Climate)
- NRCS-RCPP Partnership

State

Rangeland Compost Protocol

American Carbon Registry

CAPCOA

AB32 Scoping Plan (Ag and Working Lands)

CalRecycle Waste Sector Plan (compost incentives)

Natural Resources Agency/DoC **(SALC)**

Cap & Trade Revenue

Greenhouse Gas Reduction Fund

Healthy Soils Initiative CDFA 2017 7.5 M

State Funding Programs

Wildlife Conservation Board

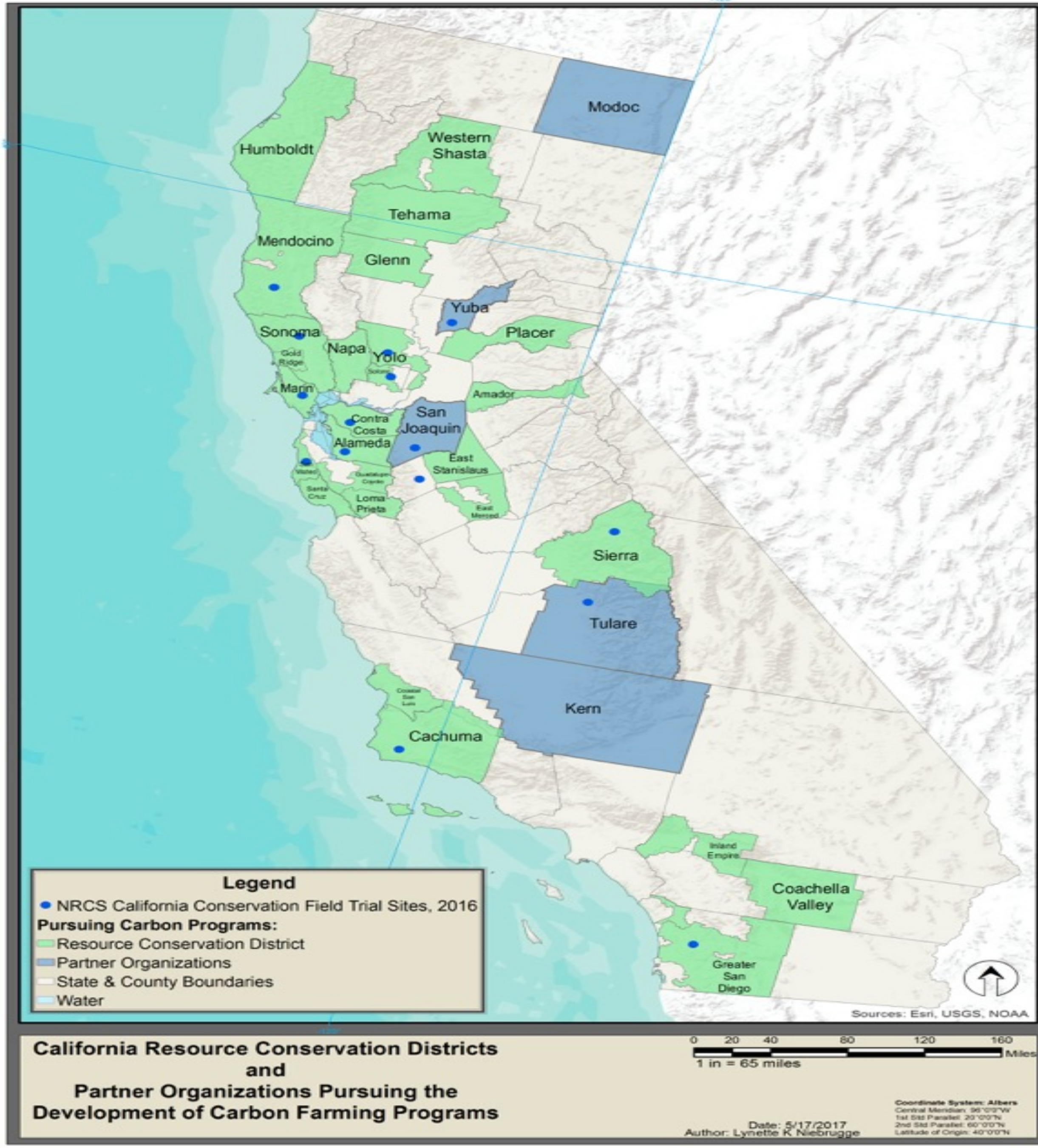
State Coastal Conservancy

Fish and Wildlife

Global

emerging markets for climate-beneficial products

Scaling Up: Carbon Farming with CA Resource Conservation Districts



Good News: Excess Carbon Dioxide in the Atmosphere Can Be Transformed to Food, Fuel, Flora, Fiber, ***and Soil Organic Matter***, Yielding Production, Soil Health and other Ecosystem Benefits ***and*** New Economic Opportunities for Agriculture

