Can our regeneration of soils and natural hydrological cycles safely cool the climate?

Due to our past emissions, atmospheric CO2 levels have risen abnormally from 280 to now 400 ppm. Due to our ongoing emissions, ocean buffer and lag effects they and associated dangerous climate extremes are locked in rise further; risking the collapse of many bio-systems and communities.

We can no longer prevent these rises nor their dangerous consequences by just reducing future CO2 emissions by any level. In addition we must now also cool the climate; safely naturally and urgently.

Fortunately we can still do this but only be restoring the natural hydrological processes that govern 95% of the heat dynamics and balance of the blue planet and which we have impaired via our soil and forest degradation over the past 10,000 but particularly the past 300 years.

Naturally over 90% of the incident solar energy entering the troposphere is safely transmitted back out to space via a range of hydrological processes. These have created and regulated the Earth’s temperature, rainfall and climate for billions of years and buffered and stabilised past extremes.

Through our extensive degradation of our soils and bio-systems we have not only oxidised vast quantities of the carbon that had been sequestered in them but in so doing fundamentally impaired the terrestrial hydrology and through that its former capacity to regulate and cool the climate.

Conversely by regenerating these soil and hydrological processes we should be able to restore the natural heat balances and cool climates to help offset the dangerous climate extremes and safely secure our safe climate. We should be able to do this practically and effectively provided we;

1. Regenerate the Earth’s soil carbon sponge and its capacity to infiltrate and retain rainfalls and sustain the growth and transpiration of bio-systems, particularly forests, across most lands.

2. In doing so, restore the former transfer of some 25% of the solar energy reaching the Earth’s surface back into the atmosphere via latent heat fluxes to significantly cool those surfaces.

3. Restore the extent of vegetation cover of our soils to enhance its albedo reflectance and shade soils so as to prevent them from absorbing solar radiation and being eroded into dust aerosols.

4. In doing so, limit the formation of haze micro-droplets by these dust micro-nuclei and thus the absorbance of up to 20% of the incident solar radiation by these humid hazes that warm the air.

5. Reduce their absorption of solar radiation and thus temperature by shading bare soils and thereby their re-radiation of the heat driving both the natural and enhance greenhouse effect. This enables us to safely turn down the key input factor driving the greenhouse effect from both water vapour molecules that govern some 60% of the effect or CO2 molecules that governs 20% of this effect.

6. Reduce the level and duration of the warming humid hazes by coalescing them into larger cloud droplets to naturally form more extensive, denser clouds with higher albedo reflectance and cooling. Such clouds naturally covered over 50% of the planet and reflected over 33% of the incident solar radiation back out to space, systemically cooling the climate. The balance between the effects of such warming hazes and cooling clouds largely regulates the Earth’s heat dynamics and climate.
In turn the microbial, salt and ice precipitation nuclei that govern the hygroscopic coalescence of the hazes into dense clouds are fundamental in regulating the Earth’s temperature and climate as are the soil and vegetation conditions, that govern the production, particularly of the key microbial nuclei.

7. Restore former rainfalls by restoring the natural production of the precipitation nuclei to coalesce the aridifying humid hazes into dense clouds and then rain. Restoring this rain is fundamental not just to reduce the hazes but to recharge the natural soil carbon sponges and in soil reservoirs that supply bio-systems and drive the hydrological cycle and its cooling processes. Forests may be critical in this in producing the microbial precipitation nuclei that drive much of the Earth’s rainfall.

8. Re-open the night time re-radiation ‘windows’ by removing the persistent humid hazes so as to allow much of the heat absorbed each day to be re-radiated back out to space. Currently these windows are blocked by the water hazes as evidenced by over 60% of the observed ‘greenhouse’ warming being associated with increased night time temperatures, even though CO2 levels do not vary greatly between night or day. Their removal to re-open these ‘windows’ can help to safely cool regions and restore the natural heat balance and our safe climate.

While there is little scientific dispute about the veracity or capacity of these hydrological processes to govern or cool the climate of the blue planet, they, their interactions and effects are very variable in space and time and makes them very difficult to fully understand and model mathematically. As such, and because they were known to be so significant, they were assumed to be too big to be influenced by humanity and thus not a key causal factor in our recent ‘anthropogenic’ climate crisis.

Instead research and policy focused on the clear abnormal rise in CO2 levels and its real but minor greenhouse effects as both the primary cause of and focus for any solution to this crisis. Despite globally investing over 30 years and $60 billion on these assumptions, we need to face the inescapable reality that humanity has massively impacted these hydrological processes via our degradation of soils and bio-systems over 10 billion hectares or 60% of the land surface and that this has consequences. We cant avoid and now must face and address these consequences.

We may have less than 10 years in which to initiate practical widespread mitigation and adaptation measures before dangerous climate feedbacks and their consequences limit our capacity to do this. While the abnormal rise in CO2 levels over the past 300 years, well before our recent rise in fossil fuel use, is a clear symptom of our widespread degradation of our soils and their hydrology, we must not let this symptom mask our understanding of the primary cause or natural solution to our crisis.

We need to urgently and safely cool the climate to offset the dangerous pending climate extremes. We can do this naturally and practically but only if we urgently regenerate our soils and bio-systems.

This will involve drawing down massive quantities of carbon from the air back into our soils so as to restore the Earth’s soil carbon sponge and hydrological cooling. This will reduce the CO2 symptom over time and avoid our need to experiment with desperate, dangerous geo-engineering delusions.

