Scenario 300: Reducing Atmospheric CO_2 to 300 ppm by 2061.

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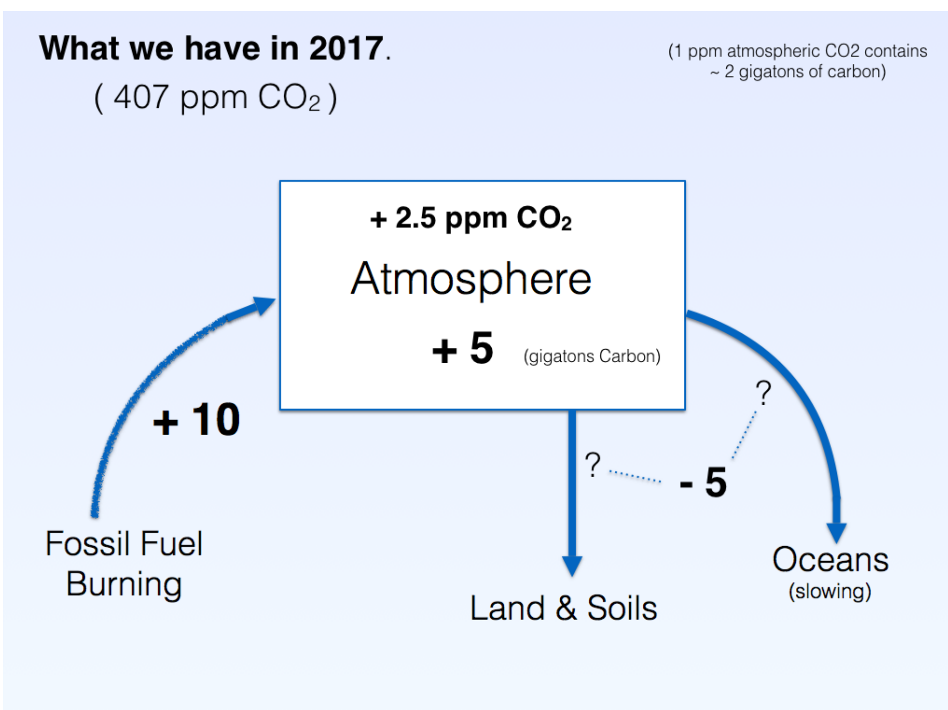
Danger in the Arctic: The Urgency of the Climate Situation

Atmospheric carbon dioxide levels have increased from 315 ppm in 1958 to 407 ppm in 2017. this is the first time in at least 2 million years that these levels have been reached on planet Earth. In the last five years, the yearly rise is accelerating and is now about a 2.5 ppm increase per year. At that rate, CO_2 will exceed 500 ppm before 2060. Evidence of the impact of rising greenhouse gases is the rapid loss of mountain glacier ice and the accelerating loss of the Arctic ice cap. As the Arctic Ocean loses its ice cover in the summers, it is warming the seawater and releasing large amounts of methane gas to the atmosphere, particularly from the shallow East Siberian Shelf. Remaining at 400 ppm will continue to warm and further acidify all the oceans. The possibility of a runaway greenhouse spike from the release of trapped methane in methane hydrates and permafrost might be slight at the present time, but it will increase as the oceans warm. A "Business as Usual" increase to 500 ppm will accelerate that possibility significantly to a very dangerous level.

Slide #1 below summarizes the present situation. Fossil fuel burning is adding 10 gigatons (billion tons) of carbon to the atmosphere each year. About half of that is being absorbed by processes on the land and its soils, or in the oceans. The increase in CO_2 is acidifying the ocean and ocean warming is slowing the ocean's ability to absorb more. (It's like warming your soda drink.) It would be good to reduce the stress on the oceans by burping out excess CO_2. Reducing fossil fuel emissions will help, but not nearly enough return to 300 ppm within a safe time frame. **Managing the Land in better ways appears to be the only option to drawdown enough carbon within a few decades. Is this a reasonable possibility?**