Photo: Abe Collins, CarbonFarmersofAmerica.org

Thank you

www.carboncycle.org

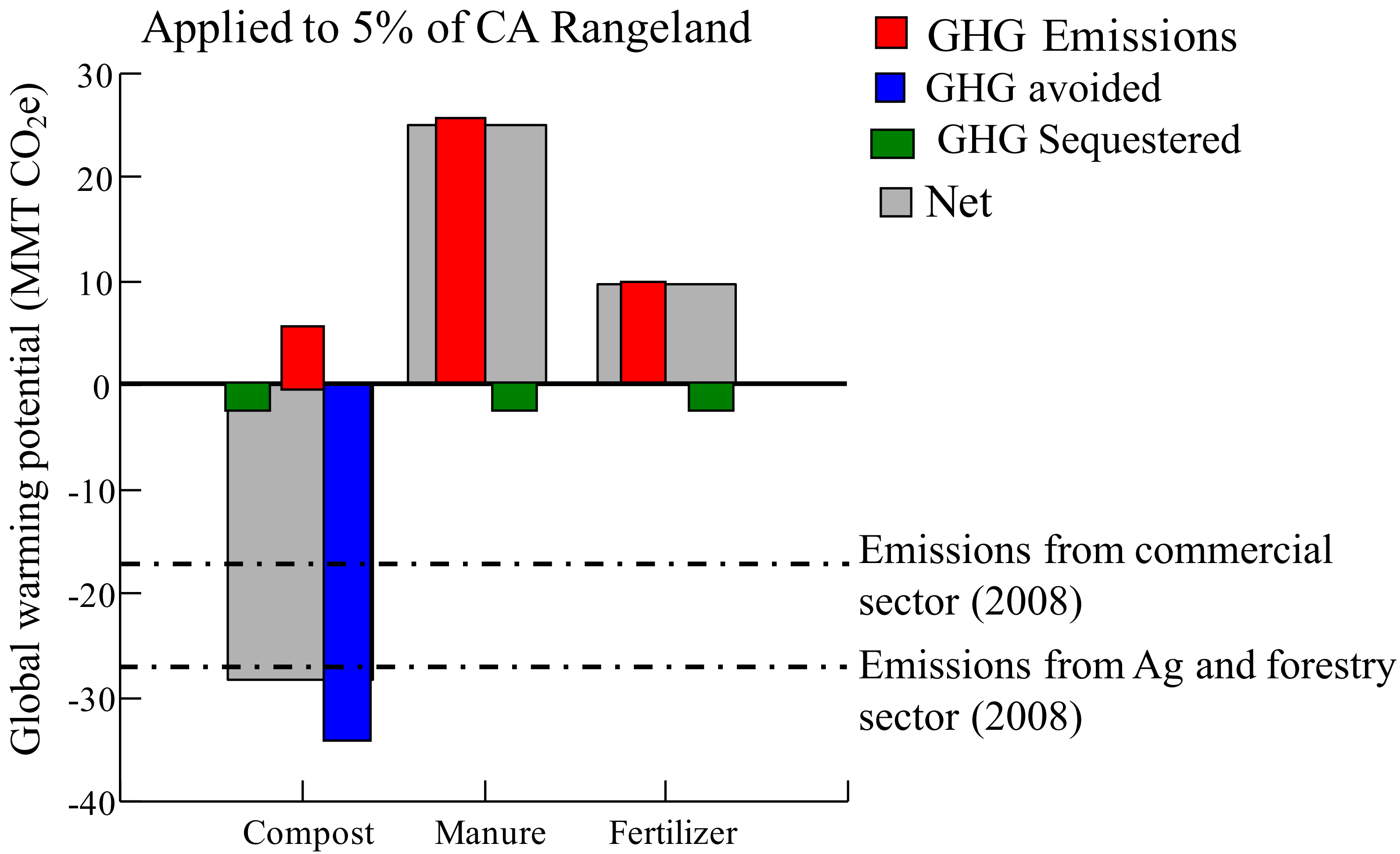
www.MarinCarbonProject.org

Jeff Creque

jcreque@carboncycle.org

The Rhizosphere

Life Cycle Assessment suggests significant GHG mitigation potential statewide

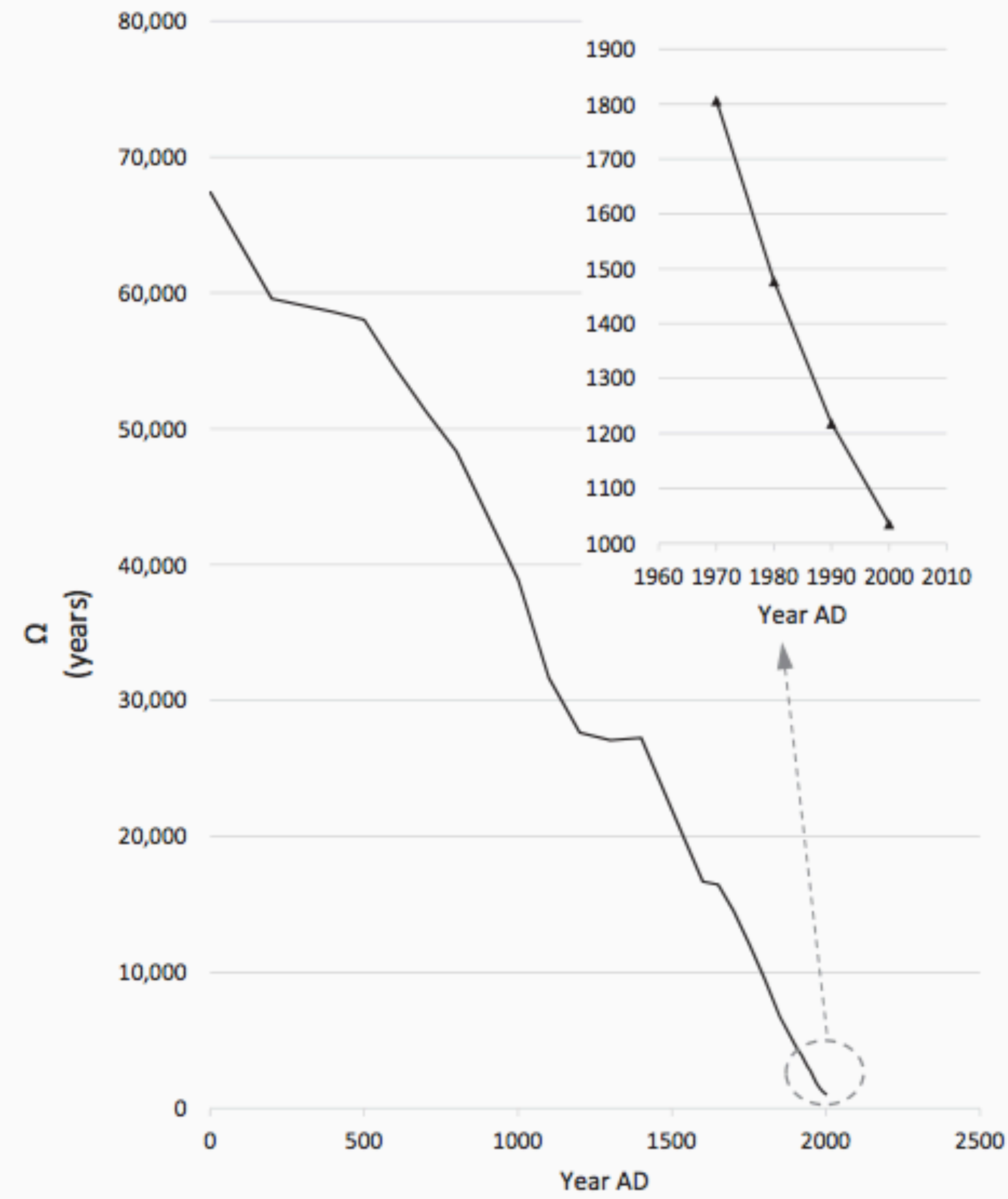


DeLonge et al. 2013

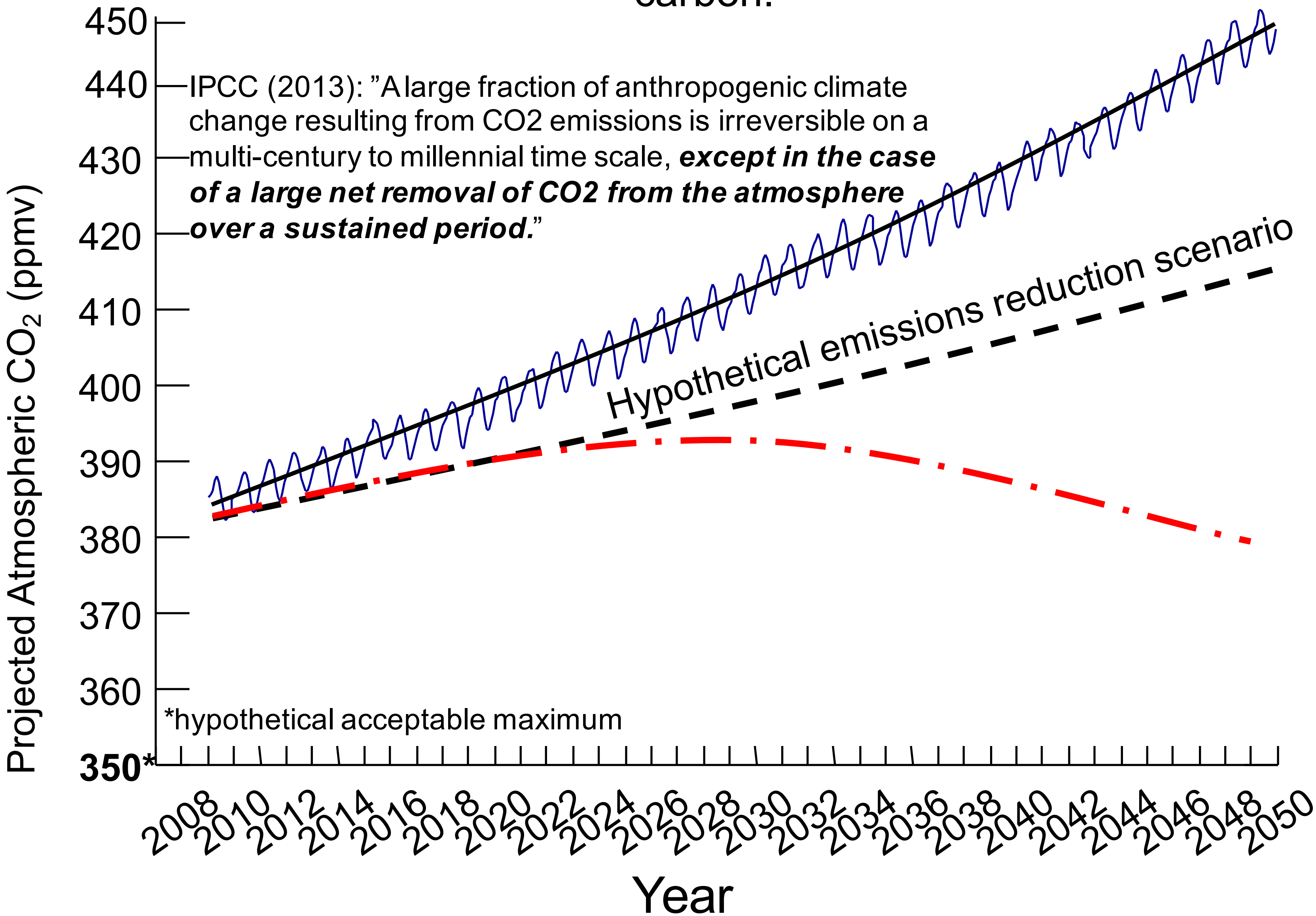
A Disturbing Trend (2)