We can however be confident that as nature did in creating our soils, bio-systems and stable climate, nature will again use these same ecological and hydrological processes to regenerate and re-stabilize its bio-systems and climate; the key question being will it be with our help, or after and without us?

Walter Jehne
Global Soils Week; Berlin  A discussion paper for an open forum on:

Can restoring our soils and their hydrological processes naturally cool regions, the planet and offset dangerous climate extremes?

1. The processes governing the Earth’s climate; The scientific reality and our assumptions from models.

For 4 billion years the Earth has maintained a buffered mean temperature 33°C above that expected by physics. This elevated temperature has been maintained despite major planetary and volcanic changes to the gaseous composition of our atmosphere and the sun’s ever increasing intensity or ‘solar constant’.

For 4 billion years this buffering and elevated temperature has enabled the Earth to sustain liquid oceans enabling life to evolve. Both these effects are due to the unique capacity of water to absorb and transfer vast quantities of heat via its phase changes and the role of the immense quantities of water, in its oceans, ice, atmosphere and on land, in governing 95% of the Earth’s natural heat dynamics, balance and global climate.

While this has been accepted scientifically for centuries it was because water was such a dominant driver of the Earth’s climate, including of some 60% of the natural greenhouse effect, that it was assumed that humans could not possibly have altered its dynamics and thus the global climate. These hydrological processes are also highly variable in time and space and thus difficult to model mathematically or demonstrate how they could be contributing to the observed climate reality and changes.

Consequently attempts to explain and our assumptions and models about the cause of the recent abnormal human induced climate change largely ignored these hydrological dynamics as a possible causal factor.

By contrast the clear abnormal rise in CO₂ levels and the fact that it is a greenhouse gas, made it easy to assume and promote that this was the dominant and primary cause of the recent global warming, climate changes and its increasing dangerous hydrological feedbacks and extremes.

However, even with these assumptions, initial analyses confirmed that the rise in CO₂ and its greenhouse effect, by itself, could account for only a very small global temperature rise, well below the observed levels. To account for the actual higher observed rise, greenhouse models had to include a ‘force multiplier’. They have done this by assuming that the water vapor component of the greenhouse effect, which is often four times larger than that of CO₂, is a secondary positive feedback induced by the minor warming from the CO₂ effect. This has been rationalised on the assumption that the amount of water that can be held in the air is governed primarily by the temperature, which in turn is assumed to be governed by the CO₂ level and its greenhouse effect.

This conflicts with reality, in that the amount of water held in the air, either as vapor or haze micro-droplets, at concentrations of up to 50,000ppm, is not governed just by the air temperature or the CO₂ level, which while increasing is only at 400 ppm, but by the balance between:

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

Contrary to these assumptions and models, water is not removed from the air as the temperature declines but simply condenses to form haze and fog micro-droplets. These remain in the air till either re-evaporated to water vapor or precipitated by precipitation nuclei.
Instead of being a convenient secondary positive feedback 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 that have their own profound climate effects, largely independent of the temperature or the CO$_2$ concentration and its greenhouse effect.

Given their dominant effect on our climate and potential role in climate changes, we need to understand these hydrological processes and:

- How they can influence regional and the global climate,
- How we may have influenced them,
- Whether we can restore these processes to possibly safely cool our climate.

Globally to date we have impaired the escape of some 3 watts per square meter or some 1% of the incident solar radiation back out to space which in turn has induce our abnormal global warming.

Can we, by restoring these natural hydrological dynamics, generate a safe global cooling of some 3 watts per square meter to restore our safe climate? If so, how can we do this practically, at global scales and in time?

This analysis has reviewed the published science to re-examine the processes known to contribute in our understanding of the Earth’s heat dynamics and climate and the recent abnormal climate changes. Can some of these processes enable us to safely and naturally reverse the causal factors and safely cool the climate?

This analysis indicates that we may be able to do this practically and safely but only if we restore key natural processes governing the heat dynamics, balance, cooling and climate of the blue planet.

The following outlines the scientific evidence for how these hydrological processes govern the Earth’s climate. How by regenerating them we may be able to safely cool and restore our stable Holocene climate and:

1. Regenerate the Earth’s soil carbon sponge and capacity to retain rainfall and sustain bio-systems.
2. Cool soil surfaces and regional climates by enhancing their transpiration and latent heat fluxes.
3. Enhance the albedo, reflectance and insulation and thus the cooling of soil surfaces
4. Limit the formation of water micro-droplets in the air to reduce their absorbance of solar radiation.
5. Limit the re-radiation of infra red heat from our soils to significantly ‘turn down’ the greenhouse effect
6. Coalesce the warming hazes of micro-droplets into clouds to enhance their albedo and cooling effects.
7. Aid the nucleation of raindrops and rainfalls to sustain the Earth’s hydrology and heat dynamics
8. Re-open night-time radiation windows to hydrologically cool regions and the planet
9. Restore rainfalls by inducing low pressure regions and the inflow of humid marine air.
10. Increase the integration and efficiencies of these natural hydrological processes and cooling effects.

Walter Jehne
Healthy Soils Australia
How we may be able to safely cool the climate by the regeneration of natural hydrological processes to:

1. Regenerate the Earth’s soil carbon sponge and capacity to retain rainfall and sustain bio-systems.

Given that restoring the Earth’s hydrological processes and balance may be critical to cooling the climate, our options for doing this would depend fundamentally on them having access to an adequate supply of water.