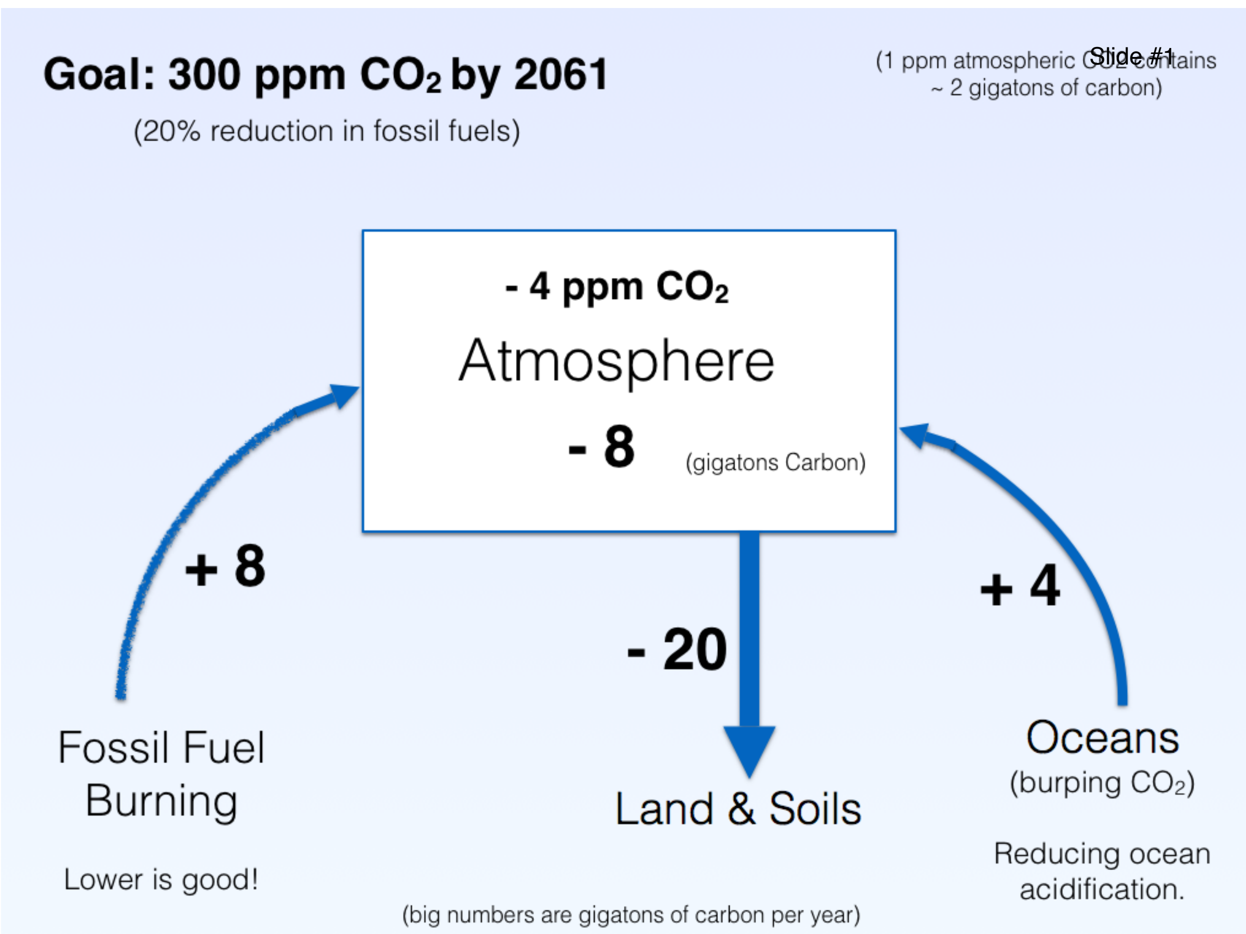


Scenario 300: Land ecosystems must drawdown 20 gigatons of carbon from the atmosphere on a yearly basis to reach 300 by 2061.

Scenario 300 proposes that the restoration of degraded ecosystems of several types could capture enough carbon in soils to reduce the atmospheric CO_2 concentration from about 410 ppm in 2018 to 300 ppm before Halley's Comet returns in 2061. Millennials born at the beginning of the 21st Century will be reaching their retirement years and it is hoped that they will have a future to look forward to. Seeing this famous Comet return for their first viewing could be a time of celebration for the many tough choices they had to face and a time of reflection at their successes and failures. How can our generation help them be prepared for what is coming?

To reach this monumental goal of 300 within a timeframe of about four decades would require good management on about half of the available lands. If the net soil carbon increase reached 20 billion tons, it would be enough to rapidly draw down atmospheric CO_2 levels by several ppm every year. Is there enough land to do this? Does nature have the capacity with good human management?

The Slide #2 below proposes that we could achieve a 4 ppm yearly drawdown if the land ecosystems captured 20 gigatons (GT) of carbon each year. As the CO_2 levels begin to drop, the reduced partial pressure of CO_2 in the atmosphere will eventually allow the oceans to "burp" out some CO_2 to the atmosphere. How much of the CO_2 reduction in the atmosphere will be neutralized by CO_2 coming out of the oceans? I have estimated one third of the net difference between carbon captured by the soils and the fossil fuels being burned. This number will vary



Slide #2

depending on factors like water temperatures and it will slow down the return to 300 ppm. The good news is that ocean acidification will gradually be reversed. Slide #2 shows a 20% reduction in fossil fuel burning, down from 10 GT to 8 GT. One third of the difference between land and fossil fuels is 4 GT coming out of the oceans. If this estimate is too low, then the return to 300 ppm will take longer and oceans acidification will reduced faster. If the estimate is too high, the reverse is true. Slide #2 shows that CO_2 can come down by 40 ppm in a decade **if we can learn how to capture 20 GT of carbon in the land ecosystems and soils yearly.**

Do Earth's ecosystems have the capacity to capture 20 GT of carbon yearly?

The "Road Map to 300" (slide #3) below gives several pathways to achieve this. While there are potentially 29 billion acres to work with, this scenario uses only about half of this potential. If half of the available land is managed well in a holistic way, the Earth still has plenty of capacity to do this. In the Road Map, there are 13.5 billion acres in the "Half Earth" column. The final column shows that these 13.5 billion acres could capture 26 GT of carbon annually.

Road Map to 300 - Several Pathways

(Half Earth Plan - 5% to 10% wetlands is essential in grasslands, farms and forests.)

Ecosystem Land Type	Potential Billions of Acres	"Half Earth" Billions of Acres	Yearly Carbon Capture (tons/acre)	Billion Tons (per year)
Grasslands & Semi-Deserts (degraded but restorable)	13	6	x 1	6
Regenerative Farms Permaculture	6.3	3	x 2	6
Forests	7.1	3	x 2	6
Wetlands	2	1	x 6	6
Living Shorelines (Rising Sea Levels)	1	0.5	x 4	2
Arctic Permafrost (Azolla and Grazing Herds)	→	→	→	Part of Grasslands Total
Total	~ 29	13.5		↓ 26 GT C

Potential Billions of Acres Source: Robin White et al, *Pilot Analysis of Global Ecosystems: Grasslands*, WRI, p.51

Slide #3 - January 2018

To do this requires 6 billion acres of grasslands to capture 6 GT of carbon per year, averaging 1 ton / acre. 3 billion acres of farmlands and croplands can capture another 6 GT by averaging 2 tons per acre per year. Forests are similar with 3 billion acres capturing 6 GT of carbon and also averaging 2 tons C per acre per year.