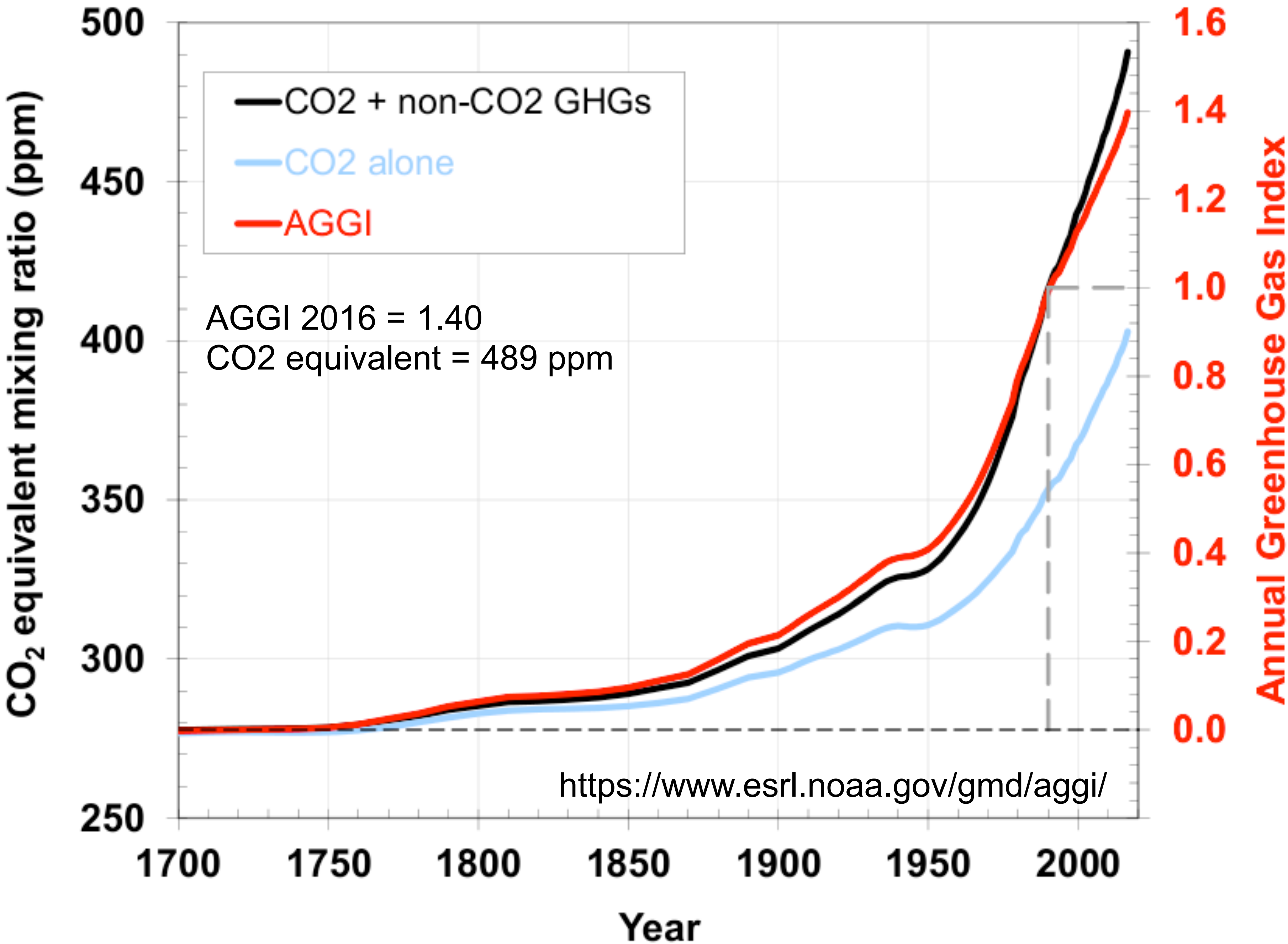
Years of phytomass potentially available to feed the global human population. Calculated from the total stored phytomass energy of the planet divided by the metabolic energy needs of the global population for 1 y (i.e., joules/joules per year = years) assuming an 8.4-MJ per capita daily diet for the entire year. Rapidly decreasing trend line indicates increasing consumption of phytomass by humankind. Little margin remains to safely continue the current trend.

(Schramski et al 2015)



We can ***only*** meet our GHG reduction goals by investing in our **soils and working land vegetation** as major sinks for atmospheric carbon.





CO2 + non-CO2 GHGs
CO2 alone
AGGI
AGGI 2016 = 1.40
CO2 equivalent = 489 ppm
https://www.esrl.noaa.gov/gmd/aggi/
CO_2 equivalent mixing ratio (ppm)
Annual Greenhouse Gas Index
Year
500
450
400
350
300
250
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1700
1750
1800
1850
1900
1950
2000

The 4‰ Initiative:

Ministry of Agriculture, Agrifood and Forestry, France:

Increasing global soil OM by 0.4% annually would offset *all* global CO_2 emissions

- the "*4‰ Initiative: soils for food security and climate*" aims to show that **food security and combating climate change are complementary** and to support agriculture in providing solutions to climate change while feeding the world.

- http://agriculture.gouv.fr/agriculture-et-foret/environnement-et-climat

The American Carbon Registry™

Methodology for Compost Additions to Grazed Grasslands

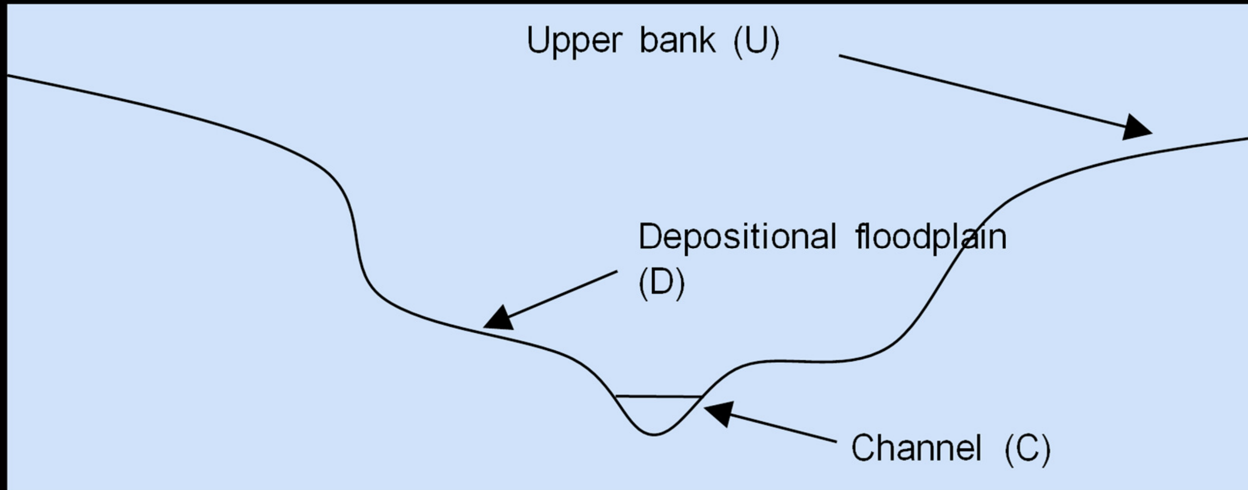
Version 1.0

October 2014

A nonprofit enterprise of

WINROCK INTERNATIONAL

Stream Restoration


Upper bank (U)
Depositional floodplain (D)
Channel (C)

Potential terrestrial carbon sequestration on an 8,000 acre Santa Barbara Ranch through implementation of conservation practices identified through the Carbon Farm Planning Process

Practice	Average Annual CO_2e Reduction	20 yr CO_2e Reduction	CO_2e Reduction at Maturity
Rangeland Compost	638 Mg	98,847 Mg	162,619 Mg (30 years)
Cropland Compost (590)	2,060 Mg.	23,200 Mg	43,374 Mg at 5% SOM
Shelterbelts (380)	98 Mg CO_2e;	1,960 Mg	7,840-19,260 Mg at 80 years.
Hedgerows (422)	6 Mg CO_2e	120 Mg	120 Mg CO_2e
Prescribed Grazing (528)	1,460 Mg	29,200	29,200
Riparian Restoration	410 to 1,725 Mg	6,144-25,867 Mg at 15 years	18,431-188,117 Mg at 45 years.
No Till (329)	39 Mg	780 Mg	780 Mg
Minimum-Tillage (345)	100 Mg	2,000 Mg	2,000 Mg
Silvopasture (381)	660 Mg	13,200 Mg	214,000 Mg
Nutrient Management (590)	610 Mg	12,200 Mg	48,800
Totals	**6,081- 7,396 Mg**	**187,651 - 207,374 Mg**	**527,164- 708,270 Mg**