While there is abundant water in the Earth’s oceans that cover 71% of its surface to an average depth of 4 km and while they are also the Earth’s primary heat sink, climate buffer and source of most evaporation and rain, as vegetation extended over the land surface from 420 million years ago this greatly altered the Earth’s hydrology, heat dynamics and balance, but particularly its ability to cool the climate.

As fungi and then plants colonized the Earth’s rocky land they left organic detritus. This formed soils that in turn could retain rain and enable bio-systems to extend rapidly over the 14 billion hectares of land surface. In doing so this fundamentally changed the Earth’s hydrology so that the land now receives more rain and transpires and cycles more water and heat per unit area than the ocean. These bio-systems have also greatly changed the composition of the gases and aerosols in the atmosphere, their heat effects and thus the climate.

Whereas the rain that fell on the rocky landscape pre life would have mostly rapidly run off back to the oceans, the draw down of many thousands of billion of tonnes of carbon from the air into these soil carbon sponges, greatly changed the Earth’s hydrology and climate as each gram of carbon may retain 8 grams of soil water. Instead of running off, up to 1 meter of rainwater may have been retained in these ‘in soil reservoirs’, feeding springs, wetlands, lakes and rivers and aiding productive bio-systems to extend globally. It is this additional soil water and the bio-systems it enabled that now helps govern the Earth’s heat dynamics, balance and climate.

For example, by forests and grasslands can support leaf areas 10 times greater than their land area and thus transpire far greater volumes of water, for longer, than the evaporation of water from flat surfaces. In so doing such forests and these soil carbon sponges can transfer much higher quantities of latent heat from the surface into the air to cool that surface. Because of these soil carbon sponges, the area of leaves and the longevity of their transpiration can result in cooling effects that far exceed that from evaporation from the oceans.

To a large extent It was the formation of these soil carbon sponges and bio-systems that created the hydrology and buffering that enabled and underpins our relatively stable Holocene climate. They also underpinned the water, food, habitats and bio-materials that enabled agriculture and human concentrations to develop. Over the past 10,000 but particularly the past 300 years, we have massively cleared, degraded, oxidized and desertified over half of these bio-systems and soils and in so doing impaired their hydrology and our climate. The abnormal rise in CO2 levels over the past 300 years, well before exponential fossil fuel use, results from and is a symptom of our oxidation and degradation of these soil carbon sponges and their bio-systems.

It follows that if we are to restore our safe climate we must address not just its symptom but more importantly regenerate the basis of these former bio-systems, their hydrology, heat dynamics and our safe climate. As nature did 420 million years ago and after many past cataclysmic events, we can only do this by regenerating the Earth’s soil carbon sponges to supply the water to regenerate the bio-systems our future depends on.

To do that we need to restore the capacity of our residual bio-systems to draw down carbon from the air back into our soils, not just to reduce the symptom of their degradation, but to regenerate our soil carbon sponges. Innovative land managers are doing this, sustainably bio-sequestering up to 10 tons of carbon per hectare per annum. While less than leading natural bio-systems, our imperative is to extend such grass roots initiative to regenerate our soils and landscapes urgently throughout all communities as our primary action to restore the Earth’s hydrology, heat dynamics, stable cooler climate and our future wellbeing.
How we may be able to safely cool the climate by the regeneration of natural hydrological processes to:

2. Cool soil surfaces and regional climates by enhancing their transpiration and latent heat fluxes.

By regenerating the Earth’s soil carbon sponge, our soils and landscapes should be able to infiltrate and retain far more rain. Instead of being lost in eroding flood runoff this water will be available to extend the longevity of green growth within our residual vegetation as well as help re-vegetate degraded areas.

In doing so these plants will be able to transpire most of this retained rainfall back into the atmosphere. This will greatly cool these soils and environments in that, for liquid water to transpire, it needs to be transferred first into water vapor. This requires up to 600 calories of heat per gram of transpired water, depending on the initial water temperature, that has to come from that environment to be transferred as latent heat fluxes into the lower atmosphere.

These fluxes of transpired latent heat are significant, naturally cooling the land surface and vegetated habitats. Tropical forests can be 15°C cooler than adjacent cleared areas due largely to their different latent heat fluxes. Forested urban areas in Canberra, in a temperate region, can be 7°C cooler than nearby areas without trees.

Globally 24% of the incident solar energy entering the Earth’s troposphere is transferred from the surface back into the lower atmosphere via these latent heat fluxes from the transpiration and evaporation of water. While the evaporation from the ocean until their recent warming may have been relatively constant, by clearing and aridifying over 50% of the former vegetated land surface, we have significantly impaired the Earth’s natural transpiration levels and their cooling latent heat fluxes. This has significantly warmed surface environments.

Conversely we can rapidly and safely cool regions by regenerating green vegetated landscapes to restore these cooling latent heat fluxes. As forests produce leaves whose wind exposed area can be 10 times greater than the area on which they are growing, such forests can transpire water and cool regions far more effectively than the evaporation of water from two dimensional water surfaces, particularly when cooled from below.

Consequently despite the Earth’s natural, and now residual, forest area being much smaller than its oceans, the area and longevity of this transpiration and cooling effect, particularly with increased wind exposures makes the regeneration of our forests a key priority to safely cool regions and our climate.

However, these cooling latent heat fluxes need water. They cannot occur if our soils do not have water.