Wetlands are so valuable and should be included to rehydrate all the other ecosystems. If 5% to 10% of of the restored land was wetlands, the task of capturing carbon would be so much easier because they capture so much sediment and nutrients. A billion acres of wetlands can capture 6 GT of carbon annually. The fifth row is called "Living Shorelines." As the oceans continue to rise until after the continents begin to cool, we have the choice to "build a wall" and fight the rising tides …or… we could restore much of the coast to what it once was, a biodiverse area with salt marshes, seagrasses, kelp forests, mangroves and coral beds. I estimate that 0.5 billion acres of living shorelines would produce 4 tons C per acre. Human civilization will have to move "uphill" for awhile, but restoring living coastlines and populations of forage fish can bring back a fishing industry that has been largely depleted.

It will require huge changes in the way humanity interacts with nature and with each other. Our actions must become less competitive as we work together to enable symbiosis in the recovery of greatly degraded ecosystems. It will be the greatest challenge in human history and will require several decades to accomplish. It can be inspiring too, as vast areas of land come back to life. As these ecosystems restore the water cycle and build deep carbon rich soils, there can be sufficient food and water for the human population as well as the many other organisms we depend on. As CO_2 levels fall and small water cycle processes like infiltration and transpiration increase, the continents will begin to cool. Eventually continental cooling and ice formation at higher altitudes will begin to cool the oceans. Soil formation on the land will reduce erosion and ocean "dead zones" will diminish. As ocean acidity begins to drop, shellfish will also be less stressed and productive. Slide #4 below shows some possibilities in the next four decades.

Scenario 300 Step Up - 4 Decades

(Events)

Decade	Fossil Fuels (gt / yr)	Land Use (gt / yr)	Oceans (gt / yr)	Net Total (gt /yr)	Decade Total (gigatons)	Decade Total (ppm CO_2)	Atmospheric CO_2 - End of Decade
2019	Methane Spike declared imminent. A global biodiversity restoration plan begins with support from many nations, many US states & Native American tribes.						415 ppm
2020's	By 2029 - 40% Fire Reduction - 40% Ag Chemical Reduction 40% Trawling Reduction - 10 million in Global Restoration Corps						405 ppm
2030's	By 2039 - 1 billion grazing animals reversing desertification (half are wild herds) - 30 million beaver in North America & 20 million in Asia						380 ppm
2040's	By 2049 - Living Shorelines & Permafrost Restoration Programs are in full gear. Oceans still rising but ice forming in higher altitudes.						340 ppm
2050's	By 2059 - Rising Water tables refill Aral Sea & Great Salt Lake. 200 million Beaver on 4 continents. Fungi help restore deep soils to 20 billion acres						300 ppm
2061	World Celebrations Watching Halley's Comet in July 2061					Goal >>	300 ppm

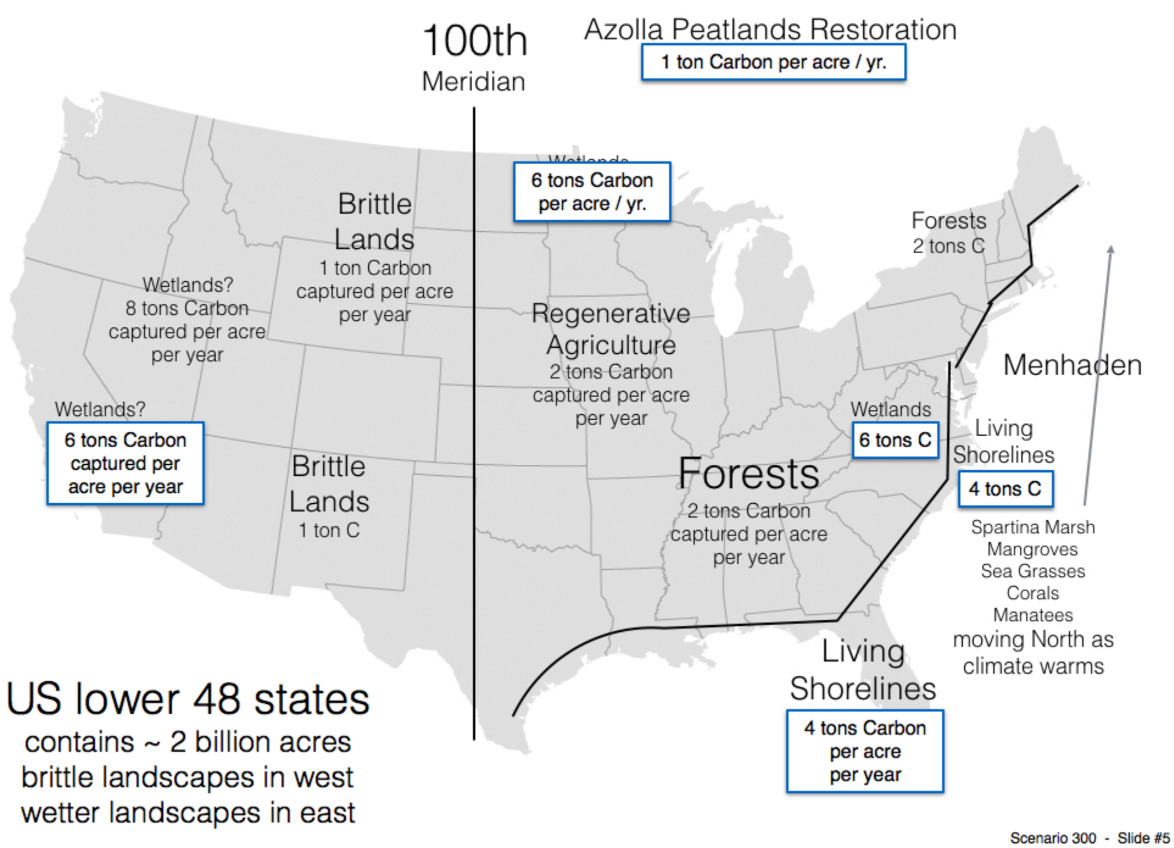
Slide #4

Also in Slide #4, we see that it takes two decades to “ramp up” restoration processes. In the 2020’s CO2 levels only drop by 10 ppm. (1 ppm / year) As more people get involved and land restoration accelerates, we see a 25 ppm drop in the 2030’s. In the 2040’s and 2050’s we have reached the “Half Earth” plan of restoring 13 billion acres on the planet. By 2030 the amount of carbon being captured by soil processes reaches 20 GT / year as shown in Slide #2. CO2 levels in the atmosphere are now dropping by 4 ppm per year or 40 ppm per decade. We can reach 340 ppm by 2049 and 300 ppm by 2059 according to this scenario.