Estimated Additional Soil Water Holding Capacity With Carbon Farm Plan Implementation, Cachuma Ranch, (8,000 acres) Santa Barbara County, CA

Table 15. Estimated Additional Soil Water Holding Capacity (WHC) With Plan Implementation

PRACTICE	DESCRIPTION	20 YEAR SOM INCREASE (Mg)	ANNUAL WHC INCREASE BY YEAR 20 (AF)
Compost application on Rangeland (NRCS practice standard in development)	Application of 1/4" of compost to 4300 acres of permanent pasture.	53867 Mg	493.78
Compost application on Cropland (590)	Application of 1" of compost to 617 acres of cropland.	23637.05 Mg	216.67
Shelterbelt (380)	13.6 miles (90 acres) of 50' wide shelterbelts	1068.12 Mg	9.79
Prescribed Grazing (528)	Grazing management to favor perennials and improve production on 7300 acres.	15912.80 Mg	145.86
Riparian Restoration	Restoration of 94 acres of riparian system along 7.75 miles of stream corridor Planting of native trees and shrubs.	3043.23 Mg (derived from Lewis et al 2015)[1]	27.89
No-till system-Tillage Management (512).	Convert tilled forage fields to permanent pasture; minimize tillage on croplands	425.06 Mg	3.89
Minimum-Tillage (345)	Conversion of tilled crop fields to minimum tillage on	1089.91 Mg	9.99
Silvopasture (381)	Establish trees on approximately 1,000 acres) of treeless pasture.	4027.24 Mg (derived from Gaman 2008)	36.91
TOTAL		**103,070.36**	**917.52**

[1] Lewis et al 2015 model coefficients indicate annual increases of soil carbon = 0.2 kg/m^2. 1 acre = 4046.85642 m^2.

The Carbon-Soil-Water-Climate Connection

If California's working lands, i.e., 46 million acres of grasslands, pastures and arable lands, achieved even a 1% increase in SOC (from 1% to 2%) in the plow layer alone, the associated water holding capacity increase would be roughly 7.6 million acre feet and the CO_2e sequestered would be 1.5 Billion tonnes.

Across 10 million arable acres of CA, this represents 200 million metric tons of SOM, or 366 million metric tons of CO_2e and 1.6 million acre feet of water.

(Recall: the French 4%% Initiative calls for an ***annual*** SOM increase of 0.4%)

Assumptions:
based on the plow layer (top 6.7" of soil) only; including deeper soil strata will increase potentials accordingly;
1% increase in SOM results in 1 acre-inch increase in soil water holding capacity per acre;
1% increase in SOC represents 2% increase in SOM;
1 metric ton (2,200 lbs) of soil C represents 3.67 metric tons of CO_2e;
1% increase in (plow layer only) SOC is about 10 short tons or 9 metric tons SOC/acre.

NRCS Carbon-Conservation Practices

- 34 Carbon-Beneficial Practices:
- COMET-Planner.com

COMET-PLANNER PRACTICES 2015

Cropland Management
Conventional Tillage to No-Till
Conventional Tillage to Reduced Till
Improved Nutrient Management
Conservation Crop Rotation
Cover Crops
Strip cropping
Mulching
Combustion System Improvement (Improved Fuel Efficiency of Farm Equipment)

Cropland to Herbaceous Cover
Conservation Cover
Forage and Biomass Planting
Herbaceous Wind Barriers
Vegetative Barriers
Riparian Herbaceous Cover
Contour Buffer Strips
Field Border
Filter Strip
Grassed Waterway

Cropland to Woody Cover
Tree/Shrub Establishment
Windbreak/Shelterbelt Establishment
Windbreak/Shelterbelt Renovation
Riparian Forest Buffer Establishment
Hedgerow Planting
Alley Cropping
Multistory Cropping

Grazing Lands
Range Planting
Silvopasture Establishment on Grazed Grasslands
Restoring Degraded Rangeland with Compost Addition
Prescribed Grazing

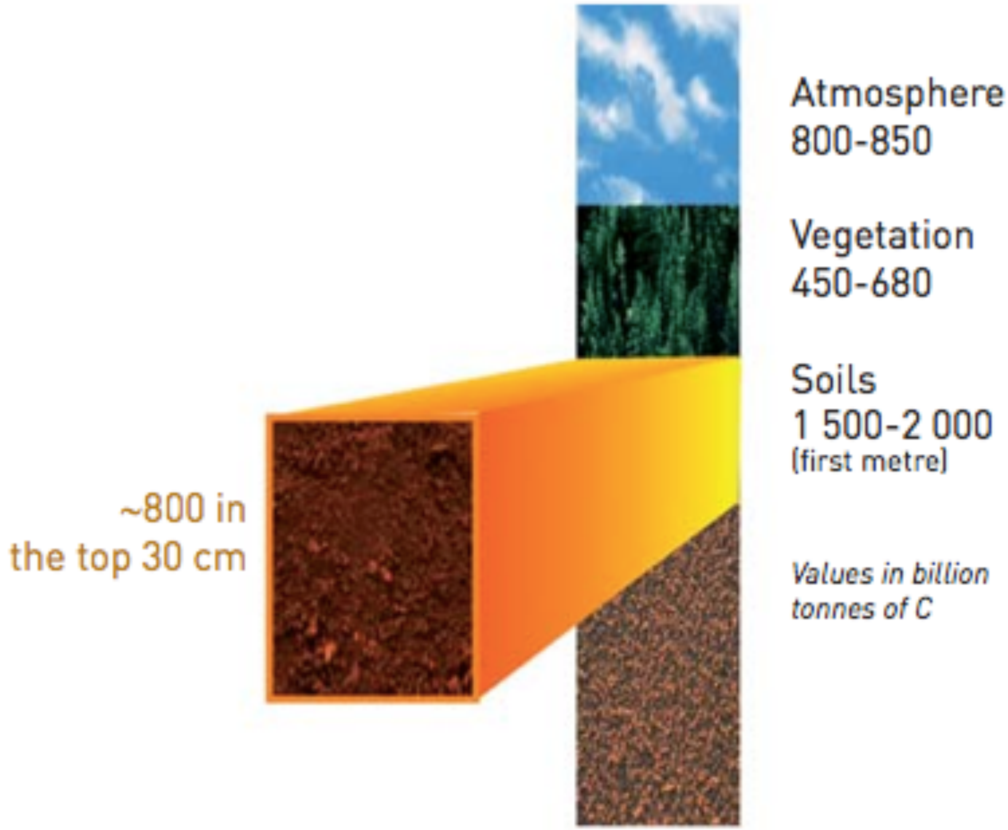
Restoration of Disturbed Lands
Land Reclamation – Abandoned Mine Land
Land Reclamation – Currently Mined Land
Land Reclamation – Landslide Treatment
Critical Area Planting
Riparian Restoration

Carbon dioxide has a strange property. It transmits visible light but it absorbs the infrared radiation which is emitted from the earth. Its presence in the atmosphere causes a greenhouse effect [....] It has been calculated that a temperature rise corresponding to a 10 per cent increase in carbon dioxide will be sufficient to melt the icecap and submerge New York. All the coastal cities would be covered, and since a considerable percentage of the human race lives in coastal regions, I think that this chemical contamination is more serious than most people tend to believe.

At present the carbon dioxide in the atmosphere has risen by 2 per cent over normal. By 1970, it will be perhaps 4 per cent, by 1980, 8 per cent, by 1990, 16 per cent [about 360 parts per million, by Teller's accounting]. *if we keep on with our exponential rise in the use of purely conventional fuels. By that time, there will be a serious additional impediment for the radiation leaving the earth. Our planet will get a little warmer. It is hard to say whether it will be 2 degrees Fahrenheit or only one or 5.*

But when the temperature does rise by a few degrees over the whole globe, there is a possibility that the icecaps will start melting and the level of the oceans will begin to rise. Well, I don't know whether they will cover the Empire State Building or not, but anyone can calculate it by looking at the map and noting that the icecaps over Greenland and over Antarctica are perhaps five thousand feet thick.