Thus the extent, effectiveness and longevity of these cooling latent heat fluxes depends totally on the water status of our soils and the capacity of the earth’s soil carbon sponge and their ‘in-soil reservoirs’ to hold and make available that water. As these soil carbon sponges and ‘in-soil reservoirs’ have been degraded via our land management they cannot now hold and sustain the water supplies to plants needed to sustain the former cooling latent heat fluxes. This applies even in degraded regions with increased periodic rain that runs off.

It follows that we need to regenerate these natural soil carbon sponges and ‘in soil reservoirs’ to restore and sustain the latent heat fluxes that so substantially cooled and buffered our former safe climate. Once we do the increased transpiration from our residual and naturally re-vegetated forests and shelterwoods should help to restore the significant latent cooling effects that naturally regulated our former safe climate.
How we may be able to safely cool the climate by the regeneration of natural hydrological processes to:

3. Enhance the albedo, reflectance and insulation and thus the cooling of soil surfaces

By regenerating the extent and longevity of green vegetation across the land surface we can not only restore their natural transpiration and thus fluxes of latent heat to cool these soils and habitats but also directly protect the surface soils from; exposure, heating, wind scour and erosion.

These protective plant and litter covers often have a higher albedo effect, reflecting more incident short wave solar radiation back into the sky and out to space, than identical soil types without this plant cover. While light colored perennial ground covers such as snow and ice may reflect 90% of this radiant heat, light or glaucous vegetation may reflect 30% back to the sky. By contrast, exposed dark soil may reflect less than 10%, instead absorbing 90% of this radiation which can raise the temperature of that soil to near 60°C on hot days.

This heating, particularly above 30 °C can have a profound negative effect on the microbial health, hydrology and nutrient dynamics and thus bio-productivity of that soil. Conversely shading and insulating soils, via plant covers can help keep them cooler, ideally below 20 °C even on hot days, where there are sustained cooling latent heat fluxes. This can have a profound effect on the regional and our global climate as discussed later.

The protection of soil surfaces by perennial vegetation can also greatly reduces their vulnerability to erosion by wind and water. While erosion from rain splash and sheet runoff was minimal when most of the rain naturally infiltrated into the former natural organic soil sponges and in soil reservoirs formed by this vegetation, our clearing of this vegetation, soil degradation and annual cropping systems that exposes soils for long periods has often greatly increased runoff and erosion rates. This destruction of these vegetation covers has also increased the exposure of soil surface to wind and thus the evaporation from and desiccation of these soils.

Similarly while high natural fungal proliferation in moist protected soils mostly aided the formation of soil aggregates and their stability to wind and water erosion, similar dry bare soils without such aggregation that were exposed to wind often rapidly desiccated and eroded producing vast could of fine dust aerosols.

However over the past 10,000 but particularly past 300 years of our intense burning, deforestation, cultivation, and overgrazing of forests, soils and pastures we have extensively eroded and degraded the Earth’s soils resulting in their exposure, overheating and now extensive aridification with climate change. Less than half of the Earth’s primary vegetation and surface soils have survives as we have created 5 bha of man made desert.

For example most of inland Australia has lost up to 1 meter of their former natural topsoil via repeated dust storms over the past 150 years of European agriculture. Similar erosion has and is occurring in many nations. Many of these soils and bio-systems have lost up to 90% of their available nutrients and soil carbon in the erosion of their top-soils. We now often have to farm residual sub-soils in a far more aridifying environment.

Given that these residual sub-soils are all that we have left on which to grow food for up to 10 billion people it is critical that we regenerate them urgently despite them having lost their former protective vegetation cover, high carbon contents, good structures, water holding capacities and available nutrient reserves. We can do this but to do so need to keep them protected and covered, not bare, so as to enhance their albedo reflectance and keep them cool, and in so doing help prevent their major heating effects to our climate.

While we may be well aware of the consequences of this soil degradation to the residual productivity of our soils and landscape we rarely consider how this degradation has affected their hydrology, heat absorption, temperatures and the major effect this has, at the scales involved, on the Earth’s heat dynamics and climate. This will be examined further subsequently along with our capacity to reverse this by re-vegetating these soils.
How we may be able to safely cool the climate by the regeneration of natural hydrological processes to:

4. Limit the formation of water micro-droplets in the air to reduce their absorbance of solar radiation.

Each day an average of 342 watts per square meter of incident solar radiation enters the Earth’s troposphere. Some of this radiation is absorbed by water micro-droplets in the air to warm the atmosphere and climate. We can limit this warming by limiting the vast quantities of water vapor that are evaporated and transpired daily into the air and the formation, level and retention of these micro-droplets which depends on the numbers of two types of aerosol nuclei in the air.

The first type are small (less than 0.2 microns) micro-nuclei including dust, pollutant particulates and a range of volatile organic compounds from plants and algae such as di-methyl sulphide that are naturally abundant in the air and form persistent humid hazes of liquid water micro-droplets. These are highly effective while in their liquid phase at absorbing solar radiation and warming the air. Because of their very small size and electrostatic charge, these haze micro-droplets stay suspended and are too light to fall out of the air under gravity as rain, instead inducing the ‘humid droughts’ and pollutant brown hazes that are now more common and extensive.