Is this a practical plan? Will humanity be able to change this rapidly? Many can not imagine such a complete turnaround if our management of the planet’s lands and biodiversity. Do we have a choice? As the news and evidence from the Arctic continues to shock us with the possibility of a runaway greenhouse and rapidly increasing methane levels, we will continue to maintain “Business as Usual” at our own peril. This plan may not be “practical” in the present cultural context, but there are serious consequences already evident in abundance.

Human extinction is possible as we proceed to 500 ppm. Human extinction may even be probable, but it is not necessary. We can turn this around by using what we already know about restoring the land and becoming a symbiotic catalyst to rehydrating and cooling the planet. We can do this. …so let’s get started.

Slide #5 below shows a Strategy Map for the “Lower 48 States” in the USA. It should be considered a brainstorming tool and not a proposal. It does give a general plan for the 2 billion acres in this area. This area now burns enough fossil fuel to put about 2 billion tons of carbon into the atmosphere every year. **How could these lands capture 3 or even 4 billion tons of carbon and make the USA a net carbon sink?**



As we learn to capture carbon on the national level, we can also learn how to make North America and other continents net carbon sinks. **Remember, the goal is to restore ecosystems capable of capturing 20 billion tons of carbon per year.** When that level is reached, carbon dioxide will be falling out of the sky, dropping by several ppm every year.

Resources - Building a case for Scenario 300:

Pilot Analysis of Global Ecosystems: Grassland Ecosystems, by Robin White, Siobhan Murray, Mark Rohweder, World Resources Institute, 2000. This PAGE report is the source of my "Potential Billions of Acres" column on Slide 3. The "Half Earth" column is the area needed to achieve the scenario's goal of 300 ppm by 2061. So there is a 50% slack in the requirements except for wetlands. The goal of restoring 1 billion acres of wetlands is can be done if wetlands are incorporated into the plans for restoration of other systems. Wetlands can raise the water tables several feet in dry areas as we have seen in Zimbabwe and in Nevada, improving grazing opportunities there. Wetlands established in areas with higher rainfall can also improve resiliency of forests and farms. If 5% to 10% of these lands were managed as wetlands, the benefits would be enormous and a lot of carbon would be captured, too. This percentage would be about 1 billion acres.

Bio4climate Videos: Biodiversity for a Livable Climate (bio4climate.org) is a non-profit in Massachusetts dedicated to restoring the lands, waters, and biodiversity of the planet. We have produced ten conferences in our four years exploring how to do this and continue to learn at a rapid rate. Our web site has documented these conferences and its diverse range of speakers and participants. All of our speaker presentations have been video recorded and are available to the public in the You-tube format. There are now over 180 videos on the bio4climate website. Many of these will be highlighted as resources below.

Walter Jehne, an Australian scientist has outlined a global strategy for ecosystem restoration in response to the Virgin Earth Challenge. His plan also shows 20 billion tons of annual carbon sequestration by ecological restoration is possible if humans have the will to make it happen. Two Links to Walter's work below:
https://irp-cdn.multiscreensite.com/d6b81fb6/files/uploaded/2017%20-%20Regenerating%20Earth%27s%20Soil%20Carbon%20Sponge.pdf

http://www.globalcoolingearth.org/regenerate-earth/

Rangelands, Grasslands, and Deserts: Goal is 6 billion tons carbon capture per year.
[13 billion acres available - Half Earth Plan > 6 billion acres x 1 ton C / acre per year]
Much of world's rangelands are degraded and some are severely degraded. Allan Savory describes areas of seasonal rainfall as "brittle" environments. Areas that receive less than 20 inches of rainfall a year tend to be more brittle, but seasonality is important. In the "lower 48" United States lands west of the 100th meridian generally receive less than 20 inches of rain and are more brittle than lands east of this line. Most of these areas globally were once thriving biodiverse grasslands, but many are now growing "deserts" with vast areas of bare ground. Grasslands require grazing, hoof disturbance, and nutrients in the form of dung and urine from dense animal herds which provide these animal impacts and move on to fresh pasture. They don't return until the impacted area has adequately recovered. Depending on brittleness, this

might range from a few weeks to two years. While many rangelands are not very productive, Allan Savory has demonstrated that these lands can come back within three or four years if managed holistically.
Many of these lands are now bare ground most of the year. Either they are devoid of animals, or subjected to continuous grazing or they are used as monoculture crop lands for grains, cotton, and other crops. These crop lands are usually high input operations using chemical (NPK) fertilizers, pesticides, and irrigation water. Another problem in these brittle landscapes can be fire, both wildfires and intentional burns add much CO_2 to the atmosphere.

The African Centre for Holistic Management in Zimbabwe - Allan Savory's contribution's continue in Zimbabwe working with the African Centre. He is most impressed by the rising water tables and the return of wildlife to the areas being grazed by communities using movable kraals. Water cycle improvements in infiltration insure that a lot of carbon is going into the ground.

The "Road Map to 300" table shows Grasslands and Deserts covering 13 billion acres. If only half of this land was managed in a way that captured 1 ton of carbon per acre each year that would be 6 billion tons of carbon per year added to the soil. Is 1 ton of carbon captured per acre possible with good management? We are learning that it is not only possible but can also be very profitable.

