Working with Nature to Cool Climates through plants, soil, and water

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We can easily, safely, naturally, and quickly cool our local and regional climates by working with a variety of natural hydrological cooling processes. These processes need nothing more than living landscapes with abundant plant life and a functional soil sponge to soak up the rain—created by plant roots, microbes, and other soil life. Many people around the world—in cities, suburbs, farms and ranches—are already successfully restoring these processes, and you don't need a science degree to understand how to do it. The co-benefits are enormous, providing resilience to extreme weather events, as well as improvements in clean water supplies and food security.

In the following explanation of the heat dynamics of the Earth, I'm drawing partly on the work of Australian climate scientist and soil microbiologist Walter Jehne, who takes us back to basics, Climatology 101. At the end of this article, I will describe the co-benefits in more detail and explain the principles at work behind all living landscapes with a functional soil sponge—principles we can use to guide our own creative approaches to restoration.

The basic heating and cooling dynamics of the Earth

Water has governed the vast majority of the heating and cooling dynamics of the Earth and its atmosphere for the past 4.2 billion years. This is due not just to its volume (given that 71% of the Earth's surface is covered by water to a mean depth of 4,000 meters) but also due to its unique molecular capacity to absorb incoming solar radiation while in the liquid phase, as well as absorb re-radiated infra-red heat while in the gaseous water vapor phase.

Atmospheric CO_2 levels also varied over these 4.2 billion years—from 950,000 ppm to as low as 100 ppm—as vast quantities of atmospheric carbon were bio-sequestered through photosynthesis initially into marine chalk, coral, and limestone and then into soil humus and fossil fuels. Atmospheric CO_2 contributes to both the natural greenhouse effect, and the recent intensification of it, but the vast majority of the Earth' heating and cooling dynamics were, and still are, governed by water.

It is this unique capacity of liquid water to absorb the sun's incoming heat and of water vapor to absorb heat as it rises back out to space from the surface of the earth that created warm liquid bodies of water within which life could evolve, and the natural greenhouse effect, *without which we would all be frozen*. Natural mists and hazes, and the water vapor and other gasses that naturally accumulate in the atmosphere together create blanketing effects that have enabled the Earth to raise and maintain its mean temperature some 33^{o}C above what it would be without these effects.

This lovely warm temperature allowed the Earth to sustain liquid oceans and for life to evolve in them some 3.8 billion years ago. For the past 3.5 billion years this warming "blanket" of water vapor wrapping the earth has been reinforced by aerosols from marine algae that rise into the air, draw water to them and form marine hazes of water micro-droplets. These marine hazes aid the natural water-vapor dominated greenhouse effect to regulate the Earth's livable climate.

Symbioses of fungi and ocean plants colonized the land and formed the foundation of living soil sponges 420 million years ago, as lichen crept across the surface of rocks, they soaked up rain and gradually made it possible for the 13 billion hectares of land surface to be covered with plants. Root exudates and decomposing organic matter from these plants sped up the formation of a vast network of soil sponges that could soak up massive amounts of rain, hold it on land for larger plants and other species to use, cool land surfaces, and slow water's movement back to the oceans.

The resulting forests and grasslands provided (and still provides) additional cooling to balance out the natural greenhouse effect—including shading the earth's surface through plant canopies; transferring heat away from the surface via latent heat fluxes from plant transpiration and evaporation of dew; creating symbiotic hygroscopic biological precipitation nuclei (airborne microbes, pollen grains, and volatile organic compounds) to condense mist and haze into clouds and raindrops; reflecting heat back out to space from white, fluffy, high albedo clouds that form above forests; and spreading the circulation of water and its cooling effects from the coast to the interior of continents as the biotic pump moves "atmospheric rivers" of water through the sky

All these help to balance the Earth's heat dynamics and naturally regulate the earth's temperature, rain cycles, and water flows.