Edward Teller, 1959

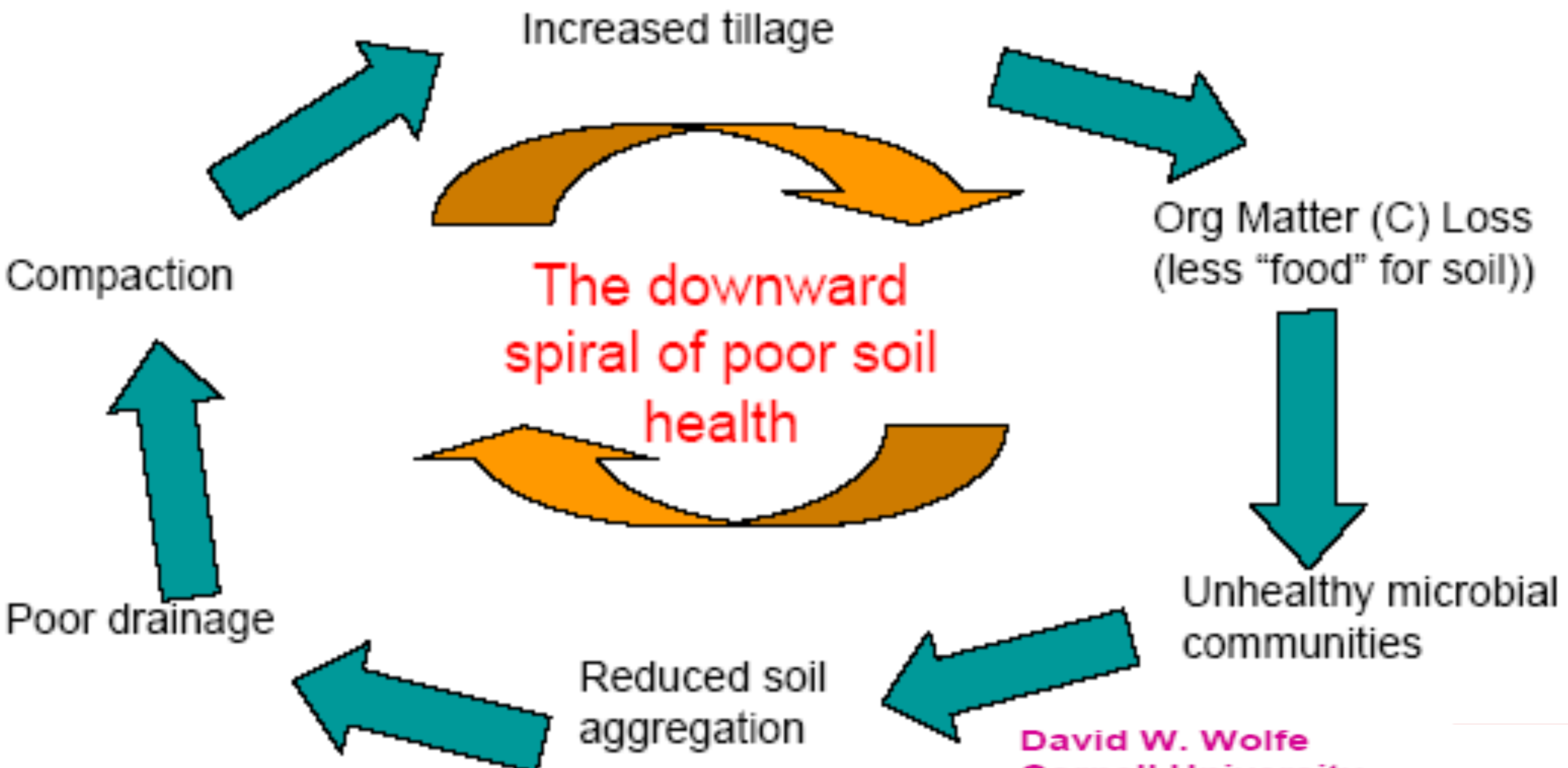


▲ Terrestrial carbon stocks (Gt).


Prescribed grazing; high intensity- short duration grazing; time-control adaptive multi-padddock grazing; rational grazing…

Tillage, Soil Health, and Carbon Sequestration

Assessing the whole soil system

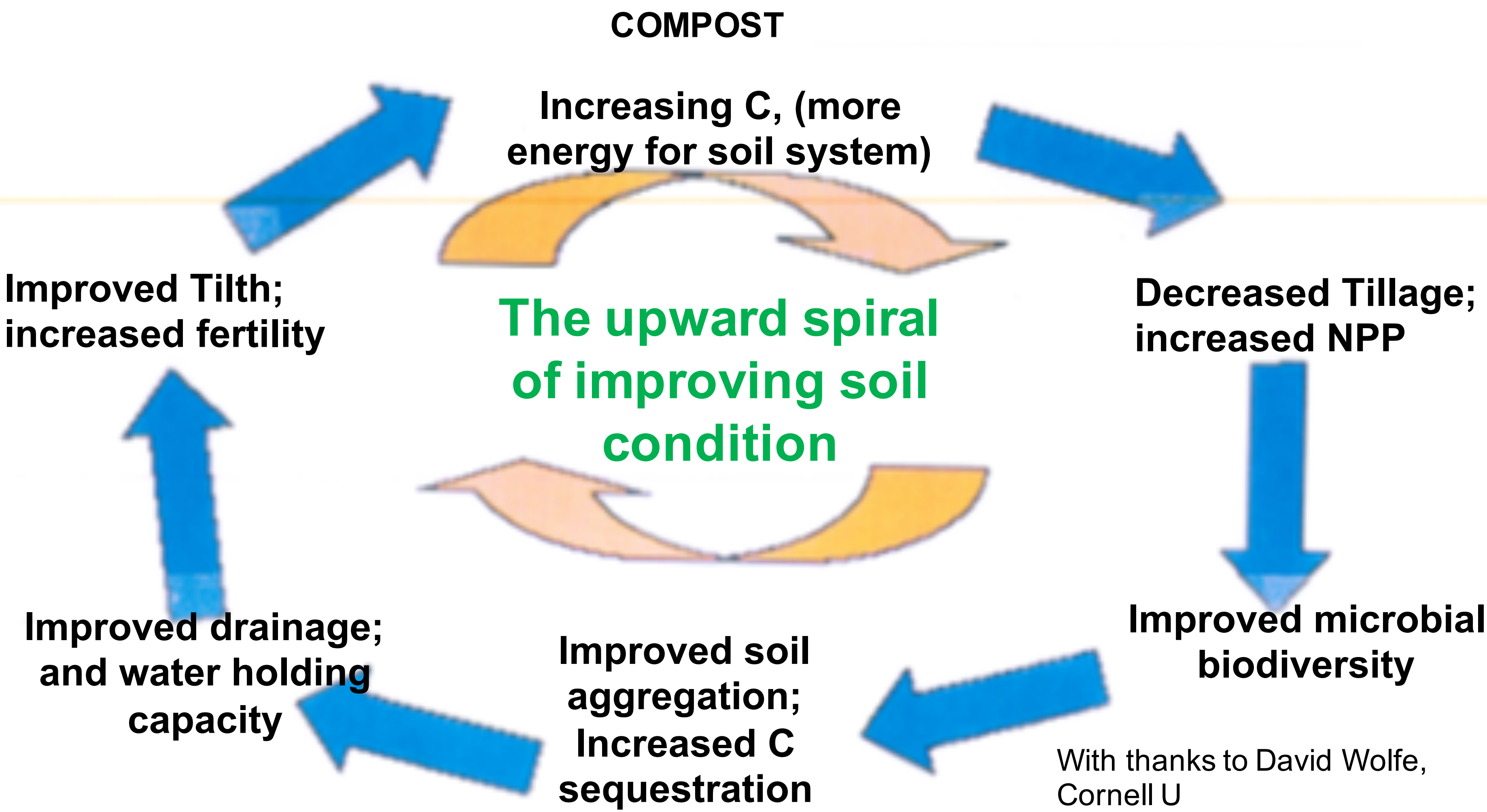


David W. Wolfe
Cornell University
dww5@cornell.edu
www.climateandfarming.org

Soil Health and Carbon Sequestration

Soil C and System Change

Assessing the whole soil system



A SUCCESSFUL CARBON FARM PLAN CULTIVATES CARBON FARMERS!