Richard Teague from Texas A&M found many examples using multi-paddock grazing where carbon capture was between 1 and 2 tons per acre per year. Dr. Teague spoke at the first Bio4climate conference at Tufts University in 2014. Link is below:
https://www.youtube.com/watch?v=rhDq_VBhMWg&list=PLsWWRqCX9eSakMuHMosBKzdhb_NAtn2cB&index=4

Teague also gave a more detailed presentation at the Quivira conference in 2015.
Link: https://www.youtube.com/watch?v=crG4L4J-OEg Richard's summary at Quivira [37:30 to 39:53 Minutes] emphasized that academics must work with the leading ranchers and farmers to document how effective holistic management can be. He estimates that these leading ranchers and farmers are 20 to 30 years ahead of the academics in their ability to restore the land.

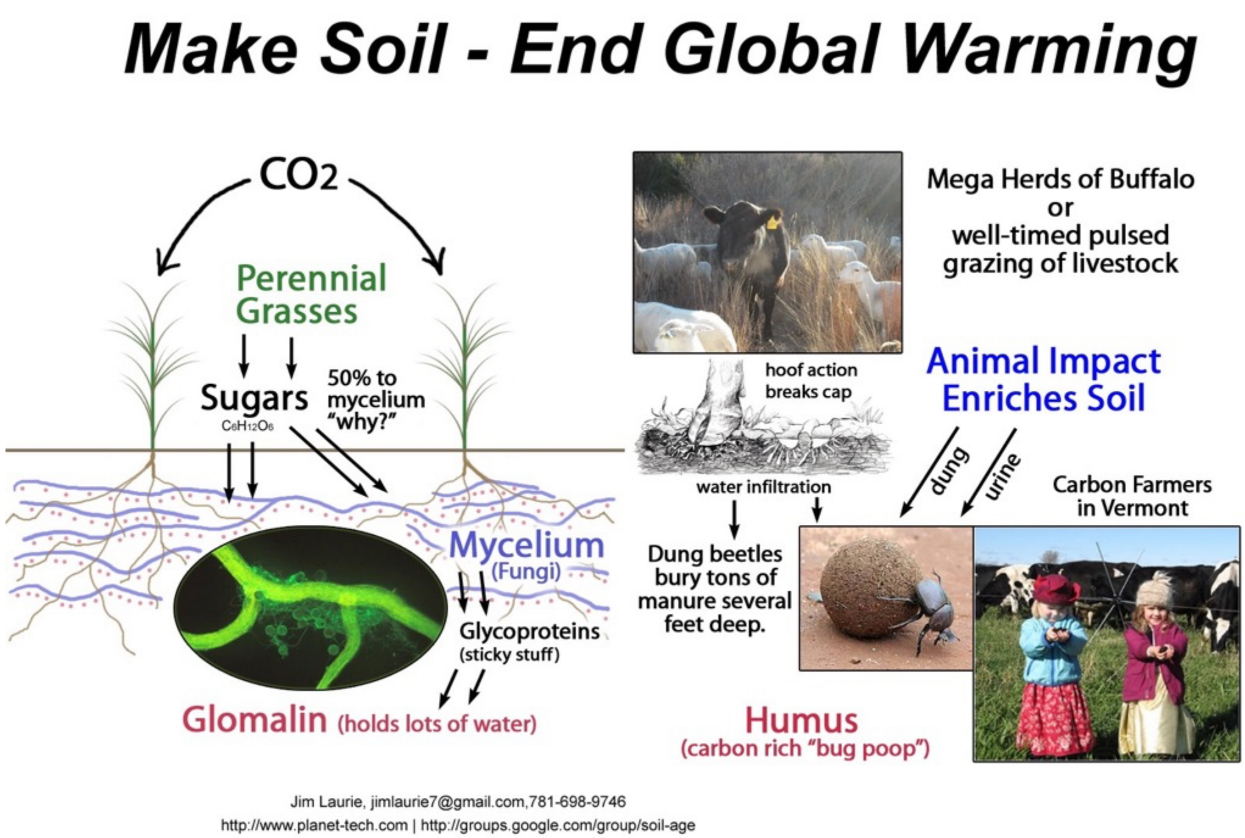
Christine Jones' working on the Colin Seis ranch in Australia has been studying pasture cropping (grazing mixed with cover crops and crops sown into pastures). She is also measuring accumulated carbon levels down to 2 feet. Most studies don't look past 6 inches of soil. The Seis Ranch has been getting about 1.8 tons carbon per acre per year over ten years, but in the last two years it has risen to 3.6 tons C per acre per year. Important to note that no fertilizers are being used and mineral density in the crops is improving as carbon levels rise. Links follow:
http://www.amazingcarbon.com/PDF/JONES%27CarbonThatCounts%27.pdf
http://www.soilsforlife.org.au/cs-winona

Gabe Brown in North Dakota has had even better results when he finally became mixing grazing with cover crops and crops sown into pasture. On some pastures Gabe is now capturing carbon at about 7 tons per acre per year. This area only receives 16 inches of annual rain and has a short growing season. The importance of mycorrhizal fungi is to be emphasized in both the Seis and Brown study. By refusing to use chemical fertilizers, pesticides, and antibiotics, Gabe Brown's lands are rich in mycorrhizal fungi and soil insects and costs of production are far lower.

Gabe's TED talk link: https://www.youtube.com/watch?v=QfTZ0rnowcc [11:15 - 15:30 minutes] By integrating cover crops and multi-species grazing, he has seen organic matter rise from 4.2% to 11.1% from 2006 to 2013. This is a 6.9% OM rise in 7 years. **I calculate that to be about 7 tons of carbon captured per acre per year. This is an area with 16 inch rainfall and a 5 month growing season.**

David Johnson from New Mexico State speaking at the "Climate Reckoning" conference produced by Bio4climate in November 2017 amplified the message about fungi. **In his research, his results show a capture rate of 10.7 tons C per hectare per year. (4.33 tons C per acre per year.)** His method was no-till, no-chemicals, but he does not use grazing animals. In his presentation, he referred to Gabe Brown's work. **His calculation for carbon capture at the Brown Ranch is 20.63 tons C per hectare per year or 9.1 tons C per acre per year!** Link: https://www.youtube.com/watch?v=neIIPRRnXQQ&feature=youtu.be [28:10 - 36:15 min.]