These micro-nuclei and humid hazes were fundamental in the evolution of the Earth’s climate. Indeed the production of aerosols such as di-methyl sulphide by marine algae from some 3.5 billion years ago, was and still is critical in maintaining the Earth’s humid atmosphere and its direct absorption of incident solar radiation. Together with the natural greenhouse effect; of which over 60% is governed by water vapor and 20% by CO₂, the water in the atmosphere has maintained the Earth’s temperature at some 33°C above background levels, enabling the Earth to sustain liquid water, its hydrological heat dynamics and for life to flourish and sustain.

Humans have recently greatly increased the addition of these micro-nuclei to the air; including via some 3-5 billion tonnes per annum of fine dust aerosols due to our land degradation and desertification as well as billions of tonnes of carbon and pollution particulates from burning vast areas of landscape and fossil fuels. Further aerosol micro-nuclei are also released as pollutants from most industries and urban concentrations.

These additional micro-nuclei have resulted in extensive persistent brown pollutant hazes that now cover continents and alter the Earth’s climate. Their increased absorption of solar radiation has resulted in global ‘dimming’ of up to 20% over large regions while warming the atmosphere and reducing rainfall by up to 30%. Where they form acid rain this further degrades bio-systems and their capacity to bio-sequester carbon. While not a CO₂ related effect, they are a major contributor to regional warming, aridification and our climate crisis.

As we are directly responsible for increasing these haze effects we must take responsibility and correct them. We can do this simply and safely by limiting our emissions of haze micro-nuclei: for example, by re-vegetating bare soils and deserts to limit dust emissions and filtering particulate emissions from industry and fuel use.

We can also do this by enhancing their natural removal from the air and thus their warming and aridifying effects. This involves restoring a second group of precipitation nuclei that naturally coalesce these haze micro-droplets into larger cloud and then raindrops and then precipitate them from the air as rain. These natural precipitation nuclei include: hygroscopic ice crystals, some salts and particular bacteria that are highly effective at overcoming the electrostatic charges and coalescing millions of haze micro-droplets into raindrops heavy enough to fall from the air under gravity. While the ice crystals dominate at high latitudes and altitudes and the salt nuclei over the oceans, the bacterial nuclei are critical in governing rainfall over many warmer vegetated and inland regions. Their microbial ecology in inducing cooling clouds and rain is discussed later.

While only one of the many interacting hydrological processes that govern some 95% of the heat dynamics, balance and thus stable climate of the blue planet, the fact is that we have changed them significantly and that this has serious climate consequence. It follows that we need to take responsibility for these consequences and try to regenerate thee processes and their heat dynamics if we are to secure our safe climate.
How we may be able to safely cool the climate by the regeneration of natural hydrological processes to:

5. Limit the re-radiation of infra red heat from our soils to significantly ‘turn down’ the greenhouse effect

The incident solar radiation that is not absorbed by these hazes or reflected is normally absorbed by the soil and warm it. This heat will inevitably be re-radiated back into the air, not as short wave radiation but as long wave infra red heat. As the amount of heat that is re-radiated from a soil, or any ‘black body’ is governed by its temperature, in fact the 4th power of its temperature, it follows that a soil of higher temperature will re-radiate vastly more infra-red energy relative to what that same soil would if it were cooler.

This is fundamental in understanding the natural greenhouse effect as it magnitude is dependent on:

1. How much heat is being re-radiated as infra-red energy back into the air, and then:
2. How much of this energy is absorbed by the greenhouse gases, mainly water vapor, present in that air.

To date our climate change policies and media have focused mainly on just the warming from one of the minor greenhouse gases, CO₂, and its abnormal recent rise from 300 to 400 ppm this century. In doing so, we have largely ignored the independent role of water vapor that may exist at up to 50,000 ppm in the atmosphere and variably governs over 60% of the natural greenhouse gas effect relative to the 20% governed by CO₂.

Far more fundamentally, we have also largely ignored the factors that determine how much infra red heat is re-radiated back into the air, even though this determines the size of, and drives the greenhouse effect. The fact that by keeping soil surface cool we can;

Effectively ‘turn down the heat’ so as to limit the re-radiation of heat that drives the greenhouse effect.

We can do this practically, safely and naturally across the world by simply keeping soil surface cool.

Given that it will take centuries to return atmospheric CO₂ back to pre-industrial levels and that dangerous climate extremes well before then risk collapsing our bio-systems, economies and capacity to do so, we to critically consider these options to safely cool our climate.

By limiting the absorbance of incident solar radiation by our soils, we can reduce soil temperature by as much as 40 °C over vast areas and through this fundamentally reduce the infra red heat re-radiated from the earth back into the atmosphere that drives and governs much of the magnitude of the enhanced greenhouse effect.

We can do this simply by; maximizing surface albedos and the reflectance of solar radiation, by sustaining transpiration and their latent heat fluxes to cool soils as well as by limiting the production of dust micro-nuclei. Proven practical soil and land management practices can simply and safely deliver each of these outcomes.

Certainly we can and must seek to reduce the emission and concentration of CO₂ in the atmosphere and its minor contribution to the natural and abnormal human induced gas component of the greenhouse effect. Similarly we can and must seek to reduce the formation, persistence and absorption of heat by the increased levels of humid hazes as this can contribute greatly to both the natural and now enhanced greenhouse effect. Both of these can be achieved naturally, simply and safely by regenerating our soils and landscapes.