Photo Credit: Marin Agriculture Land Trust

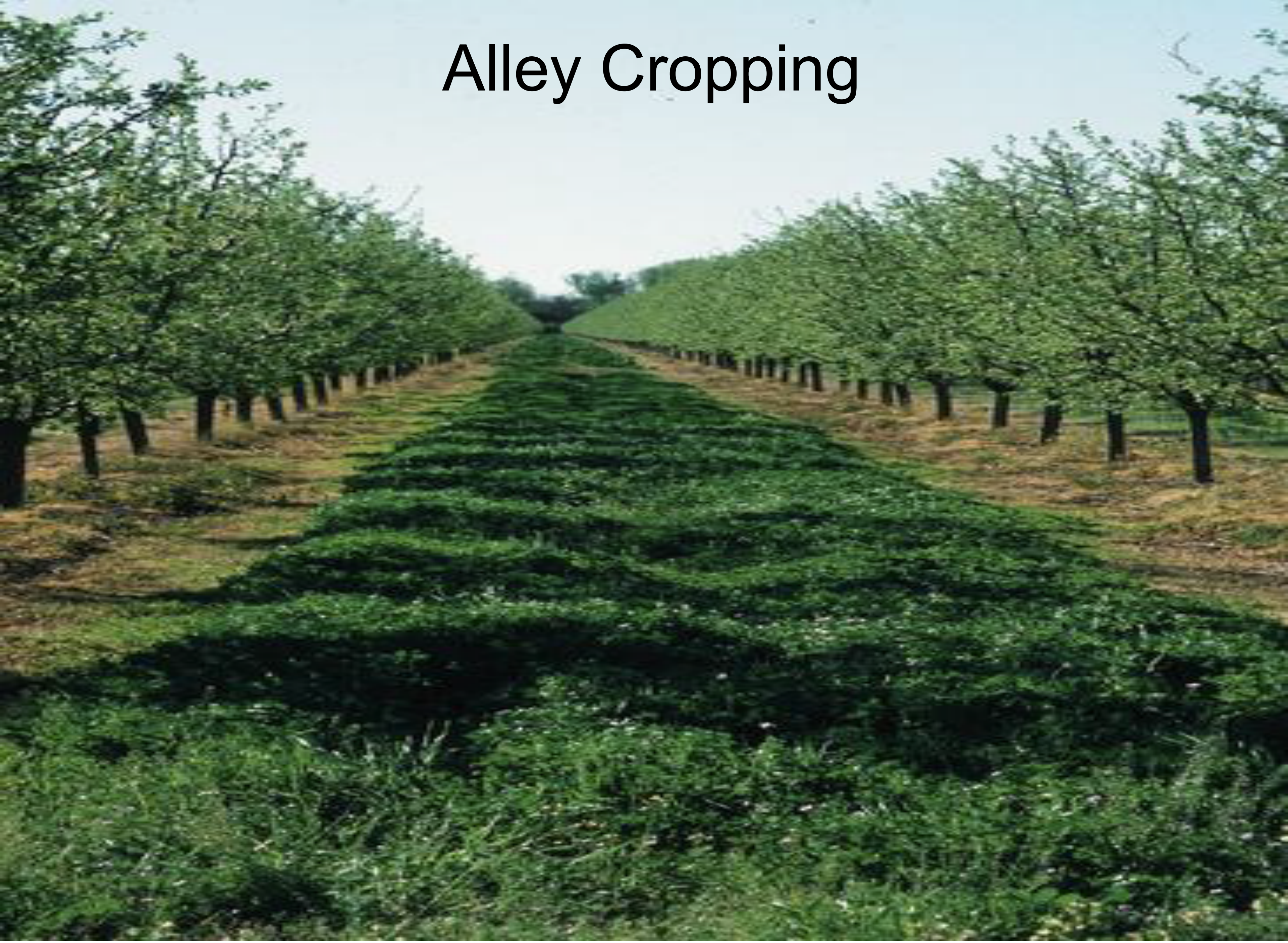
Conventional Tillage to No-Till

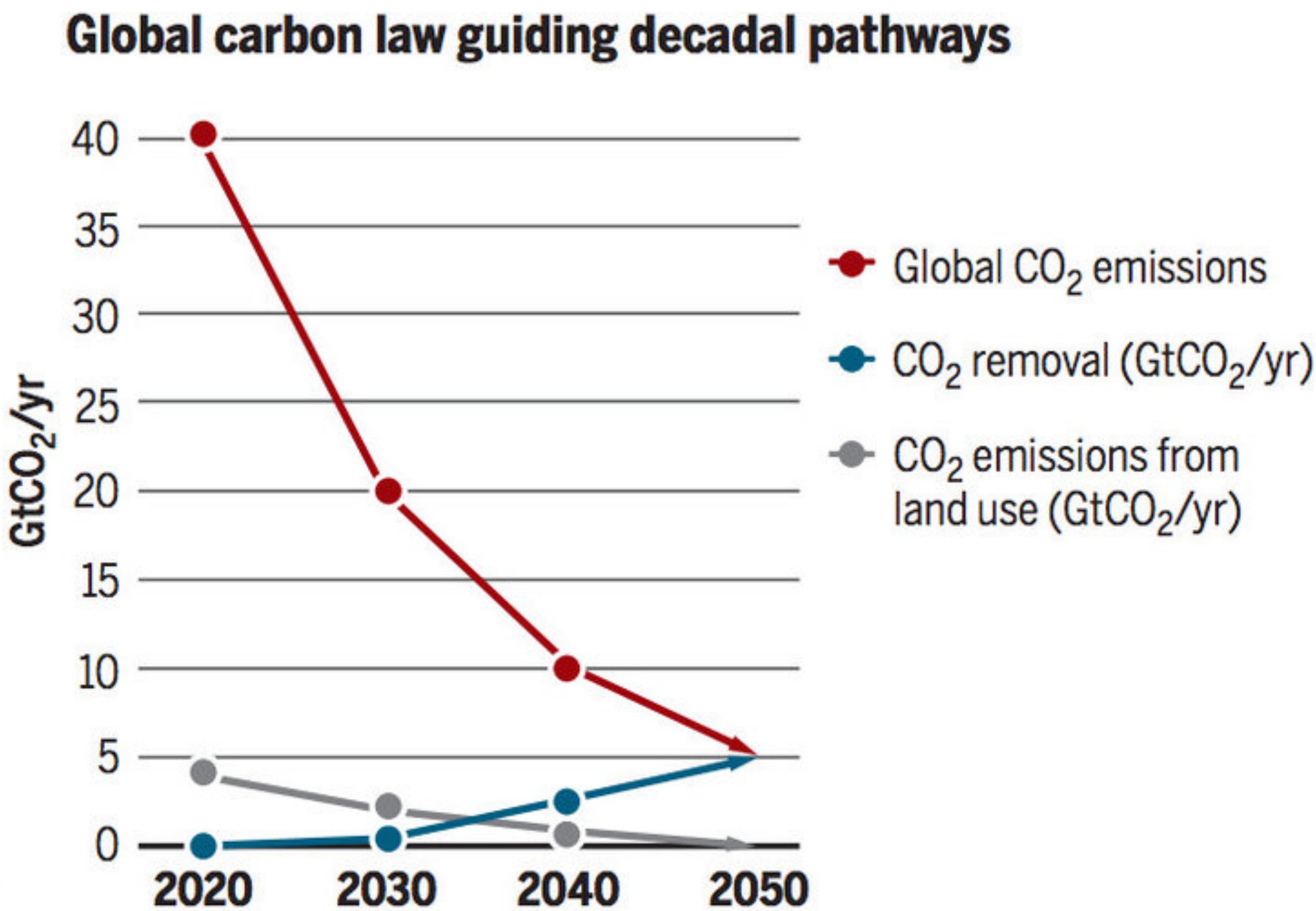
Cover Crops


Mulching

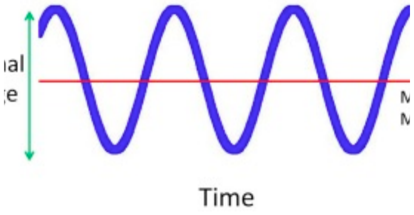

Grassed Waterway

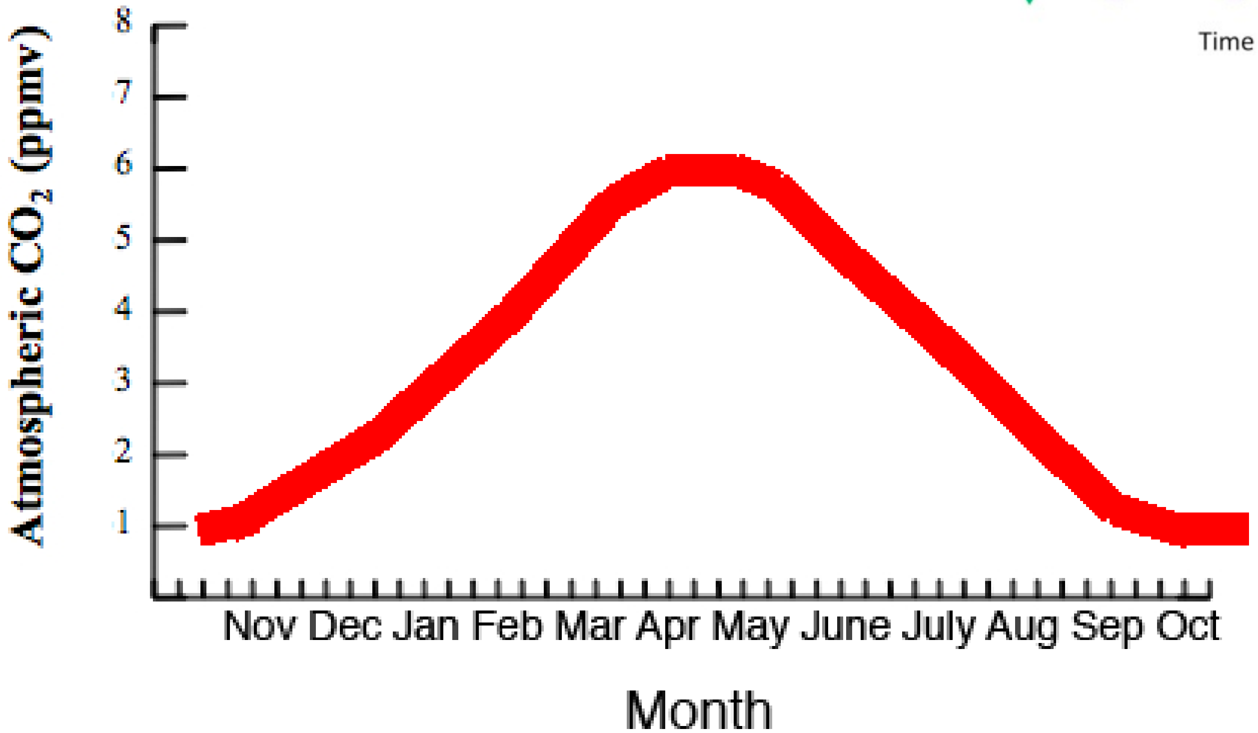