The **"Make Soil - End Global Warming"** slide emphasizes how important biodiversity is to stabilizing the climate. Look for the key players, grazing herds, perennial grasses, dung beetles, mycorrhizal fungi, carbon farmers … and more.



Grasslands Summary: We are finding many examples of grasslands **exceeding the 1 ton of carbon per acre yearly capture rate.** If we can bring one half of the land in these brittle environments under good management within two decades, we should exceed the 6 billion tons of carbon capture that is our goal for these lands. Integrating wetlands and wet meadows with these grasslands is another way to increase the carbon capture rates which we will explore later. We are discovering that good management can work even in very brittle lands and has been demonstrated on tens of millions of acres on five continents. We know how to do this. The overarching issue is that billions of acres of degraded land are still being overwhelmed by chemicals, pesticides, tillage, and/or continuous grazing, often at a financial loss to the landowner. How do we bring these restorative possibilities to range managers everywhere?

Regenerative Farms and Permaculture: Goal is 6 billion tons carbon capture per year.
[6.3 billion acres available - Half Earth Plan > 3 billion acres x 2 tons C / acre per year]

Agricultural lands are generally less brittle and receive more rainfall than rangelands. Because of this there is greater opportunity to capture carbon and using regenerative techniques with the goal of building soil with healthy mycorrhizal networks should yield 2 tons of carbon sequestered per acre per year. **If we are able to reach this goal on 3 billion acres (half of these lands) that would capture another 6 billion tons of carbon annually.**

Most agricultural lands have been the victim of severe erosion due to tillage and synthetic chemical use. They have lost over half of their organic matter making it difficult to hold water in these soils. There is a huge opportunity to reverse this process. It would require far less dependence on chemical fertilizers and pesticides. Fungi networks are essential to bring nutrients to the plants. Feed lots must be ended and the animals are needed out on the land (both rangelands and crop lands) as a nutrient pump as well as a food source. Grass fed beef (100%) and ending ethanol subsidies would reduce incentives for grain production and encourage a more nutrient dense diet.

Providing funding to ranchers and farmers on the land for ecosystem services would accelerate this conversion. Providing $20 per acre for good management on 12 billion acres described in this scenario would require $240 billion dollars. This is about a quarter of the world's military budget. Because climate change is the greatest threat to global security, this is a small price to pay.

Greg Judy is a grazier in central Missouri who has seen as much as three inches of topsoil in four years. An inch of this rich soil contains 8 tons or more of carbon per acre. **So three inches over 4 years yields 6 tons C per acre per year.** Judy counts earthworms on the land he manages and find as many 17 piles of earthworm castings per square foot. This would be over 700,000 casting piles per acre. Greg's grazing plan includes a very dense herd in an area for a short duration (1 day) and 2 to 3 months recovery time. The manure deposited is significant and the trampling of the grass brings a lot of biomass in contact with the soil to feed the earthworms. Dung beetles dry out the dung and bury most it in balls several feet deep. While the beetles are deepening carbon rich soils, the earthworms are "uppening" the same soil.

Greg Judy has written two books explaining his methods and includes his financial planning. These are great sources for land managers, farmers, and ranchers.
No Risk Ranching: Custom Grazing on Leased Land
Comeback Farms: Regenerating Soils, Pastures and Profits with Livestock Grazing

Greg discusses biodiversity restoration in his lecture at the VABF Conference in Virginia. Link: https://www.youtube.com/watch?v=W6HGKSvjk5Q Some good clips from this talk include: [10:00 to 20:00 minutes] and [49:50 to 62:30].

Joel Salatin is a farmer in the Shenandoah Valley of Virginia who has written many books on farming. He describes how 8 inches of topsoil has accumulated over bedrock in a decade. (2000 to 2010) **At 8 tons per acre per inch of topsoil, that's 64 tons C in ten years. Five tons C per acre per year is a conservative estimate.** (Remember, Scenario 300 only requires 2 tons per acre on half of the agriculture lands worldwide to see a major drawdown of atmospheric CO_2.) Salatin's description can be found in his book titled, **The Sheer Ecstacy of a Lunatic Farmer, Chapter 1, pp. 2-15.**

Mark Shepard in Wisconsin is another farmer and grazier who is planting a diverse blend nut and fruit trees mixed with perennial crops, mushrooms and grazing. He is rebuilding soils using ideas like the permaculture techniques described by Bill Mollison years ago. Shepard's book, **Restoration Agriculture: Real World Permaculture for Farmers**, is very detailed and shows farmers how to grow nutrient dense food. This approach builds extensive mycorrhizal fungi in the soil which is a good sign of carbon rich soils. The perennial plants feed much carbon in the form of sugars and enzymes to the soil microbes and fungi.

Shepard also writes about his financial plan and shows how it is more profitable than the corn system most farmers now use in his area. If we subsidized "carbon farming" methods like Shepard, Salatin, Judy and others are using, the transition to these methods could happen within the two decades required in Scenario 300. This is especially true if we stopped subsidizing soil killing chemical agriculture.

Lands managed using permaculture, perennials, and holistic planned grazing would be amazing sites for long term academic study over a time span of a decade or two. Farmers can rarely afford to do these studies and they should be rewarded for ecosystem services, not charged for expensive lab work. Understanding the value of these systems should be a national priority. We are now subsidizing the "death of soils" encouraging more chemical use. Using some of these funds for restoration studies is certainly a step in the right direction.

Forests: Goal is 6 billion tons carbon capture per year.
[7.1 billion tons available - Half Earth Plan > 3 billion acre x 2 tons C / acre per year.]

The "Half Earth Plan" for forests has numbers similar to regenerative agriculture. If three billion acres were managed "holistically" to improve water and nutrient cycles, then 2 tons carbon capture per acre each year would achieve the goal.