Given that these natural soil and hydrological processes have largely been responsible for maintaining the balance between the natural greenhouse effect, that has warmed the planet some 33°C above background levels, and the offsetting hydrological cooling effects for some 4 billion years, and given that these processes have repeated re-stabilized the Earth’s climate after major disruptions, it may be wise that we critically examine how these natural processes and balances can now be used to restore and secure our safe climate.
How we may be able to safely cool the climate by the regeneration of natural hydrological processes to:

6. **Coalesce the warming hazes of micro-droplets into clouds with enhanced albedo and cooling effects.**

As discussed above vast quantities of water vapor are transpired and evaporated into the air daily, to sustain the up to 50,000 ppm of water that may be in the air either as a gas or liquid micro-droplets. How much of this water is held in haze micro-droplets depends largely on the level of micro-nuclei that are produced both naturally from organic aerosols and/or by us from eroded dust, pollutants and particulate emissions.

As these haze micro-droplets are far too small to settle under gravity and often have electrostatic charges that prevent them from coalescing they often form extensive, persistent humid pollutant hazes and smog. While in their liquid phase, these hazes warm the lower atmosphere by absorbing solar radiation resulting in global dimming, and further warm the atmosphere by absorbing re-radiated infra red heat while in the gaseous water vapor phase, as the dominant water vapor component of the natural and human enhanced greenhouse effect.

These dual heating processes have been a major contributor to the recent abnormal warming of the climate.

These persistent humid hazes have also contributed to the aridification of vast regions via ‘humid droughts’ that are characterized by high humidity but reduced rainfalls of up to 30% due to the inability of the charged micro-droplets to coalesce and then precipitate from the air; as has to occur before there can be rainfall.

For the haze micro-droplets to be removed from the air they have to be coalesced into much larger cloud and then raindrops. To do this the charges dispersing them ust be overcome by stronger hygroscopic forces such as those in natural precipitation nuclei; primarily ice crystals, specific salts and certain highly hygroscopic bacteria that dominate the natural nucleation and precipitation of rain in warmer, inland and forested regions.

As these hygroscopic precipitation nuclei coalesce the haze micro-droplets into ever larger drops, they naturally form denser clouds with higher albedo that can reflect more of the incident solar radiation back out to space. Such clouds naturally covered some 50% of the planet and reflected 36% the solar radiation back out to space. Recent data indicates that their extent, duration, reflectivity and thus cooling effects are declining.

We have greatly impeded the effectiveness of these microbial precipitation nuclei in removing these hazes. By clearing and warming of over 50% of the land surface we have greatly increased the re-radiation of heat into the atmosphere and impeded the formation and effectiveness of the ice nuclei. By clearing 75% of the Earth’s primary forests we may have also impaired the natural formation of the hygroscopic microbial precipitation nuclei that were critical in inducing dense clouds and rainfalls in many warmer, inland and forested regions.

Much evidence associates our clearing of forests with the systemic; reduced removal of these persistent humid hazes, the reduced formation, extent and duration of dense clouds and their ability to reflect solar radiation back out to space and with observed lower rainfalls at regional, continental and global levels.

While much scientific evidence substantiates this understanding there is still many details that we don’t know. However we know that we need to find ways to restore these natural hydrological cooling processes in our atmosphere, particularly the role that the microbial precipitation nuclei played in such cloud cooling and rainfall induction. We need to better understanding these processes so as to cool and secure our safe climate.

Given that this understanding and these processes are focused at simply regenerating the natural biological and hydrological processes that created and have governed the Earth’s heat dynamics and climate for some 4 billion years they must not be seen as geo-engineering, but rather the simple restoration of the former natural processes and balances that regulated our stable Holocene climate.

None of the natural regeneration actions being examined involve other than the processes and agents already operative safely and effectively in nature.
How we may be able to safely cool the climate by the regeneration of natural hydrological processes to:

7. Aid the nucleation of raindrops and rainfalls to sustain the Earth’s hydrology and heat dynamics

Rain is clearly critical not just to remove the warming humid haze micro-droplets from the air but in doing so coalesce and convert them into larger droplets to form the dense high albedo clouds that help cool the planet.

Rain is also critical to recharge the Earth’s natural soil carbon sponges and in soil reservoirs so as to resupply water for plant transpiration and to sustain the latent heat fluxes critical to cool soils, regions and the planet.

Rain is also essential to enable these plants to capture solar energy and CO2 and convert it via photosynthesis into the sugars to form the building blocks of all life and the Earth’s soil carbon sponge and fossil carbon sinks.

While critical for life and our climate, it is significant that rain does not occur automatically but only if specific hygroscopic agents and processes are present to coalesce the millions of small humid haze micro-droplets into cloud and then raindrops large and heavy enough to fall from the air under gravity. These agents matter.

While initially based on physical processes, over time these haze and precipitation nuclei have increasingly been dominated by biological agents to the point microbes now largely govern the formation of haze aerosols and the hygroscopic bio-chemicals that coalesce the haze micro-droplets. As such the evolution of the Earth’s rainfall, hydrological, heat dynamics, balance and our climate may have become increasingly governed by these soil based microbial processes in symbiosis with their dominant bio-systems?

Certainly we need to better understand the balance between the two natural water nucleation processes that govern much of the Earth’s hydrological cycle, heat balance and climate. To understand what governs:

- The biological micro-nuclei such as di methyl sulphide, dust and particulate aerosols in forming the humid haze micro-droplets that govern the ecology of the humid hazes and their contribution to the natural greenhouse warming of the planet.
- The ecology of the larger hygroscopic microbial precipitation nuclei in coalescing millions of haze micro-droplets into cloud droplets that cool the climate and then remove them from the air as rain to perpetuate this buffered and balanced hydrological cycle.