Our human impact on water cycles

Over the past 10,000 years (but particularly the past 300 years) we have cleared and burnt forests and continually tilled soils for agriculture, creating over five billion hectares of human-made desert by destroying the structure and function of the living soil sponge and the plants that feed it. This has greatly altered the capacity of over 70% of the land surface to soak up and retain rainwater; shade, cool, and protect soil surfaces from solar heating; and sustain its former transpiration, cooling, and cloud dynamics. This continuing degradation interferes with the Earth's temperature and weather, as well as the availability of clean water, capacity to grow food, and resilience against flooding, drought, and erosion.

Land degradation can be reversed, and all of these functions can be restored.

What about CO_2?

Until now, climate research has focused on the abnormal increase in atmospheric CO_2—from the burning of fossil fuels, clearing and burning of forests, and loss of carbon from soils—and its impact on global warming through increased CO_2's influence on the greenhouse effect. Atmospheric methane, likewise, is also a concern for similar reasons. This climate narrative, while accurate within its own limits, is not the entire story, and it has shifted our attention away from potentially far more serious impacts that the degradation of soil and plant systems have had on the Earth's multiple water-driven climate systems, and the resulting local, regional, and global heating, rainfall, and water flow dynamics.

To be clear, rising atmospheric CO_2 itself is not the danger that climate scientists are trying to avert: global warming and its effects are the danger. People and bio-systems can survive in CO_2

levels of up to 10,000 ppm. If we can cool local and regional temperatures and modulate extreme weather events through alternate routes, then we can live through a rise in CO_2—and we will have to, because the oceans have to re-equilibrate before we will see any effects of our drawdown strategies.

Why we have to find other ways for cooling as we wait for carbon drawdown to take effect

The ocean acts as a mass buffer that has already absorbed much of our CO_2 emissions, and much of the additional heat (leading to an acidification problem with ocean waters that has interfered with ocean life).

As we reduce emissions and implement various drawdown strategies, the ocean will get her due process first—she will let out a long slow sigh of relief and release CO2 (just like an uncapped soda bottle does) until she has reached an equilibrium with the atmosphere above her. Only then will we see a reduction in atmospheric CO_2. Many climate policies and programs fail to recognize the fact that, due to these ocean lag effects, we cannot prevent climate extremes in our lifetimes by reducing CO_2 emissions or even drawing down carbon over the next few decades—we won't see the effects of these actions for hundreds, or thousands of years. Natural hydrological processes can help provide the local and regional cooling and resilience to extreme weather events that we need in the meantime.

The co-benefits of focusing on water

The co-benefits of restoring landscapes covered with transpiring green growth and a functional soil sponge include:

- Reduction in flooding
- Decreasing droughts, aridification, and desertification
- Reduced erosion from wind and water
- Improved water quality due to less runoff, preventing toxic algae blooms
- Lower risk of wildfires, improving air quality
- Regeneration of agricultural and natural bio-systems and their economies
- Increased biodiversity and survival of species
- Increased clean water supplies due to soil's natural water filtration and storage capacity
- Fewer conflicts over productive land and clean water resulting in war and refugees

Clean water, fertile soils, and regular gentle rainfall are necessary for life (and peace) on Earth, and the soil sponge, green growth, and forests are the only things on earth that can provide us those benefits.

Ways we can restore hydrological cooling

To do this we simply have to restore natural hydrological processes that can readily and safely provide an additional cooling effect. These processes and action steps include:

1. Restore the Earth's **soil carbon sponge** and thus its capacity to infiltrate, retain and make available rainfall to sustain green plant growth for longer and over wider areas of land. This will provide nutrient dense food, abundant clean water, and prevention of flooding, drought, and erosion. See below for principles that we will need to follow to help natural systems restore the integrity of the soil carbon sponge.

2. Sustain the area and longevity of transpiring green growth across the land to dissipate vast quantities of heat from the land surface into the upper air via **latent heat fluxes.**

3. Maintain plant covers on land surfaces so as to enhance their **albedo and reflection of incident solar radiation** back out to space.