Alley Cropping



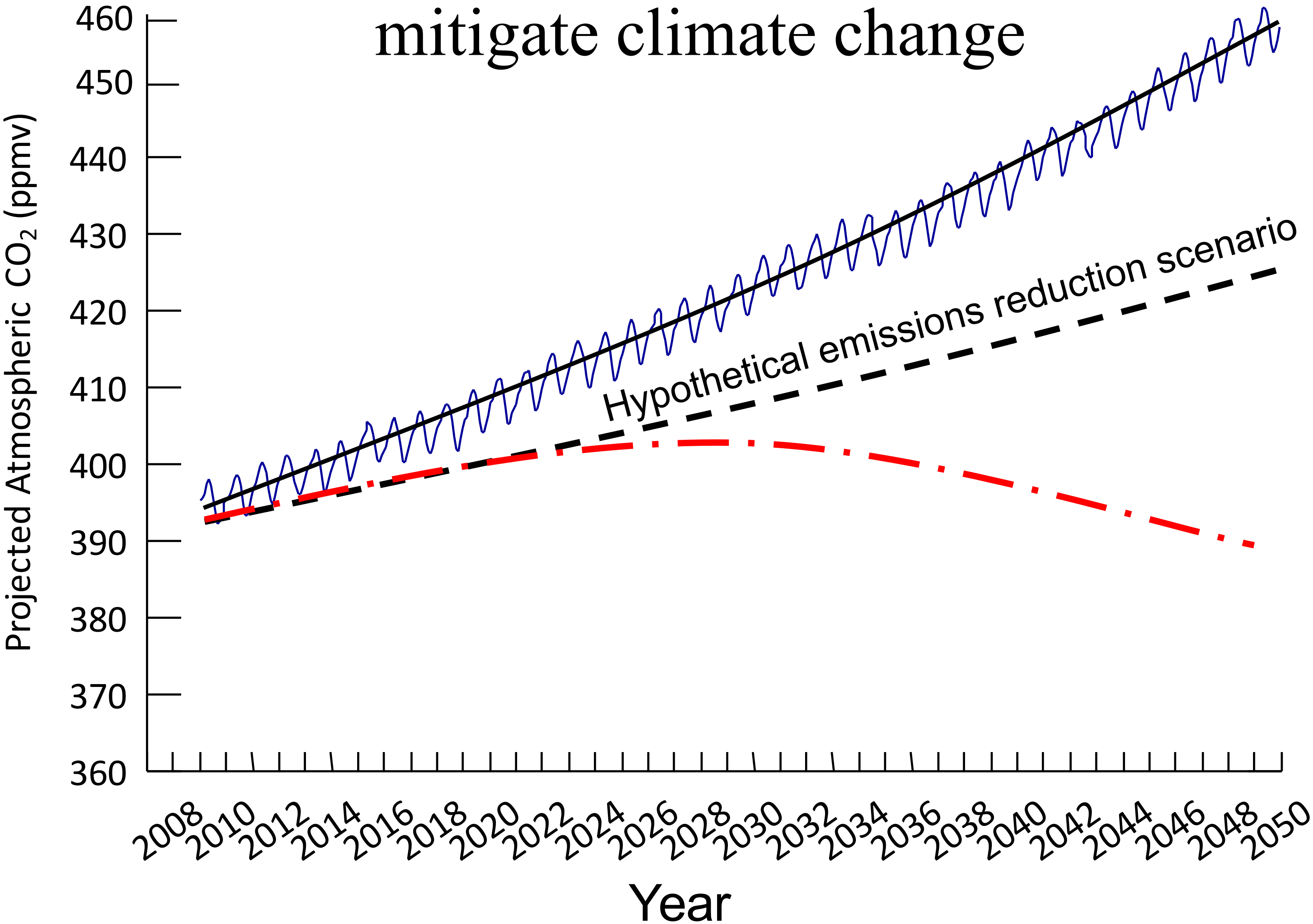

Global carbon law guiding decadal pathways
40
35
30
25
20
15
10
5
0
$GtCO_2$/yr
2020
2030
2040
2050
Global CO_2 emissions
CO_2 removal ($GtCO_2$/yr)
CO_2 emissions from land use ($GtCO_2$/yr)