Our understanding of how a healthy forest works is still very sketchy, but we are discovering that old-growth forests can capture more carbon and nitrogen than younger forests. Clear cutting every 40 years and burning the debris before replanting has been devastating to forest soils, but it was considered the best way to manage forests and unchallenged until the 1980s. What we have learned since gives hope that restoring forests can be a big part of Scenario 300.

Replanting clear cuts and selectively cutting in standing forests would be a good start. Allowing many mature forests to advance into "old-growth" stage is another possibility. Trees can feed mycorrhizal fungi and microbial networks. Grazing insects and nematodes release nitrogen for the trees slowly and their "bug poop" contains progressively more stable carbon compounds like humus and lignin. As soils in older forests mature, the amount of stable carbon in its soils continues to increase. Wood products selectively cut can hold their carbon for decades. Holistically managed forests that demonstrate the value of ecosystem services should qualify for subsidies mentioned above for well managed ranches and farms.

Jon Luoma wrote The Hidden Forest, a very good book describing research at the Andrews Forest in Oregon where many discoveries have been made since its protection in 1948. Soil processes are described in great detail in Chapters 5 and 6.
The Hidden Forest: The Biography of an Ecosystem, published in 1999.

Joan Maloof, writing in her book, Natures Temples, has focused on old-growth forests and finds that "increasing the time between logging events for managed forests and preserving old-growth forests, the carbon stored in forests and kept out of the atmosphere could theoretically double (pp. 36- 37). **Nature's Temples: The Complex World of Old-Growth Forests, published in 2016.**

Paul Stamets has done amazing research on fungi for decades and gives us many insights about forest restoration by his knowledge of mycorrhizal fungi in his book, Mycelium Running. **Mycelium Running: How Mushrooms Can Help Save the World, published in 2005.**

If forests contained 10% beaver meadows and other wetlands, the average carbon capture rates and biodiversity would rise. Rising water table would also reduce fires, a major source of greenhouse gases. This theme of integrating up to 10% wetlands into our restoration plans for improving carbon sinks keeps coming up in this document. Let's look at wetlands more closely.

Wetlands - 1 billion acres restored globally is essential: Goal is 6 billion tons carbon capture per year. [1 billion acres x 6 tons C / acre per year.]

The loss of wetlands is a big part of the climate crisis. If we are serious about reversing climate change we must learn how restore these wetlands. It is estimated that the continental United States was once 10% wetlands (Alice Outwater) due largely to beaver activity. To extend this 10% rule to the rest of the globe would mean that over 2 billion acres of wetlands might be a possibility. If we make our goal half of that over the next 40 years, it would require a billion acres of new wetlands. The scenario uses a carbon capture rate of 6 tons per acre per year which is much higher than other ecosystems but the following examples

Steven Apfelbaum has created wetlands which sequester 7 to 12 tons per acre in North Carolina and Illinois. He also stresses the importance of covering peatlands that have been exposed to the air by dropping water tables. Drying out these carbon rich soils can lead to huge fires. He agrees with Walter Jehne about the importance of reducing landcape scale fires, a huge source of atmospheric CO_2. Apfelbaum spoke at the first Bio4climate conference at Tufts in 2014. Link: **https://www.youtube.com/watch?v=gYq8WsLyPlg** [9:58 - 20:04 minutes]

Carol Evans & Jon Griggs have encouraged beaver activity on Maggie and Susie Creeks in Nevada. The wet meadows now have 2 to 3 feet of mucky black soil and the water table in the area is 3 feet higher than 15 years ago. This muck contains significant carbon, at least 100 to

150 tons per acre increase in 15 years. (This is what our climate scientists should be focussed on.) At any rate, my estimate for Susie Creek is a yearly increase of 6 to 10 tons per acre. Carol Evans is a fisheries biologist who has been studying these streams for several decades. Jon Griggs is the manager of Maggie Creek Ranch and is thrilled to see how the the vegetation can come back even in an area averaging less than 10 inches of precipitation per year. Link to their talk at our 2015 Tufts Conference: **https://www.youtube.com/watch?v=lR7w9Tritj8&t=67s**

While creating wetlands in populated area is tricky as beaver often have different priorities than humans, we are learning how to work with them. The larger opportunity is in the desiccating and abandoned brittle landscapes. These lands need animal activity. Wild herds would help but rebuilding them will take awhile. Ranchers can bring in cattle, but they are often worried about water availability.

The Nevada case mentioned above is a great example. Ranchers had a good management plan and kept the animals moving and as the creeks began to hold water longer, the beaver showed up. Without wood in those first years, they used rocks and mud and built deep channels to create permanent pools so they could survive the hot summers. The land holds much more water and the small water cycle is being enhanced. The trout and freshwater mussels are making a comeback in many of these streams.

Chernobyl - Restoration after Human Evacuation: The area around Chernobyl was a huge grain operation until the nuclear accident in 1986. Over 1000 square miles were evacuated and the area has become a curiosity for scientists who are doing research with strict exposure limits. This Exclusion Zone is now a biodiverse ecosystem with abundant wetlands and wet meadows due to beaver activity. Many threatened species have returned and are doing well including otters, moose, wild horses, and a diverse mix of water bird species. The wolf populations are doing well here approaching a hundred animals.

Because of radiation, humans will avoid this area for a long time so there is a great opportunity to see how nature can rehydrate the land and capture a lot of carbon, too. Beaver once roamed most of central Asia all the way from France to China and Mongolia before they were trapped out in the 1300's. Imagine rehydrating most of Asia's degraded grasslands by nurturing beaver activity to raise water tables and restoring wild herds along with local grazing herds. Asia would become a net carbon sink. Check out this amazing story. Nature Documentary link: **https://www.youtube.com/watch?v=yzza7Aouzn8 [History wetlands summary at 13:25 to 17:30 minutes]**

Michal Kravčík, an engineer from Slovakia has been restoring landscapes and educating communities on several continents. He wants to restart what he calls the "small water cycle in as many areas as possible. Kravcik asserts that water is now flowing off the continents faster than it is returning from the oceans as rain. This would explain why the continents have been slowly desiccating (drying out) for centuries. If the runoff exceeds the rain fall coming from the ocean, the difference would exceed the volume of Lake Erie, **every year.** Michal has been helping to slow the water down, increasing infiltration and transpiration, and cooling the planet.