4. Limit the level of dust and particulate aerosol emissions so as to limit the formation of the **persistent humid haze micro-droplets** that absorb solar energy, aridify climates, and trap heat from escaping at night.

5. Reduce paved and bare soil areas, by keeping soils covered with living plants to maintain a cooler surface due to shading and increased **retention of soil moisture.** This will reduce the **re-radiation of long wave infra red heat** which is the primary factor that drives the natural, and now exaggerated, **greenhouse effect**.

6. Reduce the length of time that transpired or evaporated **water vapor is retained in the atmosphere** either as a gas able to absorb re-radiated infra-red heat in the greenhouse effects, or as liquid haze micro-droplets able to absorb incident short wave solar energy.

7. Convert the increase in persistent humid hazes that warm and aridify climates **into dense high albedo cloud covers,** able to reflect incident solar energy back out to space thereby rapidly and safely cooling regions and collectively the global climate.

8. Restore forest covers to provide biological precipitation nuclei that will induce **the formation of raindrops** from these clouds and remove the humid hazes. Rainfall over a larger area will reduce the intensity of storms and re-supply the Earth's soils carbon sponges with the water they need to sustain active green plant growth, transpiration and its latent heat fluxes and cooling effects.

9. Allow cloud formation and rainfall to reopen **night time re-radiation windows** that are currently blocked by the persistent humid hazes, and are responsible for over 60% of the observed global warming effects to date. In doing so we can cool night time plant surfaces so as to enhance the condensation of dew that can contribute to much of the plant's water needs and survival, particularly in dry regions.

10. Doing all of the above will restore the **biotic pump** that drives regional rainfalls across whole continents by inducing the formation of **low pressure zones** over (what will be) cooler moister greener landscapes, to aid the inflow of humid air from marine and coastal regions and spread out rains across the center of continents, while lessening the destructive force of storms.

Collectively these natural hydrological processes can maintain the Earth's safe temperatures and climates within regions. As each of them has an inbuilt natural negative feedback control that prevents them or us from over-heating or over-cooling the planet, the restoration of these hydrological cooling processes is totally safe.

Do our climate models fully understand and account for water dynamics in the atmosphere?

Our focus on CO_2 and methane as greenhouses gasses has kept us from remembering an uncontested but little-known fact: Water (*not* carbon, methane, or any other gas) is the largest greenhouse gas. It represents approximately 80 percent of total greenhouse gas mass in the atmosphere and 90 percent of greenhouse gas volume. Water vapor and clouds account for 66 to 85 percent of the greenhouse effect, compared to a range of 9 to 26 percent for CO_2.

Climate scientist Walter Jehne states that, while increased atmospheric CO_2 clearly has contributed to the increased greenhouse effect, our models have not accurately accounted for water's role in climate change overall, or the clear opportunity water dynamics in the atmosphere and on land offer us for local, regional, and global cooling.

> *The clear abnormal rise in CO_2 levels and the fact that it is a greenhouse gas made it easy for scientists to assume that this was the dominant and primary cause of any recent global warming. Hydrological processes are so variable in time and space that it was hard to model how they may have changed or demonstrate how they are linked to the observed abnormal CO2 rise, the elevated greenhouse effect or projected climate changes.*
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> *Most research to assess the impacts from CO_2 rise focused on modelling its component of the greenhouse effect, largely ignoring possible hydrological dynamics…However, even with these assumptions, research confirmed that the rise in CO_2 and its greenhouse effect, could account for only a small global temperature rise, well below the observed levels. To account for the higher observed rise, greenhouse models had to include a 'force multiplier'.*
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> *This was done by assuming that the water vapor component of the greenhouse effect, which may be four times larger than that of CO_2, was a* secondary *positive feedback due to the warming from the CO_2 greenhouse effect. This was rationalized on the assumption that the amount of water that can be held in*

the air depends on its temperature, which was assumed to be governed by the CO_2 level and its greenhouse effect.