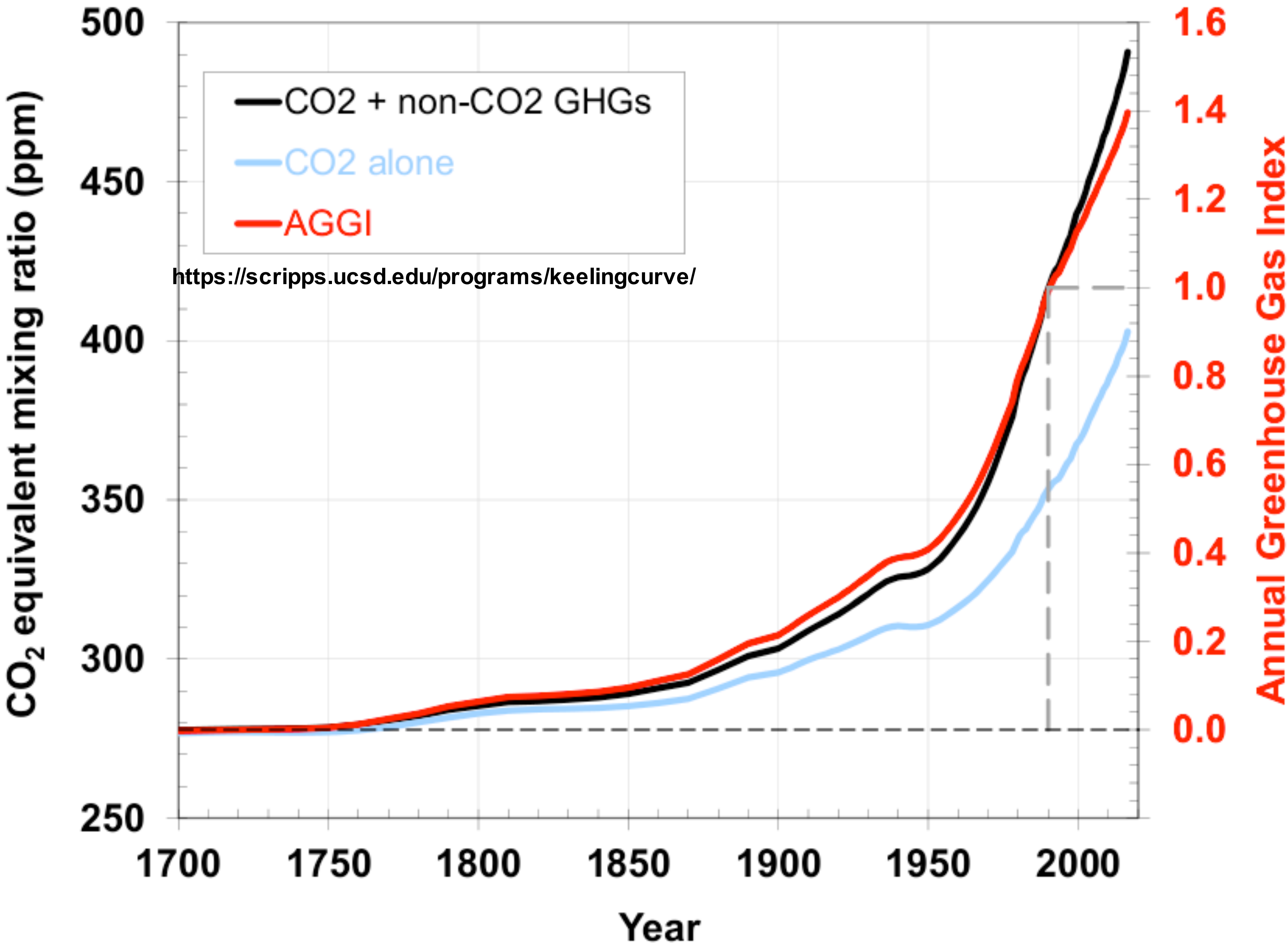
Annual Global CO2 Flux





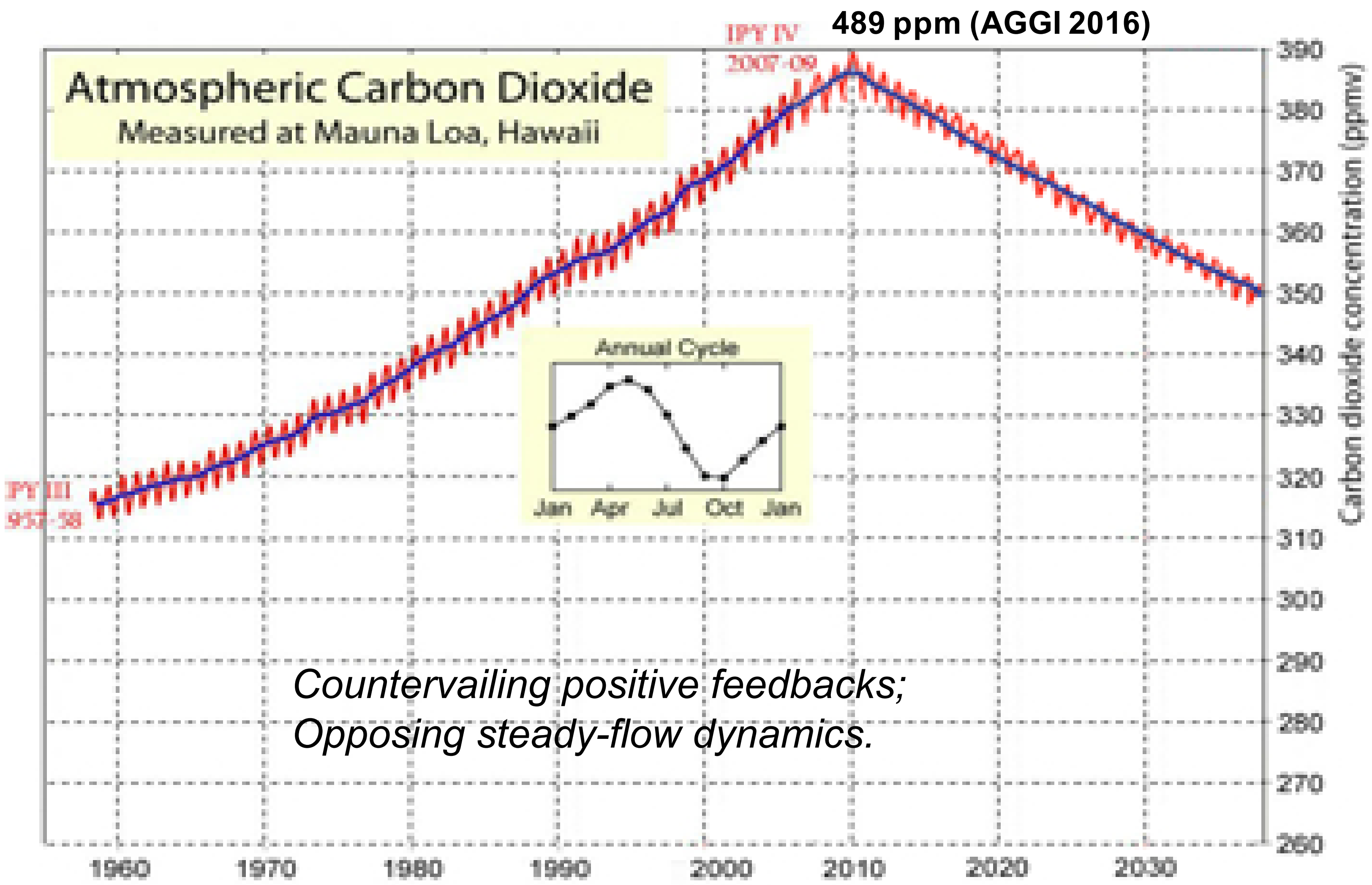
Bad News: because of positive feedbacks already occurring, reducing emissions ***alone*** will not mitigate climate change





CO2 + non-CO2 GHGs
CO2 alone
AGGI
https://scripps.ucsd.edu/programs/keelingcurve/
CO_2 equivalent mixing ratio (ppm)
Annual Greenhouse Gas Index
Year
500
450
400
350
300
250
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1700
1750
1800
1850
1900
1950
2000

Measured effect of ***unintentional*** anthropogenic forcing of atmospheric C, with hypothetical effect of ***intentional*** anthropogenic forcing of soil organic C at the global scale; "Positive Deviance"



Estimated 2017 (Pre-Project) Livestock Emissions, Marin Dairy

(from: Owen and Silver 2014; CH4 and N20 expressed as Mg CO2e/year)

Manure Pond: Assumes 397 AUs contributing to pond manure year round

CH_4: 368 (±193) kg CH_4 x 397 AU = 146,096 kg CH_4 x 34 = **4,967 Mg CO2e/yr**

N_2O: 0.9 (±0.5) kg N_2O x 397 AU = 357.3 kg x 298 = **106 Mg CO2e/yr**

Enteric Fermentation: (Assumes 616 AUs; milkers, dry cows, calves, bulls, heifers)

CH_4: ~120 kg CH_4 x 616 AU = 73,920 kg x 34 = **2,513 Mg CO2e/yr**

Corrals: (assumes manure from 616 x 0.2 AUs)

N_2O: 1.5 (± 0.8) kg N_2O x 123 AU = 184.5 kg x 298 = **55 Mg CO2e/yr**

Barns: (Assumes 450 milkers plus 75 calves = 475 AU housed 80% of the time)

N_2O: 10 (± 6) kg N_2O x 380 AU = 3,800 kg x 298 = **1,132 Mg CO2e/yr.**

Solid Manure Piles (assumes 616 x 0.2 AUs)

CH_4: 13 (±11) kg CH_4 x 123 AU = 1,599 kg x 34 = **54 Mg CO2e**

N_2O: 1.1 (± 0.7) kg N_2O x 123 = 135.3 kg x 298 = **40 Mg CO2e**

Total Estimated Dairy 2017 manure + enteric emissions: 8,869 Mg CO2e/year.

Estimated 2017 Non-Enteric (manure) emissions: 6,356 Mg CO2e/year.

Assumptions:
397 AU: 450 * 0.8 = 397; 20% of milking herd manure goes to pasture
616; includes all classes, adjusted to AUs
Corrals and manure piles are assumed to receive 20% of total manure.