To what extent has the balance between these two opposing nucleation processes and their respective hydrological warming and cooling effects governed the Earth’s heat dynamics and climate over the past 4 billion years? If this is so, what has been the effect of our gross disruption of this natural balance by:

1. Vastly increasing the production of additional haze micro-nuclei to reinforce the warming of the air and aridification of the land surface?
2. Reducing the production of the hygroscopic precipitation nuclei that previously transformed these hazes into dense cooling clouds and rain to cool the land surface?
3. Impairing the capacity of the Earth’s residual terrestrial bio-systems to regulate these processes and thus the Earth’s climate as they did naturally?

How have we via our management of our soils, forests and landscape altered these processes and through that these the Earth’s hydrological and heat dynamics and our climate?

Most critically can we regenerate these natural biological and hydrological warming and cooling processes and balances via the regeneration of our soils, their hydrology and bio-systems to restore our safe climate?

What do we need to know to do this safely to practically cool the planet in time so as to offset the pending dangerous climate extremes?
How we may be able to safely cool the climate by the regeneration of natural hydrological processes to:

8. Re-open night-time radiation windows to hydrologically cool regions and the planet

Many regions, particularly in the humid tropics, formerly had storms late each day that removed most of the warming humid hazes micro-droplets from the air and ‘re-opened’ night time radiation windows that allowed infra red heat to be re-radiated back out to space without it being trapped and held by the haze molecules. These regular rains significantly cooled these regions by allowing this night time re-radiation of surface heat but also by restoring the soil water required for transpiration and the cooling latent heat fluxes next day.

By impairing the daily nucleation and precipitation of these hazes we have effectively closed these radiation windows and limited the water for transpiration and latent heat cooling next morning over extensive regions. This is evidenced by the recent abnormal greenhouse warming being due largely to increases in night-time temperatures rather than an increase in day-time maximum temperatures. Given that these changes in daily warming effects depend on the water vapor content of the air, not CO₂ which does not vary diurnally, it confirms that much of our human induced enhanced greenhouse effect is in fact due to our changes in the water vapor dynamic of the atmosphere more so than just the progressive rise in its CO₂ symptom.

While models of the greenhouse effect have incorporated the contribution of water vapor in the warming, they have assumed that this water vapor effect is a secondary positive feedback that is driven by the rise in CO₂ levels and its greenhouse warming effect. This is based on the assumption that the quantity of water that can be held in the air, which may be up to 50,000 ppm, is regulated by the air temperature and thus the CO₂ greenhouse warming effect. They disregard that the quantity of water held in the air is in reality regulated not primarily by its temperature but by a range of haze, cloud and raindrop nucleation processes, that are substantially independent of the CO₂ level and its greenhouse effect.

This has profound significance in understanding the drivers of our abnormal greenhouse effect and its control. Rather than being confined to the impossible task of reducing CO₂ levels and its warming in time, we can restore the Earth’s natural hydrological and heat dynamics to offset this effect and safely cool the climate. All that is needed is to be willing to consider these safe options.

For example by regeneration of the natural precipitation nuclei needed to restore the regular precipitation of the humid hazes, we could re-open the night-time radiation ‘windows’ to cool many regions.

Collectively, these hydrological processes drive much of the hydrology and heat dynamics of the blue planet. Whereas on average some 342 w/m² of incident solar radiation enters the troposphere each day, what happens to over 300 w/m² of this energy is governed by these hydrological processes. Our impairment of the Earth’s natural heat dynamics and balance, to date, has caused the planet to retain an extra 3 w/m², or 1% of this incident solar energy. Our imperative is to restore the Earth’s former natural heat balance, by restoring some of the natural cooling processes to safely and practically dissipate this extra 3 w/m² back out to space.

A combination of the above natural hydrological processes and heat dynamics can readily and safely do this. While different processes dominate in different regions and bio-systems to regulate their climate, so to may different combinations of these hydrological processes be optimal to cool and restore safe regional climates.

However they all depend on the capacity of bio-systems to access adequate water to sustain these processes. To do that, we must restore regional rainfalls by restoring the microbial processes that govern the production of the precipitation nuclei regulating this rainfall, local heat balances and these climates. We also need to ensure that water is available where and when needed to sustain the hydrological cooling processes.

To do that we need to regenerate the Earth’s soil carbon sponge; by bio-sequestering carbon from the air back into our soils to supply this water while also progressively reducing the CO₂ level and symptom.
How we may be able to safely cool the climate by the regeneration of natural hydrological processes to:

9. Restore rainfalls by inducing low pressure regions and the inflow of humid marine air.

Whereas the above outline the processes governing the nucleation and restoration of rainfalls at molecular and local scales, these processes also apply at regional and continental levels in governing the global climate.

While globally evaporation rates and rainfalls should increase as the Earth warms, much of this rainfall may be in more intense unpredictable storms that destroy rather than aid water supplies or the bio-systems that need them. Similarly many regions may have less and less reliable rainfalls; despite, and often because of, the increased humid hazes. As temperatures and aridity increase large areas of already dry degraded land can may also further heat up, re-radiating vast quantities of heat and dust back into the air.

Each of the above can be expected to increase the density and kinetic energy of their molecules in the air and thus the air pressure above these regions. As air flows naturally from high to low pressure zones this will often result in an outflow of air from above dry hot high pressure regions and block any inflow of potentially cooler moister air at lower pressures.