While expedient, these assumptions conflict with reality, in that the amount of water held in the air, which is often at concentrations of up to 50,000 ppm—either as vapor or as haze micro-droplet—is governed not by the air temperature or the 400 ppm of CO_2 in the air; but by the relative balance of the following:

1. *Aerosol micro-nuclei that enable the water in the air to form persistent haze micro-droplets, and*
2. *Much larger hygroscopic precipitation nuclei able to coalesce millions of haze micro-droplets into cloud droplets—and then raindrops—to remove this water from the atmosphere.*

Contrary to our greenhouse assumptions and models, water does not disappear from the air as temperatures decline but simply condenses on micro-nuclei to form haze and fog micro-droplets. These haze micro-droplets remain in the air until they are either re-evaporated into water vapor or coalesced and precipitated by precipitation nuclei.

Instead of being an expedient secondary positive feedback process to try to enable CO_2 greenhouse models to account for the observed temperature reality, the vast but variable quantities of water in the air are governed largely by a balance of these two opposing biological nucleation processes. They have their own profound climate effects, largely independent of the temperature, the CO_2 concentration, or its greenhouse effect.

What do we do next?

While restoring these natural hydrological processes seems complex, we can restore and rebalance them all by regenerating the area and longevity of green growth in our residual bio-systems. We also need to restore the Earth's soil carbon sponge so that the additional water, nutrients and root proliferation that this enables can naturally aid the growth of these bio-systems.

As in nature, we can readily **restore the Earth's soil carbon sponge**, via management practices to:

1. **Maximize the longevity of carbon fixation** by photosynthesis on each area we influence.

2. **Limit the oxidation of that fixed carbon** to CO2 by either fire or microbial oxidation.

3. **Maximize the microbial bio-conversion of that fixed carbon** into stable soil humates and glomalin so as to limit its above ground oxidation back into CO2.

4. **Increase stable soil carbon levels** to increase the water holding capacity, nutrient availability and root proliferation capacity and thus photosynthetic productivity of that soil.

Principles for growing the soil sponge, its hydrology and cooling properties

The principles for restoring all of the above can be observed in any natural landscape. We can use biomimicry to replicate those processes as closely as possible, and ensure their function in our redesign of cities and suburbs, our management of farm and rangeland, and our stewardship of natural landscapes.

• Much of soil life is fed by liquid carbon produced by photosynthesis, exuded through living plant roots. **Keep living roots in the ground as long as possible.**

• Soil life needs protection from heat, pounding rain, and wind. **Keep soil covered year-round.**

• A diverse system is more resilient than a monoculture. **Use plant diversity to increase diversity in soil microorganisms, beneficial insects, and other species.**

• Soil life is hard at work building underground structures we depend on for water, carbon, and nutrient cycling, and for structural stability for our own infrastructure. **Try not to disturb those underground structures with tillage.**

• Like any other living system, soil ecology will succumb to overwhelming stresses. **Minimize chemical, physical, and biological stresses.**

• A healthy landscape stores and filters water, cools the surrounding atmosphere, creates mist and clouds, and prevents flooding and drought. Complex systems involving all kingdoms of life are responsible for the water cycle on land. **Plan with the whole water cycle in mind.**

• Nature never farms without animals. Animals move nutrients, create small and large pores in soil, manage flows of water, pollinate crops, balance predator/ prey relationships, and replenish soil microbes. **Plan to integrate and welcome a diversity of animals, birds, and insects into the system.**

• Every place has unique strengths and vulnerabilities. **Get to know the context of the land.**

Rather than looking to someone else's ideas about best practices—which are always context specific and from the past—if we observe and learn principles of restoration that nature uses, we can be creative in how we apply them to land management and restoration.

Rather than seeing CO2 as a pollutant or problem we can enlist it as a key natural resource: a tool and building block that can, through photosynthesis, help us to regenerate healthy soils, bio-systems, and communities across the globe.

For more information, watch: https://www.youtube.com/watch?v=K4ygsdHJjdI&t=8s

And download the Understanding Soil Health and Watershed Function manual at http://soilcarboncoalition.org/learn.

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