The Kravčík team's vision for the future is a book titled: **Water for the Recovery of the Climate - A New Water Paradigm.** The 94 page book is free an can be downloaded on the internet.

Wetlands Summary: Wetlands are also a must in other landscapes. If California returned 10% of it's agricultural lands to wetlands and beaver meadows, it would have far fewer drought problems. If forest management required slowing of water and wetlands to raise water tables, the forests would have better immunity to pests and wildfires would be reduced. Fire is not a very good tool if our aim to to reduce greenhouse gases. Keeping water at higher altitudes longer and having it go through many transpiration cycles (Kravčík's Small Water Cycles) before it reaches the sea will cool the system while it builds many water storage "bank accounts" for the inevitable dry periods.

Living Shorelines: Potential is 2 billion tons carbon capture per year.
[0.5 billion acres needed x 4 tons per acre per year]
The coastlines are very developed in many areas with large cities and little biodiversity. The sub-surface continental shelves have been plagued with dead zones from soil runoff and frequent trawling of the bottom by large fishing fleets. We are also already experiencing the impact of rising oceans and can expect sea level rise to accelerate for the next few decades.

Our goal of restoring ecosystems, building soils, and rehydrating continents will eventually reduce greenhouse gas levels and cool the continents, but oceans still contain most of the heat energy that the 'greenhouse blanket' has captured in the last century. Until much of this energy can escape through an atmosphere with reduced levels of carbon dioxide, methane, and other GHGs, we will be faced with continuing melting ice Antarctica, Greenland, and high altitude glaciers. In Scenario 300, it will still take about four decades before will an atmospheric CO_2 level of of 300 ppm. Hopefully at that 300 ppm level, we will begin to see some glacier reforming in the higher altitudes and latitudes. It will be a big day when the Arctic Ocean begins to build up ice again, but the lag time might be many decades longer.

We expect at least a 5 or 6 foot sea level rise before the year 2100 even with the swift implementation of Scenario 300. However, without Scenario 300, the situation would be far worse. We could build walls to keep the ocean out, but the expense of this will exhaust resources needed for other challenges. Could we allow the ocean to rise and create large areas of salt water ecosystems to supplement our carbon capture? Restoring these ecosystems and bringing back the plankton eating forage fish might re-invigorate the coastal food webs. Strategically limiting coastal development and learning how to help cities thrive in a more aquatic environment is needed and now.

There are already many groups working on this possibility. Restoring salt marshes, sea grasses, mangroves and corals is possible. Strategic thinking many decades into a rapidly changing future is already being done. In November 2016, Bio4climate organized an oceans conference at Harvard with the title: "Restoring Oceans, Restoring Climate." Program Link:
https://bio4climate.org/conferences/oceans-2016-program/

This conference had over 20 presentations with the presentation videos accessible in the above link. A small sample of speakers includes Tom Goreau from the Coral Reef Alliance giving examples of his work to protect and restore coral reefs. Alfredo Quarto updated us on Mangrove restoration projects on several continents. Anamarija Frankic of UMass Boston and the Green Harbors Project has been reestablishing oyster and mussel reefs along the urban coastlines.

George Buckley from Harvard gave the natural history and importance of horseshoe crabs, Dwayne Shaw, from Downeast Salmon Federation spoke about bringing back river herring in New England streams. John Todd and Brian Van Herzen gave several examples of ecological design, to bring back the ocean food webs. Katherine Deuel of the Pew Charitable Trust spoke about 'forage fish' like sardines and menhaden which are the key to bring back the big fish to places like New England. The Pew group is a leader in getting coastal communities to think about creating "Living Shorelines."

As the oceans warm and the seas rise, might we see the possibility of mangroves and corals moving into new areas farther north? Could these Living Shorelines with many diverse ecosystems become significant carbon sinks? Let's find out. We have learned a great deal in the last decade about this possibility.

Another example of strategic thinking regarding climate change is the Rice University Severe Storm Center (SSPEED). It is a collaboration between the Rice civil and environmental engineering departments was many environmental and community organizations in the Houston. The Sspeed Center is working to protect as much costal land south of Houston along the Gulf Coast as possible as a buffer to major hurricanes. Development in the Houston area has made it very vulnerable to flooding: Hurricane Ike and Hurricane Harvey have been devastating. As sea level rises, there is now a lot of interest in rethinking land use on the coast.
Proposal for Coastal Recreation Area: **http://sspeed.rice.edu/sspeed/LSCNRA.html**
Jim Blackburn, the director at SSPEED is a lawyer, environmental engineer, and nature enthusiast is featured in the this link: **https://www.youtube.com/watch?v=P0YewbjwXq8**

Can living shorelines be a significant carbon sink as the sea level rises? We are just beginning to study the possibilities, so the jury is still out. It is hopeful, though considering how much interest has increased in a very few years.

Summary:

This will be the most challenging time in human history. The consequences for not facing this challenge are huge. Sea level rise will be significant and will take decades to reverse under the best scenarios. As the Arctic Ocean becomes ice free and its waters become warmer, we face an increasing probability of a runaway methane spike. Now is the time to get started!!!

Nature's Ecosystems have the capacity to reduce atmospheric CO_2 levels to 300 ppm within a few decades. Enhancing biodiversity and Holistic Management is essential for this to happen. Humans must adopt a very different approach to ecosystem management on half or more of the available lands.

A determined human effort with millions of people involved and eager to restore these symbiotic processes, we just might see 300 ppm again by the return of Halley's Comet in 2061. It can certainly a be rewarding project for those involved.

Jim Laurie
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