In so doing it can contribute to the blockage of former moist monsoonal inflows and with that the progressive systemic aridification of these regions. The evidence from Australia and north Africa reinforce strongly that their aridification as late as 6000 years ago may have been substantially linked to such processes and changes.

Conversely other regions, such as the Amazon basin, may be naturally inducing massive inflows of cool moist marine air and thus rainfalls largely via its condensation and precipitation; creating zones of low air pressure. In turn these induce further moist inflows, rain and low pressure in a natural positive feedback process that has enabled the formation of rainforests, even on marginal soils, that without these inflows may be more arid. Through their enhanced latent heat fluxes, cloud albedos, cool soils, reduced re-radiation of heat and open night time radiation windows these rainforests then further reinforce their cooling and lower air pressure.

Given this radical contrast in the bio-systems formed under the different prevailing air pressures, what is it that triggers and drives these opposite positive feedback processes to create either semi-arid wastelands or verdant cool moist rainforests; under the high and low air pressures respectively? Can we influence and manage these to regenerate cooler moist bio-systems able to sequester more carbon and cool the climate?

To what extent could the simple natural process of hygroscopically coalescing the high pressure humid hazes into cloud and then rain droplets not just cool regions but create the low pressure to trigger and drive the positive feedbacks to a moister, cooler more bio-productive flora and landscape? To what extent could the production of the highly hygroscopic microbial precipitation nuclei by mesic forests trigger such contrasts?

What evidence is there of the marked decline in the rainfall and aridification of regions upon the removal of the mesic forests may have been associated with decreased production of these microbial precipitation nuclei? Conversely what evidence is there for the restoration of regional rainfalls where bio-systems and such nucleation processes have been restored?

What is needed to understand and regenerate these natural rain nucleation, hydrological and ecological processes well enough to safely rehydrate, cool and re-vegetate our vast areas of degraded arid landscape? While we have much scientific evidence affirming that we can; clearly there is much that we don’t yet know.

However we need to be prepared to explore and consider these options so as to understand the cause of our climate crisis and now as possibly our only means to safely cool and avoid it, hopefully in time.
How we may be able to safely cool the climate by the regeneration of natural hydrological processes to:

10. Increase the integration and efficiencies of these natural hydrological processes and cooling effects.

Each of the above processes governing the heat dynamics and climate of the blue planet reinforce the critical role that water has both as the primary medium to naturally warm and cool the planet but also to buffer and regulate the heat dynamics and balances that have created and sustained the Earth’s bio-systems and climate.

It follows that an adequate supply of water is essential to sustain these processes and our stable cool climate. Without water the cooling processes that enabled life to extend across the land would cease; with vast areas reverting to dry, hot, lifeless desert. Significantly microbial processes govern the supply of much of this water.

While the oceans have abundant water, without the humid hazes produced by the micro-nuclei from marine algae, much of the humid onshore airflows would decline threatening many bio-systems and the climate. Similarly without the; ice, salt but particularly microbial nuclei to precipitate rain from these humid airflows many of the Earth’s terrestrial bio-systems would rapidly aridify and collapse and with that their climate. Even when it rains it is only where microbial processes have enabled the creation of soil carbon sponge and in soil reservoirs that it is possible for most of the rain to infiltrate, be retained and sustain the green growth of bio-systems and thereby maintain their cooling hydrological cycles and our stable cool climates.

It follows that our widespread oxidation and degradation of these soils and their hydrology and our extensive clearing of the primary forests involved in the nucleation of rain and creation of the onshore low pressure zones that draw in the moist marine airflows, may have major climatic, not just ecological consequences; far beyond and in addition to contributing to the recent abnormal rise in CO2 levels as their lead symptom.

It follows that regenerating these soil carbon sponges and in soil reservoirs, by drawing down that carbon from the air back into our soils, may be critical to restore their hydrology, heat dynamics and our safe cool climate. Similarly understanding and regenerating the forest ecologies that result in the production of the microbial precipitation nuclei will be critical in restoring regional rainfall and the key cooling hydrological processes.

Most importantly we need to better understand and regenerate these hydrological processes urgently before the intensification of dangerous climate extremes limit our capacity to do so. Time may be limited and critical.

Whereas it may take centuries to draw down adequate carbon to restore our safe climate, once initiated such hydrological cooling may be effective in days and repeatable daily to efficiently rehydrate and cool regions.

As in nature we can also speed up these water cycles and effects. For example the Amazon cycles its rainfall daily through its trees, air and soil, each time repeatedly cooling the climate to collectively create highly productive mesic and cool bio-systems in an environment that would be much hotter and dryer without these hydrological cycles and effects. The regeneration and management of efficient hydrological cycles may also be able to cool regions even where there are limited water supplies.

Clearly not all of these hydrological cooling processes are equally important or relevant in all situations. However in most instances restoring the processes that had the greatest former natural cooling effect and those that we may have impaired most, may be the most effective and of highest priority for regeneration.

In most cases they are underpinned and would benefit from regenerating the former soil carbon sponges. Just as past civilizations survived or collapsed depending on how well they managed and sustained their healthy soils and through that their hydrology and essential water and food supplies, these same imperatives may now govern our future. We have more than enough knowledge and capabilities to do so.

The issue is will we regenerate our soils and their cooling hydrology in time, or let nature do it for, but without and after us?